



Beyond “Women’s Traits”: Exploring How Gender, Social Difference, and Household Characteristics Influence Trait Preferences

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Demand-led breeding strategies are gaining importance in public sector breeding globally. While borrowing approaches from the private sector, public sector programs remain mainly focused on food security and social impact related outcomes. This necessitates information on specific user groups and their preferences to build targeted customer and product profiles for informed breeding decisions. A variety of studies have identified gendered trait preferences, but do not systematically analyze differences related to or interactions of gender with other social dimensions, household characteristics, and geographic factors. This study integrates 1000minds survey trait trade-off analysis with the Rural Household Multi-Indicator Survey to study cassava trait preferences in Nigeria related to a major food product, gari. Results build on earlier research demonstrating that women prioritize food product quality traits while men prioritize agronomic traits. We show that food product quality traits are more important for members from food insecure households and gender differences between men and women increase among the food insecure. Furthermore, respondents from poorer households prioritize traits similar to respondents in non-poor households but there are notable trait differences between men and women in poor households. Women in female headed household prioritized quality traits more than women living with a spouse. Important regional differences in trait preferences were also observed. In the South East region, where household use of cassava is important, and connection to larger markets is less developed, quality traits and in ground storability were prioritized more than in other states. These results reinforce the importance of recognizing social difference and the heterogeneity among men and women, and how individual and household characteristics interact to reveal trait preference variability. This information can inform trait prioritization and guide development of breeding products that have higher social impact, which may ultimately serve the more vulnerable and align with development goals.

Keywords: social difference, trait preferences, cassava, Nigeria, gender

INTRODUCTION

Public sector plant breeding programs are changing rapidly. Adopting approaches from the private sector, the push toward demand-led breeding has seeded shifts in public sector breeding programs oriented toward food security and social impact. Understanding client needs is critical to demand-led breeding approaches [Demand-led breeding (DLB), 2020], underpinning all subsequent decisions around segmenting and prioritizing target users. Mobilizing "market intelligence," in addition to agroecology and value chain information, breeding programs are expected to develop market segments and associated breeding product profiles [CGIAR Excellence in Breeding platform (EiB), 2020]. While ideologically breeding programs are rapidly evolving to become more demand-led, practically this shift has revealed gaps in evidence and data needed to effectively set market-informed breeding priorities. In the private sector, dedicated and well-resourced marketing units conduct marketing research that is directly used to guide breeding priorities. These are absent in the public sector.

Market research is defined here in a broad sense to cover value chain analysis, product mapping, trait economic values and trait preference analyses, amongst others. Historically the most research attention related to market research in public sector breeding programs have focused on adoption studies and trait preference studies. Capturing trait preferences using methodologically robust and systematic approaches enable breeding programs to develop accurate and impactful product profiles to guide breeding (Ragot et al., 2018). Recent increased attention to trait preference studies on root, tuber and banana crops have enabled breeding programs to unpack breeding priorities in sweet potato (Mwanga et al., 2021), banana (Marimo et al., 2020), and cassava (Bentley et al., 2017; Teeken et al., 2018, 2021). These studies show that distinct use types and social identities, such as gender, shape trait preferences, validating the need for more demand-led approaches and thinking in breeding these historically under-resourced crops.

Understanding trait preferences has involved approaches such as direct ranking (Abeyasekera et al., 2002; Dao et al., 2015; Teeken et al., 2018), or choice experiments (Asrat et al., 2010; Blazy et al., 2011; Acheampong et al., 2018). Most trait preference studies however, do not adequately address social heterogeneity among producers, processors and consumers, despite mounting evidence that social differences matter for varietal adoption. Many studies reported that social differences such as sex, age, marital status and ethnicity affected the adoption of varieties or crops as climate change-adaptation strategies (Acevedo et al., 2020). Trait preferences vary in relation to socio-cultural context and modes of production and processing (Smale et al., 2001), and follow gender divisions of labor and market access, with documented differences in preferences between men and women across crops and contexts (Christinck et al., 2017; Weltzien et al., 2020). These insights may not be relevant for private sector breeding that is mostly concerned with optimizing revenue, but crucial for the public sector breeding for development, that distinguishes itself by explicitly focusing on social inclusion

outcomes, such as gender equality, poverty alleviation and food security as laid out in the sustainable development goals.

Gender shapes all aspects of agricultural technology development (Doss and Morris, 2001; Schut et al., 2015). It is therefore critical for breeding programs to consider gender and social differences in seeking to understand market intelligence. Building frameworks and approaches to enable this integration is critical to gender responsive breeding programs (Ashby and Polar, 2019), since the traits a breeder prioritizes in developing a new variety powerfully affects who benefits from the variety, and how (Polar et al., 2021). Gender integration into breeding programs increases their potential to be more impactful (Tufan et al., 2018). As this thinking matures, we move away from homogenous comparisons of men and women, and shift to asking which men and which women. Therefore, it is important to integrate social identities and household characteristics that possibly interact with gender to shape trait preferences to determine the success of new varieties. We chose cassava producing households in Nigeria to explore how gender, social difference, and household characteristics influence trait preferences.

Cassava producing households in Nigeria offer a compelling site of analysis building from a wealth of existing studies. Nigeria has the highest cassava production globally (FAOSTAT, 2021), where it is grown both as a subsistence and as a cash crop. A collection of recent studies explored adoption drivers of cassava in Nigeria (Wossen et al., 2017), and trait preferences for cassava products (Chijioke et al., 2021; Ndjouenkeu et al., 2021; Teeken et al., 2021), including gender analysis of trait preferences (Teeken et al., 2018). The gender differences in trait preferences observed in these studies mainly reflect the gendered roles along the crop value chain. For example, women play an important role in cassava production (Curran et al., 2009; Walker et al., 2014), and perform most of its processing and marketing in Nigeria (Ilona et al., 2017). In the South East and South South regions of Nigeria, women play an important role in cassava production, shifting away from a formerly yam dominant cropping system and as men increase their engagement in non-farm activities (Korieh, 2010; Osuji et al., 2017; Alozie, 2019; Amah et al., 2021).

There is large regional variation in cassava processing and markets in Nigeria. Cassava is mostly produced in the southern part of Nigeria. Gari and fufu are the two major food products produced by smallholder cassava farmers for market and home consumption. Gari is a dry semolina-like pregelatinized granulated flour and fufu is a wet fermented paste obtained by water submersion (Bechoff et al., 2018). Gari is most often consumed as the paste product eba which is obtained by mixing gari with hot water (Bechoff et al., 2018; Awoyale et al., 2021). The South West and North Central zones in Nigeria are relatively more connected to larger scale, urban markets, while in the South East and South South home consumption and regional markets dominate (Abdoulaye et al., 2013, 2015). Cassava based food products and how they are processed differ regionally. In the South West and North Central regions, small- and medium- scale processing centers service households, while in the South East and adjacent parts of the South South cassava is processed within the household (Teeken et al., 2018).

These individual, household, community, and regional variations challenge breeding programs seeking to deliver new cassava varieties to heterogeneous populations of adopters.

Balogun et al. (2021) present the application of a comprehensive survey and analysis methodology package incorporating a novel core adaptive conjoint method (1000minds, 2020), which combines multivariate analysis to capture trait typologies. Trait preferences were asked in relation to the cassava gari value chain. This paper builds from this cassava trait preference study to relate the trait rankings to individual, household, and farm characteristics of respondents collected with an adapted Rural Household Multi-Indicator Survey (RHoMIS) (Hammond et al., 2017). We present results that explore the relationship between trait rankings and individual-, household-, and farm- level characteristics. We build from this to analyze interactions between gender and food security, poverty level, and region to deepen the understanding of how diverse gender experiences drive trait preferences.

METHODS

Sampling

This study followed the sampling strategy of the Cassava Monitoring Survey, which identified states that contribute up to 80% of the total cassava production in Nigeria (Wossen et al., 2017) which are situated in four geopolitical zones of Nigeria: North Central, South East, South South and South West. Close to two-thirds (66%) of total production is in the southern part of the country, while about 30% is in the North Central zone (FAOSTAT, 2021). The second sampling stage involved the selection of two states per zone with the highest cassava production. From these states, sixteen major cassava growing communities were selected based on key informant interviews with Agricultural Development Program (ADP) officers at the state and Local Government Area (LGA) level. Focus group discussions (FGDs) were held in each community with village leaders and community members to capture information on cassava livelihood activities and relevant social groups, as well as verify the prioritized 11 traits. FGDs were further used to determine economic values in the scenarios compared during the 1000minds survey (1000minds, 2020). In the final stage, a list of smallholder cassava value chain actors was compiled. Survey participants were sampled from this list based on their dominant role in the cassava value chain, gender, and social group to ensure representation of all groups with cassava expertise in the communities. More detail of the sampling and FGDs is presented by Balogun et al. (2021).

Survey Implementation

The study was carried out in February and March 2020. Written consent was obtained after participants were informed of the purpose of the study. Ethical approval to conduct the research was granted by the IITA Internal Review Board. A total of 792 respondents participated in the survey (310 men and 482 women). **Figure 1** shows the states covered within the 4 geopolitical zones.

Trait Data Collection

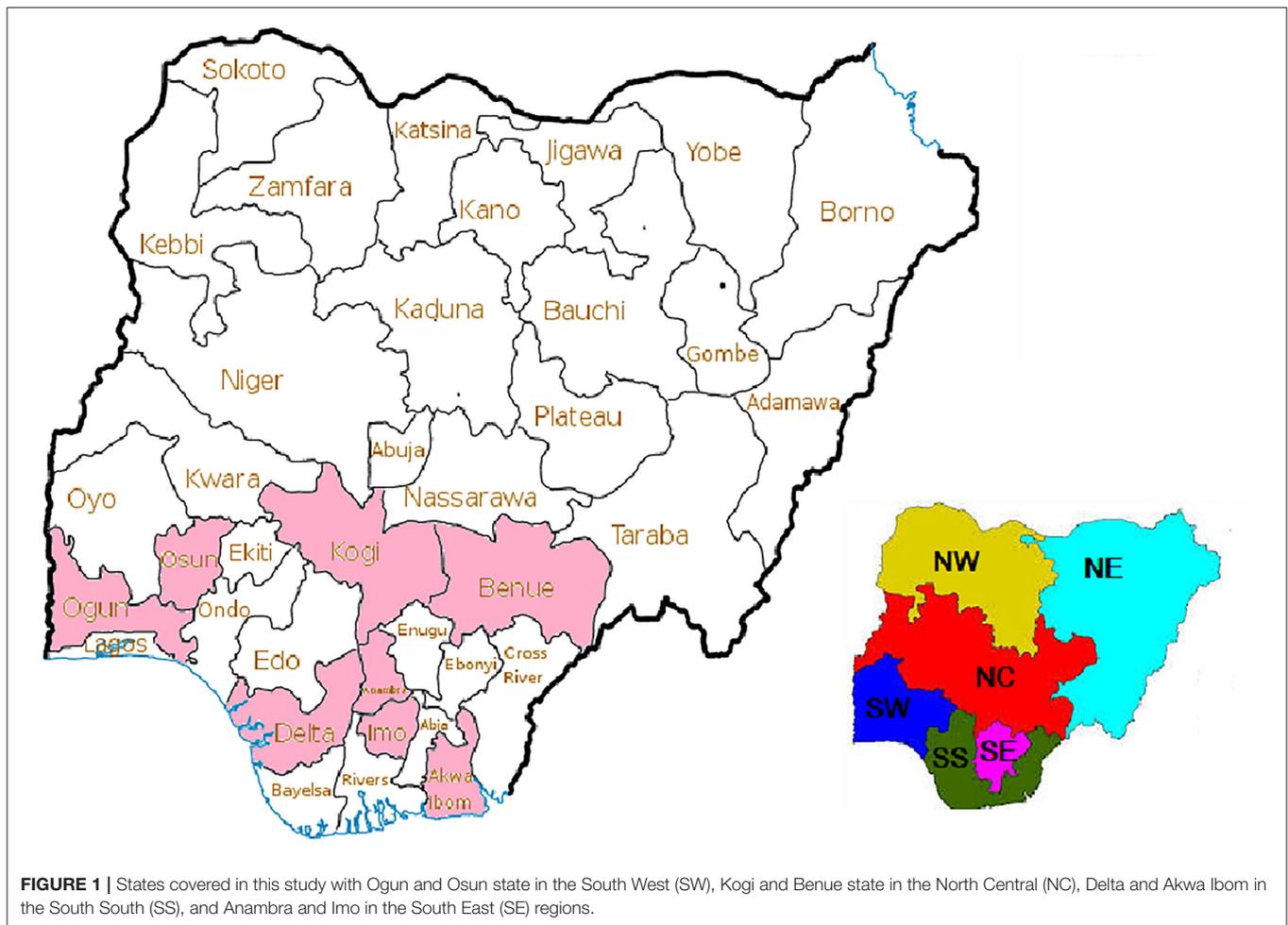
The 11 traits included in the 1000minds survey (1000minds, 2020) were determined based on reports, findings, published research (Bentley et al., 2017; Wossen et al., 2017; Teeken et al., 2018, 2021; Ndjouenkeu et al., 2021) and a literature review (Awoyale et al., 2021). They were also informed by discussions with experts and verified by the community-level FGDs. Trait data collection was based on a pairwise trade-off assessment of 11 cassava traits. We used an online survey tool, 1000minds survey (1000minds, 2020), which follows pairwise comparison of traits based on conjoint analysis that applies the Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) method (Hansen and Ombler, 2008). The traits and trait rankings included in the 1000minds survey were defined using parameters calculated as the economic effect of increment per unit change of each trait independently. These parameters were determined during the FGDs. A detailed description of the 1000minds survey (1000minds, 2020) algorithm can be found in Hansen and Ombler (2009). Outputs of the 1000minds survey (1000minds, 2020) assign trait rankings to each respondent ranging from most preferred (1) to least preferred (11) trait for all 11 cassava traits. Trait definitions from FGDs, exact trait level calculations, and details of the methodology are presented in Balogun et al. (2021). Definitions of cassava traits used in this study are described in **Supplementary Table 1**.

Individual and Household Level Data Collection

Household level data were collected using an adapted version of the Rural Household Multiple Indicator Survey (RHoMIS) (Hammond et al., 2017). This study's version of RHoMIS, included the following modules: Food availability, Household Dietary Diversity Score (HDDS), Household Food Insecurity Access Scale (HFIAS), Progress out of Poverty Index (PPI) (Desiere et al., 2015) for Nigeria version 2012 (Schreiner, 2015) and a gender equity indicator. This shortened version was developed together with the creators and data managers of RHoMIS to assure indicators remained valid and could be calculated. This shorter version was developed to decrease the respondents' time burden. Additional variables were collected at the individual and household level to complement the RHoMIS variables for analysis. The full set of variables presented in this study and their definitions can be found in **Supplementary Table 2**.

Analyses

Using SPSS, a Pearson's correlation coefficient (Pearson's r) analysis (Weaver and Wuensch, 2013) was conducted to assess the relationship between traits. The strengths of association were classified as weak ($r = 0.10$ – 0.20), moderate ($r = 0.21$ – 0.40), or strong ($r = 0.41$ – 1.00) and positively (+) or negatively (-) signed. The 1000minds survey (1000minds, 2020) results in trait rankings from 1 to 11, with 1 being most favored. Therefore, a negative association is read as increasing priority for that trait (a rank that increases toward 1) as the associated variable increases, while a positive association infers a decreasing priority for that trait (lowering in rank



toward 11) as the associated variable increases. The results in **Table 1** have been interpreted with this understanding, with the exception of trait mutual correlations. Relationships were considered significant at a probability level of 0.05 (p -value ≤ 0.05).

For Odds Ratio and Wilcoxon test, the variables for Poverty Probability Index (PPI) and Household Food Insecurity Access Scale (HFIAS) were transformed to binary groups to manage the complexity of the interactions in the analysis. For interpreting the PPI scores (0–100), the poverty likelihood 2011 lookup table (Schreiner, 2015) was used as \$1.90 per day purchasing power parity (PPP) 2011 poverty line to convert PPI score to poverty likelihood percentages (PPI index). According to this table 100–95.4% of all the respondents with a PPI score of 10 or lower are classified as poor. Therefore, respondents with a PPI index below 10% were grouped as “poor,” and those with a PPI above 10% as “non-poor.” For HFIAS, the four categories generated were transformed into two categories: “food secure” and “food insecure” (combining mildly food insecure, moderately food insecure and severely food insecure). Reducing the HFIAS categories was necessary due to the unequal distribution of respondents in each, but doing so could potentially mask

more nuanced analysis of the impact of food security on trait preferences.

A cumulative logit model using Procedure Logistic in Statistical Analytical System (SAS 9.4, Cary, NC, USA) was used to investigate the effects of different social variables on trait prioritization. All the traits were ordinal responses (rank of 1–11). Our model response profile is associated with a higher ordered value (lower rank) hence we modelled the probability of prioritizing each trait less (rank of 12). Odds Ratio, Maximum Likelihood Estimates, and Chi-square test (95% confidence interval level) were the metrics used as measure of association. For each of the groups modelled, we considered women (Gender), poverty index below 10% (PPI), and Food secure (HFIAS) levels as our comparison group. Furthermore, we investigated the different possible comparisons between the four regions in Nigeria: South West, South South, South East, North Central. In other words, we investigated the probability of prioritizing a trait by men with reference to women and so on. Wilcoxon rank-sum test was conducted using the `wilcox.rank` function in base R package of R statistical software version 3.5.2 (R Core Team, 2018) to test for gender differences in trait prioritization between the groups.

RESULTS

Through these analyses, we demonstrate the importance of considering social difference through multiple approaches. We argue that this layered approach to analysis improves opportunities to triangulate results and capture richer trait preference data to inform inclusive product profile development. By starting at the highest level, the relationship between traits, we set the stage for how trait preferences could be understood without recognizing socio-demographic and geographic variables. However, correlations that include these variables, as well as the interactions between these variables, demonstrate that their inclusion will result in more accurate breeding decisions. Finally, a heatmap supports these observations by visualizing the how gender, food security, poverty, and geography can be brought together to identify trait preferences, synthesizing the lessons established through this layered approach and facilitating their integration into breeders' product profiles.

General Correlation Between Traits, Individual, and Household Characteristics Trait-Trait Correlation

Most of the correlations found between traits were weak (Table 1A). The strongest negative correlations were between fresh root yield and the quality traits: gari color, gari texture and gari taste. The strongest positive correlations were between gari texture, gari taste and gari color. Pearson correlations between traits revealed overall negative correlations between traits related to product quality (gari taste, texture, color and swelling) on the one hand with those related to yield (fresh root yield, root size, dry matter content), storability and maturity time on the other. Product quality traits positively correlated with one another; notably gari taste and texture, gari color with taste and texture, and root color with gari color. Exceptions to this were the negative and significant correlation between gari swelling and root color. Related to yield, fresh root yield positively correlated with dry matter content and maturity time,

while dry matter negatively correlated with root size. Lastly, there was a weak positive correlation between disease resistance and ground storage.

Individual, Household, and Farm Characteristics

At the individual-level, there was a positive and significant correlation between female respondents and product quality trait rankings (gari taste, texture, color and swelling, root color). However, female respondents had a negative correlation with yield and agronomic traits (fresh root yield, root size and maturity time) (Table 1B). At the household-level, female-headed households and households with married couples showed inverse correlation results. Gari texture positively correlated with female respondents from female-headed households, but negatively correlated with female respondents that were part of a couple. Also, women in couples favored root size or disease resistance, while women in female-headed households did not. When women controlled more of the total value of activities, they favored gari color, texture and swelling more, and shorter maturity time less. This was the opposite when men controlled more of the total value of activities (Table 1B). These correlation results reinforce the role of gender in shaping trait preferences, and also indicate that household composition and intrahousehold dynamics further influence these rankings.

Land owned, age, crop sales, or value of crop produced did not correlate with any trait, while dietary diversity negatively correlated with root color. As a households' nutritional requirements (HHsizeMAE) increase, the less product quality traits (gari texture and color) were valued. Surprisingly, if respondents stated that they belonged to the dominant ethnicity in their community, they favored fresh root yield (Table 1B). The yearly production of cassava per household had several significant correlations. As production increased, prioritization of traits root yield, root size, dry matter, disease resistance and maturity time increased. However, the product quality traits of gari color, texture and taste decreased. An increase in home consumption of cassava was related to a reduction in favoring

TABLE 1A | Pearson correlations among cassava traits.

Traits	gari_ taste	gari_ texture	gari_ color	gari_ swelling	fresh_root_ yield	root_ size	dry_ matter	ground_ storage	disease_ resistance	root_ color	maturity_ time
gari_taste	1	0.277**	0.129**	-0.067	-0.294**	-0.287**	-0.092**	-0.190**	-0.192**	0.034	-0.222**
gari_texture	0.277**	1	0.247**	-0.02	-0.291**	-0.259**	-0.126**	-0.143**	-0.259**	0.017	-0.276**
gari_color	0.129**	0.247**	1	0.017	-0.300**	-0.267**	-0.165**	-0.152**	-0.252**	0.213**	-0.266**
gari_swelling	-0.067	-0.02	0.017	1	-0.170**	-0.119**	-0.151**	-0.001	-0.099**	-0.163**	-0.169**
fresh_root_yield	-0.294**	-0.291**	-0.300**	-0.170**	1	0.073*	0.246**	-0.098**	-0.086*	-0.212**	0.108**
root_size	-0.287**	-0.259**	-0.267**	-0.119**	0.073*	1	-0.121**	0.065	-0.007	-0.081*	0.059
dry_matter	-0.092**	-0.126**	-0.165**	-0.151**	0.246**	-0.121**	1	-0.230**	-0.164**	-0.144**	-0.009
ground_storage	-0.190**	-0.143**	-0.152**	-0.001	-0.098**	0.065	-0.230**	1	0.093**	-0.191**	-0.078*
disease_resistance	-0.192**	-0.259**	-0.252**	-0.099**	-0.086*	-0.007	-0.164**	0.093**	1	-0.135**	0.013
root_colour	0.034	0.017	0.213**	-0.163**	-0.212**	-0.081*	-0.144**	-0.191**	-0.135**	1	-0.077*
maturity_time	-0.222**	-0.276**	-0.266**	-0.169**	0.108**	0.059	-0.009	-0.078*	0.013	-0.077*	1

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

TABLE 1B | Pearson correlations between cassava traits and selected social characteristics.

Social characteristics	gari_taste	gari_texture	gari_color	gari_swelling	fresh_root_yield	root_size	dry_matter	ground_storage	disease_resistance	root_color	maturity_time
Individual											
Gender	0.099**	0.083*	0.142**	0.109**	-0.072*	-0.122**	0.05	-0.079*	-0.06	0.092**	-0.145**
Age	0.04	0.018	-0.006	-0.038	-0.089*	0.029	-0.013	-0.069	0.013	0.083*	0.070*
Ethnicity	0.017	0.004	0.019	0.049	-0.094**	0.007	-0.013	0.003	0.005	0.01	-0.012
Farm											
yearly_production	0.037	0.223**	0.244**	0.141**	-0.142**	-0.187**	-0.160**	0.073	-0.159**	0.081*	-0.106**
home_consumption	-0.046	-0.069	-0.074*	0.006	0.087*	0.095**	0.006	0.06	-0.048	-0.065	0.016
LandOwned	-0.015	0.032	0.054	-0.059	-0.022	-0.008	0.033	-0.034	-0.006	0.056	0.009
farmsize_acre	0.073	0.138**	0.181**	0.074	-0.015	-0.082	-0.051	0.085	-0.127*	-0.009	-0.091
CropDiv	0.044	-0.124**	-0.075*	-0.075*	0.056	0.004	0.086*	-0.183**	0.059	0.063	0.110**
Cropsales	-0.006	-0.011	-0.053	-0.001	-0.005	0.035	-0.041	0.068	0.035	0.025	0.011
Valuecropproduce	-0.006	-0.009	-0.052	0	-0.004	0.033	-0.039	0.067	0.033	0.025	0.01
House hold											
HHsizeMAE	0.004	0.094**	0.131**	0.048	-0.043	-0.034	-0.009	-0.038	-0.056	0.051	-0.085*
HDDS	0.051	0.052	0.092*	-0.066	-0.036	-0.048	-0.004	0.004	-0.051	0.113**	0.009
HFIAS	-0.037	-0.130**	-0.097**	-0.056	0.057	0.095**	0.077*	-0.058	0.077*	-0.023	0.061
FoodInsecure_yn	-0.051	-0.088*	-0.075*	-0.086*	0.052	0.107**	0.075*	-0.038	0.059	-0.047	0.06
PPI_Likelihood	0.034	0.104**	0.056	0.06	-0.005	-0.028	0.021	-0.093**	-0.004	-0.081*	-0.107**
PPI_Below10	-0.047	-0.079*	-0.025	-0.011	0.034	0.012	0.049	0.057	-0.012	0.038	0.012
PPI_10to30	0.036	0.034	-0.006	-0.032	-0.053	-0.008	-0.082*	-0.005	0.022	0.022	0.063
PPI_over30	0.025	0.088*	0.056	0.075*	0.028	-0.008	0.048	-0.097**	-0.015	-0.106**	-0.128**
Gender_MaleControl	0.029	0.079*	0.130**	0.081*	0.013	-0.056	-0.042	0.02	-0.035	-0.045	-0.134**
Gender_FemaleControl	-0.045	-0.095*	-0.122**	-0.085*	-0.007	0.07	0.046	-0.041	0.03	0.049	0.147**

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

root size, while as the farm size increased, product quality traits gari texture and color was less favorable. In general, household and farm characteristics that related to larger production and market-orientation correlated to output-related trait preferences.

As household food insecurity increased (HFIAS), there was an increased interest in product quality traits (gari texture and color) and a decreased interest in root size. As households had higher probability of being in poverty (higher PPI index), respondents favored product quality traits (gari texture) less, while favoring ground storage and short maturity time more. This pattern was mirrored when the indicator was separated into poverty categories (<PPI 10% being "non-poor"), with the "poor" category (PPI above 30%) (Table 1B).

Gender, Poverty, Region, and Food Security as Drivers of Trait Ranking

To explore relationships between trait prioritization and selected variables of interest, we focused on gender, region, food security and poverty using Odds Ratio estimates. Building from the exploratory analysis of correlations, this reduces the potential of interpreting possible spurious correlations to allow for more explicit comparisons between potential market segments.

Gender

Women tend to prioritize food product quality traits and root color more, while men tend toward root size and maturity

time, as well as ground storage and disease resistance. The traits prioritized by women show larger differences between men and women than other traits, with gari color showing the largest difference (Tables 2, 3). Women are more likely to prioritize root color (men are 35% more likely to rank it low), gari taste (51%), texture (31%), color (59%) and swelling (44%) than men. Men, on the other hand, are less likely to lowly rank root size (men are 35% less likely to rank it low), in ground storability (28%), disease resistance (26%) and maturity time (41%), with maturity time showing the largest difference (Table 3). For dry matter content and fresh root yield there is no difference between men and women.

Household Food Insecurity Index

Analysis of the HFIAS categories revealed 265 (34%) people as severely food insecure, 352 (45%) people as moderately food insecure, 63 (8%) people in mild food insecure and 105 (13%) people in food secure. In simplifying this to only compare between food secure and food insecure households, we see distinct differences in their likelihood to prefer some traits over others. Food insecure households are less likely to rank gari texture low (33%) but are more likely to give a low rank to root size (57%) and dry matter content (41%) (Table 3).

TABLE 2 | Odds ratio estimates for the differences between women and men, Food Secure vs. Food Insecure and Non-poor vs. Poor, and between the different regions for each of the 11 traits.

Category	Reference	Gari taste	Gari texture	Gari color	Gari swelling	Fresh root yield	Root size	Dry matter	In ground storage	Disease resistance	Root color	Maturity time
Men	Women	1.428**	1.319*	1.667***	1.484**	0.768*	0.649***	1.193 _{ns}	0.75*	0.771*	1.381*	0.598***
Food insecure	Food secure	0.781 _{ns}	0.668*	0.770 _{ns}	0.765 _{ns}	1.396 _{ns}	1.574**	1.410*	0.782 _{ns}	1.19 _{ns}	0.802 _{ns}	1.260 _{ns}
Non-poor	Poor	1.216 _{ns}	1.428**	1.147 _{ns}	1.047 _{ns}	0.855 _{ns}	0.931 _{ns}	0.828 _{ns}	0.779 _{ns}	0.994 _{ns}	0.873 _{ns}	0.932 _{ns}
North Central	South West	1.018 _{ns}	0.839 _{ns}	<i>ns</i>	1.170 _{ns}	0.958 _{ns}	0.667***	1.029 _{ns}	1.207***	1.538 _{ns}	0.615***	0.777***
South East	South West	1.073 _{ns}	0.475***	0.560***	0.577***	1.010 _{ns}	1.256**	1.559***	0.504***	1.618 _{ns}	1.199 _{ns}	2.477***
South South	South West	0.559***	0.600 _{ns}	1.499***	1.261**	0.480***	1.015 _{ns}	0.904 _{ns}	0.846 _{ns}	2.253***	1.872***	1.454 _{ns}
South East	South South	1.919 _{ns}	0.792***	0.374***	0.457***	2.103 _{ns}	1.237*	1.725***	0.595***	0.718 _{ns}	0.641 _{ns}	1.704***
North Central	South East	0.948 _{ns}	1.766 _{ns}	1.863 _{ns}	2.028 _{ns}	0.949 _{ns}	0.531***	0.660 _{ns}	2.395***	0.951 _{ns}	0.513***	0.314***
South South	North Central	0.549***	0.715 _{ns}	1.437***	1.078*	0.501***	1.522 _{ns}	0.878 _{ns}	0.701 _{ns}	1.465***	3.043***	1.871 _{ns}

*Indicate *p*-value < 0.05, ***p*-value < 0.01, and ****p*-value < 0.001 levels of significance respectively.

TABLE 3 | More (+) or less (–) odds (%) of ranking a trait low comparing the social binary categories of men/women, Food Insecure/Food Secure and Non-poor/Poor [based on the Poverty Probability Index (PPI) and Household Food Insecurity Access Scale (HFIAS)].

Trait	Men (comp. to Women)	Food insecure (comp. to Food Secure)	Non-poor (comp. to Poor)	SE (comp. to SW)	NC (comp. to SW)	SS (comp. to SW)	SE (comp. SS)	NC (comp. to SE)	SS (comp. to NC)
Gari taste	51					–44			–45
Gari texture	31	–33	43	–52			–21		
Gari color	59			–44		55	–63		44
Gari swelling	44			–42			–54		8
Fresh root yield						–52			–50
Root size	–35	57		25	–33		24	–47	
Dry matter		41		56			73		
In ground storage	–28			–49	21		–41	140	
Disease resistance	–26					125			47
Root color	35			148	–35	87		–49	204
Maturity time	–41				–28		70	–69	

Odds values are based on calculated odds ratios (Table 2).

Poverty Probability Index

In analyzing the PPI index, 575 people fell below a PPI index of 10% and were classified as non-poor, while 217 people were above a PPI index of 10% and classified as poor. Gari texture is the only trait significantly different between households that were classified as poor, and those that were not (Table 2): non-poor households are 43% more likely to rank gari texture low than households that were classified as poor (Table 3).

Regional Differences

Building from previous analysis, we find distinct regional variation in the prioritization of product quality traits (Table 2). Overall, gari texture, gari color and gari swelling were less likely to be ranked low (less odds in ranking the trait low) in the South East, compared to the South South and South West. Gari taste was less likely to be ranked low in the South South, compared to the South West and North Central. Lastly, gari color was more likely to be ranked low in the South South compared to the North Central and South West (Table 3).

There were regional variations in the prioritization of agronomic traits (Table 2). The highest differences were observed for root color, disease resistance and in ground storage. Root color was 148% more likely to be ranked low in the South East and 87% more likely to be ranked low in the South South when compared to the South West. The same trait was 204% more likely to be ranked low in the South South when compared to the North Central. In the North Central root color was less likely to be ranked low compared to other regions. Disease resistance was 125% and 47% more likely to be ranked low in the South South when compared to the South West and North Central respectively. Inground storage was 21% and 140% more likely to be ranked low in the North Central when compared to the South West and South East respectively, while the same trait was less likely to be ranked low in the South East. Maturity time was less likely to be ranked low in North Central when compared to the South West and South East, while the same trait was 70% more likely to be ranked low in the South East compared to the South South. Fresh root yield was about 50% less likely to be ranked low

in the South South when compared to the South West and North Central. Root size was less likely to be ranked low in the North Central when compared to the South West and South East, but more likely to be ranked low in the South East when compared to the South West and South South. Lastly dry matter was more likely to be ranked low in the South East when compared to the South West and South South (Table 3).

Social Categories' Interaction With Gender

Social differences are not experienced homogeneously. Therefore, it is critical to not just compare across these categories, but also understand the complexities within them. To move beyond previous analysis, we use a Wilcoxon test to investigate the interaction of gender with each of the following categories: food insecurity, poverty, and region (Table 4). We find that, in comparing the average trait ranking among food insecure households, women prioritize gari-related traits and root color more than men, while men prioritize agronomic traits more. This pattern was not observed for food secure respondents, where the only differences found between men and women were in the rankings of gari taste and maturity time. There was much less difference between women and men from non-poor households than between women and men from poor households. Among

non-poor households only gari swelling was more prioritized by women, and men prioritize fresh yield and root size was more than women.

There are very clear interactions of sex with region. In the South West, women prioritize gari-food product quality traits and root color more than men do. Consistently, men prioritize agronomic characteristics more than women. However, there is no difference in prioritization between men and women for gari swelling and in ground storability. For the North Central, there are only three traits that differ in average ranking for men and women: gari swelling is ranked higher by women, while fresh yield and root size are ranked higher by men. For the South East and South South only fresh yield is ranked higher by women than men, and men prioritize in ground storability more in the SS.

Summative Heatmap

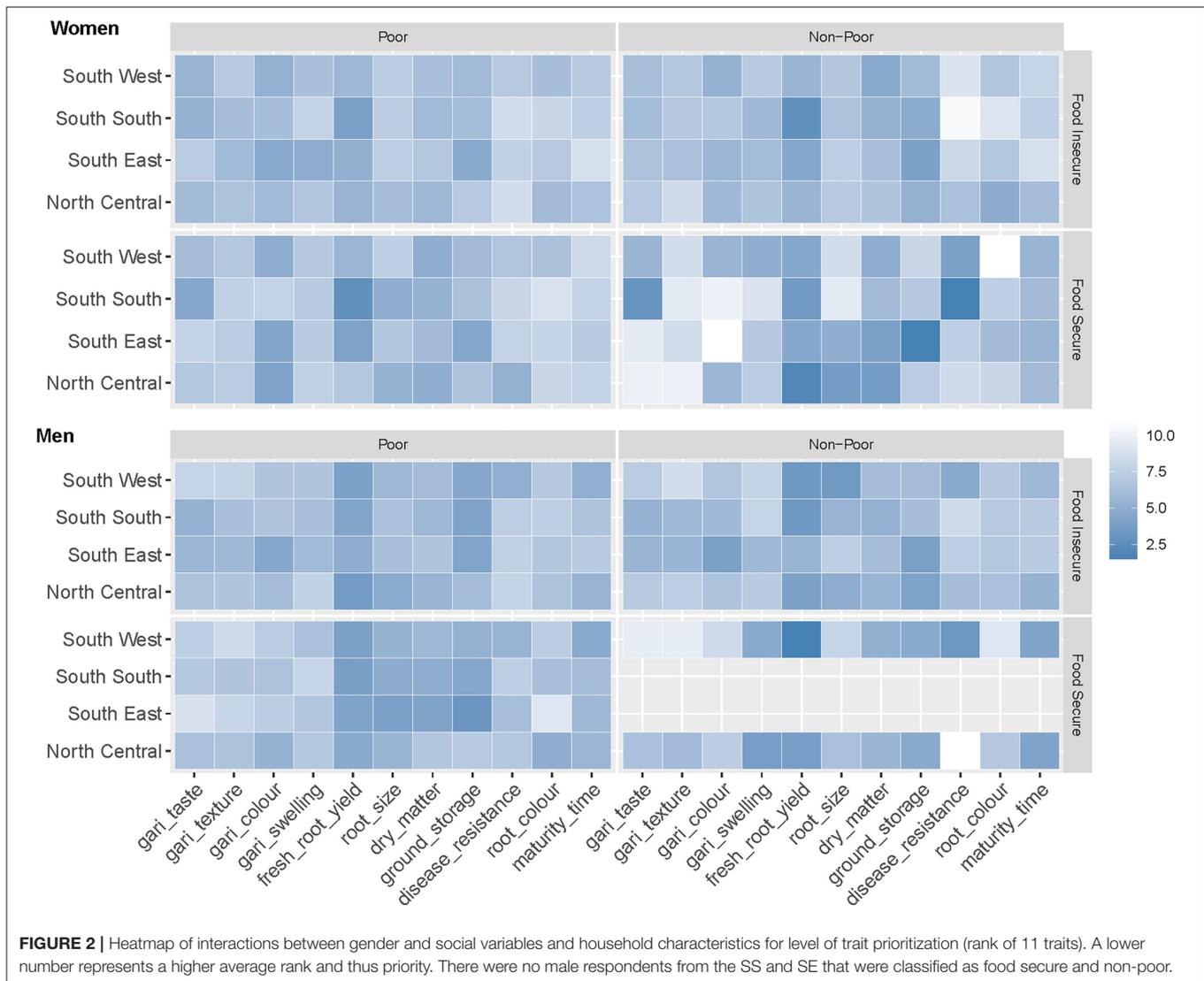
Figure 2 shows the interactions between gender and all the other social variables using a trait ranking heatmap as a broad-brush summary of results. From this visual, we observe that food insecure non-poor women in the South South give very low priority to disease resistance but very high priority to fresh root yield. Women from non-poor food secure households in the South West give very low priority to root color, while

TABLE 4 | Wilcoxon test for independent samples comparing gender differences for trait prioritization within food security, poverty and regional differences.

Social/regional category	N	Gari taste	Gari texture	gari color	Gari swelling	Fresh yield	Root size	Dry matter	In ground storage	Disease resistance	Root color	Maturity time	
Food secure	P-value	0.023	0.788	0.058	0.539	0.766	0.317	0.142	0.671	0.643	0.090	0.016	
	Median women	54	7	9	5.5	7	3	6	5	6	7.5	8.5	7
	Median men	58	9	9	7	8	4	5	6	5.5	7	7	6
Food insecure	P-value	0.053	0.041	0.001	0.003	0.032	0.003	0.259	0.016	0.016	0.001	0.002	
	Median women	428	6	7	5	6	5	7	6	5	9	7	8
	Median men	252	7	8	7	7	4	6	6	4	8	8	7
Poor	P-value	0.008	0.008	0.000	0.013	0.067	0.011	0.291	0.008	0.248	0.046	0.000	
	Median women	341	6	7	5	6	5	7	6	5	9	7	8
	Median men	234	7	7.5	7	8	4	6	6	4.5	8	8	6.5
Non-poor	P-value	0.297	0.900	0.250	0.060	0.267	0.020	0.370	0.852	0.0350	0.139	0.067	
	Median women	141	6	8	6	7	4	7	6	4	9	7	8
	Median men	76	8	8	6	8	4	6	6	4	7	8	6.5
North Central	P-value	0.081	0.753	0.057	0.031	0.011	0.030	0.517	0.356	0.998	0.058	0.185	
	Median women	123	7	8	6	7	5	6	6	7	9	5	6
	Median men	76	8	8	6	9	4	5	6	5	9	6	6
South East	P-value	0.111	0.787	0.914	0.065	0.301	0.431	0.557	0.472	0.738	0.187	0.062	
	Median women	104	8	6	4	5	5	8	7	4	9	7	10
	Median men	93	6	6	4	6	5	7	7	3	8	8	8
South South	P-value	0.156	0.735	0.387	0.711	0.046	0.485	0.537	0.027	0.158	0.247	0.359	
	Median women	133	5	6.5	7	8	2	7	5	5	10.5	9	7
	Median men	69	6	7	7	8	4	7	6	4	9	8	7
South West	P-value	0.000	0.001	0.000	0.149	0.000	0.003	0.093	0.157	0.000	0.011	0.000	
	Median women	122	5	7	5	7	6	8	5	6	8	7	8
	Median men	72	9	9	8	7.5	4	5	6.5	5	5	8	5

Values are ranks, so a lower number means a higher rank.

P < 0.05 are in bold.



women from non-poor food secure households in the South East give very low priority to gari color. Furthermore, food secure non-poor women from the South South give a very high priority to disease resistance while women in this category from the South East give a very high priority to in ground storability. There were no food secure non-poor men in the South South and South East represented among the respondents. Food secure non-poor men in the North Central gave very low priority to disease resistance while food secure poor men in the South West give very high priority to fresh root yield.

DISCUSSION

This study sought to broaden the narrative around trait preference studies, to move beyond oversimplification and comparison of men and women by providing richer analysis of end users of cassava varieties. The intention is to more accurately analyze the data guiding breeders' understanding of smallholder cassava farmers in Nigeria, and their preferences, to develop

more informed product profiles. Teeken et al. (2018) outlines the importance of applying a gender lens to understanding trait and varietal preferences, finding differences in trait preferences between women and men across South East and South West. This study expands this approach, with a larger set of respondents, new approaches and tools for deeper analyses.

Gender Continues to Matter

This study found significant differences in prioritization between women and men of differential cassava trait preferences in Nigeria. This confirms both earlier primary studies on trait preferences (Bentley et al., 2017; Wossen et al., 2017; Teeken et al., 2018), as well as reports outlining differential gender roles along the cassava value chain and women's high involvement in cassava processing and marketing (Curran et al., 2009; Walker et al., 2014). Balogun et al. (2021) also showed that women are more likely to prefer quality traits. Our results follow these earlier findings that women prefer product quality traits, while men prefer productivity-related traits. This confirms the

opportunity for breeding programs to prioritize product quality traits, especially gari color, taste, texture and swelling. There is need to develop high throughput phenotyping approaches, experimental designs, and extensive genetic studies to reflect the importance of these traits. Doing so would reflect the value breeding programs place on gender equality goals.

Interestingly this broad bifurcation of trait preferences, women favoring product quality traits and men favoring productivity related ones, was reflected even when looking at household types and value of household activities. Households headed by single women reflected a preference of quality traits, while preferences shifted toward productivity traits for couples in households. Chiwona-Karltun et al. (1998) also found unique preferences for female-headed households, which reflected their social vulnerability. This study observed a similar preference pattern when control of value of household activities was higher for women or men. Together these results support the argument that gender analysis should be central to breeding priority setting because preferences remain strongly correlated with sex of the respondent, the role of women within households, and their control of resources.

Regional Differences Are Complex but Draw Lessons Important for Breeding

Product quality is of utmost importance in South East Nigeria. There is a cultural context shaping the relationship between cassava and its food products in this region, where harvests and processing are regulated to specific days, and farmers seek to add as much value as possible to the cassava that is harvested from small plots (Teeken et al., 2018). Furthermore, as the Pearson correlation between the traits has shown, quality traits become more important when more of the roots are used for home consumption. That root color is far more important in the South West and North Central than in other regions can relate to the longer fermentation practiced in these regions, which can cause discoloration of the roots. In the other regions, gari is colored using red palm oil (Awoyale et al., 2021; Chijioko et al., 2021; Teeken et al., 2021). Teeken et al. (2021) found that a variety disliked because of discoloration in the South West (where there is long fermentation) was not clearly disliked in the South East. Some of the regional differences in variation in gar fermentation may also reflect product quality trait differences (Ndjouenkeu et al., 2021).

It is also remarkable that in-ground storage is not prioritized in the North Central region. This could relate to more commercially oriented cassava farming in this region, where there is also an existing seed system (Bentley et al., 2020). In this case, harvesting more roots at the same time for the market is more important than the need for storability. In the South East, there is a concentration of poorer female farmers (Orr et al., 2018), where farming on small plots for home consumption and relatively small local markets. This may necessitate more in-ground storability (to facilitate piece-meal harvesting) compared to other regions. Prioritization of root size and maturity time in North Central may equally be explained by the more commercially organized markets demanding for

marketable larger roots. We observed that root size in the South East is less important than in the South West where there are market connections to other states and cities (Abdoulaye et al., 2013).

The South South was unique in the high priority on gari taste and fresh root yield but low priority given to gari color and root color. One explanation can be that gari and eba are relatively less important in the diet of people in the South South where fufu is more important, but cassava is also consumed in starch dough form (Etejere and Bhat, 1985). Furthermore, most gari is colored yellow by adding palm oil which makes the shininess more important than the actual color (Ndjouenkeu et al., 2021). The importance placed on fresh root yield here could be explained by the land scarcity and relatively small plot sizes in the South East and South South when compared to other regions (Korieh, 2010; Teeken et al., 2018). It can also be explained by the predominance of landraces in the South South (Pircher et al., 2019) that are good for food product quality so the quality is already assumed good in any future variety improvement scenario. Counter to the observed gender trait differences, women in South South and South East prioritize fresh root yield. This can be understood by the major role women have within agriculture in these regions where men are more involved in other businesses and rely on the expertise of women with regards to farming and/or are fully involved in similar practices when cassava farming and processing is concerned (Enete et al., 2002).

These observations suggest a clear regional difference in trait preferences that can be related to the relative importance of different food products (Dufour et al., 2021). Specific regional (food) cultural factors (Ntunmgia, 2012) should be considered when developing variety replacement strategies. Such differences should be considered to make a new variety more competitive or have strong complementarity (Mbwentchou Yao, 2021) to the most popular varieties in the region. In-ground storability seems crucial for smaller scale farmers that live under less secure circumstances requiring flexibility, while early maturing high yielding varieties with lower in-ground storage ability complement better to the variety portfolio of larger farmers that can afford a more fixed farming schedule.

Considering Poverty and Food Security Could Help Develop More Impactful Breeding Products

We found a strong correlation between food insecurity and difference in cassava trait preferences between men and women. As households become more food insecure, the differences in prioritization between men and women increases. This could be because cassava occupies a greater part of the diet and income generation within food insecure households. Gegios et al. (2010) show a negative relation between nutritional status of children and high consumption profile of cassava. The quality and market price of the product and its eating experience might therefore become relatively more prevalent. Similar tendency is true when considering Poverty Probability where gender differences appear among households that are poor. This could indicate that within non-poor households' the

division of labor is less pronounced making men and women, prioritize traits more similarly (Alawode et al., 2017). This also highlights the overall importance of gari swelling for women and yield for men as these traits cut across food insecure and poor households.

Combining insights from different social identities and household characteristics, it is clear that gari texture is the most crosscutting trait in terms of its importance. Gari texture highly influences gari quality and market price. This confirms findings of Ezedinma and Nkang (2008) that good texture/taste is a major reason that influences willingness to pay for gari. Considering food security however added nuance to this assumption: Women in food insecure and poor households value texture more, while gari texture is the only trait that is generally (men and women combined) also valued more by food insecure households and poor households (Table 3).

Food security, region, and poverty level all interact with gender in defining trait preferences, reflecting the importance of looking at heterogeneity among social groups especially in defining breeding priorities. This research has identified quality traits and food security traits like in ground storability as essential if breeding programs intended to positively impact poor and food insecure households. These results reinforce the importance of recognizing social difference and the heterogeneity among men and women. Individual and household characteristics interact to reveal traits that are highly variable across differences. This information can inform trait prioritization for product profiles, labelling traits that are cross-cutting in importance as "non-negotiable." Furthermore, the demonstrated grouping of traits per region would be highly informative for breeding programs to consider regionally focused breeding pipelines. Together, this study has potential to guide development of breeding products that have higher social impact, which may ultimately serve the more vulnerable and align with development goals. Deeper understandings of social dimensions provide insights into the true experience of farmers in order to develop product profiles that support the public and breeding programs' development and social impact objectives.

DATA AVAILABILITY STATEMENT

The datasets related to this study can be found in the CKAN <http://data.iita.org> repository of IITA: Teeken, B., Garner, E., Afolabi, A., Balogun, I., Olaosebikan, O., Bello, A., Madu, T., Okoye, B., Egesi, C., Kulakow, P., & Tufan, H. A. (2021). Beyond "women's traits": Exploring how gender, social difference and household characteristics influence trait preferences [Data set]. International Institute of Tropical Agriculture (IITA). <https://doi.org/10.25502/RHJ9-2228/D>.

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ETHICS STATEMENT

The studies involving human participants were reviewed and approved by internal review board of the International Institute of Tropical Agriculture. IITA has the mandate to carry out research in Nigeria including human subjects based on an agreement with the Nigerian government. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

HT conceived the original manuscript idea and wrote the manuscript. BT and EG analyzed the data and wrote the manuscript. AA and IB analyzed the data. OO, AB, TM, and BO contributed to fieldwork and reviewed the manuscript. CE and PK reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2021.740926/full#supplementary-material>

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Conflict of Interest: IB is employed by AbacusBio Limited.

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