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A gendered conjoint analysis of tilapia trait preference rankings among urban consumers in Zambia: Evidence to inform genetic improvement programs

Seamus Murphy [a,1], Steven M. Cole [b,*,2], Alexander M. Kaminski [c], Harrison Charo-Karisa [a,3], Rose Komugisha Basiita [b], Cynthia McDougall [d,4], Keagan Kakwasha [b], Tabitha Mulilo [b], Surendran Rajaratnam [d,5], Wagdy Mekkawy [d,6]

[a] *WorldFish, Abbassa, Abou-Hammad, Sharkia 44662, Egypt*
[b] *WorldFish, Plot 18944 Lubansenshi, Lusaka, Zambia*
[c] *Institute of Aquaculture, University of Stirling, Stirling FK9 4LA, UK*
[d] *WorldFish, Jalan Batu Maung, Bayan Lepas, 11960 Penang, Malaysia*

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ABSTRACT

Zambia has experienced a rise in per capita fish supply in recent years due in part to growing domestic aquaculture production and expanding import markets that supply farmed Nile tilapia to mostly urban markets. While urban consumers enjoy a wide variety of local fish species, including wild-caught native tilapia, little is known regarding the consumer preferences for farmed tilapia traits. Understanding aquaculture consumer markets is needed, including more detailed evidence of differences in tilapia trait preferences between women and men of differing socioeconomic backgrounds. Such data may add value to current and future genetic improvement programs, inform the design of domestic production systems and aquaculture marketing campaigns, and improve the food and nutrition security potential of the sector. This study assessed consumer preference rankings of farmed tilapia traits in four major urban sites in Zambia in 2018. Women and men consumers of different socioeconomic status (SES) participated in the study ($N = 313$). Using a pairwise ranking method and multi-criteria survey tool, consumers made a choice between values of different morphometric traits: total body weight, length, width, and height, skin colour, and head and tail sizes. Men reported a stronger preference for traits that were ranked higher overall by the sample, including larger body weight ($p < 0.001$), darker skin colour ($p < 0.05$), and taller body height ($p < 0.05$). Women reported stronger preferences for traits that were ranked lower overall, including shorter body height ($p < 0.01$) and smaller body weight ($p < 0.001$). Controlling for several covariates believed to influence consumer trait preferences for farmed tilapia (e.g., SES, age, educational level, and household size), nonparametric regression analysis revealed strong consumer preferences by men for thicker body width ($p < 0.05$), larger body weight ($p < 0.001$), and taller body height ($p < 0.05$). Consumers of lower SES had a stronger preference for darker skin colour than consumers of middle SES ($p < 0.05$). These findings confirm existence of differences in consumer preferences for farmed tilapia traits in urban Zambia and should be considered in genetic improvement programs. Fish breeding thus should be more gender-responsive and pro-

* Corresponding author.
E-mail addresses: s.cole@cgiar.org (S.M. Cole), a.m.kaminski@stir.ac.uk (A.M. Kaminski), hkarisa@worldbank.org (H. Charo-Karisa), B.Komugisha@cgiar.org (R.K. Basiita), cynthia.mcdougall@sei.org (C. McDougall), K.Kakwasha@cgiar.org (K. Kakwasha), surendran@ukm.edu.my (S. Rajaratnam), Wagdy.Mekkawy@csiro.au (W. Mekkawy).
[1] Current address: Independent Consultant, The Forge, Mace Lower, Claremorris, Mayo F12 K497, Ireland.
[2] Current address: International Institute of Tropical Agriculture, Plot 25 Mikocheni Light Industrial Area, Mwenge Coca-Cola Road, P.O. Box 34441, Dar es Salaam, Tanzania.
[3] Current address: World Bank, 1818 H Street, N.W., Mail Stop MC 13-1302, Washington, DC 20433 USA.
[4] Current address: Stockholm Environment Institute, 10th Floor, Kasem Uttayanin Building, 254, Chulalongkorn University, Henri Dunant Road, Pathumwan, Bangkok 10330, Thailand.
[5] Current address: Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
[6] Current address: Commonwealth Scientific and Industrial Research Organisation, Australia.

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poor. Differences suggest limitations in genetic innovations to meet the needs of diverse consumer groups, requiring complementary production and marketing interventions within the aquaculture industry.

1. Introduction

Tilapia is one of the most produced, distributed, and consumed farmed fish species in the world (Garlock et al., 2020; Kumar and Engle, 2016), providing consumers with a relatively inexpensive and important source of animal protein for enhanced food and nutrition security (Béné et al., 2016; Bogard et al., 2018; Prabu et al., 2019). Tilapia culture is now promoted in several low- and middle-income countries to help boost national fish production (Kaminski et al., 2018; Kassam and Dorward, 2017). To realize the potential of the farmed tilapia industry, public and private sectors in these countries have significantly invested in increasing productivity and efficiency for commercial and industrial viability (Ponte et al., 2014), as well as making efforts towards sustainability (Yacout et al., 2016) and maximising food security outcomes (Akuffo and Quagrainie, 2019; Murphy et al., 2020).

Genetic improvements have been shown to be an economically feasible and powerful way to increase efficiency in aquaculture and facilitate greater expansion of the sector as cumulative gains in breeding programs are passed down to hatcheries, farmers operating at different scales, and other value chain actors (Ponzoni et al., 2011). Improving production related traits remains a priority of both plant and animal breeding programs (Colihueque and Araneda, 2014). Trait preference research in low-income countries has, however, largely focused on producers' preferences over end-users such as traders and consumers (Baidu-Forson et al., 1997; Asrat et al., 2009; Banla et al., 2018). Past studies have highlighted the value of understanding consumer trait preferences and the differentiation of marketable sizes and characteristics of tilapia between consumer groups, not only for developing new strains or improving adoption rates among producers, but also for aquaculture marketing campaigns and supply chain decisions (Gephart et al., 2020; Pasch and Palm, 2021), thus supporting food security and nutrition objectives (Lipton, 2007; Njuki et al., 2011; Chikowi et al., 2021). Such programs further inform management of commercially viable and sustainable production systems that are tuned to emerging consumer markets (Kaminski et al., 2024; Ahmed et al., 2012; Kleih et al., 2002).

Including consumer preferences into selective breeding programs and production systems design can tailor aquaculture products to various market segments and make them more available to different social groups (Chikowi et al., 2021), especially young people and women who are oftentimes excluded from aquaculture research and development (Brugere et al., 2023; Kruijssen et al., 2018). Furthermore, actively incorporating the needs and demands of resource-poor or marginalized groups into the development of the value chain – in this case selecting for traits preferred by farmed tilapia fish consumers into the breeding program – generally results in positive development outcomes such as increased adoption rates (Ashby and Polar, 2019) and improves overall value chain governance (Kaminski et al., 2020; Partelow et al., 2023). Actors who are less empowered or marginalized are often less served as clients of breeding programs, which has consequences not only for social and gender equality but also for adoption, and thus for nutrition, poverty reduction, and resilience (McDougall et al., 2022).

While at a relatively nascent stage of development, the aquaculture industry in Zambia has experienced recent growth, making it the sixth largest producer of farmed fish in Africa (Tran et al., 2019). The estimated total national production in 2018 was 21,567 t (Ministry of Fisheries and Livestock, 2019). The aquaculture industry is almost exclusively made up of tilapia production, the bulk of which is produced by large commercial farms located in Southern and Lusaka Provinces (Kaminski et al., 2018; Avadí et al., 2022). These farms grow exotic, genetically improved Nile tilapia (*Oreochromis niloticus*) strains imported from hatcheries in Asia (Genschick et al., 2017). The almost exclusive reliance on exotic strains by commercial farms in Zambia is due, in part, to the limited supply of any viable, native, genetically improved tilapia strains in the country (Hasimuna et al., 2020).

To address this issue, the Zambian government recently embarked on a breeding program to develop a genetically improved strain of the native tilapia species, *Oreochromis andersonii*, selected from among local populations (African Development Bank, 2016; Genschick et al., 2017; Basiita et al., 2022). Farmed tilapia is playing an increasing role in changing patterns of fish consumption where there is rapid growth in farmed fish supply and where the price of wild-caught fish is rising significantly due to limited supply (Tran et al., 2019; Harris et al., 2019; Longley et al., 2014). This presents an opportunity for the aquaculture industry to prioritise the traits preferred by producers, processors, traders, and consumers and target various segments of the market. Globally, research on end-user preferences for tilapia morphology is limited (Mehar et al., 2019). Two studies have touched on tilapia trait preferences in Zambia, restricting their analysis to broader categories of tilapia sizes or products preferred by urban consumers (Genschick et al., 2018; Malumbe and Musuka, 2013). These studies found that, overall, wealthier consumers prefer larger, fresh tilapia and lower-income consumers depend on small, dried pelagic species found in the capture fisheries of Zambia. Similar results were found in Malawi, with the addition that the sex of consumers significantly affected preferences for species and size (Chikowi et al., 2021). These findings suggest that the bourgeoning aquaculture sector in Zambia should take heed of such differences and actively strive to target the bottom of the economic pyramid (Genschick et al., 2018).

Consumer preferences for fish in Africa are largely driven by socioeconomic circumstances, and especially the availability and accessibility of fish as compared to other animal-source foods (Obiero et al., 2014; Githukia et al., 2014). In general, preferences for fish in Africa are largely motivated by their price point (de Bruyn et al., 2021). Tilapia however, and especially farmed tilapia, is more expensive than most fish on the market but cheaper than most meats in many African countries (Darko et al., 2016). In Zambia, consumer preferences for fish are driven by cultural and socioeconomic factors such as ethnicity and wealth (Genschick et al., 2018). Preference for tilapia over other fish species in many African countries is shaped by hedonic attributes such as taste, colour, and freshness (Obiero et al., 2014; Darko et al., 2016). It is important to note that in terms of immediate *utility* from a breeding program perspective, not all preferred traits in these sorts of studies can be selected for genetic modification. This study focuses only on traits that can be included in genetic improvement programs.

A study in Egypt for example, found gender and wealth differences in consumer preferences for different morphological measurements and sizes of tilapia, suggesting better product targeting when considering these differences (Murphy et al., 2020). In Bangladesh and India, Mehar et al. (2022) found different gender and geographical differences in preferences and overall ranking of different fish species. Similar studies on preferences for tilapia in Bangladesh concluded that farmers and breeders could respond to preferred traits such as freshness, taste, or size by improving farm management and value chain practices (Mehar et al., 2023). Expressing preferences into well-defined traits and assessing trade-offs in genetic improvement programs can make fish value chains more inclusive (McDougall et al., 2022).

This study explored tilapia trait preference rankings of women and men consumers from different socioeconomic groups across four major urban sites in Zambia. The study's two main objectives were to: 1) generate more precise information on the morphometric traits of farmed tilapia considered by consumers; and 2) determine whether tilapia trait preference rankings differ by sex and socioeconomic status of the consumer.

2. Methods and materials

This study adopted a mixed-methods research approach that involved two stages of inquiry. The first was an initial qualitative scoping study on tilapia products available in the urban market and the trait measurements and characteristics reported by different end-user groups. The scoping study informed the design of the second stage of the research, which was a quantitative study on farmed tilapia trait preference rankings of urban consumers differentiated by socioeconomic status and sex.

2.1. *Qualitative scoping study*

Between October and December 2017, the qualitative scoping stage of the research was carried out in four district capitals of Zambia: Lusaka, Ndola, Kitwe, and Solwezi. Semi-structured interviews were conducted with a diverse group of value chain actors, including producers, traders, retailers, and consumers (Table 1). The main goal of this stage of the research was to record descriptions of tilapia products that different value chain actors produce, trade, and consume to inform the design of the second stage rankings survey. Specifically, the scoping study identified candidate variables of priority tilapia traits and generated mean estimates of their morphometric measurements and characteristics. Two aids were employed when interviewing respondents: 1) an anatomical picture reference of a Nile tilapia (Fig. 1); and 2) a tilapia trait dictionary.

Trait dictionaries have been used as methodological tools in phenotypic data collection by several breeding centres across the CGIAR network (Shrestha et al., 2010, 2012). These tools were first developed by the Gene Ontology Consortium to provide "controlled vocabularies" from a validated set of lexicons to ensure data collection of relevant descriptions of the biological attributes of gene products (Ashburner et al., 2000; Smith et al., 2007). In this study, the tilapia trait dictionary was designed to help enumerators target detailed characterizations of tilapia morphology by providing a list of phenotypic traits and scales of measurement that were breeder-defined and market-tested (Ashburner et al., 2000; Shrestha et al., 2010, 2012; Smith et al., 2007).

It is worth noting that several terms emerged in the development of the trait dictionary, which echoed findings in the wider literature of food studies and portion-size estimation research regarding variance in "palm size" and "fillet size" descriptions among consumers (Anderson et al., 2008: p. 40; Faulkner et al., 2016: p. 2379; 2017: p. 202; Flynn et al., 2012: p. 522). Caution was taken when examining mean estimates from the qualitative sample to draw our primary phenotypic measurements of body length, body width, and body height. This was supplemented with an additional supermarket and street survey of frozen and fresh tilapia products, which provided rough benchmarks not only on fillet size, but also on pricing, packaging, and product characteristics such as carcass colour and origin of source (Table 2).

The qualitative interviews that were conducted generated some interesting perceptions from different value chain actors about what characteristics customers (and consumers more specifically) from urban markets in Zambia prefer in their tilapia. We present a few of these insights here to showcase how they helped inform the design of the quantitative study described further below.

Table 1
Stage one scoping study sample.

Respondent type	Women	Men	Total
Consumer	31	24	55
Informal fish retailer	17	6	23
Shop or supermarket manager	2	7	9
Wholesaler or distributor	1	4	5
Small-scale fish farmer	3	11	14
Large-scale fish farmer	1	2	3
Total	55	54	109

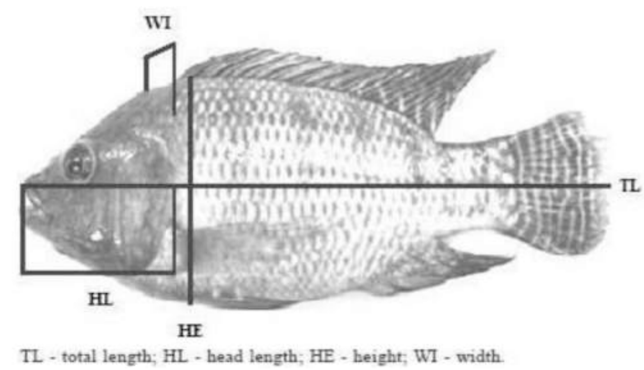

Fig. 1. Anatomical picture reference of a tilapia product used as an interview aid in the study.

Table 2
Supermarket survey results.

Average supermarket monthly sales	Solwezi	Kitwe	Ndola	Lusaka	#Fish	Fish/g
Tilapia Family Pack	55	69	99	284	5.5	181.82
Tilapia Small Family Pack	98	78	112	198	7.4	135.14
Tilapia Medium (size)	138	47	69	194	6.2	161.29
Tilapia Small (size)	133	146	189	210	7.8	128.21
Mixed Red Tilapia	17	47	34	95	8.3	120.48
Wild Tilapia	368	322	73	189	6.4	156.25
Fresh Catch - Tilapia Whole Round	0	0	0	64	5.4	185.19

A sales manager from Chilenje (Lusaka) reported that,

> "Customers know the colour of the Kafue and the Lake Kariba farmed fish. There is a slight difference in the colours. Kafue is a little redder on the under belly. People say this fish tastes better, so they look for the redness" (October 26, 2017).

A sales manager from a nationwide supermarket operating in Lusaka pointed out that his customers mainly look at the colour and size of fish when they buy fresh tilapia. The sales manager went on to explain that he felt most consumers like the darker colour of the tilapia produced by one of the large fish farms in Lake Kariba. Concerning the sizes of tilapia that different customers prefer, he said,

> "Restaurants tend to like the smaller sizes. Most consumers like the medium size and the guys [men] they sometimes buy the big size to throw on the braai [a space for grilling meats outdoors]" (October 29, 2017).

From the qualitative interviews, preferences for colour and product origin seem to differ by region, with one retailer in Solwezi explaining supply source is also involved,

> "Tilapia is the most sold fish. Consumers like it the most. They do not want the fish imported from China when they come here. They do not want the fish [from the largest importer in the country]. Farmed fish [from Lake Kariba] is darker and bigger and the fish imported from China is lighter [in colour] and smaller" (October 17, 2017).

Finally, a woman consumer purchasing tilapia in Kitwe explained that she prefers to buy darker coloured fish to the lighter coloured fish because the former is "more tasty." She also commented on the size preferences of fish in her household, explaining that,

> "I mostly buy the medium sizes and a few bigger ones because my husband likes big fish" (October 19, 2017).

A stakeholder consultation workshop was held with hatchery operators, aquaculture scientists, and public officials, where the scoping study's summary trait findings and definitions were presented, discussed, and validated. During this one-day assembly in December 2017 at the headquarters of the Department of Fisheries in Chilanga, Zambia, thirteen morphometric traits were identified as candidate response variables to be included in the quantitative study in the second stage of the research (Table 3). Arguably, we could have included additional traits to better reflect the range of choice options for body weight, width, length, and height, head and tail size, and skin colour. For example, we asked about "smaller" versus "larger" body weight and indicated "smaller" means $<$300 g, while "larger" means $>$300 g. We could have instead proposed a range of options such as "small," "medium," and "large" and provided a range for each. We opted for fewer traits with key cut-off points because we felt that including more traits in this study could lead to the collection of less reliable data given the additional choice options and time needed to choose between different tilapia traits.

2.2. Quantitative trait preference rankings survey

A quantitative trait preference rankings survey was carried out between June and July 2018 in the same four urban district capitals as those included in the scoping study. The survey was conducted with 313 consumers (Table 4) from among 23 markets where fish and other produce are sold (Fig. 2). Urban consumers were chosen as the focal end-user group for the quantitative study given that much of the tilapia produced by the commercial sector in the country is sold in these urban areas (Kaminski et al., 2018). The consumer sample was identified using a stratified probability-sampling framework. District sub-samples were determined based on the relative number of functioning markets in each district town to the total number of markets across all four district towns. Consumers were randomly selected within markets by enumerators who invited every fourth person in a particular market to interview as they conducted transect walks.

Table 3
Morphometric trait variables.

Morphometric trait variable	Variable description
Larger body weight	Total weight including gut and gonads >300 g
Smaller body weight	Total weight including gut and gonads <300 g
Thicker body width	Distance along first ray of dorsal fin >3.8 cm
Slimmer body width	Distance along first ray of dorsal fin <3.8 cm
Longer body length	Distance from upper lip of mouth to end of caudal fin >22 cm
Taller body height	Distance between cranial point of pectoral fin and lateral line >6.9 cm
Shorter body height	Distance between cranial point of pectoral fin and lateral line <6.9 cm
Larger head size	Distance from cranial point of upper lip to rear operculum >6.1 cm
Smaller head size	Distance from cranial point of upper lip to rear operculum <6.1 cm
Larger tail size	Distance along fin edge from front to rear of caudal fin >4.4 cm
Smaller tail size	Distance along fin edge from front to rear of caudal fin <4.4 cm
Darker skin colour	Reported as darker or reddish flesh colour of scales or underbelly
Lighter skin colour	Reported as lighter or pale flesh colour

grams (g); centimeters (cm).

Table 4
Stage two quantitative study sample.

District	Women	Men	Total
Lusaka	72	39	111
Kitwe	33	45	78
Solwezi	31	21	52
Ndola	28	44	72
Total	164	149	313

The survey was administered using the 1000minds "Potentially All Pairwise RanKings of all possible Alternatives" (PAPRIKA) method (Hansen and Ombler, 2008; Lee et al., 2015; Moreno-Calderón et al., 2020)[7] utilizing tablets and accompanied by the anatomical picture reference of a Nile tilapia. The PAPRIKA method is a common approach in plant and animal breeding research that elicits preferences in an adaptive, interactive, and automated manner by asking the fewest number of trade-off questions needed to pairwise rank all hypothetical alternatives, either explicitly or implicitly, using two traits at a time (Claret et al., 2012; Cox et al., 2007; i Furnols et al., 2011; Slagboom et al., 2016). In our study, consumers were presented with a choice between two alternative tilapia traits (see Fig. 3 for an example). Following their selection, the rankings were registered, and a binary weight (0/1) was assigned to each trait before a new choice of alternatives was presented. With each trait selection, the preferences of consumers were logged as an explicit pairwise ranking until all traits were scored either explicitly or implicitly by association of their relative weighting to other implicitly ranked pairings (Hansen and Ombler, 2008; Sullivan and Hansen, 2017).

2.3. Quantitative data analysis strategy and variable descriptions

Given that rankings tend to follow a non-normal distribution (Lako et al., 2018; Lawless and Heymann, 2010; Silva et al., 2020), response variables were examined using the Shapiro-Wilk test. The test observed non-normal distributions of all morphometric trait preference rankings. Accordingly, we employed a nonparametric local-linear kernel regression model to examine the effect of the independent variables of interest (sex and socioeconomic status (SES) of the consumer) on the preference rankings for a particular trait, holding several covariates constant. In this model type, the relationship between the preference trait rankings and the independent variables was modelled in linear form by estimating a weighted mean within a local neighbourhood of each observation (Cid and von Davier, 2015).

Following Rios-Avila (2020), the nonparametric regression model of the preference rankings for a particular trait of tilapia product (y_i) given the k dimensional vector of exogenous variables (W_i) is given by

$$y_i = g(W_i) + \varepsilon_i \tag{1}$$

Eq. (1) assumes that $E(\varepsilon_i) = 0$; W is related to y through some unknown nonlinear functional form; y is locally linear, or differentiable, at the point $W_i = a$; no omitted variable problem exists. The function $g(.)$, which makes no known functional form, can be estimated by modelling the conditional mean function as a locally weighted average estimator given as

$$\widehat{g}(w) = E(y_i)|W_i = w) = \frac{\sum y_i K(W_i, w, h)}{\sum K(W_i, w, h)}$$

Where $h = \{h_{w1,\ldots}h_{wk}\}$ is a vector of bandwidths, $K(\cdot)$ is a joint kernel function given as

$$K(W_i, w, h) = \prod_{j=1}^{k} K_j(W_{ij}, w_j, h_{wj})$$

[7] https://www.1000minds.com/paprika

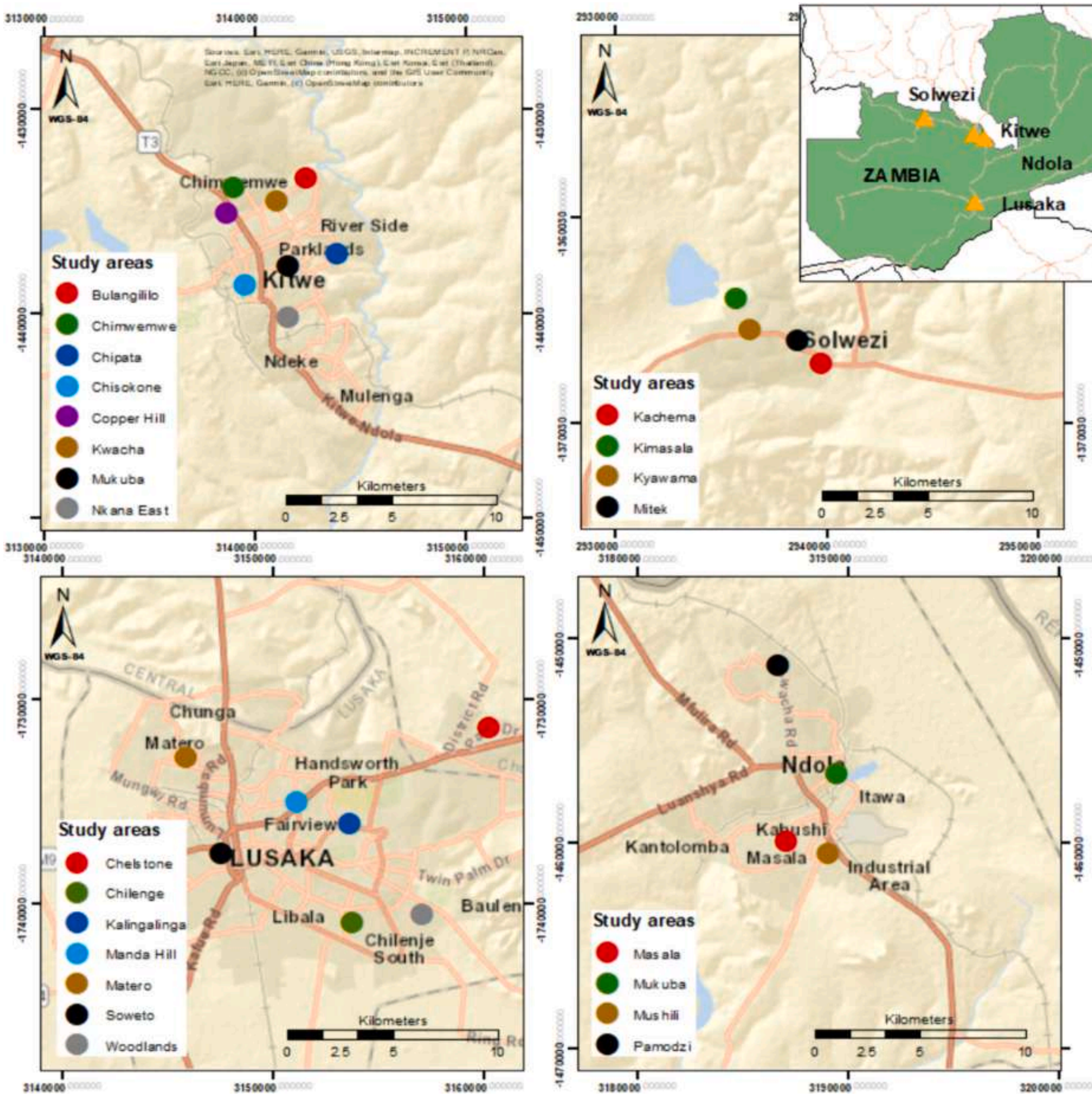

Fig. 2. Maps of district and urban market areas sampled in stage two of the research.

and $K_j(W_{ij}, w_j, h_{wj})$ is a kernel function defined by the point of reference w_j and the bandwidth h_{wj}

$$K_j(W_{ij}, w_j, h_{wj}) = k_j\left(\frac{W_{ij} - w_j}{h_{wj}}\right) \quad (2)$$

Eq. (2) assigns a higher weighting value to observations closer to the explanatory variable and a lower weighting value to observations distant from the explanatory variable and uses the vector of bandwidths h to determine how much information is used for the estimation of the conditional mean (Cattaneo and Jansson, 2018; Kauermann et al., 1998). This procedure can be implemented in the statistical software package Stata using the command *npregress* kernel.

The independent variables included in the kernel regression models are similar to those included in other recent fish preference and demand analyses in and outside of Africa (e.g., see Claret et al., 2012; Murphy et al., 2020; Chikowi et al., 2021). The variable indicating sex of the consumer = 1 if the respondent was female and zero (0) if male. Three binary variables that indicate the consumer's SES were created in the following manner. Using a similar approach in Friesen et al. (2016), we selected several variables from the original dataset for inclusion in a principal component analysis (PCA). PCA is a statistical technique that is often used to develop SES indices. The relevant SES variables we included in the PCA were: 1) whether meat is consumed daily in the household; 2) whether three meals are consumed in the household per day; 3) whether children in the household attend private (versus public) schools; 4) whether there is access to electricity in the household; and 5–7) whether someone in the household owns a mobile phone, a refrigerator, and a vehicle. After running the PCA, the output listed several principal components that are independent orthogonal linear combinations of the variables we included in the PCA. These principal components were listed in decreasing order of the proportion of the explained variance. As is common in such analyses, we chose the first component to use as the SES variable as it accounted for the largest proportion of the variance (eigenvalue = 1.7; % of the variance = 24.3). The SES variable was then ranked into tertiles, dividing consumers into roughly three equal groups. This SES categorical variable was used to create three binary variables representing low, middle, and high SES. Covariates included in the models were age of the consumer (years) and their marital status (married = 1, and 0 otherwise), three dummy

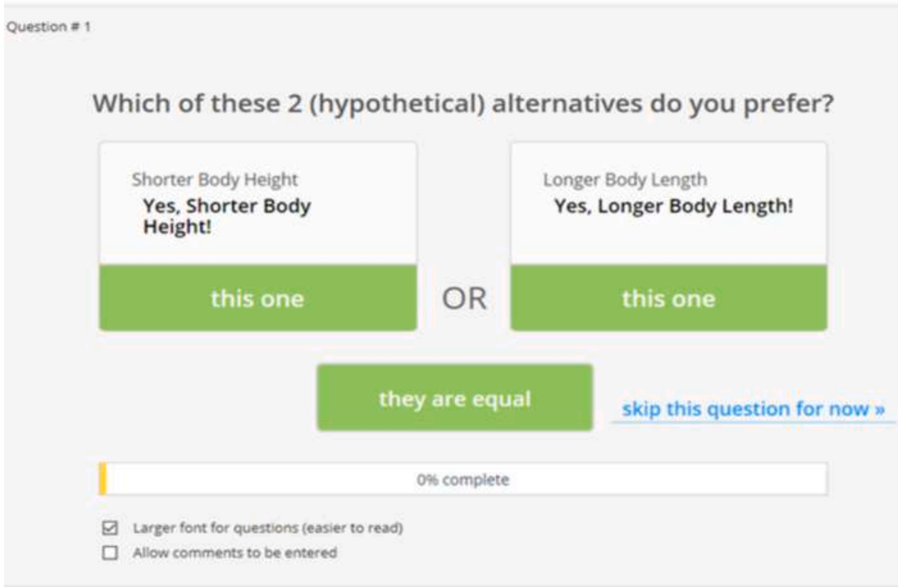

Fig. 3. Example of 1000minds survey question presented during stage two of the research.

variables indicating the level of educational attainment of the consumer (primary, secondary, or tertiary), household size, and four dummy variables representing the districts included in the study.

We focused our descriptive statistics and regression analysis in this paper on six trait preferences with median rankings that scored in the top six preferences of at least 40% of the overall sample.[8] This was considered an adequate cut-off point for ensuring sampling rigour following reports from previous studies (Pryce et al., 2018). Boxplots were used to provide a graphical summary of data to identify the median values for preference rankings by consumers. Wilcoxon rank-sum test and the Kruskal-Wallis equality-of-populations rank test were conducted to determine whether medians of trait preference rankings between women and men consumers and between consumers of different SES were significantly different. Lower values of trait rankings indicate a stronger preference by consumers, while higher values indicate a weaker preference. We used Stata 16.0 (StataCorp, College Station, TX, USA) to carry out all our analyses.

3. Results

Box plots indicating median consumer trait preference rankings overall and by sex of the consumer are presented in Fig. 4. Among all consumers, thicker body width was ranked highest, with a median rank (and 25th, 75th percentiles in parentheses) of 3.0 (1.5, 4.0). In overall trait preference rankings, thicker body width was followed by larger body weight at median rank 4.0 (2.0, 7.0) and darker skin colour at median rank 4.0 (2.0, 9.0), larger head size at median rank 5.0 (3.0, 9.5), and longer body length and taller body height of 6.0 (4.0, 8.0) and 6.0 (4.0, 8.5), respectively, as the fifth and sixth median ranked traits.

When disaggregated by sex of the consumer, median preference rankings significantly differed between women and men consumers for five tilapia traits, including three traits that were ranked in the top six most preferred traits of the overall sample. Among these three more preferred traits, men reported a stronger preference for larger body weight ($p < 0.001$), darker skin colour ($p < 0.05$), and taller body height ($p < 0.05$) compared to women. Women reported a stronger preference for shorter body height ($p < 0.01$) and smaller body weight ($p < 0.001$) compared to men. These two traits were ranked 7th and 12th by the overall sample.

The analysis found two significant differences in median trait preference rankings across the three SES groups for the traits darker skin colour and larger tail size (Table 5). Consumers from the low and high SES groups indicated they preferred darker skin colour ($p < 0.05$), with median preference rankings of 4.0 (1.8, 7.0) for the low SES group and 4.0 (2.0, 8.5) for the high SES group compared to 5.0 (3.0, 10.0) for the middle SES group. Consumers from the middle and high SES groups reported that they preferred larger tail size ($p < 0.05$) more compared to consumers from the low SES group, with rankings of 7.0 (4.0, 9.0) and 7.0 (4.0, 10.0) for the middle and high SES groups, respectively, and 8.0 (6.0, 10.5) for the low SES group.

The descriptive statistics for the variables that were included in the six kernel regression models are presented in Table 6. Of the 313 tilapia consumers surveyed, 52% were women. As was previously detailed, consumers were ranked into roughly equal groups indicating their SES. Mean age of the sample was 31.8 ± 0.6 years old. Only 54% of the sample indicated they were married and 60% indicated they attained their secondary education. Mean household size was 5.2 ± 0.1 members. Thirty-five percent of the consumers were surveyed in markets in Lusaka District, while 25%, 23% and 17% were surveyed in markets in Kitwe, Ndola, and Solwezi Districts, respectively.

Results from running the six kernel regression models are presented in Table 7. The average predicted values (or conditional means) of the six trait preference rankings, holding all the independent variables constant, are presented at the top of the table. When looking at the results from left to right of the table, consumers ranked thicker body weight highest (3.5 ± 0.2), followed by larger body weight (4.9 ± 0.2) and darker skin colour (5.6 ± 0.3), compared to the other three traits included in the analysis.

Interpretation of the marginal effect of a trait preference ranking with regards to the independent variables of interest (sex and SES of the consumer) requires some care as a positive estimate indicates lower, not higher, preference for a trait. For example, when the effect of the variable sex of the consumer (female = 1) is positive, it indicates that women had lower preference for the trait compared to men. This is shown in Table 7, where the effect of being female on the preference ranking for thicker body width was 0.8 ± 0.4, indicating that women had a lower mean preference for the trait than men by 0.8. Similarly, women

[8] Note, regression analyses of the effects of the independent variables on the preference rankings of the other seven less preferred traits were also carried out. Results can be found in Appendix I.

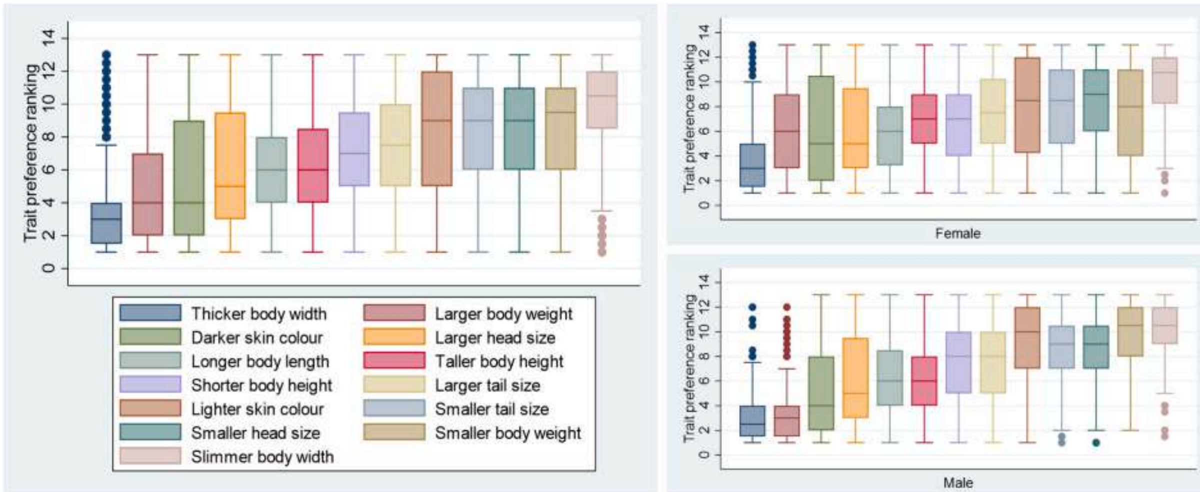

Fig. 4. Box plots indicating median consumer trait preference rankings for the overall sample (left-sided figure) and disaggregated by sex of the consumer (right-sided figures).

Table 5
Median trait preference rankings by socioeconomic status.

			Socioeconomic status (SES)						
Tilapia trait	Total		Low		Middle		High		*p*-value
Thicker body width	3.0	(1.5, 4.0)	3.0	(1.5, 4.0)	3.0	(1.5, 5.0)	3.0	(1.5, 4.0)	0.923
Larger body weight	4.0	(2.0, 7.0)	4.0	(2.0, 7.0)	4.0	(2.0, 8.0)	3.0	(2.0, 7.0)	0.471
Darker skin colour	4.0	(2.0, 9.0)	4.0	(1.8, 7.0)	5.0	(3.0, 10.0)	4.0	(2.0, 8.5)	0.019
Larger head size	5.0	(3.0, 9.5)	5.3	(3.0, 9.0)	5.0	(3.0, 9.0)	5.0	(3.3, 10.0)	0.832
Longer body length	6.0	(4.0, 8.0)	7.0	(4.0, 9.0)	6.0	(4.5, 9.0)	6.0	(4.0, 8.0)	0.310
Taller body height	6.0	(4.0, 8.5)	6.8	(5.0, 8.5)	6.0	(4.0, 8.5)	6.0	(4.0, 8.0)	0.161
Shorter body height	7.0	(5.0, 9.5)	7.0	(4.5, 9.0)	7.0	(4.0, 10.0)	7.0	(5.0, 9.5)	0.542
Larger tail size	7.5	(5.0, 10.0)	8.0	(6.0, 10.5)	7.0	(4.0, 9.0)	7.0	(4.0, 10.0)	0.018
Lighter skin colour	9.0	(5.0, 12.0)	9.3	(6.5, 12.0)	8.0	(4.0, 11.5)	10.0	(6.5, 12.0)	0.102
Smaller tail size	9.0	(6.0, 11.0)	8.8	(5.3, 10.0)	9.5	(6.0, 11.0)	8.5	(6.0, 10.5)	0.186
Smaller head size	9.0	(6.0, 11.0)	8.8	(5.0, 10.5)	9.0	(6.0, 10.5)	9.5	(7.0, 11.0)	0.164
Smaller body weight	9.5	(6.0, 11.0)	9.5	(5.0, 11.8)	9.0	(5.0, 11.0)	10.0	(7.8, 11.8)	0.078
Slimmer body width	10.5	(8.5, 12.0)	10.8	(8.8, 12.0)	11.0	(9.0, 12.0)	10.5	(8.0, 12.0)	0.908

Median trait preference rankings reported (25th, 75th percentiles in parentheses). A Kruskal-Wallis test was used to determine any median differences in trait preference rankings across the three SES groups. Total sample ($N = 313$); Low SES ($n = 108$); Middle SES ($n = 101$); and High SES ($n = 104$).

Table 6
Descriptive statistics of variables included in the kernel regression models.

Variable	Mean	SE
Sex of the consumer (female = 1)	0.52	(0.03)
Low SES	0.35	(0.03)
Middle SES	0.32	(0.03)
High SES	0.33	(0.03)
Age of the consumer (years)	31.75	(0.61)
Marital status (married = 1)	0.54	(0.03)
Primary education attained	0.20	(0.02)
Secondary education attained	0.60	(0.03)
Tertiary education attained	0.19	(0.02)
Household size (number)	5.22	(0.14)
District - Lusaka	0.35	(0.03)
District - Ndola	0.23	(0.02)
District - Kitwe	0.25	(0.02)
District - Solwezi	0.17	(0.02)

Sample size $N = 313$ consumers. Standard errors (SE); socioeconomic status (SES).

consumers had a lower mean preference ranking for tilapia of larger body weight (bigger size) than men consumers. The magnitude of this effect of being female on this trait preference ranking was estimated to be relatively large (2.8 ± 0.5), suggesting clear differences between women and men consumers' preferences for bigger-sized tilapia by an order of almost three ranking places. While there was no statistically significant sex effect on the preference ranking for the darker skin colour trait, the effect of being a consumer of middle SES on this trait was statistically significant and relatively large (1.6 ± 0.6). This suggests consumers of middle SES had lower mean preference for darker skin tilapia compared to consumers of low SES. Concerning the other three trait preference rankings for larger head size, longer body length, and taller body height, the study found no statistically significant sex or SES effects on the preference rankings for these traits except for taller body height. Women consumers had a lower mean trait preference ranking for taller body height (0.7 ± 0.4) than men consumers.

While the effects of district location on the trait preference rankings were not the focus of the study, the analysis did find that consumers from Lusaka District had higher mean preference rankings for larger head size compared to consumers from Kitwe District and the magnitude of the effect was estimated to be relatively large at −1.9 ± 0.6. In addition, consumers from Solwezi District had lower mean preference rankings for thicker body width (1.2 ± 0.6) compared to consumers from Kitwe District. And consumers from Ndola District had lower mean preference rankings for taller body height (1.1 ± 0.5) compared to consumers from Kitwe District.

Table 7
Kernel regression estimates of the mean of six tilapia trait preference rankings as a function of sex and socioeconomic status of consumers and other covariates.

	Thicker body width		Larger body weight		Darker skin colour		Longer body length		Larger head size		Taller body height	
	Estimate		Estimate		Estimate		Estimate		Estimate		Estimate	
Conditional mean	3.54	(0.16)***	4.89	(0.20)***	5.60	(0.26)***	6.20	(0.17)***	6.21	(0.22)***	6.48	(0.17)***
Effect												
Sex of the consumer (female = 1)	0.77	(0.35)*	2.82	(0.45)***	0.76	(0.57)	−0.37	(0.40)	0.57	(0.51)	0.70	(0.36)*
Middle SES	0.01	(0.41)	−0.33	(0.55)	1.61	(0.62)**	−0.38	(0.50)	0.07	(0.50)	0.00	(0.47)
High SES	0.21	(0.41)	−0.55	(0.54)	0.73	(0.64)	−0.86	(0.49)	0.32	(0.55)	−0.78	(0.44)
Age of the consumer (years)	0.00	(0.02)	0.03	(0.03)	0.07	(0.03)*	−0.01	(0.02)	0.05	(0.03)	−0.01	(0.02)
Marital status (married = 1)	0.11	(0.34)	0.09	(0.48)	−0.36	(0.52)	0.16	(0.40)	0.40	(0.55)	0.49	(0.38)
Secondary education attained	−0.23	(0.47)	0.09	(0.54)	−0.54	(0.65)	−0.38	(0.48)	0.71	(0.62)	0.08	(0.44)
Tertiary education attained	0.33	(0.68)	0.76	(0.72)	−0.30	(0.93)	0.62	(0.70)	0.65	(0.79)	0.03	(0.58)
Household size (number)	−0.04	(0.07)	0.03	(0.09)	−0.06	(0.11)	0.10	(0.09)	0.03	(0.11)	0.05	(0.09)
District - Lusaka	0.45	(0.41)	0.15	(0.60)	0.03	(0.62)	−0.58	(0.49)	−1.94	(0.62)**	−0.34	(0.42)
District - Ndola	0.34	(0.43)	−0.35	(0.53)	−0.04	(0.69)	−0.06	(0.49)	−0.63	(0.66)	1.06	(0.48)*
District - Solwezi	1.17	(0.58)*	−0.08	(0.67)	−0.54	(0.75)	−1.00	(0.57)	−0.01	(0.79)	−0.15	(0.57)
Bandwidth observations	304		304		304		304		304		304	
R^2	0.56		0.60		0.58		0.61		0.57		0.52	

Sample size $N = 313$ consumers. Kernel regression estimator used with bandwidth parameters set at 400 replications. Standard errors (in parentheses) were calculated using the bootstrap method. * = significance at 0.05; ** = significance at 0.01; and *** = significance at 0.001.

4. Discussion

Across the aggregate sample in our study, six morphometric traits emerged as being most preferred by urban consumers (1st to 6th in rankings). These six traits, in order of overall preference, were: thicker body width, larger body weight, darker skin colour, larger head size, longer body length, and taller body height. Of these six traits, men ranked three of them higher than women did, including thicker body width, larger body weight, and taller body height. Two of the seven traits ranked lowest by the overall sample (7th to 13th in rankings) were ranked higher by women consumers than by men consumers. These two traits were shorter body height and smaller body weight. Two median trait preference rankings for darker skin colour and larger tail size were found to be significantly different across the three SES groups.

Most differences between women and men held after running the nonparametric kernel regression models that controlled for several covariates believed to influence consumer demand and preferences. Women consumers had lower preference ranking of larger body weight (bigger-sized fish) and much stronger preference for smaller body weight (see Table 8 in Appendix I) than men consumers. Research suggests that women's consumption of smaller fish products may be influenced by household dietary strategies and the need to incorporate fish into children's meals (Ahern et al., 2020). Adding to this, studies have found that Zambian consumers prefer to eat smaller fish whole rather than divide and share one large portion (Avadí et al., 2022; Malumbe and Musuka, 2013). Consuming smaller-sized fish in Zambia may also be driven by economic considerations as lower-income consumers purchase cheaper fish products (Genschick et al., 2018). While unfounded in the literature, men may prefer bigger-sized fish simply because they require on average more calories per day than women.

The results from our study have significant implications for genetic improvement programs that select for growth, among other traits like disease resistance (Benzie et al., 2012; Gjedrem et al., 2012; Khaw, 2015; Ponzoni et al., 2011; Tran et al., 2021), to cater for the variability in the sizes of fish products preferred across different consumer groups in Zambia. The results are also important for informing the production and marketing strategies of tilapia farmers using both improved and non-improved strains depending on access in Zambia. Echoing arguments made by Genschick et al. (2018), these findings suggest that some producers in the aquaculture industry in Zambia could aim to produce and supply smaller fish products to meet the market demand for smaller-sized fish that is more preferred by urban women consumers, while simultaneously meeting the demand of men consumers who generally prefer larger-sized fish. Import suppliers are already doing this to some degree as they import tilapia of different sizes targeted to specific consumer segments (Kaminski et al., 2018). Domestic fish farms could complement these efforts, for instance, by shortening the production cycle and harvesting fish at a smaller size. In theory, if there is a market for smaller-sized tilapia, this creates an opportunity for smallholder producers using more extensive fish farming practices and who may otherwise struggle to produce larger-sized fish (Kaminski et al., 2018) to produce smaller-sized fish and fill this niche in the market (Dan and Little, 2000). A recent study by Kaminski et al. (2024) details how shorter production cycles and targeted production of smaller-sized fish can reduce feed conversion ratios (FCR) and increase cash flows for smallholder producers. Furthermore, the strategy of purposely producing smaller-sized fish may allow producers to double stock mixed-sex fingerlings in ponds and/or cages and potentially forego sex reverse hormones that are often difficult to access by smallholder producers (Bostock et al., 2022).

Regression estimates also predicted stronger preference among men consumers for thicker body width and taller body height. Notably, these included preferences for selective breeding traits that are recognized for their high heritability values and genetic correlation to harvest weight (Charo-Karisa et al., 2007; Fernandes et al., 2015; Mengistu et al., 2020; Nguyen et al., 2007; Reis Neto et al., 2017), as well as their breeding value to strains adopted in low-input pond systems (Charo-Karisa et al., 2007; Mengistu et al., 2020). Genetic improvement programs in Zambia that employ socially inclusive selective breeding techniques may use these findings to inform which morphometric traits they focus on and include in their product profiles, although additional studies are required to understand the trade-offs and implications of prioritizing these traits over the welfare of diverse consumer groups. Cost-benefit analyses are further needed to assess the overall marketability and profitability of selecting for such traits, especially factoring in market prices and whether they are determined by weight rather than size of fish. While the trial by Kaminski et al. (2024) suggests that growing smaller-sized fish has significant effects on FCR, the profitability was lower than growing larger-sized fish, though this depended on the context and costs of each producer.

Certain preferences such as darker skin colour, larger head size, and longer body length – traits preferred by consumers in urban markets – could also be a focus of future genetic improvement programs. The study found that consumers of lower SES prefer tilapia of darker skin colour more than consumers from middle SES. We are not aware of any consumer studies in Zambia that have explored this topic in detail. Our qualitative scoping study provided some indication that skin colour is important as an indicator used by consumers to identify better tasting fish and/or the source of fish (i.e., domestically produced or imported). Together these mixed-methods results could inform future research that, for example, tests whether fish colour (which is easy to measure) could be used to select for better fish taste (which is more difficult to measure). Nonetheless, more research on this trait preference for darker or lighter or different skin colour is needed as many studies elsewhere have shown that consumer market preferences are heavily shaped by their preferred colour of fish, like in the case of farmed salmon (Alfnes et al., 2006; Bjerkeng, 2008; Kawamura et al., 2017).

There was a significant regional effect on preferences for larger head size, with consumers from Lusaka preferring this trait compared to those from markets in Kitwe District. In Zambia, preferences for fish heads have been reported, particularly among men (Nölle et al., 2020). On the Zimbabwean side of Lake Kariba, local markets emerged for tilapia fish heads among communities surrounding large-scale fish farms, preferred for their culinary and nutritional qualities (Hishamunda and Ridler, 2006; 7). In Uganda, Nile perch (*Lates niloticus*) fish heads are the most prized by-products of consumers around Lake Victoria due to a belief that consuming fish heads increases cognitive ability (Kabahenda and Hüsken, 2009).

While sex or SES of the consumer had no effect on preferences for longer body length, this trait was nevertheless important to urban consumers as it was ranked among the top six most preferred tilapia traits overall. Such findings warrant further investigation, particularly given its significance to selective breeding of *O. niloticus* (Rutten et al., 2004; Silva et al., 2015).

5. Conclusion

This study examined tilapia trait preference rankings of women and men consumers of different socioeconomic status across four major urban sites in Zambia. The study found significant differences between median preference rankings of women and men consumers for tilapia traits ranked both higher and lower by the overall sample. When several covariates believed to influence consumer trait preferences for farmed tilapia were controlled for in the regression model, strong consumer preferences by men for thicker body width, larger body weight, and taller body height were found, whereas women had a stronger preference for smaller body weight. Consumers of lower SES had a stronger preference for darker skin colour than consumers of middle SES.

Overall, the study findings suggest that preferences for farmed tilapia traits in Zambia differ across urban consumer groups and should be considered when genetic improvement programs set their priority objectives and breeding strategies to ensure they are both gender-responsive and pro-poor. Findings also suggest that genetic innovations alone cannot meet the needs of women, men, and consumers of different socioeconomic status, thus there is need for complementary production and marketing interventions within the aquaculture industry in Zambia. For example, genetic improvement programs could select for larger body weight while offering smallholder producers the opportunity to cultivate smaller-sized fish using shorter production cycles.

Whether our study findings can be considered for other species in Zambia or for farmed tilapia in nearby countries is unclear due to the specificity of the interaction between the species and urban populations sampled. Rather, the study findings can be used as starting points to help inform qualitative or quantitative studies on trait preferences for other species or farmed tilapia in countries in the region.

In terms of methodological insights from our study, the PAPRIKA method used emerged as both effective and appropriate for use and should be considered an ideal method for use in future studies. Trait preference studies have recently begun to augment the PAPRIKA method by including the economic costs associated with each trait in the questionnaire as well as the interdependent trade-offs produced by choosing one trait over another (Byrne et al., 2016; Kerslake et al., 2015; Martin-Collado et al., 2015). The use of economic weighting with preference rankings thus allows for further validation of consumer demand and market values for traits of interest (Omasaki et al., 2017). Also, the combination of qualitative and quantitative methodologies to collect our data, along with sound statistical analyses, strengthened the reliability and validity of our estimations and model outcomes. These methodological considerations underscore the credibility of our findings and their applicability to informing targeted interventions in the Zambia aquaculture sector, aimed at meeting consumer preferences and enhancing market competitiveness.

CRediT authorship contribution statement

Seamus Murphy: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Steven M. Cole:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Alexander M. Kaminski:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Harrison Charo-Karisa:** Writing – review & editing, Writing – original draft. **Rose Komugisha Basiita:** Writing – review & editing, Writing – original draft, Conceptualization. **Cynthia McDougall:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Keagan Kakwasha:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Tabitha Mulilo:** Investigation, Data curation. **Surendran Rajaratnam:** Writing – review & editing, Writing – original draft, Software, Formal analysis. **Wagdy Mekkawy:** Writing – review & editing, Writing – original draft, Software, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Author statement on the use of generative AI and AI-assisted technologies in the writing process

Authors of this manuscript did not use generative AI and AI-assisted technologies in the writing process.

Appendix I

Table 8
Kernel regression estimates of the mean of seven tilapia trait preference rankings as a function of sex and socioeconomic status of consumers and other covariates.

	Shorter body height		Larger tail size		Smaller tail size		Smaller head size		Lighter skin colour		Smaller body weight		Slimmer body width	
	Estimate		Estimate		Estimate		Estimate		Estimate		Estimate		Estimate	
Conditional mean	7.04	(0.18)***	7.49	(0.18)***	8.13	(0.18)***	8.35	(0.18)***	8.49	(0.23)***	8.56	(0.21)***	10.03	(0.16)***
Effect														
Sex of the consumer (female = 1)	−1.10	(0.45)**	0.52	(0.42)	−0.87	(0.41)*	−0.26	(0.40)	−0.84	(0.56)	−2.29	(0.50)***	−0.43	(0.35)
Middle SES	0.00	(0.54)	−1.34	(0.43)**	1.08	(0.47)*	0.39	(0.45)	−1.21	(0.59)*	0.04	(0.61)	0.04	(0.41)
High SES	0.51	(0.48)	−1.22	(0.51)*	0.52	(0.51)	1.18	(0.51)*	−0.33	(0.64)	0.71	(0.60)	−0.44	(0.43)
Age of the consumer (years)	−0.03	(0.03)	−0.02	(0.03)	−0.01	(0.03)	−0.02	(0.02)	−0.01	(0.03)	−0.02	(0.03)	−0.02	(0.02)
Marital status (married = 1)	−0.06	(0.41)	0.28	(0.47)	0.23	(0.45)	−0.34	(0.43)	−0.72	(0.55)	−0.31	(0.55)	0.05	(0.40)
Secondary education attained	−0.20	(0.55)	1.08	(0.54)*	−1.00	(0.47)*	0.13	(0.50)	0.00	(0.72)	0.18	(0.66)	−0.23	(0.46)
Tertiary education attained	−0.88	(0.67)	0.98	(0.70)	−0.87	(0.59)	−1.04	(0.67)	0.44	(0.87)	0.31	(0.74)	−0.73	(0.66)
Household size (number)	0.16	(0.08)*	0.12	(0.09)	−0.13	(0.10)	−0.06	(0.09)	−0.05	(0.11)	−0.04	(0.10)	−0.07	(0.09)
District - Lusaka	0.59	(0.50)	−0.15	(0.50)	0.03	(0.53)	1.05	(0.53)*	0.75	(0.65)	0.10	(0.57)	−0.44	(0.45)
District - Ndola	−0.28	(0.49)	0.47	(0.48)	0.12	(0.52)	−0.12	(0.50)	0.18	(0.70)	−0.04	(0.58)	−0.64	(0.48)
District - Solwezi	1.50	(0.68)*	0.89	(0.75)	−0.36	(0.65)	−0.34	(0.64)	−0.14	(0.79)	−0.33	(0.64)	−0.62	(0.52)
Model evaluation														
Bandwidth observations	304		304		304		304		304		304		304	
R^2	0.57		0.55		0.56		0.60		0.58		0.60		0.60	

Sample size $N = 313$ consumers. Kernel regression estimator used with bandwidth parameters set at 400 replications. Standard errors (in parentheses) were calculated using the bootstrap method. * = significance at 0.05; ** = significance at 0.01; and *** = significance at 0.001.

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