https://doi.org/10.1186/s40066-024-00466-4

Agriculture & Food Security

RESEARCH Open Access

Evaluating consumer preferences for reduced cooking time, taste and colour of beans in rural and urban communities in Uganda

Robert Asiimwe[1], Enid Katungi[1*], Pricilla Marimo[2], Clare Mukankusi[1], Jean Claude Rubyogo[1,4] and Vivienne Anthony[3]

Abstract

Background Common bean breeders strive to deliver farmer- and consumer-preferred varieties that are well-adapted to distinct production environments, changing markets and end uses. However, there is information gap on the key traits that customers prefer and are willing to pay for. This paper examined the preferences and willingness to pay for reduced cooking time and other selected traits in the Ugandan bean markets using a choice experiment data elicited from 1152 urban and rural bean consuming households. A latent class model was used to assess preferences and the willingness to pay for reduced cooking time.

Results Results indicated that taste, cooking time, bean swelling on cooking, and grain color were the preferred attributes in decreasing order among non-bean-producers. About 72% of the urban consumers were willing to pay 41 shillings, 53 shillings and 42 shillings above prices for reduction in cooking time from 120 (status quo) to 90, 75, and 60 min, respectively. For consumers who also grow their beans for food and surplus for sale, reduced cooking time is important but not as much as yield and climate resilience. The study identified four distinct customer segments—two among bean-producing households and two among non-bean-producing households. Gender, education, level of altruism/openness to change, household economic status, and price sensitivity were the major factors influencing segment membership.

Conclusions The study findings demonstrated that breeding to reduce cooking time will generate a significant social savings in terms of less cooking fuel, water and time, but cooking time ought to be considered alongside other attributes preferred by consumers and farmers to succeed. Results also suggest that women urban consumers attach more importance to higher levels of intrinsic traits (non-visible but experienced by consumers) compared to men—thus promotional campaigns popularizing new varieties should target women to stimulate demand.

Keywords Choice experiment, Bean traits, Economic valuation, Preference heterogeneity

Introduction

Demand-led breeding approaches that are used by the private sector have been gaining popularity in public breeding programs [1, 2]. This represents a translational change in the breeding focus from crop adaptation and genetic yield gain to also include other economic traits.

*Correspondence:
Enid Katungi
e.katungi@cgiar.org
Full list of author information is available at the end of the article

The aim is to enhance the efficiency of public breeding programs by ensuring that the varieties developed are well-aligned to customers' changing needs. This investigation provides quantitative data and insights about the preferences of consumers in the target market segments so as to inform the design of new varieties and their product profiles that are used in bean breeding program [1]. There is limited quantitative information on demand of important traits that breeders should prioritize, since most breeding programs previously focused on post-breeding analysis of farmer preferences to select and release varieties that fit well into the farming systems [3]. Additional information on customer preferences has often relied on adoption studies usually conducted as part of evaluating the performance of the breeding programs. Although the analysis of post-breeding preference is essential, emphasis has been on the needs of farmers with less attention to other customers in the value chain when setting breeding priorities [3–5]. Moreover, farmer participatory variety selection (PVS) is often qualitative and performed with small groups of farmers, which might not fully support meaningful market segmentation [3]. Similarly, adoption studies are often designed with different objectives other than supporting preference analysis. Thus, such studies may not elicit the preferences of consumers and farmers in a manner that can guide breeders when setting targets for market-led breeding. As such, there is currently limited information upon which the research teams can rely to understand customer preferences and design demand led product profiles [6].

Customer preferences of a crop variety may differ based on traits important for production (e.g., yield, resilience), intrinsic traits (e.g., taste, texture, cooking time, storage quality, grain swelling capacity), processing quality and visual characteristics (e.g., color, grain size, shape). Few studies have analyzed preferences for intrinsic traits such as short cooking time among urban consumers [11] for common bean (*Phaseolus vulgaris*) in Tanzania, and [12] for Cowpea (*Vigna unguiculata*) in Nigeria. These studies were conducted a decade ago and with limited geographical coverage (i.e., two markets in Dar es Salaama and two markets in Morogoro for common bean and markets in Niger state of Nigeria in case of cow pea) to be generalizable. Other studies mainly in plant genetic resource economics [e.g., 7, 8, 9, 10] analysed preferences for crop variety attributes, focusing on rural farming households. Although rural farmers also double as consumers, their preferences for intrinsic traits can easily be overshadowed by their concerns about needing production traits; thus, fail to represent the preferences of consumers in urban areas. In addition, climate change and urbanization are forcing production systems and food habits to change rapidly, hence the need to continuously assess consumers' and farmers' preferences to update old data and support implementing demand-led breeding.

This study analyzed customer preferences and demand for selected intrinsic, visual and production traits of common bean in Uganda in urban and rural communities using a discrete choice experiment method. The study assessed consumers' preferences in two types of households—those that purchase rather than grow their beans for food (predominantly urban and peri-urban), and households that grow their beans to eat (predominantly rural), with a possibility of participating in the market as sellers or buyers or both. The study focused on and compared consumers' willingness to pay/accept (WTP/A) for reduced cooking time of dry beans (unprocessed), grain swelling capacity, taste, color, resilience to climate variability and yield in Uganda. By assessing consumers' WTP/A for bean traits, such as taste, reduced cooking time, grain swelling and color, the study provides information on customer preferences about these traits in beans that has been lacking. The study especially focused on reduced cooking time because of its potential to generate multiple benefits that contribute to development goals: nutrition outcome, gender and environmental conservation. Beans cooked for a long time lose some nutrients, increase biomass consumption (mostly firewood and charcoal) and increase drudgery for women and children who spend much time gathering firewood and cooking. According to [13], cooking methods that expose food to higher temperatures and or water for a long period of time (e.g., boiling) are detrimental to nutrient content. [14] reported that boiling beans for long time reduces its protein content while soaking beans reduces iron in grain while increasing it in the water. In such a case, the authors encourage consumption of cooked beans with its broth to recover some of nutrients. Faster cooking beans are relevant for Ugandan consumers as beans are mainly boiled without soaking to avoid change in its taste. Reduced cooking time is also important for the economy, good health and mitigation of climate change. In Uganda, soli[1]d biomass remains a key source of energy for cooking beans [16], despite efforts to popularize various strategies for reducing biomass consumption, notably, inter-fuel substitution policies, institutional incentives and food processing.

Cooking time for beans depends on many factors, such as storage duration, storage condition and genotype [17, 18]. While beans are usually stored under uncontrolled environments in Uganda, beans are cultivate during two seasons and stored under pleasant temperatures. The

[1] Solid fuel cooking in Sub-Saharan Africa accounts for 1.2 and 6% of global CO2 and black carbon emissions, which contribute to global warming [15].

context of consumption and production implies a brief a storage duration before consumption, with a high possibility of making impact on cooking time through altering genotypes. Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), in collaboration, with the National Agricultural Research Organisation (NARO) and the University of Queensland are developing bean varieties requiring reduced cooking time. The goal is to provide convenience to consumers and promote consumption of beans for its high beneficial effects on human health by minimizing on nutrient loss associated with prolonged cooking under methods, such as boiling [14]. Besides, breeders' research on genetic transformation aimed at reducing cooking time in staple crops can reduce biomass consumption directly by reducing volumes used in cooking and indirectly by encouraging adoption of other strategies—thereby playing a complementary role. Reduced cooking time also lowers the amount of water required for cooking, overall enabling households to save on the cost of cooking. However, all these benefits will not be realized if consumers and farmers do not recognize and value the trait. Currently, there is lack of information about consumer demand for reduced cooking time (i.e., how much time for cooking is preferred) and its importance as a target for breeding improvement. One Ugandan study [19] analyzed preferences for reduced bean-cooking time using attribute levels (a range of defined dimensions for each product characteristic or attribute) in decreasing order. However, the focus was a processed product (precooked bean); thus, not realistic for breeding for dry grain consumption.

Second, the study examined if consumers in rural and urban areas respond differently to changes in the same variety trait. Data are needed to enable breeders to select, prioritize and focus on the right combinations of traits to satisfy consumers, and producers in each market segment, and where possible stimulate market creation. Producers are the first clients of the breeding products. If their preferences differ from those of consumers in urban areas, it is essential for breeders to be aware of this in order to optimize likelihood of adoption. For example, if producers value yielding capacity higher than they value reduced cooking time, then breeders should ensure that yielding capacity of a new faster cooking variety is competitive to other improved varieties. Third, the study identified factors that explain preference heterogeneity among bean consumers and producers.

This paper is organized into four sections. Section "Background information" provides brief background information about the bean production context in Uganda. Study methods including the theoretical framework, designing the choice experiment and its implementation, describing the study area and sample selection procedures are discussed in Sect. "Materials and methods". Sect. "Results" presents and discusses the empirical results. Conclusions are drawn and recommendations discussed in Sect. "Discussion".

Background information

Common bean is an integral component of traditional diets in Africa and Latin America [20]. Its consumption in the East African community (EAC) is projected to double in under 24 years (2006–2030) [21]. The growth in demand for common bean in EAC is driven by macroeconomic factors, such as rapid population growth, political stability and sustained economic growth [21]. These factors will continue to increase the importance of common bean for EAC countries (including Uganda) as a staple food and income source for smallholder growers in the future.

Uganda is Africa's second largest producer of common bean after Tanzania [22]. Due to its importance, government of Uganda has been implementing favorable trade policies (such as market liberalization, and lifting cross border trade barriers to enable significant incentives for market-oriented production. The government has also put in place development strategies that promote bean production and consumption in the country. For example, the Uganda's National Development Plan III (2020/21-2024/25) under its Agro-Industrialization programme recognizes common bean as a key pathway to increase agricultural production and productivity through upscaling research on bio-fortifying and multiplying nutrient dense food staples. The same plan through the human capital development programme seeks to strengthen the foundations for human capital development through promoting consumption and delivery of bio-fortified and fortified foods, especially in schools, with a focus on common bean (especially high iron and zinc varieties) among other staples [22]. Through beans research conducted by NARO and its collaborators since 1996, 16 high yielding and resilient bean varieties have been developed and adopted by over 65% of farmers [78]. As result, the bean subsector has experienced rapid growth with total output volumes increasing from 400,000 tons to about 800,000 tons during the same period [17], while total domestic consumption demand doubled from 400,000 tons to about 800,000 tons during the same period [21]. Furthermore, bean exports have grown ninefold during the same period; from 37,000 MT (contributing US$ 12.64 Million) in 1994 to 218,000 MT (contributing US$ 99.6 Million) in 2018 [23]. However, rapid growth (33.7% per year) occurred in the last decade following diversification in export destinations. Besides the traditional import destinations, such as Kenya (52MT in 2017) and South Sudan (10MT in 2017), Ugandan beans are now exported to United Arab Emirates, Pakistan, and India and the export volumes have seen a rise from 37,000 tons in 1994 to 218,000 ton in 2017 [23]. Per-capita bean consumption in Uganda is about 25 kg per annum, providing 25% of total dietary calorie intake and 45% of protein intake [21].

Despite current market expansion for common bean in Uganda, production interventions are still needed to respond to the emerging customers' preferences, including processing quality, convenience, economic gains and resilience against climate change. For example, increasing fuel/energy costs (which affect cooking time could threaten continued growth in consumption [19]. In Uganda, beans are generally cooked without soaking for a period that ranges from 120 to 180 min depending the genotype, type of cooking energy, storage duration and conditions [19]. Households with limited access to cooking energy prefer a bean variety requiring less cooking time due to lack of required resources to support extended cooking [10]. Although breeders have access to Mattson Cookers and have been screening varieties for short cooking time, prolonged cooking time remains a concern among consumers. Rapid urbanization and growing interest of many consumers preferring plant-based proteins are likely to increase preferences for food attributes, such as convenience, taste, nutritional quality, and safety. If preferences for beans in urban areas are changing, breeders need to know them to respond to these needs.

In addition, a high share of rain-fed cultivation (over 95%) exposes bean production to the effects of climatic variability, which places agriculture and the nation's food security at a higher risk due to rainfall seasonality [24]. Because most bean growers are resource constrained, they need technologies such as improved varieties to deal with increasing incidences and severity of diseases associated with climate change.

Materials and methods

Approach and analytical framework

Market valuation research techniques are broadly categorized into stated and revealed preference approaches [25]. Revealed preference techniques measure preferences based on observations of actual choices made by people thus avoiding the potential problems associated with hypothetical responses (e.g., strategic responses or a failure to properly consider behavioral constraints). However, revealed preference techniques may not be suitable for quantifying preferences of consumers who have not experienced the product [26]. In such a case, stated preference methods that elicit responses to predefined alternatives in the form of ratings, rankings, or choices can be used to determine preferences for both market and non-market goods [27]. Although dry beans are available on the market, the attribute combinations tested in this study are not yet available in a bean variety, hence necessitating the use of non-market valuation tools from the stated preference techniques to determine the value attached to each.

We applied a discrete choice experiment (DCE) technique, because it is flexible and was suitable for analyzing the value of bean attributes. A DCE is a stated preference technique that presents a relatively simple task compared with other stated preference techniques that require the respondent to either rank or rate each attribute. The DCE requires respondents to choose their preferred alternative from a 'choice set' comprising different alternatives. Each alternative in the set is described by several characteristics known as attributes and responses that are used to infer the value placed on each attribute [28]. Thus, the choice reflects the trade-offs that each individual makes between the attributes of a choice set. When a price or cost factor is included as an attribute in a choice set, economic values associated with the other attributes can be estimated [27].

The DCE method derives from microeconomic consumer theory and integrates consumer behaviors with their economic valuation of attributes contained in the goods [29]. According to [29] consumer theory, individuals derive satisfaction not from the goods themselves, but from the attributes contained in those goods. In stating a preference, an individual is assumed to state the alternative with attributes that give him/her greater satisfaction (known as utility) than the available alternatives [28]. The utility derived from the alternative is assumed to depend on the utilities from attributes and their levels [29].

In other words, the utility U_{jit} that individual , i, derives from a bean variety alternative, j, in a choice set t, can be described as

$$U_{jit} = \beta_i X_{jit} + \varepsilon_{jit} \tag{1}$$

where vector X_{jit} consists of attribute variables relating to alternative j in choice set t; β_i is a vector of coefficients of the attribute alternatives for individual i that represent his/her preferences, while ε_{jit} is a vector of unobserved random component that may influence utility. Thus, DCE is used to determine the significance of attributes that describe the good or service, and examines the extent to which an individual trades against their preferences for different attributes. In the context of plant breeding, it is important to know which attributes are highly demanded by consumers. Information from DCE can be useful when selecting priority attributes for use in design of a variety profile as well as setting targets to match customers' preferences. DCE data can also be analyzed to identify market segments, which are important for consumer targeting when designing product profiles and new variety dissemination.

The basic model for analyzing DCE data is multinomial logit (MNL), which assumes that preferences are homogenous across respondents. However, market studies have established that consumer preferences are heterogeneous, and accounting for this heterogeneity is necessary to ensure that estimates from analysis are unbiased, accurate and reliable [30]. Several models have been developed to account for heterogeneity, including the covariance heterogeneity (CovHet) model [31, 33], the random parameter logit (RPL) also referred to as mixed logit model [31, 32], and the latent class model (LCM) [34]. The study in [33] provides a detailed comparison of models for integrating and explaining preference heterogeneity in choice experiment data. RPL and LCM are commonly used to incorporate variations in parameters of some attributes across participants (e.g., consumers). The RPL assumes a continuous distribution to address heterogeneity by interacting some sociodemographic factors with the alternative-specific constant and specifying a heteroscedastic variance terms. The LCM casts heterogeneity as a discrete distribution and uses implicit segmentation to group respondents into clusters of homogenous preferences and analyze demand for attributes in each cluster [38]. In LCM, preferences within segments are relatively homogenous, but choices from one segment to another are assumed to be independent. The model estimates the probability of belonging to a certain segment, which is used to compute segment relative size. The choice between RPL (Mixed Logit) and LCM depends on the research objectives, the data availability, and the model performance [76, 77].

In this study, an LCM was adopted to test and account for heterogeneity in the analysis of the demand for the selected bean traits in Uganda. The LCM was suitable for the study, because it allows identifying consumer segments, which can be described based on observable characteristics, such as socio-economic, demographic and geographical location. Segments enable estimating the average WTP values and investigating heterogeneity at the segment level, which would be most policy relevant when assessing the welfare impact of introducing new bean varieties to different population segments. [31] shows that the latent class model can account for scale heterogeneity and preference uncertainty. The LCM was used by [19, 37] in the Ugandan agricultural context and more recently by [35] in evaluation of health care providers' preference for payment mechanism in Kenya, by [36] to analyse consumers' valuation of cultured beef burger in United Kingdom, Spain and France and by [75] on acceptance of covid_19 vaccine in USA. Based on the log-likelihood function, Akaike Information Criterion, and Bayesian Information Criterion from data used in this study, a latent class model had the lowest absolute values compared with the fixed effects model, mixed logit model and (Appendix A).

Formally, in the LCM, the utility that individual i (i.e., consumer or farmer), who belongs to a particular segment s, derives from choosing bean variety alternative j in set t can be written as

$$U_{jit/s} = \beta_s X_{jit} + \varepsilon_{jit/s} \tag{2}$$

where X_{jit} is a vector of attributes associated with bean product (variety) alternative j in choice set t and β_s is a segment-specific vector of coefficients to be estimated. The differences in β_s vectors enable this approach to capture heterogeneity in bean variety attribute preferences across segments. Then, ε_{jit} is a vector of unobservable random component of the utility function assumed to be identically and independently distributed. We follow a Gumbel distribution, where the probabilistic response function for any individual i is

$$P_{ji/s} = \frac{\exp(\beta_s^t X_{jit})}{\sum_{j=1}^{J} \exp(\beta_s^t X_{jit})} \tag{3}$$

If M* is a segment membership likelihood function that classifies the individual into one of the s finite number of latent segments with some probability, P_{is}, the membership likelihood function for individual i and segment s is given by

$$M_{is}^{*} = \lambda_s Z_i + \xi_{is} \tag{4}$$

where ξ_{is} consists of unobserved factors and Z represents the vector of the observed socioeconomic characteristics of the individual or that of the household in Eq. 4. Several socio economic factors, such as age, dependency ratio, gender, education, and wealth status, were included in Eq. 4 based on the literature on bean consumption choices [19, 37, 39, 40]. In line with this literature, we expect that female and male consumers derived different utility from different bean attributes. Similarly, education, wealth or employment status maybe linked to preference heterogeneity for a faster cooking bean through their influence on opportunity cost of time and demand for convenience. Households with higher dependency ratio are also likely to demand for attributes that enhance their food security. Consumers with pro-change attitudes, and those that perceive beans as nutritious and health food could have higher preference for faster cooking bean varieties as prolonged cooking is associated with nutrient loss. Finally, we attempt to control for the effect of external environments on cooking time by including proxies such as regional dummies and the form of beans commonly consumed in the membership model (Eq. 4).

If we assume that the unobserved factors in the individual membership likelihood function are independently and identically distributed across individuals and segments, and follow a Gumbel distribution, the probability that individual i belongs to segment s is

$$P_{is} = \frac{\exp(\lambda_s^t Z_i)}{\sum_{s=1}^{s}(\lambda_s^t Z_i)}, \quad (5)$$

where λ_s ($s = 1, 2, \ldots S$) are the segment-specific coefficients to be estimated. These denote the contribution of the various individual characteristics to the probability of segment membership. A positive (negative) and significant λ implies that the associated individual characteristic, Z_i, increases (decreases) the probability that the individual i belongs to segment s. P_{is} sums to one across the S latent segments, where $0 \leq P_{is} \leq 1$. Following [42], we used a subjective approach to cluster the sample (based on whether they produce or do not produce beans) to reduce the effect of standard error clustering. We expected the independent and identically distributed (IID) assumption to hold within each subjectively determined subsample (that is bean- or non-bean-growing respondents).

Equations (3) and (5) are brought together to derive a latent class model that simultaneously accounts for bean variety choice and segment membership. The joint probability that individual i belongs to segment s and chooses bean variety alternative j is given by

$$P_{ijs} = (P_{ij/s}) * (P_{is}) = \left[\frac{\exp(\beta_s^t X_{jit})}{\sum_{j=1}^{J}\exp(\beta_s^t X_{jit})}\right] * \left[\frac{\exp(\lambda_s^t Z_i)}{\sum_{s=1}^{s}(\lambda_s^t Z_i)}\right] \quad (6)$$

In estimating the LCM (Eq. 6), as adopted from [44], we also modelled allocating individuals to a segment as conditional on their preferences, which, in turn, depends on their characteristics in Eq. 4. After estimating attribute coefficients in the LCM, willingness to pay or accept (WTP/WTA) can be measured as the ratio of the marginal utility of the attributes and coefficient of monetary attribute/yield. Since the attributes are binary coded {0,1}, the trade-offs are estimated using the formula in the following equation:

$$W = -\left(\beta_k/\beta_y\right) \quad (7)$$

where W is the WTP/WTA, β_y is the coefficient of the monetary attribute (in case WTP) or yield (for estimating WTA). The vector β_k are the coefficients of attributes. The negative disutility from price (cost) was used as a surrogate for marginal utility of income [44], because we did not have an accurate measure of income in the data. For consumers in bean growing households, we only computed WTP for the segment that had a negative price coefficient. Then, for the entire bean-growing households, we followed [45] and used yield to analyze farmers' willingness to accept a trade-off between each attribute (i.e., resilience to environmental stresses and grain quality) and yield to draw insights on how farmers value each attributes. We note that with a choice experiment being hypothetical, some participants might overvalue their important attributes via an assumption that researchers will be persuaded to invest, where impacts are high. In that case, our WTP/WTA could be over-estimated.

A consideration in choice experiment data is non-attribute attendance. We tested for attribute non-attendance on the urban subsample; assuming that production attribute could have been unattended to. We followed the approach used by Hess and Hensher (2010) and used the coefficient of variation to determine existence of attribute non-attendance. Three models were estimated as follows: the first model assumes climate resilience was unattended to. In the second model, we assumed that yield was unattended to and in the third model, both climate resilience and yield were assumed to be unattended to. Results in Appendix D shows that none of the models had a coefficient of variation above equal to or above 2. Hence, we conclude that there was no attribute non-attendance in sample.

Selection of attributes and choice experiment design

Our first step was defining a dry bean variety, the chosen product, in terms of its attributes and the levels of those attributes. In Uganda, dry beans are handled by different value-chain actors (from production to retail trading) and consumed by people in diverse categories of households (e.g., economic status and food culture). These diverse consumers and handlers have varied trait preferences for the raw grain and cooked product. Thus, the first step of designing the DCE involved understanding traits desired by different customers along the value chain and identifying the most important traits to consider in the choice sets.

Stakeholder consultations and a desk review of grey and published literature were undertaken, and the most important bean variety traits and their levels were identified [11, 47, 48]. This step also provided background information for the study. For example, climate-crop models predict that heat and drought will cause widespread losses in common bean yields, and this justifies more emphasis on breeding to increase heat tolerance and drought resistance [49]. Accordingly, breeders pay keen interest in a genotype's ability to consistently give high yields across environments—a combination of high levels of mean yield and yield stability [50]. The yielding capacity of a variety and its resistance to environmental stresses usually obtain high ranking from farmers during participatory variety selection [51, 52]. However, there is little literature documenting quantitative demand for these traits.

Opportunities and challenges faced by actors in the bean value chains may shape their preferences. Consultations were conducted with different types of stakeholders (i.e., processors, seed companies, urban low-grade restaurants, schools, prisons, individual consumers, farmers, traders, and key local government officials) in 2 districts in Northern region, 3 districts in Eastern region, 3 districts in Western region and 2 districts in Central region. These districts were purposefully selected to represent densely populated urban centers, important rural bean producing and consuming areas, as well as bean export transition routes. Six large-scale traders (of stock size 8–36 tonnes per month), three seed companies, one processor and two exporters were consulted. The manager of the Uganda grain council, and institutional consumers (i.e., schools, prisons) were also consulted. Additional stakeholders that included restaurant owners, small-scale traders, aggregators, and on-spot consumers were selected from major district grain markets. The district production, and marketing officers as well as the district commercial officers were key in assisting the team to get contacts of the farmers, traders, and institutional managers. Before the team consulted any one in a particular district, the leader first reported to the district headquarters to seek approval and check compliance with standard operations procedures for COVID-19 from the respective district chief accounting officer (CAOs) as well as conduct consultations with district local government staff.

Four (two females and two males) experienced researchers from the Alliance of Bioversity and CIAT, Makerere University and NARO with formal training in value-chain analysis led discussions with a total of more than 60 stakeholders. Meeting with stakeholders mostly occurred in places, where they make a living (home or workplaces) or transactions points (markets and restaurants). A checklist designed and pre-tested in a nearby market was used and focused on bean attributes important for stakeholders, current bean varieties used in their business/diets, and challenges met while handling bean varieties. Consumers were asked to mention the attributes they normally consider when purchasing beans for consumption; traders were asked about the traits their consumers look for when purchasing or ordering beans and district production officials were asked to mention the attributes they normally consider when deciding which varieties to recommend to farmers for cultivation. For each attribute mentioned, respondents were asked the rationale behind the preference. This allowed the research team to ascertain continued importance of the attribute into the future. Follow-up questions also facilitated more contextualized definitions of attribute levels.

The information from literature and stakeholder consultations was further refined in brainstorming sessions by the research team to identify converging and diverging attributes. All attributes encountered during the stakeholder consultations along the bean value chains are listed in Table 1 [51].

Six attributes that were mentioned several times during the consultations with value chain actors and/or with stronger implications for household nutrition, food security, convenience and environmental protection objectives were selected for the choice experiment. First, we included cooking time because of its multiple benefits to the consumers and environment conservation. In Uganda, beans are consumed frequently in a normal week [53], with each meal taking an average of 115 min to cook [19]. Four levels of cooking time (i.e., 120 min, 90 min, 75 min and 60 min) were selected in a range of 60 and 120 min provided by the CIAT breeders. The reference level was set at 120 min to reflect the current average cooking time. As yield has been choice driver for farmer variety selection during farmer participatory variety selection (PVS) and a pathway to achieving food security, we included four yields levels (i.e., 60 kg/0.25 acres; 90 kg/0.25; 120 kg/0.25acre and 150 kg/0.25 kg) that were selected given the average farm yield (74 kg/0.25acres), bean farm sizes [53] and variation across locations [54]. The three levels of resilience to environmental stresses (i.e., 10%, 10–30% or 30%) represent yield loss in the event of excessive rains or rain shortages during a growing season. This attribute was included to explore whether farmers' choices match the concerns of climate change. Finally, we included taste, grain swelling capacity and colour to investigate, for the first time, how intrinsic and visual attributes may be valued across consumer segments and whether they may play a role in differentiation of beans selected by growers and non-growers. Our hypothesis is that there are trade-offs towards production attributes among growers. Three qualitative levels of taste (i.e., not tasty; somehow tasty and tasty) were chosen to correspond to the highest (5-tasty), the median (3-somehow tasty) and the lowest (0-not tasty) on 5 point scale in a standard organoleptic test. The attribute "grain swelling", is a relative increase in volume after boiling beans to readiness for eating. This attribute was included to test if household food demand has any effect on bean variety choice. Grain colour: "yellow" and red are

Table 1 All traits mentioned during stakeholder consultations

Traits	Short trait definition/description
Preparation and consumption traits	
Cooking time	Duration (minutes) it takes to boil beans to reach a texture to be eaten
Grain swelling	Volume gain by the grains upon cooking
Soup thickness	boiled bean broth viscosity
Nutritional content (Zinc and iron)	Amount of zinc and/or iron in the beans. Consumers typically prefer bean grains with high amounts of the two nutrients
Taste/texture	The mouthfeel of the cooked beans before seasoning
Soup/post-cooking color	The color visually observable of the broth of the beans after boiling
Soft bean coat after cooking	Defined as resistance of the seed coat when chewing [57]. Ability of the bean coat to disintegrate in the mouth easily together with its contents after boiling the beans
Keeping fresh longer on the shelf	Maintenance of characteristics such as shiny look, cooking faster and seed coat softness exhibited by freshly dried grain for a longer time
Shelf life after cooking/keeping longer after cooking	Time in hours the boiled beans can maintain their original odor, flavor and appearance or how long these parameters are maintained at levels considered acceptable to consumers
Low flatulence	Not causing or causing little intestinal gas after their consumption
Market attributes	
Consistent color during storage	Ability of the grain to maintain original shiny color from harvest up to the end of a 6-month storage period
Grain size	Dry grain size in terms of diameter and length. Described as small, medium and large with majority preferring medium size grain
Price	Dry grain buying price from a given point of sale paid by consumers or farmers (who buy grain from markets for planting)
Production attributes	
Climate resilience/variety adaptability	Crop's ability to give consistent yields across different environments
Yield	Amount of grain in kilograms/tons harvested per unit area (normally per hectare)

[a] According to UBoS (2016), all areas gazetted as City, Municipality, Town Council or Town Board by the respective authorities can be treated as urban and the areas surrounding these as peri-urban

[a] This the average for male headed households in 2014, while that of women was 5.7 in the same year

among the popular varieties released from breeders in Uganda, but white grain is also available in some markets and emerging as an export type. Red was used as a reference, because it was the most popular on the market. Price was included as percentage increase in a retail price of dry grain reflecting changes of 0%, 15% and 30% from the status quo. Definitions of attributes' levels in DCE are summarized in Table 2. Appendix B provides detailed attribute descriptions.

The defined attributes and their levels were used in generating statistically efficient and practically manageable experimental design [55]. The seven attributes and their levels were combined into choice sets using a computer-aided discrete choice design "dcreate" package in Stata 16 [56]. The "dcreate" package creates efficient factorial designs for DCEs using the modified Fedorov algorithm to maximize the D-efficiency of the design based on the covariance matrix of a conditional logit model.

The choice sets were reduced to 84 scenarios, which were split into four blocks of seven sets and each choice set consisting of two alternatives. Blocking improves the quality of choice data without compromising the diversity of choices, minimizes respondent fatigue and improves the cognitive ability of the respondents [57]. In each choice set, options A and B offered an altered bean variety, while option C represented the status quo (opt-out). We included a no-buy option in the choice set, such that the respondent is not forced to select one of the two alternatives presented to them, which more closely mimic real purchasing decisions. The option for maintaining the status quo reflects a choice for consumers (or farmers) who may prefer to continue consuming (growing) the bean varieties currently used. The alternative-specific constant (ASC) was coded to equal 1 for option A or B and 0 for options C the [8, 37 6]. If the ASC is positive and significant, then the propensity of the individual to choose the alternative varieties is high and vice versa.

To improve the visual appeal and ease of interpreting choice sets, attributes were illustrated using images on cards. Prior to implementing the choice experiment, the designed cards were pre-tested with households in nearby communities not included in the sample, but with similar characteristics of typical bean consumers/farmer. A sample of the final set of cards is presented in Fig. 1.

The choice experiment was introduced to the respondents with an explanation and clear description of

Table 2 Attributes and attribute levels used in the choice experiments

Traits	Levels	Base level
Cooking time	a) Not fast cooking (2 charcoal stoves)-120 min b) Somewhat fast cooking (1.5 charcoal stoves)—90 min c) Fast cooking (1.25 charcoal) 75 min d) Very fast cooking (1 charcoal stove)-60 min	Not fast cooking (2 charcoal stoves)
Grain swelling	a) Does not swell b) Swells	Does not swell
Taste	a) Not tasty b) Somehow tasty c) Tasty	Not tasty
Grain color	a) Red b) White c) Yellow	Qualitative attribute
Climate resilience (yield loss)	a) More than 30% yield loss (not resilient) b) 10–30% yield loss (somewhat resilient) c) Less than 10% yield loss (resilient)	Not Resilient
Yield (Per quarter an acre	a) 60kgs/0.25 acres b) 90kgs/0.25 acres c) 120kgs/0.25 acres d) 150kgs/0.25 acres	60 kg per quarter an acre
Price	a) 30% increase b) 15% increase c) 0% increase	0% increase

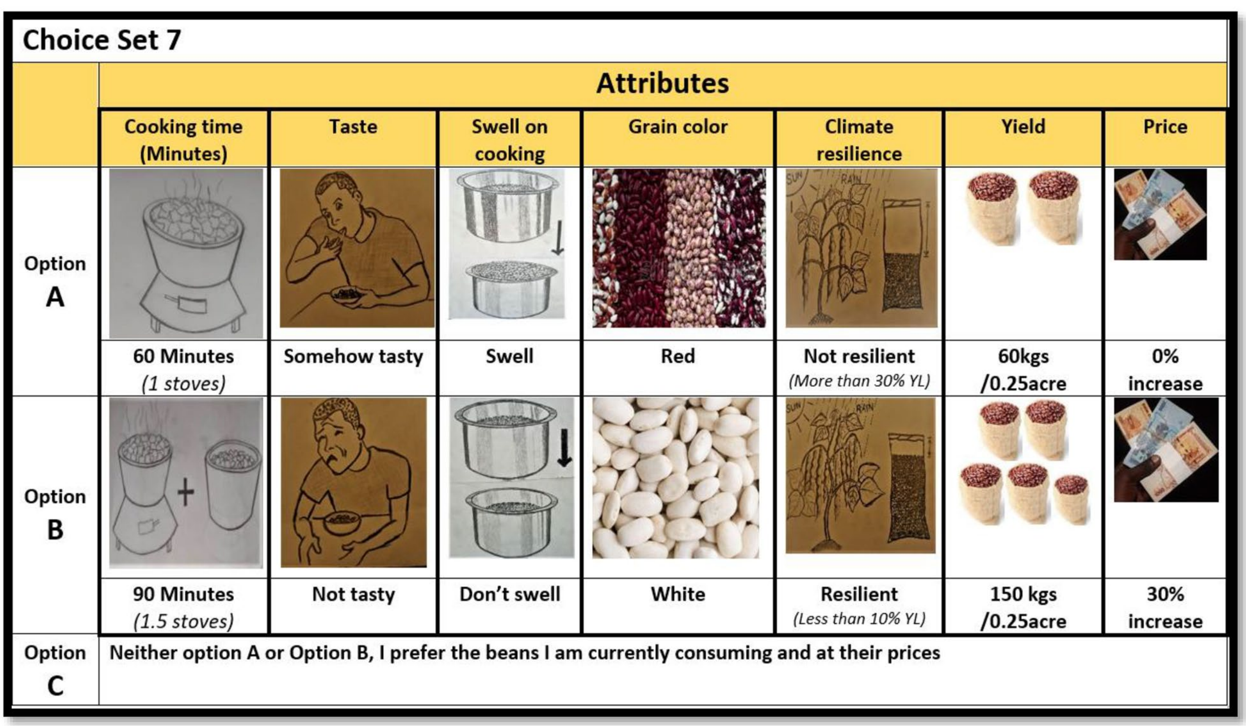


Fig. 1 Sample choice set

attributes and levels. Following [37] respondents were reminded that there was no right or wrong answer, and only their realistic choices were important. Respondents were advised to resist temptation of giving responses that aim at influencing decisions as interviewers were only interested in their opinions. Each enumerator was

Table 3 Distribution of districts surveyed (Wet zone refers to geographical areas /zones that receive normal and heavy rainfall while dry zones receive sporadic rains which is highly variable in terms of certainty of its couurence.)

Stratum (Rainfall zone)	Zonal Agricultural Research Development Institute (ZARDI)	Surveyed Districts	# districts	# villages	Sample size
Wet (normal to high rainfall)	Bulindi	Kibaale	1	2	48
	Buginyanya	Butaleja, Kamuli, Mbale* Jinja*	4	8	192
	Kachwekano	Kabale*, Rukungiri*	2	8	192
	Mukono	Butambala, Kalungu, Mityana*, Wakiso*	4	12	288
	Rwebitaba	Kyenjojo	1	2	48
	Mukono	Kiboga, Nakaseke	2	4	96
Dry (semi-arid)	Mbarara	Isingiro	1	2	48
	Nabuin	Abim	1	2	48
	Ngetta	Alebtong, Amuru, Kole, Nwoya	4	8	192
Total			20	28	1152

*Municipality districts. Source of data [60]

provided with a cheap talk script to ensure that a standard message was used across respondents in an attempt to mitigate potential hypothetical bias that typically affect choices in a stated preference studies following Cumming and Taylor, 1999 in [38].

Data source and collection

Sample size determination

Various design issues in stated choice experiments are linked and include the sample size, number of choice situations presented to the respondent, number of attributes and their levels, including their ranges. [58, 59] address the issue of required minimum sample size for providing efficient parameter estimates. Accordingly, the minimum acceptable sample size, N, is determined by the desired level of accuracy of the estimated probabilities, $\widehat{p}$. Let p be the true proportion of the relevant population (proportion of households consuming beans in Uganda), α be the level of allowable deviation as a percentage between $\widehat{p}$ and p, and γ be the confidence level of the estimations such that $\Pr(\left|\widehat{p}-p\right| \leq \alpha p) \geq \gamma$ for a given N. The minimum sample size is

$$N \geq \frac{q}{Sp\alpha^2}\left[\Phi^{-1}\left(1-\frac{1}{2}\alpha\right)\right]^2 \quad (8)$$

where $q = 1 - p$, $\Phi^{-1}\left(1-\frac{1}{2}\alpha\right)$ is the inverse cumulative distribution function of a standard normal distribution evaluated at $(1-\frac{1}{2}\alpha)$ and S is the number of choice tasks each respondent faces. Estimates show that between 80% and 90% of households consume beans in Uganda [53]. Given that data was collected around harvest or just after harvest for most parts of Uganda, consumption was expected to be high. Therefore, we used 90% for p and set α at 1%. All respondents answered 7 choice sets. Using Eq. 7, the minimum sample size required was 1054 respondents.

Study areas and data collection

Study data were collected through a survey of rural and urban-based households sampled from different parts of Uganda, where bean is an important crop or food in household diets. A stratified multistage proportionate-to-size sampling method was used to account for differences in production context and consuming population sizes. In the first stage, 69 districts from 13 bean-producing sub-regions were stratified into two strata according to climatic conditions: wet zones covering 39 districts and dry zone covering 30 districts based on rainfall received (Table 3). The second stage involved selecting districts from each stratum. Since most recent agricultural census lacked data on bean area at the district level, the probability of selecting a district was computed based on district population size and sub-region bean area. These were applied as probability weights to select 14 districts from wet zone (i.e., stratum one) and 6 districts from the dry zone (i.e., stratum two). In total, 20 districts were selected across the four major administrative regions (Central, Eastern, Northern and Western) of Uganda. Six of the districts were urban municipalities, while 14 were predominantly rural.

The survey supervisor visited the district/municipal council offices and acquired a list of sub-counties for rural districts and divisions for municipal councils. Then, a simple random sampling technique was used for selecting one division from the municipal council. In the rural districts (the remaining 14 out of 20), one sub-county was randomly selected per district from the list of sub-counties obtained from the district headquarters.

At every sub-county/division, a list of villages/wards was obtained from the sub-county/division headquarters and used to select two villages with the highest bean production. In total, 48 villages/wards were selected from the 20 districts. A list of households for each village/wards was obtained from village local council one (LCI) leaders. For villages without a listing of households, the research team constructed one with the help of village leaders. After confirming with village leaders that the village households' listing was based on geographical proximity, a random number generator was used to select 24 households without replacement. Using systematic random allocation, the 24 selected households were placed into four blocks of six households each. Each research assistant was randomly assigned to a new block number every day to eliminate enumerator bias. Overall, 1152 households were selected for the survey. Approximately, 35% of sampled households were in urban and peri-urban areas, while the rest were from the rural areas.

Data were collected through face-to-face interviews from December 2020 to February 2021 using a 4-part semi-structured questionnaire. The first part comprised of household location, demographic and socio-economic characteristics, bean preparation and consumption at the household level. The second part consisted of the choice experiment that provided data used to evaluate the trade-offs consumers make between variety attributes and price. At the time of administering the questionnaires, the seven attributes were well-explained to the respondents in English or local dialects in cases, where respondents could not understand English. The same hypothetical scenario was read out to every respondent when introducing each card. The hypothetical scenario was "Imagine you or a family member has gone to the shop or market to buy beans for eating today or planting (growers). You see three bean varieties A, B, and C. A and B are new to you, but C is what you have been mostly consuming. You are supposed to select only one of the three (no mixes). All varieties are described using seven (7) attributes. All other attributes not included are considered to be the same in all options present. Which of the three varieties A, B or C would you choose?

The third module consisted of customer attitudes and perceptions (answered by all), and beans production by the household (only answered by bean-growing households). Consumer attitudes and perceptions were expected to shape their consumption decisions. Statements related to health, nutrition, environmental, production system, market availability and price aspects of beans consumption were included in the module and respondents asked to indicate on five-point Likert scale to what extent the statements applied to them. The study used factor analysis to derive a few underlying variables for econometric modelling. The fourth part of the questionnaire covered general food consumption, main income sources, household livestock and productive assets (land, farm equipment and, off-farm income generating assets, such as sawing machines) ownership, housing conditions and ownership of household goods.

Results

Descriptive results

Descriptive sample characteristics are presented in Tables 4 and 5. The distribution of the selected sample characteristics is fairly representative of the Ugandan population (table in Appendix C.1) and some are similar to results reported in the national representative studies [61]. These comparisons validate our sample as representative of national bean growers and consumers.

Majority of the respondents in bean growing households (93%) and non-bean growing households (97%) were females, which was expected, since women are more involved in decisions of bean purchase, varieties to plant and bean food preparation. About 77% of sampled households were headed by males aged 44 years, on average, with 8 years of formal education. Growing and non-bean-growing households differ significantly in terms of their socio-economic and bean-consumption characteristics. Non-bean growing household heads were, on average, six years younger (39 vs 45 years) and more educated (10 vs 8 years of formal schooling) than their counter parts in the growers sub-sample. As expected, non-agricultural employment was higher among non-bean growers, but a bigger proportion of the households were involved in non-salaried trade and small and medium business, accounting for 70% in non-growers sample (Table 4). The dependency burden is higher among bean growers than non-growers, estimated at an average of (47% vs 43%) children aged 0–16 years per 100 working adults, respectively.

Approximately 71% of households interviewed reported that they mostly consumed beans in dry form in a wide range of colors, but popular ones were red mottled/speckled (consumed by 60%), black (consumed by 14%) and yellow (consumed by 7%). While the beans chosen for consumption were described by visual attributes, such as color, the main reasons for choosing such beans at the time of purchase were their intrinsic attributes, i.e., taste and short cooking time, good soup (table 15 in appendix C). Same attributes received high rating and ranking by consumers, as shown in table 15 in Appendix C. In Brazil [48] also found that consumers chose black beans because of their thick broth, i.e., intrinsic attribute. Besides intrinsic attribute, beans' wide adaptability to climatic conditions, tolerance to low soil fertility and demand in the market received

Table 4 Descriptive statistics of discrete characteristics of bean growers and non-bean growers subsamples

Descriptive variable	All (*n* = 1024)	(Bean growers (*N* = 786)	Bean non-growers (*N* = 238)
Sample distribution by Location (%)			
• Rural	68.85	88.68	3.36
• Urban	31.15	11.32	96.64
Sample distribution by Region (%)			
• North/Eastern	42.68	36.56	63.03
• Western	27.54	31.59	14.29
• Central	29.79	31.97	22.69
Socio = demographic characteristics (%)			
• Sex household head	43.61	45.00***	39.08
• Household head is female (proportion)	24.80	22.26	33.19 ***
• Respondent if female	94.4	92.65	97.33
Off farm employment type			
• None	37.11	46.31***	6.72
• Non-agriculture salaried	14.36	11.58	23.53***
• Non-agriculture–self-employed	48.54	42.11	69.75***
Agronomic system (%)			
• Use fertilizer	13.87)	18.078***	0
• Pesticides	26.66	34.48***	0.84
Does household mostly consume dry beans (%)	71.00	71.25	70.17
Source of energy for cooking (%)			
• Charcoal/briquette	34.08	17.94	87.39***
• Firewood	65.72	82.06 ***	11.76
• Electricity	0.20	0.00	0.84
Methods of bean preparation (%)			
• Cooked as bought or stored	80.96	78.37	89.50
• Soak before cooking	9.18	7.79	15.13**
• Use a pressure cooker	0.59	0.51	0.08
• Add rock salt/lake salt	30.18	35.75	11.76
• Add paracetamol	1.37	1.27	1.67
• Add sodium bicarbonate	0.68	0.76	0.42
Add burnt crop residue ash	4.49	5.34***	1.68
Source of bean consumed			
• Own production	63.87	82.70	1.68
• Both own production and market	11.43	14.76	0.42
• Market	24.71	2.54	97.90

Note: *t* tests were done between urban/peri-urban and rural households; **, *** indicate significance at 5% and 1% levels of significance, respectively

high ratings from farmers among the examined traits. The high rating of these attributes reflects the multiple functions of beans to farmers in Uganda as a source of food and income. There were notable differences between urban and rural bean markets, with the latter having high diversity of colors perhaps because of the bean diversity grown, since not all beans grown are marketable (some are produced for subsistence needs) creating a divergence in bean color produced and those marketed (table 15 in Appendix C). For example, black beans were popular in Northern Uganda, because these perform relatively well under drought conditions, have good taste and faster cooking. However, these are rarely marketed, because black colored grain is less competitive on the domestic market, especially in urban areas. Other bean varieties with limited marketability due to unattractive color were "Bulangiti (Aziweye)" in Gulu and Khaki in Kabale districts.

Households that source their bean from the market paid a price of USh.2751–2971 (USD 0.75–0.81)

Table 5 Descriptive statistics of continuous characteristics of bean growers and non-bean growers subsamples

Variable	All sample (*n* = 1024)	Bean growers (*N* = 786)	Bean non-growers (*N* = 238)
Age of Household head	43.61 (13.79)	44.98***(14.15)	39.08(11.43)
Household head's years of completed education	8.44 (4.09)	7.94 (3.94)	10.12 (3.9)
per capita landholding (ha)	0.656 (1.45)	0.825 (1.55)	0.10 (0.083)
Altitude	1219.558 (207.78)	1223.458 (208.605)	1206.659 (205.08)
Agricultural index			
Wealth index	− 1.05 (2.11)	− 1.38 (2.14)	0.04 *** (1.64)
Number of days in a week household normally cooks dry beans	3.53 (1.81)	3.69*** (1.87)	3.0 (1.87)
Kgs of dry beans normally cooked at a time	0.97 (0.59)	1.07*** (0.62)	0.66 (0.38
Average cooking time (minutes) per kg of dry bean	131.38 (65.02)	124.99 (62.89)	156.88*** (67.33)
Price of beans at the time of purchase (USh/Kg)	2803.73 (899.24)	2751.27*** (935.27)	2972.46 (749.78)

Note: *t* tests were done between urban/peri-urban and rural households; **, *** indicate significance at 5% and 1% levels of significance, respectively. [NB]Exchange rate Ush to USD = 3650

per kg (Exchange rate at the time of this study was 1 USD = USh.3650). At the time of the survey, the prevailing price in the urban/peri-urban areas was slightly lower than normal, but significantly higher (by about 700 Uganda shillings) than the price in the rural areas. Both the frequency of cooking beans and the average quantities of beans consumed were higher among bean growers compared to non-growers, which is consistent with findings in [53] and could be due to differences in household sizes. The average quantity of beans cooked in the growers sub-sample was 1.07 kg and significantly higher than in non-growers sub-sample (0.66 kg) (Table 5).

On average, it took 1–2 h to boil beans in dry form depending on the method used. Boiling beans in a pressure cooker took about 1.15 h[2], while other methods (charcoal or firewood) took about 2 h (Table 5). Most households (approx 71%) reported that they cook dry beans, from storage without soaking, using biomass: in form of charcoal for non-growers subsample (87%) and firewood for bean growing households (82%) (Table 4). When asked why they do not soak first; several respondents indicated that they were not used to soaking, others said soaking changed the taste of the boiled beans, while others believed that it was only applicable to very old beans that may take too long to cook. Pre-soaking and/or adding rock salt, while boiling beans was practiced by few respondents and only when they perceived beans to have over dried—thus, would take significantly more time cooking than the relatively new or recently dried beans. Accordingly, pre-soaking was prevalent at 14% among non-bean growers whose beans may take longer in storage warehouses and at only 7% for bean growers (Table 4). The average cooking time differ between growers and non-growers sub-samples, perhaps due to differences in external factors such as storage, climatic conditions that may expose the bean to hard-to-cook defect. For example, households that consume dry bean only from own production, took 29.4 min[3] lower to cook than time taken by those that obtain their dry bean from the market. Since consumers in non-growers households were more likely to buy from the market (97% vs 17.3%) than those in growers households (Table 4), it is possible that non-growers are more exposed to hard-to-cook defects than growers. However, the moisture content of dry beans was never measured during the survey.

Perceptions and attitudes towards beans

Table 6 presents mean scores of respondents' perceptions about beans linked with nutrition, health, cost and safety. The results showed that nutrition perceptions and health perceptions rated highest at 4.54 and 4.19 mean scores, respectively, on a five-point Likert scale. On the other hand, consuming beans, because they are consumed by others or buying from the same place ranked least at 1.80 and 1.88 mean scores, respectively.

Factor analysis of responses to questions about perceptions and attitudes towards bean consumption identified four factors. These were interpreted based on the variables that 'factored' together as well as the relative magnitude of the factor loadings, in absolute terms (Table 6), coefficients presented (in bold). Positive (negative) loadings in Table 6 indicate that the statement and the cluster/principal component are positively (negatively) correlated. Large absolute values of the loadings indicate that a statement has a strong effect on that principal

[2] Only six people reported using pressure cooker for boiling dry beans.

[3] Average Cooking time was 126.93min per kilogram for dry bean is sourced from the own production, and 156.36 min for dry bean sourced from the grain market.

Table 6 Factor analysis of perceptions of and attitudes towards bean consumption

Variable	Rotated factor loadings				Mean	Std. dev
Perception and attitudinal statements	***Factor1* Altruistic and open to change**	***Factor2* Health and nutrition**	***Factor3* Conservative**	***Factor4* Price sensitive**		
Statements coded according to the 5-point Likert Scale: *1 = Definitely does not apply; 2 = Somehow does not apply; 3 = Neutral; 4 = Somehow applies; 5 = Definitely applies*						
I consume beans, because they are a healthy option compared to animal protein (Perceptions about healthy diets)	0.03	0.79	0.10	− 0.02	4.19	1.23
I consume beans, because they are nutritious (perception about nutrition)	0.04	0.80	− 0.03	− 0.01	4.54	0.83
I consume beans, because their production is friendly to the environment (perception about the environment)	0.28	0.33	-0.17	0.43	3.45	1.47
I consume beans, because they are affordable compared to other sauces (perceptions about price)	0.12	− 0.14	0.02	0.78	4.06	1.35
I consume beans, because I want to help farmers who grow them earn some money	0.63	0.13	− 0.15	0.21	2.28	1.54
I would prefer traditional bean varieties to improved ones	− 0.03	0.18	0.59	0.16	2.72	1.58
I consume this variety, because it is being consumed by others	0.75	0.02	− 0.00	0.05	1.8	1.33
I consume this variety, because it is what is available in nearby market	0.68	0.03	0.09	0.18	2.54	1.56
I consume this variety, because it is what I grew up consuming	0.62	− 0.02	0.32	0.12	2.65	1.68
I always purchase beans from the same place	0.49	− 0.10	0.45	− 0.20	1.88	1.29
I always buy the same variety of beans if it is available on the market	0.10	− 0.10	0.77	0.04	2.89	1.61
Price is the first factor I consider before purchasing beans in the market	0.12	0.05	0.23	0.62	3.31	1.66

component. The first factor labelled 'altruistic (showing concern about others wellness) and open to change' perceptions, consisted of questions related to attitudes and behavior of consumers driven by the interest to help others and/or interest in environmental conservation. This factor included questions on bean variety consumption because of others' consumption, whether it would help farmers earn an income, whether it is available in nearby market or, whether it is what they grew up consuming. The second factor, 'health and nutrition' consisted of attitudes and behaviors of consumers driven by healthy and nutritional motives. The questions that were grouped together included those related to beans being perceived as healthier than animal-based foods and beans being perceived to be nutritious. The third factor, labelled, 'conservative' perceptions, represented consumers who were conservative in their choice of bean varieties to consume. This group of consumers stated that they would prefer traditional bean varieties to improved ones and would always buy the same variety of beans if it is available on the market. The fourth factor labelled 'price sensitive' group—are consumers who choose beans, because they are a cheaper option compared to other foods and for whom price is the first factor considered when purchasing beans.

Indices for each factor loading were created by calculating the factor scores for each household. For all indices, higher values indicated stronger perceptions or attitudes towards bean consumption. The calculated indices were used as class predictors in estimating the membership function in the LCM to account for the influence of perceptions and attitudes in consumer preferences.

Econometric results from the latent class model

Equation 6 was estimated using the Stata 16 lclogitml2 package [36, 45]. An LCM was estimated for the full sample and the results compared with LCM estimates from separate subsamples: bean-growing and non-bean-growing subsamples. Households in the bean growing subsample were mainly rural-based, situated about 2kms from the nearest bean market, and consuming beans mainly from their own production.

Since different variables explain heterogeneity in the two subsamples, separate models provided results that are more robust. Accordingly, subsequent analyses were based on separate subsamples. The non-growers model was estimated from 1666 choices based on data from 238 respondents, while the bean growers' model used 5502 choices from 786 respondents. Two alternatives with varying attribute levels and the no-buy option were

Table 7 Criteria for determining the optimal number of segments

Segments	Number Parameters	LLF	CAIC	BIC
Model 1—Non-bean growing households				
2	40	− 757.32	1751.72	1711.72
3	65	− 717.64	1820.56	1755.56
4	90	− 698.54	1930.53	1840.52
Model 2—Bean growing households				
2	42	− 3218.48	6742.18	6700.18
3	69	− 3162.44	6826.32	6757.32
4	96	− 3093.95	6885.54	6789.54
5	123	− 3042.39	6978.64	6855.64

included in the specification of the utility function. All attribute variables (except price) were dummy coded, given a value of one where applicable and zero otherwise. In the next step, the number of segments was determined based on the Bozdogan consistent Akaike Information Criterion (CAIC) and Bayesian Information Criterion (BIC) statistics for each model (Table 7). Following [8], we estimated each model with varying numbers of segments, and assessed changes in the BIC and CAIC statistics. The BIC and CAIC statistics were minimized in two segments, indicating that it provided the optimal solution in this empirical application. The second segment coefficients for LCM model in either subsample (bean-growing and non-bean growing) were normalized to zero to allow identifying the remaining coefficients in the model's membership function [35]. All other coefficients were interpreted relative to this normalized (second) segment. Other work [62] shows that membership coefficients of base segment (two) in the membership function can be implicitly interpreted in relation to the signs of the estimated statistically significant parameters for the non-base segments.

We first present and discuss results from the non-bean growing households who are pure consumers and mostly urban-based, and then follow with results from estimations within the bean-growing plus bean-consuming households' subsample.

Results for non-bean growing subsample

Two-segment LCM estimates of non-bean growers' attribute preferences Results are reported in Table 8. The upper part of the table presents the utility coefficients associated with bean attributes, while the lower part shows the coefficients of the segment membership determinants. Results suggest that bean consumers who did not grow beans they consume belonged to two segments of homogenous preferences (Table 8). The two segments showed a positive and significant ASC, which implies that respondents in both segments preferred the alternative bean varieties to the ones they are currently consuming. A higher ASC for segment two than for segment one implies that segment two respondents were less satisfied with their currently consumed beans and thus more likely to take up the new varieties presented.

Segment one was the largest, accounting for 72% of non-bean-growing households. Consumers in this segment derive high utility from several attributes, particularly, taste; cooking time; grain swelling capacity and grain color. These attributes provide a positive and significant effect on consumers' utility in this segment. Taste had the greatest positive coefficient indicating that this attribute is the most important determinant of bean choice for consumption and was followed by cooking time and grain swelling capacity among the majority of non-bean growers. Taste had a highly significant effect on utility for segment one than for segment two consumers. Customers in segment one also preferred red to white beans, but were indifferent between yellow and red.

The membership coefficients indicate that being female and having a higher education level increased the likelihood of belonging to segment one. However, the effect of education diminished after attaining secondary level, meaning that additional qualifications do not influence customer preference for beans. Consumers that are altruistic and open to change are also likely to belong to segment one, while consumers that are price sensitive have less likelihood of membership in this segment. We labelled this segment the "*choosy non-poor*" (*balance non-poor consumers*) consumers, because members in this segment-derived utility from many attributes, have higher levels of education, and are less sensitive to bean prices.

Results also revealed differences in ranking of attributes between consumers in segment one and segment two (constituting 28%). Consumers in segment two derive greater utility from cooking time and taste but are indifferent when it comes to color and the grain swelling capacity. We labelled this segment as "*not so choosy poorer*" (*price conscious not so choosy*) consumers, since members in this segment experienced greater disutility from higher levels of the price and easily accepted a wide range of grain colors.

Characterization of segments: non-bean growers profiling The relative size of each segment was estimated by inserting the estimated coefficients of each model separately into Eq. (5). This generated a series of probabilities that a given household belongs to either of the two segments. Each household was assigned to a segment, where it showed the largest probability of membership [8].

Table 8 Two-segment LCM estimates of non-bean growers' attributes preferences

	Segment 1		Segment 2	
	Utility function: bean variety attributes			
	Coefficient	Std. err	Coefficient	Std. err
Natural log of price	− 1.60*	0.76	− 7.20**	2.42
Cooking time = 60 min	0.67***	0.23	0.95	0.67
Cooking time = 75 min	0.84***	0.3	− 1.48*	0.79
Cooking time = 90 min	0.65**	0.23	2.17***	0.63
Tasty	2.44***	0.25	1.45**	0.63
Somehow tasty	1.36***	0.27	− 0.20	0.78
Beans swell	0.78***	0.21	− 0.48	0.5
White color grain	− 0.39*	0.21	− 0.17	0.44
Yellow color grain	0.18	0.16	− 0.52	0.52
Resilient (less than 10% loss)[a]	− 0.50**	0.23	− 0.27	0.5
Somehow resilient (30–10% loss)[a]	− 0.33**	0.16	− 0.60	0.45
Yield = 150 kgs/0.25acre	− 0.03	0.22	− 0.37	0.66
Yield = 120 kgs/0.25acre	0.11	0.23	1.73**	0.68
Yield = 90 kgs/0.25acre	0.25	0.17	0.17	0.46
Alternative-specific constant	0.83**	0.37	1.98**	0.8
Segment membership function: individual/household characteristics				
Respondent is from Eastern/Northern region[&]	2.03	1.79	–	
Respondent is from Western region[&]	1.51	1.43	–	
Respondent is female	1.93**	1.02	–	
Dependency ratio	3.23	1.98	–	
Respondent has some secondary education	0.53	0.65	–	
Respondent has tertiary education	0.12	0.73	–	
Age of the respondent in years	0.01	0.03	–	
Altruistic and open to change perception	0.79**	0.35	–	
Health and Nutrition perceptions	− 0.49	0.33	–	
Household mostly consumes dry beans	1.53	0.95	–	
Natural log of quantity of beans consumed	1.25***	0.63	–	
Wealth proxy (proportion of income spent on food	0.11**	0.17	–	
Type of Off farm employment			–	
dummy-Non-agricultural Employment-Salaried	0.97*	0.65	–	
dummy-Non-agricultural employment–non-salaried (combines casual + petty trade)	− 1.38**	0.96	–	
Natural log of altitude	1.66	1.72	–	
Constant	− 14.18	13.37	–	

Notes: [a] Loss as a result of either above or below normal rainfall; Significance levels—10% (∗), 5% (∗∗), and 1% (∗∗∗)

Descriptive statistics for the characteristics of each segment are given in Table 9.

Results indicate that three quarters of the non-bean-growing subsample belonged to the "*choosy non-poor"* households. Most respondents in this segment were younger females residing in households with a higher proportion of working members and slightly larger in size. These households bought beans in larger quantities, but less frequently compared to households in segment two and had average positive wealth index; constructed using the principal component approach adopted from the method by the World Bank as elaborated by [63]. The *choosy non-poor*, non-bean-consuming households were mainly headed by men and about 68% of them consumed beans in dry form—thus experienced long time cooking beans. Their average cooking time of one kg of beans was 127 min as most (86%) cooked them without pre-soaking. Approximately 50% of consumers in this segment were likely to buy the same variety repeatedly as long as it

Table 9 Characterization of non-bean growers

Segment (% share)	1 (72%)		2 (28%)		t test statistic
Segment descriptors	Choosy non-poor consumers		Not choosy, bottom poor consumers		
Variable	Mean	Std. Dev	Mean	Std. Dev	
Respondent is female	0.93	0.25	0.83	0.38	8.15***
Age of the respondent (years)	32.01	11.79	34.36	9.85	− 4.74***
Age of the household head (years)	39.02	11.58	36.44	9.62	5.30***
Household head's years of completed education	10.68	3.88	10.00	3.80	4.05***
Number of people living in the household	5.10	2.45	4.97	2.13	1.29
No. of household members eating lunch at home	4.31	2.60	4.24	2.21	0.61
No. of household members eating supper at home	5.03	2.49	4.51	1.74	5.09***
Proportion of working to total household members	0.38	0.19	0.32	0.16	6.84***
Number of days in a week dry bean are cooked	2.82	1.79	2.82	1.75	− 0.04
Distance (Kms) to the nearest bean market	0.41	0.60	0.34	0.44	2.57***
Kgs of beans purchased at a time	3.29	10.01	1.62	1.51	4.38***
Kgs of dry beans cooked at a time	0.69	0.36	0.56	0.25	9.05***
Number of children in the household	2.53	1.76	2.66	1.97	− 1.75*
Household wealth index score	0.16	1.83	− 0.13	1.46	3.86***
Number of days household last bought beans	0.48	2.12	0.06	0.23	5.28***
Altruistic and open to change perceptions	− 0.21	0.97	− 0.58	0.56	9.46***
Health and nutrition perceptions	0.14	0.82	0.21	1.01	− 1.76*
Conservative perceptions	0.22	0.96	0.01	0.99	4.92***
Price sensitive perceptions	− 0.25	1.07	0.46	0.90	− 15.60***

T tests show significant differences between the two segments at the 10% ($*$), 5% ($**$), and 1% ($***$) significance levels

is available on the market, thus we can say that they had conservative choices.

Households in the *not choosy poor* segment were smaller in size and represented about one quarter of consumers in non-bean growers. They had a negative average wealth index (poor), were less educated, had fewer working household members and were more likely to buy beans in small quantities but at a higher frequency. They were extremely price sensitive and did not mind about grain color. In other words, consumers in *not choosy poor* segment bought beans available on the market as long as their taste and cooking time preferences were met. Consumers in choosy non-poor segment though open to change were more conservative compare to consumers in *not so choosy poor* segment. They resided closer to market outlets, where they bought their grain and perhaps had better access to bean market information than choosy non-poor consumers who resided slightly far from the market. In the Ugandan context, retail outlets selling dry beans tend to be concentrated in slums because of low rental costs. Thus, consumers in segment two (*not choosy poor*) may buy more frequently, because they are nearer the market or because they lack ability to purchase in large quantities, since they live from hand to mouth. Consumers in *not choosy poor* segment ate bean as frequently as those in segment one (i.e., *choosy non-poor*) but their quantities are smaller compared to that consumed by the latter, perhaps because they have less access due to resource constraints.

Willingness to pay among non-bean growing consumers All consumers in non-bean growing households were willing to pay a high premium price for shorter cooking time and taste. Consumers in segment one (*choosy non-poor households*) were willing to pay 41 shillings, 53 shillings and 43 shillings above prices at the time of the survey for reduction in cooking time from 120 (status quo) to 90, 75, and 60 min, respectively (Table 10). Members in the same segment would also pay 152 shillings premium for tastier beans higher than price they would pay if beans were not tasty (baseline scenario) and 11.4 shillings premium for yellow-colored over red beans, but will require a discount of 24.4 shillings if they were to choose white over red beans. Grain swelling is another intrinsic trait valued by majority of the consumers in segment one; willing to pay 48shilling above the current price, while WTP was not significant for segment two.

On the other hand, consumers in segment two (*not choosy poor households*) were price sensitive, meaning that their preferences did not translate into purchasing

Table 10 Segment-specific valuation of bean variety attributes

Attribute	Segment 1 (*Choosy non poor consumers* Coef. (95% CI)	Segment 2: *not choosy poor consumers* Coef. (95% CI)
Cooking time = 60 min	41.69** (1.41–81.96)	13. 22* (1.43–27.89)
Cooking time = 75 min	52.50* (3.07–108.09)	– 20.66 (– 46.35–5.02)
Cooking time = 90 min	40.67* (0.33–81.67)	30.22*** (14.36–46.08)
Tasty	152.09** (8.65–295.52)	20.15** (3.08–37.22)
Somehow tasty	84.53** (0.50–168.57)	– 2.79 (– 24.94–19.36)
Beans swell	48.50* (– 5.01–102.03)	– 6.69 (– 20.25–6.86)
White color grain	– 24.39* (– 61.20–13.97)	– 2.40 (– 13.96–9.16)
Yellow color grain	11.39** (– 8.64–31.43)	– 7.18 (– 21.77–7.41)
Resilient (Less than 10% loss)[a]	– 31.24** (– 61.20–01.21)	– 3.79 (– 17.65–9.48)
Somehow resilient (30–10% loss) [a]	– 20.51 (– 43.77–2.76)	– 8.27 (– 19.81–3.27)
Yield = 150 kgs/0.25acre	– 1.62 (– 28.39–25.14)	– 5.14 (– 22.33–12.03)
Yield = 120 kgs/0.25acre	6.55 (– 22.69–35.82)	24.11* (2.66–45.55)
Yield = 90 kgs/0.25acre	15.89 (– 9.23–41.02)	2.24 (– 10.19–14.91)

Significance levels—10% (∗), 5% (∗∗), and 1% (∗∗∗)

[a] Loss as a result of either above or below normal rainfall

power. For example, though these consumers desire reduced cooking time, the highest average WTP for this trait was 36 shillings above the price at the time of the survey for a reduction in cooking time of 25 percent (i.e., 90 min down from 120 min). Cooking time of 75 min was insignificant, suggesting that a further reduction from 90 to 75 min was not a significant reduction for this segment. However, reduction to 60 min was significant and fetched an additional 13 shillings on top of the prevailing price, holding other factors constant. Similarly, their WTP for taste was seven folds lower than that of consumers in segment one.

Results from bean-growing subsample

Two-segment LCM estimates of bean growers' attribute preferences Two segments were identified in the subsample of bean growing households, majority (89%) of whom are located in rural areas. The positive and significant ASC showed that respondents in both segments preferred the alternative bean varieties to the status quo (the one they currently have). The two segments were similar in terms of loading evenly on both production and consumption-related attributes of beans—thus mindful of both production and consumption traits. Results suggested that bean growing households preferred production and consumption attributes in hierarchical order, with preference for taste, yield and climate resilience weighed highest. Similar to urban consumers, reduced cooking time was preferred among rural bean growers, but seemed to weigh lower than taste, high yielding capacity and climate resilience traits (Table 11). The price attribute had a positive and significant coefficient in segment two, which contradicts traditional wisdom of price coefficient carrying a negative sign. This was surprising and could be that price among segment two consumers was interpreted as a quality signal based on signaling theory [43].

Respondents from the Central region with higher access to bean traders participating in national or international markets were more likely to be members in segment two than in segment one. Other factors that influenced segment membership were population pressure (proxied by per capita land size), use of fertilizers/ use insecticide, and respondent's beliefs towards others (Table 11). These findings were consistent with those from some other studies conducted in Uganda (e.g., [, 1937].

Characterization of the bean growers' segments Table 12 presents the descriptive statistics for the characteristics of each segment. The results showed that 38% of bean-growing households belonged to segment one and 62% to segment two. Being mainly rural, these households were generally farther away from the bean markets (about 2kms). The households in segment one had a significantly higher agricultural asset index and more tropical livestock units than those in segment two households, thereby portraying the former as wealthier agricultural households. In addition, segment one respondents were more likely to be female (61%), comprising mainly of youth and middle-aged farmers (below 55 years) compared to respondents

Table 11 Two-segment LCM estimates of bean growers' attributes preferences

Attribute	Bean growing sub-sample			
	Segment 1		Segment 2	
	Coefficient	Std. err	Coefficient	Std. err
Natural log of price	− 2.74***	0.83	2.49***	0.35
Cooking time = 60 min	0.29	0.22	− 0.00	0.13
Cooking time = 75 min	0.33*	0.19	0.18*	0.09
Cooking time = 90 min	0.56**	0.21	0.31***	0.11
Tasty	2.25***	0.19	1.24***	0.09
Somehow tasty	1.12***	0.2	0.65***	0.09
Beans swell	0.63***	0.15	0.51***	0.07
White color grain	− 0.06	0.22	− 0.36***	0.1
Yellow color grain	0.62***	0.17	0.35***	0.07
Resilient (less than 10% loss)[a]	1.23***	0.19	0.93***	0.1
Somehow resilient (30–10% loss) [a]	1.22***	0.19	0.82***	0.09
Yield = 150 kgs/0.25acre	1.32***	0.23	1.11***	0.11
Yield = 120 kgs/0.25acre	0.92***	0.21	1.11***	0.11
Yield = 90 kgs/0.25acre	0.96***	0.26	0.71***	0.12
Alternative-specific constant	4.38***	0.39	0.76***	0.17
Segment membership function: individual/household characteristics				
Respondent is from Eastern/Northern region[&]	− 0.58**	0.28	–	
Respondent is from Western region[&]	0.21	0.62	–	
Respondent is female	0.21	0.26	–	
Dependency ratio	0.71	0.58	–	
Respondent has some secondary education	0.03	0.27	–	
Respondent has tertiary education	0.37	0.38	–	
Age of the respondent in years	− 0.01	0.01	–	
Altruistic and open to change perception	− 0.55**	0.12	–	
Health and Nutrition perceptions	− 0.01	0.12	–	
Household mostly consumes dry beans	− 0.39	0.28	–	
Natural log of quantity of beans consumed	0.07	0.22	–	
Wealth proxied by Agric assets	0.11**	0.09	–	
Type of Off farm employment			–	
dummy-Non-agricultural Employment-Salaried	0.02	0.36	–	
dummy-Non-agricultural employment-non-salaried (combines casual + petty trade)	− 0.26	0.31	–	
Farm size in acres	0.01	0.02	–	
Household used fertilizer in the most previous production season	0.67**	0.35	–	
Household used pesticides in the most previous production season	− 0.45**	0.27	–	
Household used improved in the most previous production season	0.52	0.43	–	
Natural log of altitude	0.35	0.87	–	
Constant	− 2.92	6.06		

Significance levels—10% (∗), 5% (∗∗), and 1% (∗∗∗)

^Loss as a result of either above or below normal rainfall

in segment two that had more elderly farmers. Likewise, segment one dominated segment two in having members with secondary and tertiary education as well as conservative attitudes towards food choices. We label segment one the "*resource endowed*" bean-growing households.

On the other hand, segment two members predominantly consumed beans from their own production and were more likely than members in segment one to consume a mix of dry and fresh beans. Although use of charcoal as a source of cooking fuel was low in the rural areas, more segment one (18%) than segment two (15%)

Table 12 Characteristics of bean-growers' segments

Segment (% share)	Segment 1 (38%)		Segment2 (62%)		*t* test statistic
Segment description	*Resource endowed households*		*Resource constrained households*		
Variable	Mean	Std. Dev	Mean	Std. Dev	
Region					
Central region	0.26	0.44	0.34	0.47	− 8.45***
Eastern region	0.04	0.20	0.03	0.18	1.56
Northern region	0.31	0.46	0.3	0.46	0.68
Western region	0.39	0.49	0.32	0.47	6.92***
Household is in the normal to high rainfall belt	0.50	0.50	0.49	0.50	0.96
Respondent is female	0.61	0.49	0.59	0.49	2.06**
Age of the respondent (years)	39.62	14.36	41.21	13.8	− 5.74***
Respondent is 35 years or younger (proportion)	0.47	0.50	0.39	0.49	8.20***
Respondent is 55 years or older (proportion)	0.14	0.35	0.19	0.39	− 2.29***
Education					
Some primary education	0.52	0.50	0.6	0.49	− 8.58***
Some secondary education	0.31	0.46	0.28	0.45	3.70***
Some tertiary education	0.17	0.37	0.12	0.32	7.46***
Number of people living in the household	5.93	2.53	6.11	2.61	− 3.48***
Number of people earning income	0.37	0.22	0.34	0.20	7.88***
Household assets index	− 0.17	1.55	− 0.21	1.58	1.22
Agricultural assets index	0.63	1.59	0.42	1.31	7.14***
Tropical livestock units	11.04	10.41	4.07	7.35	5.45***
Perceptions towards beans					
Altruistic and open to change	− 0.23	0.65	0.13	0.91	− 22.59***
Health and nutritious	0.0002	0.015	0.04	0.01	− 2.18**
Conservative	0.04	0.02	− 0.06	0.01	4.69***
Price sensitive	0.06	0.02	0.01	0.012	1.96**

T tests show significant differences between the two segments at the 10% (∗), 5% (∗∗), and 1% (∗∗∗) significance levels

members used charcoal to cook beans. Since charcoal is costlier than firewood, we interpreted the results to mean that households in the resource-endowed segment experienced higher cooking costs than those in segment two. This partly explains the higher coefficients of cooking time for segment one compared to those exhibited in segment two. The resource endowed growers were also more likely to be conservative and sensitive to price, perhaps because this group purchases seed compared to resource constrained growers. On the other hand, members in segment two were more altruistic and open to change between bean types and were more likely to perceive beans are health and nutritious food.

Willingness to pay/accept (trade-offs) among bean growing consumers The marginal value of each bean attribute in columns 1 and 2 of Table 13 represents the farmer's WTA compensation to forego an attribute, while column 3 of the same table shows the marginal WTP for the attribute by farmers in segment one. Across the two segments, the marginal value of resilience and taste was consistently significant for all levels, with larger magnitudes. This implies that farmers would require larger increases in yield if they were to forego adopting varieties with environmental stress resilience. For example, farmers in segment one would need a variety with yield superiority of at least 210 kg per acre for them to accept it when it is non-tastier, and 134 kg/acre for them not to adopt the resilience trait (loss only 10% yield in case of environment stress) in favor of a non-resilient variety (more than 30% potential yield loss in the event of environmental stress). This showed how important taste and resilience are to farmers. Similarly, the marginal value for bean grain swelling capacity and cooking time was significant in both segments, meaning that these two attributes were also important among bean growing households. Growers in resource constrained segment represented the majority of bean-growing households (62%) and valued the same attributes as growers in segment one but to a lesser extent. Their willingness to accept seemed not different from that of segment one households, but the former-derived higher value from red color vs white compared to segment one growers.

Table 13 Segment-specific valuation of bean variety attributes

	Willingness to accept (WTA)		WTP
	Column 1	**Column 2**	**Column 3**
Attribute	Segment 1: Resource-endowed bean growers	Segment 2: Resource-constrained bean growers	Segment 1: Resource-endowed bean growers
	Coef. (95% CI)	Coef. (95% CI)	Coef. (95% CI)
Cooking time = 60 min	38*(– 2.26–78.86)	4.80 (– 18.54–28.14)	10.59 (– 7–28.17)
Cooking time = 75 min	20.42 (– 13.79–54.63)	15.74* (– 2.04–33.52)	12.21 (– 2.77–27.19)
Cooking time = 90 min	38.26 *(0.12–76.43)	30.05** (9.10–51.00)	20.41** (3.22–37.61)
Tasty	210.23*** (127.00–293.47)	92.91*** (70.43–115.39)	82.00*** (33.82–130.19)
Somehow tasty	110.06*** (54.77–165.25)	37.06*** (18.69–55.44)	41.01*** (13.17–68.86)
Beans swell	72.13*** (35.96–108.66)	27.49*** (15.16–39.81)	23.15** (2.88–43.41)
white color grain	– 17 (– 55.97–21.44)	-8.49*** (– 7.16–24.14)	2.01 (-13.35–17.37)
Yellow color grain	46.75*** (15.36–78.13)	43.21*** (27.29–59.13)	24.69*** (8.22–41.16)
Resilient (Less than 10% loss)[a]	134.97 (45.68–142.93)	67.62*** (44.55–90.69)	44.87** (10.69–79.06)
Somehow resilient (30–10% loss)[a]	94.31*** (45.69–142.93)	57.26*** (39.16–75.37)	44.66*** (17.58–71.75)
Yield = 150 kgs/0.25acre	–	–	47.98*** (21.21–74.74)
Yield = 120 kgs/0.25acre	–	–	33.54*** (12.64–54.45)
Yield = 90 kgs/0.25acre	–	–	35.2*** (15.78–54.63)

Significance levels—10% (∗), 5% (∗∗), and 1% (∗∗∗)

[a] Loss as a result of either above or below normal rainfall

Before we turn to WTP, it is important to note that price had a positive coefficient for resource constrained bean growers. Thus, the marginal value for WTP for an attribute was estimated for farmers in segment one only, where price had a negative and significant coefficient but omitted for segment two, because a positive price coefficient could not permit estimation of realistic WTP. The segment one (i.e., *resource endowed*) bean-growers demonstrated WTP for the traits important to them. Among the bean traits examined, they showed highest WTP for taste, followed by yield and resilience. Their value from cooking time was similar to the value they obtained from yellow color, but lower than that derived by segment two growers. The *"resource endowed"* bean-growing households would pay a 20 shillings mark-up for fast-cooking beans at 90 min but would not pay premiums for any further reductions.

Discussion

This study explored consumers' preferences for selected intrinsic and extrinsic attributes of common bean using choice experiment data from non-bean growing and bean-growing households. An important aspect identified for consumers in bean growing and non-growing households was its sensorial characteristics. Taste has an overriding importance in determining consumption quality of beans and was the most preferred intrinsic attribute among bean growing and non-bean growing consumers. Cooking time is valued, because shorter cooking time implies saving on the cost of cooking fuel, water and time spent in the kitchen. Faster cooking varieties enable use of less biomass fuel, lesser time spent watching over beans as they cook, which, in turn, leads to lower budget spent on consuming beans. For example, the average cooking time for dry beans is 128 min per kg, at a cost of US$ 1.40 spent on biomass fuel, water and time. In terms of possible savings, a consumer can save about U$0.49 per bean meal and about US$1.68 in cooking beans per week, considering an average of 0.97 kg of beans cooked per meal and 3.53 times of cooking per week, after breeding successfully introduces beans with 35% reduced cooking time. However, there were differences in WTP for reduced cooking time between growers and non-growers perhaps due their differences in purchasing power or the cost of cooking. As shown from descriptive results and also noted in [19 14], most urban-based consumers use the high-cost energy fuel source (charcoal)[4], while rural-based consumers use firewood (i.e., cheaper cooking fuel). Charcoal is popular among urban consumers, because it is more convenient, given

[4] Charcoal costs twice as much as firewood and costs same as buying beans.

urban housing conditions and lifestyle. For example, households living in one-roomed houses or apartments lack space to accommodate use of firewood (i.e., cheaper cooking fuel)[5]. The few households with space that would allow use of firewood are employed in demanding jobs or businesses, thus lacking time for kitchen work. Besides, using a relatively expensive source of fuel (Charcoal vs firewood), consumers in urban depend on the market for the beans they consume.

Grain swelling is another intrinsic trait valued by majority of the consumers in urban and rural, albeit with different weight. The trait allows more people to be served with the same one kilogram of grain prepared as revealed by one restaurant owner during stakeholder consultations along the value chain. She said, "*I used to cook and serve a variety called Masavu to my customers because of its bigger grain and faster cooking. However, Masavu does not swell like the variety Nambale short. With Nambale short, I can serve 8–9 people (meal portions/plates) from one kg of Nambale short and yet with Masavu I cannot go beyond 6 plates* "(Own survey). Similar findings were reported in [64] for African rice consumers. However, the *resource-endowed* bean growers differed from the *choosy non-poor* consumers in urban areas in their willingness to pay for intrinsic attributes, such as grain swelling capacity. For example, "*resource-endowed farmers*" were willing to pay half the price mark-up of what non-poor consumers in non-bean growing households were willing to pay for grain-swelling capacity. This can be attributed to differences in cost of accessing beans for consumption, being higher among non-bean growing than bean-growing households.

For the bean growers, yield and resilience were deemed more important among resource constrained growers and came second after taste among resource endowed growers. Yield got the same and highest weight as taste among the resource-constrained producers; revealing heterogeneity in the way traits are valued across farmers. The strong preference for yield and resilience among the resource constrained producers reflects changing production conditions, including decreasing landholding exerting more pressure as well as effects of climate change. For example, growers in resource constrained segment, on average, possess 0.1 ha less land per person than those in resource endowed segment. Resource constrained growers were also farming in low elevation areas compared to resource endowed, which exposes them to weather vagaries, such as floods, high disease pressure; thus the higher demand for resilience to environmental stresses.

The analysis of the latent class model provided a nuanced understanding of bean customer preference heterogeneity, showing that Ugandan bean consumers fall into four distinct segments of homogenous preferences—two among the bean-producers and two among the non-bean producers. The consumers in non-bean-growing households were composed of *choosy non-poor (72%)* and *not so choosy poor* (28%) consumers. The *choosy non-poor* consumers derived value from many traits, putting their highest weight on taste followed by reduced cooking time and grain swelling. These consumers are from households with most members working outside homes and thus needing convenience to cope with changes in lifestyle and increasing costs of urban living. The more educated household heads and female respondents were likely to belong to this segment. Female respondents may have higher preferences for reduced cooking time via two linkages. First, females endure more burden of cooking, their higher preferences might be explained by additional convenience provided by the trait. In Uganda, it is uncommon to find a husband or a son cooking beans, though, in majority of the households, especially urban areas, men pay for fuel and water used in cooking food. Thus, both women and men are expected to benefit, but in different ways as observed among Kenyan rural bean growers [39]. Bean processors will also benefit from reduced cooking time by saving on electricity. Second, some females were from female headed households, whose per capita bean consumption was observed to be higher than that of their male counterparts. This might increase their per capita cost savings from the trait; thereby contributing to its higher valuation. The *not choosy poorer* consumers showed consistent preference for fewer intrinsic attributes (only taste, reduced cooking time and yield), with price and yield regarded as important by this group, which signals scarcity and food insecurity concerns.

Among the bean growing households, the resource-endowed farmers were more discerning about the beans they bought and consumed, less likely to be influenced by the social environment, and more likely to invest in yield-boosting technologies, such as fertilizer. They have a higher propensity to consume dry beans, and preferred yellow-colored to white beans. These preferences reflect synchronization with the non-growers' consumers' preferences. This synchronization with the non-growers' market implies that this is a more commercially oriented segment among bean-growing households in the rural areas. In contrast, the resource-constrained bean growers

[5] when one lady was asked why she does not use a cheaper option, i.e. firewood, she had this to say "*firewood would be cheaper as it costs Sh.1000 vs Sh.2000 (charcoal) for the amount of beans I cook per meal*,"

(second segment are 62% of the growers sub-sample) were more land-constrained, and had less diverse income sources. They were also more likely to augment bean own production with sourcing from the market to meet their consumption requirements and more ubiquitous in terms of preferring both yellow and red beans to red. However, their use of insecticides could signal more of a response to production constraints, such as increased incidence of pests, diseases, and reduced soil fertility than any commercial orientation. Thus, it is not surprising that they derive the highest value from resilience traits.

Conclusions

The study confirmed that while majority of urban bean consumers do not have clear preferences for production traits, there seems to be emerging market segments with differential preferences for consumption traits and desires for convenience and reduced cooking costs. Urbanization is increasing diversity of needs besides meeting food expenditure budgets [65], and increase in the opportunity cost of time as more people work away from home. Therefore, it is important for the common bean breeding program to be driven by economic benefits for customer; particularly improving traits with implications for convenience, cost and time saving advantages while ensuring that taste is maintained at its highest level possible. Improved faster cooking varieties can deliver a range of benefits for consumers but also for environment by providing cost saving for consumers and reducing tree-felling for firewood. Beans cooked for a shorter time retain nutritional value. Purchasing bean from the market coupled with low use of pre-soaking method before boiling (only 14%) could be exacerbating the cost cooking by urban bean consumers. Thus, the long terms benefits will be maximized if breeding to reduce coking time is combined with building the capacity of value chain actors in post-harvest handling to improve on storage conditions. Overall, the study findings suggests that future promotional campaigns that aim to popularize consumption of fast-cooking new beans among urban consumers should target women and less poor households, to stimulate demand. With increasing demand from institutional consumers like those in restaurants, schools or prisons, other intrinsic traits such as grain swelling are growing in importance and has the potential to generate significant impact on profitability of bean enterprises, has food security implications for the resource constrained households, but could compromise on nutrient intake, since beans with high swelling capacity are likely to absorb water.

For bean growers, there is a reverse in ordering of traits, with production traits valued higher than intrinsic consumption attributes, with the exception of taste. These findings are consistent with our earlier argument that focusing on farmers alone to identify important traits through PVS is not sufficient for customer-oriented breeding. The growers' strong preference for yield and resilience reflects changing production conditions, including decreasing landholding as pressure on land grows, as well as effects of climate change. Thus, the success of satisfying urban-based consumers through enhancing intrinsic traits such as cooking time, grain swell or taste will depend on simultaneously improving on key production traits. This means that when developing product profiles, improving yield and resilience will continuously be identified for improvement besides intrinsic traits.

In light of the DCE method used to elicit data used in the analysis of preferences and WTP, there is an issue that study participants knew that they were in a hypothetical experiment and their choices could change when subjected to real market scenarios. Thus, there is still need for data on actual variety choices when the prototypes of the improved varieties become available. For example, future research can use prototypes of faster-cooking varieties and apply incentive compatible approaches such as experimental auction and estimate willingness to pay/accept. We also acknowledge that although we included resilience against environmental stresses, this was included as a composite trait and does not focus on specific constraints for targeting in a product profile. Additional research is need to carefully break down traits for resilience into disease, drought and soil fertility to analyse demand for each under different agro-ecological conditions.

Finally, the time it takes to cook beans depends on various factors, including bean moisture content. Newly harvested beans are likely to take less time to cook. In this study, we did not differentiate the genetic potential and age of the grain when assessing demand of reduced cooking time. Follow-up research is needed to carefully disentangle the two to understand how age of grain influences demand for cooking time to be able to control for it when evaluating the possible contribution of genetic transformation on satisfying the demand for reduced cooking time.

Appendix A

Comparisons of fixed effect conditional logit and LCM diagnostic results

Model	Non-growers			Growers		
	Fixed effects logit	Mixed Logit	Latent class	Fixed effects logit	Mixed Logit	Latent class
Number of observations	2781	2781	2781	10,836	10,836	10,836
Wald chi	257.21	104.37		871.73	403.58	
Prob > chi2	0.00	0.00		0.00	0.00	
Log likelihood	857.36	798.96	769.21	3479.61	3425.73	3117.43
Degrees of freedom	15	28	31	15	28	31
AIC	1018.41	1653.92	16,000.43	6986.22	6907.46	6334.28
BIC	1833.67	1819.98	1784.28	7098.58	7111.60	6699.00

Appendix B

Description of attributes

Cooking time is defined as the duration (minutes) it takes to boil beans to reach a texture to be eaten. Studies under laboratory conditions have reported between 45 and 180 min established [66, 67]. It is, however, difficult for respondents to attach exact minutes while preparing beans as they are often not conscious of the time spent. Instead, respondents are more likely to associate with amount of fuel used. We, therefore, assume that faster cooking beans use less fuel. During consultations with stakeholders along the bean value chain, we determined that most people are familiar with fuel used and an estimate of how long it takes to burn the fuel would give a close estimate of the time. After pre-testing in few communities, we established that an average cooking stove filled with charcoal will burn for 1 h hence 60 min was synonymous with one charcoal stove. In the DCE, respondents are presented with a fastest cooking variety (one charcoal stove—60 min), fast cooking (1.25 charcoal stoves—75 min), somehow fast cooking (1.5 charcoal stoves—90 min) and not fast cooking (two charcoal stoves—120 min). It is, however, important to note that fuel used to cook beans (commonly wood or charcoal) varies by location (urban or rural) and household economic status. The study uses charcoal-based levels as they are easier to quantify and less varying in terms of quality compared to wood. Given the changing consumption trends towards consumer preference for quick-to-prepare meals, the expectation is that consumers will choose the faster cooking option.

Grain swelling after boiling: During stakeholder consultations, some consumers and restaurants demonstrated desire for a bean variety that swells upon cooking. Beans that substantially gain volume on cooking yield considerably bigger portions of bean meal per individual or allow the same dry equivalence to serve more people. This has budget implications especially in consumer groups operating within tight budget limits. Bean swelling (volume gain on cooking) of up to 30% of original volume have been reported in literature [68]. However, use of such percentages in CE will be difficult for less literate respondents to interpret. Stakeholders consulted similarly expressed this as a binary response of "swelling" or "not swelling". The simple binary descriptions are used for the choice experiments design.

Taste is a subjective attribute which depends on individual preferences and the cooking methods (such as levels of seasoning and the ingredients used). To control for these variations, the study worked with boiled beans before seasoning to define taste as the mouth feel of the cooked beans before seasoning. Standard organoleptic tests utilize a scale ranging from zero to five to describe bean taste [69] from an average of various predetermined inherent constituents of taste. In this study, taste is described at three levels: a) tasty, b) somehow tasty and c) not tasty. The levels correspond to the highest (5—tasty), the median (3—somehow tasty) and the lowest (0—not tasty) levels of the standard organoleptic test.

Color of the uncooked dry grains as it appears in the markets or places of purchase determines the attractiveness of the grain in the market. Studies in sub-Saharan Africa have established that bean color carries the primary signal for consumer choice [11, 47, 70] and serves as an indicator which consumers use to perceive the presence of invisible bean attributes, such as cooking time and gravy quality. Participatory variety selection trials, [70] found that farmers used color as the main criterion for variety selection, and that red speckled/mottled bean types were most preferred. Stakeholder consultations revealed high preference for the same followed by the yellow color grains and white being the least preferred. Colors from the major bean corridors and major bean consuming areas are selected for the experiment.

Resilience in the face of climatic variability: Deriving from literature, the attribute **"Resilience to climatic variability"** was measured as a percentage yield loss in the event of excessive rains or prolonged rainfall or rain shortages during a growing season. In Uganda, the onset of rainfall has shifted by a month in some regions with no change to dates of cessation thus leading to reduced rainfall days and or changes in cropping patterns [71]. Drought accounts for 38% loss in production for beans [72], while a fall of a 10–20% in most crop yields because of abnormal weather patterns has also been predicted [73]. However, there are places, where yield losses may be much more severe, as well as areas, where crop yields may increase due to increased suitability of the areas for some crops as the areas get warmer [73]. Guided by the existing information, the attribute was measured at 3 levels of less than 10% yield loss, 10–30% yield loss and, above 30% yield loss levels. The expectation here is that respondents especially in farming households would prefer less than 10% yield loss variety in the event of unexpected weather patterns.

Yield: Participatory variety selection experiments provide evidence that yield is the major driver of variety selection amongst bean farmers in Uganda [51]. While the standard yield measure is Kilograms per hectare, farmers especially those in peri-urban and densely populated areas had problems conceptualizing an area as big as a hectare. This is because average garden sizes on smallholder farms are less than half an acre. Therefore, a quarter an acre, which is easier to envision for both farmers, consumers and research assistants is considered for the CE. Average yield of beans in 2018 was 600 kg/Ha ranging between 300 to 700 Kgs/Ha [54] (UBoS, 2020a), but yield of up to 3000 kg per hectare has been report depending on the genotype (such as climbing bean or new ones) and location [54]. The base of 600Kgs/Ha was used and four levels a) 60kgs/0.25 acres (600kgs/Ha), b) 90 kg/0.25 acres (900kgs/Ha) c) 120kgs/0.25 acres (1200kgs/Ha) and 150kgs/0.25 acres (1500kgs/Ha) of yields at farmer fields are used for the yield attribute. The yields were further contextualized in terms of number of bags or basins equivalences as guided by community guides during the actual CE implementations to ease interpreting the levels by the respondents.

Bean prices. The hypothetical price helped estimating the monetary value attributes included. Most urban dwellers participate in the grain market as consumers, while most farmers participate as sellers and as buyers of seed at planting time. Yet there are also farmers who depend solely on their own produced grain for food or seed. To be able to use price in estimating the attribute's monetary value, we used price of grain for urban consumers and price of seed for farmers. Furthermore, the price of bean in Uganda varies considerably across regions and seasons. Even though the survey was conducted in the same season (i.e., season B), adjusting it across study area based on market prices was considered a useful way to make the experiment more realistic. To be able to maintain price independent of the reference market and region, it was included in relative terms reflecting a hypothetical situation if it was to change from the status quo to better or worse. In every village, the going price of bean grain at the time of the survey was ascertained through consultation with village leaders, serving as key informants. The same key informant were asked about normal prices of seed at planting time from each source (grain, agro dealer shops). The respective prices obtained were used as the base price (0% change). After determining village level prices, price ranges were calculated using the percentage changes, written on cards (replaced using masking tape) and respondents saw monetary prices (e.g., for a village price of Sh.3450, respondent saw a price level of Ugx 3600 after rounding off instead of 5% price change on the cards). Price of grain varied considerably across time and space in 2019 ranging from 2000 to 4000USh in the retail markets depending on the variety in question [20]. Price changes of 0%, 15% and 30% were used to define price levels. Consultations with traders indicated prices variation between varieties in a range of 10–30%. The expectation here is that ceteris paribus, consumers of grain/seed would choose a cheaper product set.

Appendix C

Descriptive statistics showing additional sample characteristics, type of varieties chosen, reasons for choosing varieties at time of purchase and respondents' desirability of attributes

See Table 14

Table 14 Household socio-demographic characteristics disaggregated by location

Variables	All ($n=1024$) Mean	Std. Dev	Population
Percentage of sample that are growing beans	71.01		
Percentage of sample that is urban[a]	25.24		21
Age of the household head (years)	43.61	13.79	43
Proportion of households with female heads (1 = yes; 0 = no)	0.25	0.43	0.3
Household head's years of completed education	8.45	4.09	6.3[b]
Household engaged in on-farm activities (yes/no)	0.76	0.43	69
Number of people living in the household	6.18	4.23	5
Number of children aged 0–5 years	1.33	1.28	1.11
Number of children aged 6–14 years	1.75	1.6	1.49
Household falls in the high wealth index category	0.33	0.47	0.2
Percent of HH that consume beans			81–82

Tests significant at 10% (∗), 5% (∗∗), and 1% (∗∗∗) significance levels

[a] According to UBoS (2016), all areas gazetted as City, Municipality, Town Council or Town Board by the respective authorities can be treated as urban and the areas surrounding these as peri-urban.[b]This the average for male headed households in 2014 while that of women was 5.7 in the same year.

See Table 15

Table 15 Reasons varieties choosing varieties at the time of purchase

	Rural ($N=700$)	Urban ($N=318$)	Total ($N=1018$)
Type of Varieties bought in a year			
1. White	3.00	2.83	2.95
2. Yellow	4.57	12.89	7.17
3. Plain red	5.43	8.49	6.39
4. Mottle/speckle	55.57	68.24	59.53
5. Black	20.43	0.63	14.24
6. Green	1.00	1.26	1.08
7. Cream	3.14	2.20	2.85
8. Orange	0.29	0.00	0.20
9. Purple	0.29	0.00	0.20
10. Khaki	0.57	0.00	0.39
11. Brown	2.29	1.89	2.16
12. Grey	0.43	0.00	0.29
13. Mix	3.00	1.57	2.55
Reasons varieties are chosen			
Cheaper compared to others	10.90	6.59	9.67
Tastes better	64.33	78.68	68.55
Most available in the area	27.16	5.43	20.21
Recommended by a friend	0.60	0.00	0.49
Family members prefer it	14.03	11.63	13.38
Cooks faster	34.48	49.61	38.96
Make good soup	36.42	50.00	40.43
Sell more than other varieties	6.42	0.39	5.18
Low flatulence	3.73	3.88	3.61
Longer shelf life	1.64	1.94	1.66

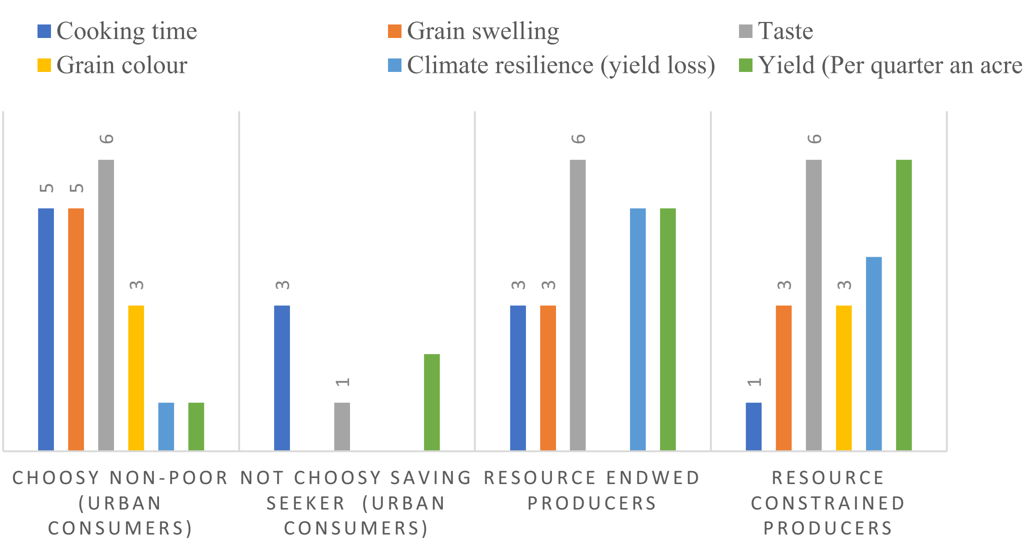
See Table 16

Table 16 Percentage of respondents rating selected production and consumption traits as important or very important and their average weighted rank

Respondent group	% Respondents selected attribute as important	Average weighted rank
Respondents only farmers		
Variety still yields well in different rainfall constraints (wide adaptability)	75.49	405.33
Variety is demanded on the market	73.93	275.67
The variety is adapted to different soil fertility levels	73.73	274.67
The variety is resistant to common field pests and diseases	71	176.67
Respondents are farming and non-farming consumers		
Cooked beans have a thick soup	90.43	253.67
Variety is bio-fortified with high iron and zinc nutrients	76.37	202.33
Cooked beans have a soft coat/skin	86.04	150.67
Beans can remain fresh overnight after being cooked (remain fresh longer	81.93	122.33
Cooked beans cause little gas in the stomach (low flatulence)	73.14	103
The beans are resistant to storage pests	65.43	78.33

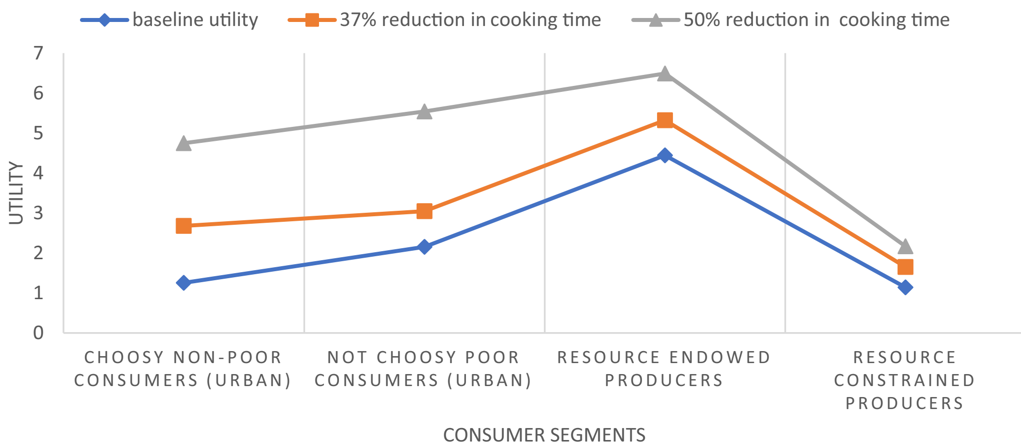
Appendix D

Consumer preferences for intrinsic, visual and 1191 production traits of bean in a decreasing order



Appendix E

Utility gained from reduced cooking time by Ugandan bean consumers in urban and rural households



Appendix F

Simulations for testing attribute non-attendance in the urban-based consumers' sub-sample

Assumptions	Coefficient of variation
Full Model	0.08
Climate resilience Unattended	0.2
Yield Unattended	0.08
Both Yield and Climate resilience Unattended	0.21

Acknowledgements

This paper is from research conducted as part of Demand Led Breeding program and was financially supported by the Australian Centre for International Agricultural Research (ACIAR); Syngenta Foundation for Sustainable Agriculture (SFSA) and Crawford Fund for a Food Secure World under the Demand Led breeding project (DLB). Authors greatly appreciate the additional financial support from Bill and Melinda Gates Foundation under the auspices of AVISA project led by CIMMYT and implemented under the umbrella of the Pan African Bean Research Alliance (PABRA). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. We gratefully acknowledge the support of National Agriculture Research Organisation staff, district administrative and production staff who supported the research administratively during data collection. We are also grateful to the research assistants who collected the data used for this article. The authors also acknowledge the editorial contribution from the Alliance Science Writing Service (SWS), provided by Vincent Johnson.

Author contributions

RA contributed to data curation, formal analysis, writing original draft, review and editing. EK contributed to study conceptualization, formal analysis, writing and editing the manuscript. PM contributed to formal analysis, review and editing. CM contributed to conceptualization, fund acquisition, project administration, review and editing. JCR and AV, both contributed to conceptualization, review and editing of the manuscript. All authors approved the manuscript for publication.

Funding

The research in this paper was financially supported by the Australian Centre for International Agricultural Research (ACIAR); Syngenta Foundation for Sustainable Agriculture (SFSA) and Crawford Fund for a Food Secure World under the Demand Led breeding project (DLB). Additional financial support from Bill and Melinda Gates Foundation under the auspices of AVISA project led by CIMMYT and implemented under the umbrella of the Pan African Bean Research Alliance (PABRA).

Availability of data and materials

Data are available upon request from the corresponding author.

Declarations

Ethics approval and consent to participate

The study protocol and materials were approved by the CIAT Institutional Review Board (#2020-IRB39). All survey respondents were aged 18 years or older and independently provided informed consent to participate in the research. Consent was sought through a statement read aloud to the participants and verbal consent was obtained from all participants. At the time of data collection, all efforts were made to minimize contact between research assistants and the respondents, therefore, verbal consent instead of written and signed consent was deemed the best option given the prevailing COVID situation. Data were analyzed anonymously.

Consent for publication

The authors declare that no part of the manuscript has been published before, nor is any part of it under consideration for publication in another journal. In addition, we affirm that all the authors have approved the manuscript for submission. Not applicable.

Competing interests

The authors declare that they have no known competing interests.

Author details

[1]Present Address: The Alliance of Bioversity International and International Centre for Tropical Agriculture, Uganda Office, Africa Region, Kampala, Uganda. [2]African Plant Nutrition Institute, Ben Guerir, Morocco. [3]Syngenta Foundation for Sustainable Agriculture, Basel, Switzerland. [4]The alliance of Bioversity International and International Centre for Tropical agriculture, Nairobi, Kenya.

Received: 9 May 2023 Accepted: 18 January 2024
Published online: 02 May 2024

References

1. Kimani PM. Principles of demand-led plant variety design. In: Persley GJ, Anthony VM, editors. The business of plant breeding: market-led approaches to new variety design in Africa. Berlin: Springer; 2017.
2. Polar V, Teeken B, Mwende J, Marimo P, Tufan AH, Ashby AJ, et al. Building demand-led and gender-responsive breeding programs. In: Thiele G, Friedmann M, Campos H, Polar V, Bentley JW, editors., et al., Root, tuber and banana food system innovations. Cham: Springer; 2022.
3. Okello JJ, Swanckaert J, Martin-Collado D, Santos B, Yada B, Mwanga ROM, et al. Market intelligence and incentive-based trait ranking for plant breeding: a sweetpotato pilot in Uganda. Front Plant Sci. 2022;13:597. https://doi.org/10.3389/fpls.2022.808597.
4. Custodio MC, Demont M, Laborte A, Ynion J. Improving food security in Asia through consumer-focused rice breeding. Glob Food Secur. 2016;9:19–28. https://doi.org/10.1016/j.gfs.2016.05.005.
5. Baffoe G, Matsuda H. Why do rural communities do what they do in the context of livelihood activities? Exploring the livelihood priority and viability nexus. Community Dev. 2017;48:715–34. https://doi.org/10.1080/15575330.2017.1366927.
6. Ragot M, Bonierbale M, Weltzien E. From Market Demand to Breeding Decisions: A Framework. Lima (Peru). CGIAR Gender and Breeding Initiative. GBI Working Paper. No. 2. 2018. www.rtb.cgiar.org/gender-breeding-initiative
7. Windle, J. and Rolfe, J. Diversification Choices in Agriculture: A Choice Modelling Case Study of Sugarcane Growers. 2005. https://ssrn.com/abstract=684298
8. Birol E, Villalba ER, Smale M. Farmer preferences for milpa diversity and genetically modified maize in Mexico: a latent class approach. Environ Dev Econ. 2009;4:521–40. https://doi.org/10.1017/S1355770X08004944.
9. Birol E, Smale M, Gyovai A. Using choice experiment to estimate farmers' valuation of agrobiodiversity on Hungarian small farms. Environ Resource Econ. 2006;34:439–69.
10. Katungi E, Louise S, David K, Farrow A, Beebe S. Relative importance of common bean attributes and variety demand in the drought areas of Kenya. J Dev Agric Econ. 2011;3:411–22. https://doi.org/10.5897/JDAE.9000108.
11. Mishili FJ, Temu A, Fulton J, Lowenberg-DeBoer J. Consumer preferences as drivers of the common bean trade in tanzania: a marketing perspective. J Int Food Agribus Market. 2009;23(2):110–27. https://doi.org/10.1080/08974438.2011.558761.
12. Ibrahim F, Nmadu J, Baba K, Gana A, Nahemiah D, Ibrahim P. Demand analysis for consumer preference of cowpea attributes in Niger State, Nigeria: a Hedonic approach. IOSR J Agric Vet Sci. 2013;5:67–72.
13. Coe S, Spiro A. Cooking at home to retain nutritional quality and minimize nutrient loss. A focus on vegetables, potato and pulses. Nutr Bull. 2022. https://doi.org/10.1111/nbu.12584.
14. Carvalho LMJ, Corrêa MM, Pereira EJ, Nutti MR, Carvalho JLV, Ribeiro EMG, Freitas SC. Iron and zinc retention in common beans (*Phaseolus vulgaris* L) after home cooking. Food Nutr Res. 2012;56:1–6. https://doi.org/10.3402/fnr.v56i0.15618.
15. Aemro BY, Mouro P, de Almeida AT. Inefficient cooking systems a challenge for sustainable development: a case of rural areas of Sub-Saharan Africa. Environ Dev Sustain. 2021;23:14697–721.
16. Mainimo NE, Okello MD, Mambo BW, Mugonola B. Drivers of household demand for cooking energy: a case of Central Uganda. Heliyon. 2022. https://doi.org/10.1016/j.heliyon.2022.e09118.
17. Arruda B, Guidolin AF, Coimbra JL, Battilana J. Environment is crucial to the cooking time of beans. Food Sci Technol. 2012. https://doi.org/10.1590/S0101-20612012005000078.
18. Balamaze J, Muyonga JH, Kyamuhangire WM, Kikafunda JK, Nakimbugwe D, Ugen M. Influence of Variety, growth location and storage conditions on development of hard-to-cook defect in Common beans (*Phaseolus vulgaris* L.). African J Food Agric Nutr Dev. 2008. https://doi.org/10.4314/ajfand.v8i3.19196.
19. Aseete P, Katungi E, Bonabana-Wabbi J, Birachi E, Ugen MA. Consumer demand heterogeneity and valuation of value-added pulse products: a case of precooked beans in Uganda. Agric Food Secur. 2018. https://doi.org/10.1186/s40066-018-0203-3.
20. Charrua AB, Havik PJ, Bandeira S, Catarino L, Ribeiro-Barros A, Cabral P, et al. Food security and nutrition in mozambique: comparative study with bean species commercialised in informal markets. Sustainability. 2021;13(16):8839. https://doi.org/10.3390/su13168839.
21. Commercial Agriculture for Smallholders and Agribusiness (CASA). Beans Sector Strategy—Uganda CASA UGANDA COUNTRY TEAM. 2020. https://www.casaprogramme.com/wp-content/uploads/CASA-Uganda-Beans-Sector-analysis-report.pdf. Accessed 13 May 2021
22. Food and Agriculture Organisation of the United Nations Statistics (FAOSTAT). 2021. https://www.fao.org/faostat/en/#data/QCL/visualize. Accessed 14 Aug 2021.
23. National Planning Authority (NPA). Third national development plan (NDP III) 2020/21–2024/25. 2020. http://www.npa.go.ug/wp-content/uploads/2020/08/NDPIII-Finale_Compressed.pdf. Accessed 13 Dec 2021.
24. Uganda Export Promotions Board. https://ugandaexports.go.ug/product/3/Dry%20Beans. Accessed 12 Dec 2021.
25. Sridharan V, Ramos EP, Zepeda E, Boehlert B, Shivakumar A, Taliotis C, et al. The impact of climate change on crop production in Uganda—an integrated systems assessment with water and energy implications. Water. 2019;11(9):1805. https://doi.org/10.3390/w11091805www.mdpi.com/journal/water.
26. Ferrini S, Schaafsma M, Bateman I. Revealed and stated preference valuation and transfer. A within-sample comparison of water quality improvement values. Water Res Res. 2014;50:4746–59. https://doi.org/10.1002/2013WR014905.
27. Hicks RL. A Comparison of Stated and Revealed Preference Methods for Fisheries Management. American Agricultural Economics Association 2002 Annual Meeting, July 28–31, 2002, Long Beach, California. Selected Paper. 2002.
28. Scarpa R, Ruto ESK, Kristjanson P, Radeny M, Drucker AG, Rege JEO. Valuing indigenous cattle breeds in Kenya: an empirical comparison of stated and revealed preference value estimates. Ecol Econ. 2003;45:409–26.
29. Hensher D, Rose J, Greene WA. Applied choice analysis: a primer. Cambridge: Cambridge University Press; 2005.
30. Lancaster KJ. A new approach to consumer theory. J Pol Econ. 1966;74(2):132–57.
31. Greene WH. Econometric analysis. 3rd ed. New York: Prentice Hall; 1997.
32. Colombo S, Hanley N, Louviere J. Modelling preference heterogeneity in stated choice data: an analysis for public goods generated by agriculture. Agric Econ. 2009;40(3):307–22.
33. Greene W, Hensher D. A latent class model for discrete choice analysis: contrasts with mixed logit. Transp Res Part B. 2003;37:681–98.
34. McFadden D, Train K. Mixed MNL models of discrete response. J Appl Econ. 2000;56:162–75.
35. Louvier JJ, Hensher DA, Swait J. Stated choice methods: analysis and application. Cambridge: Cambridge University Press; 2000.
36. Obadha M, Chuma J, Kazungu J, Abiiro GA, Beck MJ, Barasa E. Preferences of healthcare providers for capitation payment in Kenya: a discrete choice experiment. Health Policy Plan. 2020;35(7):842–54. https://doi.org/10.1093/heapol/czaa016.
37. Asioli D, Fuentes-Pila J, Alarcon S, Han J, Liu J, Hocquette J, Rodolfo M, Nayga RM. Consumers' valuation of cultured beef burger: a multi-country investigation using choice experiments. Food Policy. 2022;112:102376.
38. Kikulwe EM, Birol E, Wesseler J, Falck-Zepeda J. A latent class approach to investigating demand for genetically modified banana in Uganda. J Agric Econ. 2011;42(5):547–60.
39. Wedel M, Kamakura W. market segmentation: conceptual and methodological foundations. Boston: Kluwer Academic Publishers; 2000.
40. Katungi E, Kikulwe E, Emongor R. Analysis of farmers' valuation of common bean attributes and preference heterogeneity under environmental stresses of Kenya. African J Agric Res. 2015. https://doi.org/10.5897/AJAR2014.8979.
41. Kilima FTM, Bolle EM. Factors underlying consumers'choice of dry common bean in Dar Er Salaam, Tanzania. Afr J Food Agric Nutr Dev. 2020;20(2):15619–36. https://doi.org/10.1869/ajfand.90.18350.
42. Llorca M, Orea L, Pollitt MG. Using the latent class approach to cluster firms in benchmarking: an application to the US electricity transmission industry. Oper Res Perspect. 2014;1(1):6–17. https://doi.org/10.1016/j.orp.2014.03.002.
43. Gonçalves T, Lourenço-Gomes L, Pinto L. Modelling consumer preferences heterogeneity in emerging wine markets: a latent class analysis. Appl Econ. 2020;52(56):6136–44. https://doi.org/10.1080/00036846.2020.1784389.

44. Zhu Q, Zhang Z. On using individual characteristics in the MNL latent class conjoint analysis: an empirical comparison of the nested approach versus the regression approach. Mark Bull. 2009;1:20.
45. Yoo H. lclogit2: An enhanced module to estimate latent class conditional logit models. MPRA Paper No. 97014, 2019. https://mpra.ub.uni-muenchen.de/id/eprint/97014. Accessed 4 Jul 2021.
46. Hu W, Hünnemeyer A, Veeman M, Adamowicz W, Srivastava L. Trading off health, environmental and genetic modification attributes in food. Eur Rev Agric Econ. 2004;31(3):389–408. https://doi.org/10.1093/erae/31.3.389.
47. Atilola B. Product attributes and consumer preference: The case of common beans in Zambia. Master's thesis Kansas State University, Kansas USA. College of Agriculture. 2018. https://krex.k-tate.edu/dspace/bitstream/handle/2097/39205/. Accessed 30 Mar 2021.
48. Kläsener GR, Ribeiro ND, Casagrande CR, Arns FD. Consumer preference and the technological and nutritional quality of different bean colors. Acta Scientiarum Agron. 2020. https://doi.org/10.4025/actasciagron.v42i1.43689.
49. Beebe SE, Ramírez J, Jarvis A, Rao IM, Mosquera G, Bueno JM, Blair MW. Genetic improvement of common beans and the challenges of climate change. In: Yadav SS, Redden R, Hatfield LJ, Lotze-Campen H, Hall A, editors. Crop adaptation to climate change. Oxford: Wiley; 2011. p. 356.
50. Okii D, Mukankusi C, Sebuliba S, Tukamuhabwa P, Tusiime G, Talwana H. Genetic variation, heritability estimates and GXE effects on yield traits of Mesoamerican common bean (*Phaseolus vulgaris* L) germplasm in Uganda. Plant Genetic Resources. 2018;16(3):237–48.
51. Mukankusi CM, Nkalubo S, Katungi E, Awio B, Luyima G, Radeny M. Participatory evaluation of common bean for drought and disease resilience traits in Uganda. CCAFS working Paper no. 143. Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security; 2015.
52. Bruno A, Katungi E, Stanley NT, Clare M, Maxwell MG, Paul G, Richard E. Participatory farmers' selection of common bean varieties (*Phaseolus vulgaris* L.) under different production constraints. Plant Breed. 2018;137:283–9.
53. Larochelle C, Katungi E, Beebe S. Disaggregated analysis of Bean consumption demand and contribution to household food security in Uganda. Cali: International Center for Tropical Agriculture; 2015.
54. Uganda Bureau of Statistics (UBoS). Uganda Annual Agricultural Survey 2018. https://www.ubos.org/wp-content/uploads/publications/Annual%20Agricultural%20Survey%202018%20Statistical%20Release%20May%202020.pdf. Accessed 13 Dec 2021.
55. Kassie GT, Abdulai A, Wollny C. Valuing traits of indigenous cows in Central Ethiopia. J Agric Econ. 2009;60(2):386–401. https://doi.org/10.1111/j.1477-9552.2008.00191.x.
56. Hole AR. 2015. DCREATE: Stata module to create efficient designs for discrete choice experiments. Statistical software components S458059. Boston: Boston College Department of Economics. https://EconPapers.repec.org/RePEc:boc:bocode:s458059
57. Kuhfeld WF. Marketing Research Methods in SAS: Experimental Design, Choice, Conjoint, and Graphical Techniques (Cary, NC, USA: SAS Institute Inc., 2005. oai:CiteSeerX.psu:10.1.1.69.2574 http://support.sas.com/techsup/technote/ts722.pdf).
58. Rose JM, Bliemer MCJ. Sample size requirements for stated choice experiments. Transportation. 2013;40(5):1021–41. https://doi.org/10.1007/s11116-013-9451-z.
59. Bliemer MCJ and Rose JM. Efficiency and Sample Size Requirements for Stated Choice Studies. Working paper: ITLS-WP-05-08, 2005) http://hdl.handle.net/2123/19535
60. Uganda Bureau of Statistics (UBoS). The National Population and Housing Census 2014—Main Report. 2016. https://unstats.un.org/unsd/demographic-social/census/documents/Uganda/UGA-2014-11.pdf. Accessed 06 Aug 2020.
61. Larochelle C, Katungi E, Cheng Z. Pulse consumption and demand by different population subgroups in Uganda and Tanzania. Cali: International Center for Tropical Agriculture; 2017.
62. Kontoleon A, Yabe M. Market segmentation analysis of preferences for GM derived animal foods in the UK. J Agric Food Ind Organization. 2007;4:1150–1150. https://doi.org/10.2202/1542-0485.1150.
63. Howe L, Hargreaves J, Huttly S. Issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries. Emerg Themes Epidemiol. 2008. https://doi.org/10.1186/1742-7622-5-3.
64. Rutsaert P, Demont M, Verbeke W. Consumer Preferences for Rice in Africa. In: Wopereis MCS, Johnson D, Ahmad N, Tollens E, Jalloh A, editors. Realizing Africa's rice promise. Boston: CABI Publishing; 2013. p. 293–301.
65. Prajitha VV, Vipin Chandran KP. Urbanisation and its impact on the pattern of consumption: evidence from Kerala. Int J Adv Multidiscip Res. 2020;7(8):8–13. https://doi.org/10.22192/ijamr.2020.07.08.002.
66. Mughi I, Ochwo-Ssemakula M, Edema R, Mukankusi C. Variability in cooking time, iron and zinc content in common bean (*Phaseolus vulgaris* L.) genotypes. J Sci Agric. 2015;5:6–11. https://doi.org/10.25081/jsa.2021.v5.6559.
67. Mendoza FA, Wiesinger JA, Lu R, Nchimbi-Msolla S, Miklas PN, Kelly JD, et al. Prediction of cooking time for soaked and unsoaked dry beans (*Phaseolus vulgaris* L.) using hyperspectral imaging technology. 2018. Plant Phenome J. https://doi.org/10.5061/dryad.ch4ns27.
68. Sánchez-Arteaga HM, Urias-Silvas J, Espinosa-Andrews H, García Márquez E. Effect of chemical composition and thermal properties on the cooking quality of common beans (*Phaseolus vulgaris*). J Food. 2015. https://doi.org/10.1080/19476337.2014.988182.
69. Calvo MS, del Rey JA. Sensory analysis of beans (*Phaseolus vulgaris* L.). Biotechnol Agron Soc Environ. 1999;3:201–4.
70. Nkalubo ST, Namayanja A, Ugen AM, Paparu P, Otim M, Aseete P. Breeding for bean anthracnose resistance: matching breeding interventions with people's livelihoods through participatory variety selection. Uganda J Agric Sci. 2013;14(1):45–55.
71. Mubiru DN, Komutunga E, Agona A, Apok A, Ngara T. Characterising agrometeorological climate risks and uncertainties: crop production in Uganda. S Afr J Sci. 2012;108:108–18.
72. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and Ministry of Water and Environment (MWE). National Irrigation Policy. Agricultural Transformation Through Irrigation Development. Kampala, Uganda, 2017. https://www.mwe.go.ug/sites/default/files/library/Uganda%20National%20Irrigation%20Policy.pdf. Accessed 13 Dec 2020
73. Thornton PK, Jones PG, Alagarswamy G, Andresen J. Spatial variation of crop yield response to climate change in East Africa. Global Environ Change. 2009;19(1):54–65. https://doi.org/10.1016/j.gloenvcha.2008.08.005.
74. Katuuramu DN, Luyima GB, Nkalubo ST, Wiesinger JA, Kelly JD, Cichy KA. On-farm multi-location evaluation of genotype by environment interactions for seed yield and cooking time in common bean. Sci Rep. 2020;10:3628. https://doi.org/10.1038/s41598-020-60087-2.
75. Daziano RA. A choice experiment assessment of stated early response to COVID-19 vaccines in the USA. Health Econ Rev. 2022. https://doi.org/10.1186/s13561-022-00368-w.
76. Hensher DA, Rose JM, Greene WH. Applied choice analysis. Cambridge: Cambridge University Press; 2015.
77. Esmaili A, Aghabayk K, Shiwakoti N. Latent class cluster analysis and mixed logit model to investigate pedestrian crash injury severity. Sustainability. 2023;2023(15):185. https://doi.org/10.3390/su15010185.
78. Akwango-Aliau D, Lukwago G, Ariong RM, Kiyingi I, Obongo I, Adur S, Angundupo S, Ndhokero J, Luzinda H, Akongo T, Magala D, Mutonyi S, Bwanika G, Bua A, Baguma Y, Agona A. Impact of NARO bean and maize technologies on farmer livelihoods and contribution to Uganda's economy. Entebbe: National Agricultural Research Organisation; 2022. p. 143.

Publisher's Note