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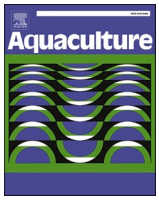

Tilapia (*Oreochromis niloticus*) trait preferences by women and men farmers in Jessore and Mymensingh districts of Bangladesh

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ABSTRACT

Research reporting user trait preferences for fish, particularly in relation to guiding genetic improvement programs are rare, even in tilapia where demand for genetically improved fish has underpinned the expansion of fish farming. The present study investigated gender-disaggregated trait preferences for tilapia by fish farmers in Bangladesh using open-ended questions and stated choice experiment, using 1000minds software. Men and women from smallholder fish farming households shared preferences for some traits of tilapia, but differed in others or in the strength of preference, mostly influenced by the prevailing yet constraining social norms around gender-appropriate work for fish farming, mobility and household responsibilities. Feed intake was the shared top priority for 'improvement' for both genders, and confirms the relevance of ongoing efforts in breeding program. However, the importance given to *body shape* by these users was revealed although more work will be needed to understand the precise requirements given potentially contradictory rankings within and between genders. A number of priority traits reacted to as freshness and taste could be easily improved with better farm management practices and/or improvement in value chain practices.

1. Introduction

Nile Tilapia (*Oreochromis niloticus*) is one of the most farmed finfish in the world with 4.4million tons produced globally (FAO, 2022). Part of this global success has been the wide distribution of genetically improved strains (Ponzoni et al., 2011; FishStatJ, 2016) that are fast growing and have good feed conversion ratios permitting profitable production (e.g., Dey et al., 2000; Asian Development Bank, 2005; Acosta and Gupta, 2010; Haque et al., 2016). Having successfully focused on improving harvest weight (Khaw et al., 2015) genetic improvement programs now include other traits such as disease-resistance, carcass quality, cold or salinity tolerance (Neira, 2010; Gjedrem and Rye, 2016). The rapid and wide adoption of improved tilapia strains implies the improved traits meet the needs of users. This includes the needs of smallholders and poorer farmers who access the strains and for which there is evidence that improved strains provide increased farm profitability (Ibrahim et al., 2019; Tran et al., 2021). There have been no published studies, however, specifically documenting tilapia trait preferences for these groups of users.

Over the last decade, researchers in terrestrial agriculture have identified that needs and preferences of certain market or value chain segments such as poorer farmers, youth and women farmers are often not fully considered in agriculture and which may lead to examples of low adoption rates of improved crops or livestock by those groups (Tufan et al., 2018; Ashby and Polar, 2019). These issues remain largely unexplored in aquaculture. In a recent systematic literature review, Mehar et al. (2021) reported few studies of user preferences for fish and none specifically for traits to be included in a genetic improvement program or using gender disaggregated data. The review discovered around 15 studies that explored tilapia characteristics preferred by different users in the value chain. The different traits documented in these studies were related to growth characteristics (such as growth,

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survival rate, width, body texture (fat content, skin texture, appearance including color of the external fish body or the fillet), quality (taste, smell, nutrition value, freshness) and found some evidence for different preferences among different user groups or market segments. Since that review additional work was reported on tilapia from Egypt, (Murphy et al., 2020) and carps in Bangladesh and India Mehar et al. (2022). In Egypt a market assessment of consumer preferences for different morphological measurements and sizes of tilapia showed gender differences with e.g., women more likely to prefer longer tilapia (Murphy et al., 2020). In Bangladesh and India, Mehar et al. (2022) conducted a study based on primary surveys of rohu carp (*Labeo rohito*) fish traits using an interdisciplinary approach considering user (smallholder and consumer), breeder and social scientist perspectives. The study found there was considerable overlap in the top preferences ranked by men and women, however there were significant differences in emphasis and ranking in regards to the preferences. Additionally, the authors found interesting geographical differences between India and Bangladesh for the desired trait by men and women. These differences suggested the utility of exploring gender-disaggregated trait preferences in fish.

Given the global expansion of improved tilapia strains and their acceptance by smallholders suggest the improved strains meet user needs, but there are no published studies specifically addressing that issue. Even if the present tilapia genetic improvement programs do address user needs it would be useful to understand whether there are additional needs not yet met which could be addressed through genetic improvement. The study by Murphy et al. (2020) was able to describe consumer preferences for different morphological measurements and suggested these might influence breeding programs, but their results would be difficult to interpret for effective practical use in selective breeding programs (see discussion in Orr et al., 2021).

The present paper reports a parallel study of Nile tilapia undertaken at the same time as the Rohu one, by the same team, to understand the gender-disaggregated preferences of smallholder farmers in Bangladesh. The present study explored general preferences for tilapia traits by fish farmers that used: a) open-ended questions to assess general preferences of farmer from consumer and producer perspectives; and, b) a stated choice experiment using 1000 minds software to assess tradeoffs in choices between traits identified after a rigorous identification of relevant traits from published studies on breeding programs. Specifically, the objectives were to identify whether there were differences in trait preferences (1) between producers and consumers of tilapia, and (2) between men and women in producing households.

2. Study area and methods

Bangladesh was chosen given its importance as an aquaculture producing country and tilapia because of its growing role in that production. Bangladesh was ranked 3rd in terms of tilapia production volume in world and in Asia after China (1st) and Indonesia (2nd) (FAO, 2019). Several improved strains of tilapia have been introduced, including Genetically Improved Farmed Tilapia (GIFT) that has been introduced on multiple occasions (Hamilton et al., 2020). Production from tilapia has risen markedly since its first introduction in 1994 (Hussain et al., 2014) and it is farmed by a range of aquaculture operators including smallholders and has captured a growing part of the fish market for poorer consumers (Asian Development Bank, 2005; Toufique, 2015).

A scoping study of farmers and market actors in Jessore district collected information on traits of interest at broad level, including their economic and market value, to assist design the main survey. The main survey used a multi-stage sampling process to select districts, sub-districts (*upzilla*), blocks, villages and respondents for the primary data. The districts and sub-districts were chosen based on the highest percentage share in total freshwater fish farming production for the respective administrative unit (Fig. 1). The two major farmed fish producing districts (Mymensingh and Jessore), selected for the present study accounted for around 16% of total tilapia production in

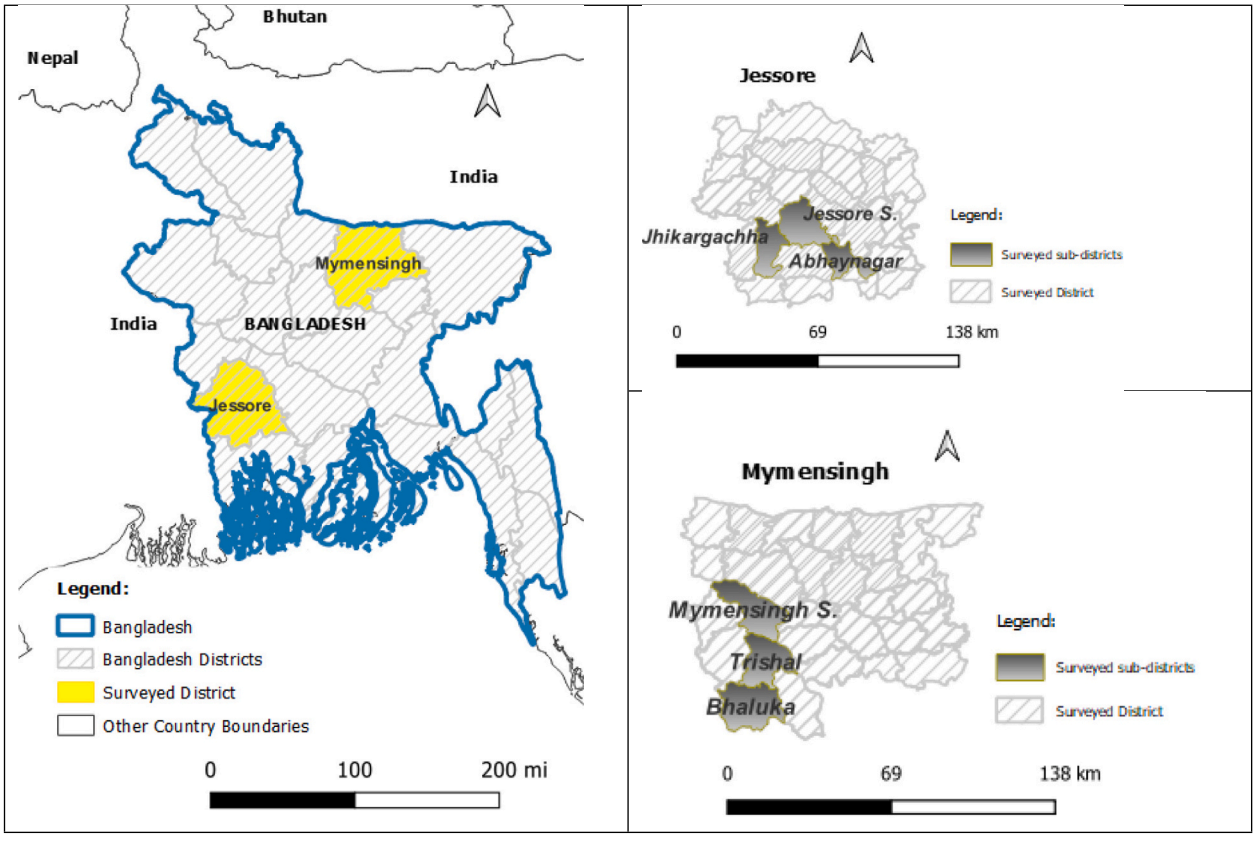

Fig. 1. Surveyed location.

Bangladesh (FRSS (Fisheries Resources Survey System), 2017). These districts were also major commercial production districts with 10 to 14 t per hectare (Anwar, 2011). In both districts, three major tilapia growing sub-districts were selected (Supplementary Table 1). The number of villages and households to be sampled were derived from a power-exercise using optimal design software. The villages were randomly selected in each sub-district from the Bangladeshi census list 2011. In the selected villages, a census of fish farmers with basic details like name, gender and area of cultivation was carried out, and 12 farmers from the list were randomly selected for interview. A total of 144 dual-headed households were interviewed, out of which 127 farmers reported cultivating tilapia in last cultivation season (2017–18) before execution of the survey (March–April 2018). So, this paper uses information from 127 dual-headed farm households (127 men, 127 women) and 101 respondents (63 men, 38 women) for the 1000 minds exercise (www.1000minds.com). The 1000minds sample number was lower because farmers were asked to respond for only one fish among Catla, Tilapia and Rohu and the present study included only those nominating tilapia. All the respondents were given a signed informed consent form (in Bengali language) which explained the content, purpose of the study, contact details of the principal investigator (PI) and assured confidentiality of their responses so that they made an informed judgment about whether they wished to participate. To ensure complete anonymity, results are presented in the aggregate across all survey respondents.

The information was collected using a pre-tested structured questionnaire. The structured questionnaire was designed using a concurrent mixed-method approach and the two-part survey was pretested with farmers in two villages to allow for refinement and adjustment (Neuman, 2007; Borg and Gall, 1979). Part 1 of the survey contained open-ended questions designed to identify trait preferences of interest of respondent. Part 2 used stated choice experiment (where respondents identify traits with trade-offs among pre-selected traits identified during scoping study using the paprika method and designed in 1000minds software (Table 1). For more detail for software and method, please refer Mehar et al. (2022). In both parts, men and women were interviewed separately in each household, with women being interviewed by female enumerators. Enumerators were trained to probe respondents to inform practical choices of traits and allow us to examine intra-household data based on separate interviews with men and women in each household.

To capture farm households' preferences about fish trait consumption by farmers and their families, information from women respondents were collected. This information was collected using open-ended survey questions about what characteristics they considered when they select fish from their own pond or if they have to buy from market for household consumption. The survey also contained a set of closed-ended questions regarding farm and fish management details asked from the adult, whether male or female, in each household who was primarily responsible for fish farming. The stated choice experiment software (1000minds) is cloud-based and was carried out wirelessly on tablets while rest of the information was collected with paper-based mode. To assist more accurate identification of tilapia fish and traits, reference booklets with pictures of fish species were provided to respondents.

Table 1
Trait's choices included in 1000minds survey.

Trait	Bangladesh
Weight (kg)	■ On average 22 g
	■ On average 83 g
	■ >1.45 kg gram
Price (kg^{-1})	■ 100 Taka
	■ 156 Taka
	■ 210 Taka
Length (inches)	■ Around 8 in.
	■ Around 11 in.
	■ Around 15 in.
Taste	■ As it is
	■ Original/Sweet/Good
Body shape	■ Round
	■ Flat
	■ Slender
Skin color	■ Grey
	■ Lighter color combination of red, black, golden
	■ Dark color combination or red, black, golden
Eye color	■ Grey/ash
	■ Black (silvery/shiny)
Gill color	■ Pink
	■ Slightly red/faded up
	■ Red

3. Results

3.1. Sample characteristics: individual and farm characteristics

3.1.1. Individual respondents' characteristics

In terms of the individual characteristics of the survey respondents (Table 2), most men respondents in Bangladesh reported fish farming as their primary occupation followed by agriculture. As expected, cultural norms and gender division of paid and unpaid work in these contexts positioned men as income earners and women as caregivers. Few women respondents reported their primary or secondary occupation to be fish farming and many reported 'home-maker' instead. It is noteworthy, however, that women respondents reported engaging in and contributing to household fish production, particularly fish feeding, monitoring and other production activities, confirming that both genders can be assumed fish farmers in practice. The majority of both men and women respondents were from middle-aged groups (30–45 years) in both countries. More than two-third of men and women had completed at least primary education. Around 18 and 14% of men and women respondents had not received formal schooling, however very few of them cannot read and write.

3.1.2. Farm characteristics

In terms of fish farming characteristics, the surveyed household's's average number of years of experience in fish farming was 12.5 years

Table 2
Descriptive statistics showing the mean value of individual characteristics.

Variable	Men	Women
Age (years)		
20–30	15.0	34.9
30–45	45.6	44.5
60	24.4	18.3
Above 60	15.0	2.4
Education		
1–5 grade	17.5	14.3
6–10 grade	35.7	42.8
Above 10 grades	32.5	24.6
No formal schooling: Can sign only	11.9	11.9
No formal schooling: Can read & write	0.8	1.6
Cannot read and write	1.6	4.8
Primary Occupation		
Fish farming	78.7	0
Agriculture/crop farmer	7.1	0
Housewife	0	72
Other	14.7	1
Not reported anything	0	27
Secondary Occupation		
Fish farming	19	0
Agriculture/crop farmer	46	0
Housewife	0	9
Other	16	1
Not reported anything	2	90
Sample size	127	127

Table 3
Descriptive statistics showing the mean value of farm characteristics of surveyed households ($n = 127$). Apart from first three rows where the units are given, all other variables are in percentages.

Variable	Mean
Farm experience (in years)	12.5
Mean Pond size (in hectare)	0.5
Number of ponds (median value)	3
Aquaculture system:	
Grow-out only	84.3
Both nursery and grow-out	15.7
Tilapia monoculture	1.2
Share of Tilapia stocked:	
≤20	46
21–40	23
41–60	18
>60	13
Survival of fish from fingerling to harvest	84.9
Liming applied	97.6
Fertilizer applied	61.4
Feed Type[1]*:*	
Commercial	41
Home-based	32
Both above	24
No feed	3
Water quality check done	90
Practices for Oxygen[2]	83.4
Experience disease	37
Water Problem	
Gas formation[3]	36.2
Algae density	17.5
Excessive turbidity	16.5
No problem reported	3.0
Stop feeding fish before harvest	31.5
Average sale price of fish (taka/kg)	86

Note: [1] Rice bran, vegetable waste, maize compost, maize bran, food scrap, mustard oil cake (MOC), wheat bran. [2]The practices are applying oxygen powder, netting, hora pulling, geolits used, water founting, water showering, waving by long bamboo, swimming, rod pulling. Only 1 person mention use of Aerator for 4–5 h daily. [3]ammonia gas created at the bottom layer of the pond, due to mud or extra feed and other things that created ammonia gas in pond. Another gas formed in pond called hydrogen sulfide smell like as spoiled egg.

(Table 3). The average size of individual ponds was around 0.5 ha with the average farm having 3–4 ponds for cultivation. However, it is important to note that the usual pond size is actually smaller than this for smallholders given an upward bias produced by small numbers of farmers having large ponds The majority of households (84.3%) were involved in grow-out farming, with the rest involved in both nursery and grow-out.

PCA analyses were undertaken to determine whether there was more than one farming system included in the sample set. The analysis did not indicate clear groupings of different farming practice within the surveyed households (data not shown). Almost all household (98.8%) cultivated tilapia in a polyculture system and 69% of households reported stocking tilapia at a relatively low rate (≤40%). The majority of farmers applied lime and reported performing activities for oxygen maintenance in the pond. However, most of the techniques used were traditional and may not have been enough to generate optimal oxygen conditions as evidenced by 36% of farmers reporting ammonia or hydrogen sulfide gas formation or low oxygen problem. Only 3 % of farmers reported providing no feed, the rest mentioned providing either commercial feed (41%) which the manufacturers labels indicated had 30% crude protein, home-made feed, primarily mustard oil cake or crop (rice, wheat or maize) bran (32%) or both commercial and home-made feed (24%). Thirty eight percent of farmers did not apply any fertilizer. Survival rate of fish from fingerling to harvest size was 85%. However, 37% of farmers reported experiencing different disease (primarily ulceration, gill rot and *argulus*) during the cultivation period (Supplementary Table 2). The majority of farmers reported different types of water problem (for example, excessive algae density, excessive turbidity, gas formation (ammonia or hydrogen sulfide) or low oxygen problem. Around 31% of farmers stop feeding fish for a minimum 24 h before harvest and put them in clean water for on average 2 to 5 h. The others reported they sell most of their fish live at the pond side so they are not concerned about putting it in clean water. Farmers were able to sell tilapia on average at 86 taka per kg (i.e.US $1.02per kg at the exchange rate of 84.17 taka per US$ during the survey time).

3.2. Trait preferences

The responses to the open-ended questions were many and diverse (Table 4), so they needed to be collated and refined. Only those for which there were five or more responses atleast for one gender are included in Table 5, the additional are given in Supplementary Table 3. The number of responses for dislikes and for improvements were fewer than for likes for both genders but particularly for female respondents. There were some key similarities between men and women in the pattern of 'likes' (L), 'dislikes' (D) and preferences for 'improvements' (I) between men and women respondents (Table 5). However, statistically significant differences between men and women were found for likes and improvements.

3.2.1. Likes

The broad pattern for likes were similar for men and women, in that both genders identified the same top six ranked characteristics. However, the ranking order and number of responses differed between men and women. The first preference by both men and women was given to *economic factors* such as good price, demand and profitability as was the second preference for *pleasant taste*. The next preference given by men was *growth* followed by *good appearance*, *less boniness* and *larger size*. Whereas women ranked *good appearance* next, followed by *larger size* and *less boniness* followed by *growth*. Around 4 % of men and 6 % of women reported liking *soft texture* of the fish. Men and women differed in their preferences for lower ranked traits in terms of ranking and emphasis, each of which only attracted <5 % of the responses for their gender. <10 men (3%) reported likes for traits such as *short production period*, *more flesh content*, *easy to culture*, *nutritious*, *freshness*, *easy to cook*. Women, gave relatively greater preference to traits such *nutritious and healthy*, *live and fresh*, and *easy to cook*, approximately twice as much men as a percentage of their responses. Likes for *household consumption* was reported by 3% of women only.

3.2.2. Dislikes

Both genders reported *bad odor* as their primary dislike - 50% of men's and 70% of women's responses for dislikes. The other traits in top five ranking for dislike reported by male and female were *bad taste*, *lack of available market or demand*, *small size and requirement of more feed* hence more feed cost. However, the ranking order was different. Men reported *taste* as the second ranked dislike whereas women had reported *small size of fish* as the second ranked dislike. The other three traits were reported by less than ten women. Among the lower ranked traits, men reported relatively greater preference for *lack of available market/demand* and *high feed cost*.

3.2.3. Traits identified for improvement in production

Not all men and women provided information for traits to improve. Only 39 women provided responses as to what traits to improve and five of these mentioned having no knowledge about what could be improved. The trait ranked second by both genders was to *reduce feed intake*. Men ranked *reduce feed cost* first, unranked by women. In contrast women ranked *taste* first. All other traits for improvement reported by less than ten men and fewer women, largely related to production characteristics. The ranking from women for those production traits was generally the inverse from the men, emphasizing fish size rather the growth, production cost or fry quality.

Table 4
Open-ended categorization descriptions.

Questions	Major category	Responses
What traits you like	Pleasant Taste	Salty taste, head are tasty, head portion taste, natural taste, sweet taste
	Appearance	Good looking, striped body, Shiny, Dark eye, shiny body, dark eye color, Clear and no skin loss, red gill, dark body color, no scale loss, red gill, black body color, Black eye, Black strip, light color,
	Economic	Demand/low price, for income, high demand, easily available, easily buy in low price and available, sold in hand cash, High amount money come at once, always available and cooked, profitable, high profit
	Growth	Growing very fast, fast growth, growth rate high
	Boniness (less bone)	Less bone
	Short production period	Culture period 3–4 months, short culture period, short production period
	More flesh content	Fleshy, more flesh, rigid flesh,
	Larger size (length/ weight)	Big size, large size fish more taste, weight high
	Nutritious and healthy	Healthy, nutritious
	Household consumption	For household consumption
	Live and fresh	Live fish, fresh fish
	Hardness	Hardy when fry
	Soft texture	Soft flesh, soft, softness
What traits you dislike	Easy to culture	Easy to culture, easy to harvest, no need extra care
	Bad Odor	Muddy Odor, Bad Smell, Feedy Odor, muddy smell
	Bad Taste	Bored of this taste, small size fish taste low, watery taste, salty taste, bad muddy taste
	Lack of available market/ demand	Low demand, low price
	Small size	Small size has higher amount of bone less flesh, don't like tail portion of small size, small size and did not get market size on farm
	Need more feed, so high feed cost	Need more feed, high feed cost, feed habit, need more food, high feed consumption
	Growth strain	Improve growth, fast growing, fast growth rate species developed
What traits you like to improve[1]	Quality of fry	Brood quality, seed quality, fry/ fingerling quality, survival rate of fry/fingerlings quality
	Reduce feed cost	
	Reduce feed intake	Improve feeding habit, reduce food habit,
	Taste	Natural taste
	High Production with low input, improve culture technique	Culture period should be minimized, improve culture system, improve culture technique, improve culture system to reduce cost, increase culture system with high stocking density
	Equal size	Equal size of all fish, equal growth of all fish
	Size (in length and weight)	Large size, improve size of fish, large in size
	No knowledge	Do not know, no knowledge

Table 5
Contingency table of main preferences for tilapia characteristics by country and gender gained from the open-ended questions. The number of respondents indicating the stated preference is given (N). These data were used to calculate a ranking (R) by frequency of preference within the group of likes, dislikes or improvements (the respondents were not asked to rank their preferences in the open-ended questions). ***, ** denotes significance at $P < 0.001$ and $P < 0.05$ respectively. NS: non-significant. % is % of no. of responses of particular trait to total number of responses.

	Bangladesh					
Main preferences	Men			Women		
	Rank	N	%	Rank	N	%
Likes						
Economic (good price and demand, profitable)	1	83	23.1	1	76	29.2
Pleasant Taste	2	79	21.9	2	36	13.8
Growth	3	58	16.1	5	17	6.5
Good Appearance (related to color of skin, eye, gill)	4	36	10.0	3	26	10.0
Boniness (less bone)	5	33	9.2	=4	19	7.3
Larger size (length /weight)	6	20	5.6	=4	19	7.3
Soft Texture	7	16	4.4	6	16	6.2
Short Production Period	=8	8	2.2	13	1	0.4
More Flesh content	=8	8	2.2	9	10	3.8
Easy to culture	=8	8	2.2	12	2	0.8
Nutritious & healthy	9	7	1.9	8	11	4.2
Live & fresh	10	4	1.1	7	13	5.0
Easy to cook	11	3	0.8	11	6	2.3
Household consumption	–	0	0.0	10	8	3.1
Chi-squ (H_0: all traits of equal importance)		***			***	
Chi-squ (H_0: Men's and women's preference same)				**		
Dislikes						
Bad Odor	1	60	52.2	1	59	71.1
Bad Taste	2	19	16.5	3	8	9.6
Lack of available market/demand	3	18	15.7	4	3	3.6
Small size	4	11	9.6	2	11	13.3
Need more feed, so high feed cost	5	7	6.1	5	2	2.4
Chi-squ (H_0: all traits of equal importance)		NS			NS	
Chi-squ (H_0: Men's and women's preference same)				NS		
Improvements						
Reduce feed cost	1	33	37.1	–	0	0.0
Reduce feed-intake habit	2	25	28.1	2	12	30.8
High Production with low input, improve culture technique	3	9	10.1	=5	1	2.6
Improve Fry Quality	4	8	9.0	=5	1	2.6
Growth	5	7	7.9	4	2	5.1
Equal size of fish	6	5	5.6	–	0	0.0
Taste	7	4	4.5	1	13	33.3
Size (in length and weight)	8	2	2.2	=3	5	12.8
No knowledge	9	1	1.1	=3	5	12.8
Chi-squ (H_0: all traits of equal importance)		***			***	
Chi-squ (H_0: Men's and women's preference same)				**		
Total responses for Likes		363			260	
Total responses for Dislikes		115			83	
Total responses for improvement		89			39	
Total Number of respondents		127			127	

3.2.4. Consumption-related preferences

There were no statistically significant differences in the broad pattern of preferences for characteristics determining the choice of fish for consumption when selecting fish from ponds and markets (Table 6). The top three preferences, i.e., *larger size* (in length), *appearance, freshness* was same for both sources but the order of ranking was different. *Large size* was top ranking if selecting from a pond whereas *appearance* was ranked first when selecting from the market. *Appearance* was ranked third in both preferences. The next ranked preferences for the pond with equal ranking were *disease free* and *weight*, contrasting with the fourth and equal fifth ranking traits in markets of *live*, *healthy* and *affordable price*. Traits not reported for the pond but in the market were, *live*, *body shape* and *price*.

Table 6
The number of women respondents listing particular characteristics as their preference for harvest or purchase of fish arranged as a contingency table. Significance levels indicated as $^{**}P < 0.05$. % is % of no. of responses of particular trait to total number of responses.

Traits	Pond			Market		
	Rank	N	%	Rank	N	%
Larger size	1	43	21.5	2	36	21.4
Appearance (related to color of skin, eye, gill)	2	33	16.5	1	39	23.2
Freshness (indicated by clean, fresh gill, natural non-fishy smell, lack of softness, formalin and ice free)	3	17	8.5	3	31	18.5
Disease free	=4	16	8	7	8	4.8
Weight	=4	16	8	=6	10	6.0
Pleasant taste	5	12	6	10	4	2.4
Healthy (nutritious, contains more calcium)	=6	9	4.5	=5	12	7.1
Firmness	=6	9	4.5	8	7	4.2
Fleshy & thickness	7	7	3.5	=6	10	6.0
Live	–	–	0	4	15	8.9
Body Shape	–	–	0	9	6	3.6
Affordable price	–	–	0	=5	12	7.1
Other (family need, male fish, odor, non-spoiled condition)	8	5	2.5	=6	10	6.0
Chi-squ (H0: all traits of equal importance)			**			
Chi-squ (H0: Pond and market trait preferences are same)				NS		
Total responses		200			168	
Number of respondents		127			127	

3.2.5. Preferences from stated choice experiment

If each trait's part = −worth utility (PWU) was equal, that value would be 12.50 (100/8), i.e., the total percentage (100) divided by the number of traits. A number of traits had PWU values significantly higher or lower than parity for both men and women in (Table 7) indicating traits were not valued equally by either men or women. Men ranked *weight*, *body shape,* and *price* significantly higher than parity, and *eye color, taste* and *length* significantly less. Men gave equal importance to *weight* and *body shape*. Women ranked *gill color*, and *length* significantly higher than parity, and *taste* and *price* significantly lower. Significant differences between men and women rankings were found only for *weight, body shape* and *gill color*. Among these men had higher preferences for *weight* and *body shape*, whereas women ranked *gill color* higher than men.

The differences in of weighting of traits by men and women is evident in the differences of the shape and median weight differences in violin plots (Fig. 2).

4. Discussion

Both men and women were able to provide information relating to tilapia trait and characteristics in both the open-ended questionnaire (used with aim to identify traits of interest) and stated choice experiment (used to identify trade-offs among pre-selected traits derived from scoping study and literature review). These results confirmed the findings from the rohu carp study (Mehar et al., 2022) that women from producing households can inform priorities and trade-offs among production traits for fish despite widely held views in Bangladesh that men are fish farmers and women are only "homemakers." (Orr et al., 2021). The tilapia results were similar also to the rohu carp study (Mehar et al., 2022) in that, although women and men shared some preferences there were also differences in their preferences, some of which were statistically significant.

It is important to note that despite greater social and policy recognition of men as fish farmers (Brugere and Williams, 2017) which also appear in our analysis, women interviewed were readily able to identify a range of preferences relating to tilapia trait and characteristics including economic preferences (i.e., demand, price and profitability). The findings do imply that gendered role and division of labour or task is not the only factor determining the preferences or priorities of traits for fish. Undermining the importance of women may undermines adoption of genetically improved fish strain.

4.1. General preferences and desired improvements

Both men and women in smallholder farming households did not value traits equally, demonstrating some traits were more desirable than others. Overall, *economic factors* (i.e., demand, price, profitability) were the most important liked characteristics by both men and women. This may be because tilapia is an important source of income for these households given the rising per capita annual consumption for this fish in Bangladesh (Toufique, 2015). The other major likes and dislikes highly ranked by both genders identified important qualities related to the acceptability of fish as food product. Thus, *pleasant taste* ranked second in the likes for both genders and *good appearance* third for women and fourth for men, while the converse dislikes of *bad odor* ranked first for both genders and *bad taste* second for men or third for women. There was therefore consistency in the responses related to likes and their converse dislikes. This also applied to production or economic characteristics where lack of demand and high production cost was disliked, although at lower rank (third to fifth) than their alternative likes (first). There were, therefore, similar preferences by both genders for the more highly ranked traits, although some major contrasts were detected. For example, women ranked *growth* fifth as a like, less than men who ranked it third. The nature of this difference suggested a trend of lesser preference by women for some production traits and a greater preference for consumption related traits. Many differences in ranking between genders reflected small shifts in number of choices for a trait and more often

Table 7
Mean part-worth utility (PWU) values from 1000minds survey in Bangladesh testing preferences of men ($n = 64$) and women ($n = 39$) for the traits listed in Table 1.

Trait	Unit	Men			Women			Men-women comparison
		Rank	Mean	*t*-test[a]	Rank	Mean	t-test [a]	t-test[b]
Weight (kg)	> 1.45 kg fish	=1	15.9	4.4***	5	11.3	−1.7	2.9**
Body shape	Slender	=1	15.9	3.8***	4	13.8	1.1	2.1**
Price (kg^{-1})	210 Taka/Rs	2	15	3.3***	8	8.7	−5.5***	−1.0
Gill color	Dark Red	3	13.4	1.2	1	16.4	4.2***	−2.1**
Skin color	Darker color combination of red/black/ golden	4	12.9	0.51	3	14.2	1.9	−0.21
Eye color	Black/dark green	5	10.2	−3.4***	6	10.3	−1.9	−0.2
Taste	Original/Sweet/Good	6	9.1	−5.3***	7	9.2	−3.6***	0.8
Length (inches)	Around 15 in.	7	7.6	−7.5***	2	16.0	3.1**	−0.9

Note: *P < 0.05, **P < 0.01, ***P < 0.001. Two questions were repeated randomly for each participant were selected to repeat in the program for consistency check in their responses. The results showed 73% of participants in had similar answers for the repeated questions. [a] Null hypothesis is that, if each trait's part-worth utility (PWU) was equal, that value would be 100/8 = 12.50. [b] Null hypothesis that male and female have same preferences.

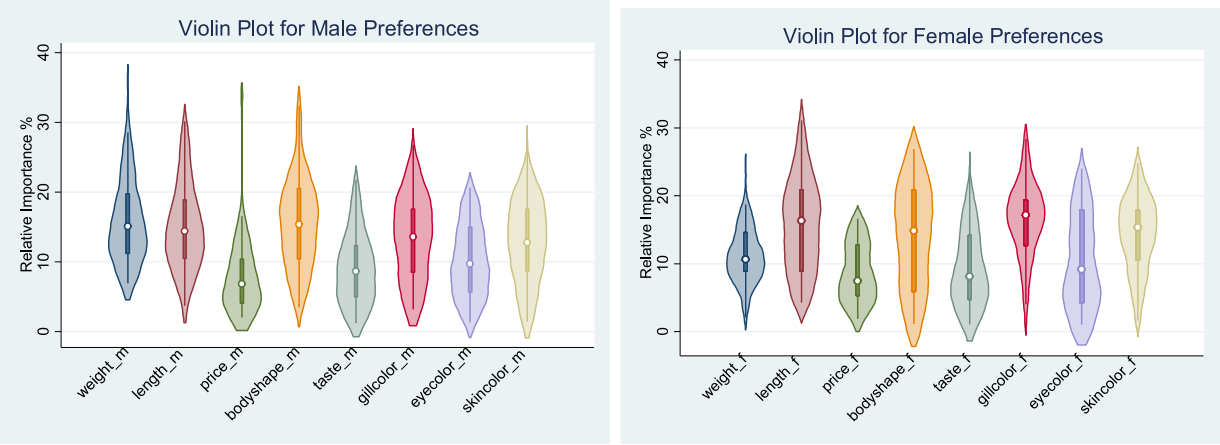

Fig. 2. Preferences for Tilapia traits by men (n = 64) and women (n = 39) farmers in Bangladesh.

in lower ranked traits, making the degree of significance to the users difficult to determine, but followed the trend indicated above. This difference in emphasis may be due to the prevailing norms and division of labor, where female members of the families are the custodian of household food security, food consumption and nutritional security (Mehar and Prasad, 2022) and men more closely involved in production and trading.

The response to questions concerning what to improve also demonstrated these trends but the reduced number of participants responding, particularly women, was perhaps also a result of these same trends. The second most preferred characteristic for improvement by both genders was *reduced feed-habit intake* a critical issue for production and profitability, and additionally emphasized by men who exclusively ranked reduced feed cost as their first ranked trait for improvement. In contrast, women ranked *taste* first and had lower rankings for other production related traits. Social and gender norms in Bangladesh constrain women's mobility and men undertake the buying the feed and selling fish to the market. Commercial feed for tilapia is used increasingly in Bangladesh, and around two-fifth of surveyed farmers reported using it. This may explain why only men mentioned *reduce feed cost* and other lower-ranked aspects related to production cost and market value. Nevertheless, most women were found to be responsible for preparing home-based feed for fish and feeding the fish on a daily basis, primarily due to the proximity of ponds to the home. This may explain their high ranking of reducing feed intake - and an indicator of the influence of the different current gender roles in farming in the rankings observed.

The information collected from the women members of the producer household showed a similar focus on the acceptability of fish as food with large size and appearance being highly ranked characteristics for selection from pond or market with other traits identified only with the market as they would not be as relevant to selection from the pond such as live fish, body shape and affordable price. Similar findings were made by Mehar et al. (2022) in their rohu study in Bangladesh and India.

The stated choice experiment which constrains choices through specific tradeoffs between traits also demonstrated that both men and women differentiated among traits preferring some traits significantly above average and some significantly below average. A similar pattern to the open-ended questions emerged in that men focused on production and profitability, ranking greater *weight* and higher *price* of fish highly, while women ranked *gill color* and *length* highly, reflecting their focus on product freshness and possibly value through their low ranking of high price. These differences were emphasized by the statistically significant differences between the preferences by men and women for *weight* and *gill color*. *Body shape* was also preferred significantly differently, and *length* was ranked differently by men and women but it is not clear what these differences mean and further work will be needed to clarify this. Both genders did not rank improving *taste* highly suggesting taste in current markets was considered at least adequate. These results contrast with those from the rohu study where the top ranked trait of men and women was the same and referred to greater weight of fish. The significant differences between men and women were significant only for two traits of rohu, which were the lowest ranked by men and women. It appears that the gender differences in the present study of tilapia reflect what could be termed a producer orientation in men and a consumer one for women. This is in contrast to the rohu study results, where women and men had responded from a producer-oriented approach (Mehar et al., 2022). Since the sub-group of farmers had provided responses for tilapia had also provided responses in the rohu study, these results imply preferences for different fishes have different influencing factors.

4.2. *Implications for trait preferences for tilapia genetic improvement program*

Only heritable traits can be altered by a genetic improvement program and because the response to selection reduces the more traits that are included, most programs can concurrently select relatively few characteristics (Orr et al., 2021). Given the considerable investment of time and money involved for a genetic improvement program the increase in value obtained from those changes need to exceed the cost of the effort. Some characteristics are also much more easily and cheaply dealt with through changes in management, either on the farm or by value chain actors such as retailers. A number of the traits identified as important to the smallholders such as *bad taste* (muddy taste, taste like feed, watery taste etc.) could be addressed relatively easily by improved farm management, or by strengthening post-harvest handling for freshness characteristics such as *eye color*, *gill color* and *skin color*.

The principal production related traits identified in the open-ended questions, by both genders, related to reducing the amount of feed used or the cost of feed. Given that feed cost constitutes the major portion of the variable cost in fish farming feed intake by fish and their feed conversion ratio, which are major trait for suggestion for improvement are already a major consideration for genetic improvement (De Verdal et al., 2017). The cost of feed itself cannot be influenced by genetic improvement programs, but the efficiency with which fish convert feed into fish protein is better in genetically improved tilapias, so reducing cost of production. For example, genetically improved farmed tilapias have been shown to be more feed efficient than other strains with greater profitability for farmers (Ibrahim et al., 2019; Trinh et al., 2021; Tran et al., 2021). Recent work has shown there may be the ability to specifically select fish for improved feed efficiency separately

to increased growth rate (De Verdal et al., 2018).

The survey did reveal interest in slender body shape and length with responses by men and women liking larger size - whether weight or length with a dislike of smaller size but a small ranking for improvement in size (length or weight) in the open-ended questions relative to other traits. The complex responses in the 1000minds questions with men strongly ranking slender body shape (=first) but not length (at 15 in.), while women had no significant preference for slender body shape but ranked length (at 15 in.) second requires further to clarify the actual preferences involved and the reasons behind them. This information may be of significance for genetic improvement programs as the current selection for faster growth, and therefore larger fish at a given age, tends to produce more rounded fish (Trịnh et al., 2013). Thus, while existing genetic improvement programs have included traits that address some of the key concerns of the smallholders surveyed there are clues that other traits for body shape may need more attention than they have received to date. Specifically, the interest in slender body shape may indicate lower preference for a rounded body. A more rounded tilapia is the result of selection for larger size at harvest (Trịnh et al., 2013). However, given the link of slender body with length and liking for larger size it is not clear whether slender may also be an indicator of size (length). So, these clues are not sufficient yet to inform future breeding. For inclusion in a genetic improvement program, traits suggested for use to the breeder need to have a unique definition, criteria and attach weight economic value (Orr et al., 2021). A gender-responsive breeding with inclusion of 'new 'identified trait(/s), therefore needs to be reliable, representative information on both men and women's preferences for well-defined heritable traits as well as validating and confirming future adoption of the improved strain or new trait(/s) from field studies.

5. Conclusion

This is the first study on gender-disaggregated user-preferences for tilapia traits, focusing on smallholder fish farming households in Bangladesh. The work was aimed particularly at assisting the breeders in understanding the needs of men and women users, specifically smallholder producers and producer/consumers. The results have shown some overlap and similarities in the preferences by men and women, but also some clear contrasts that appear related to current gender division of labor. The similarities were found in the top priority choices ranked by men and women however there were significant differences in emphasis. Both genders had a preference for reduced use of fish feeds, related to reducing costs of production, but men focused more on this and other production improvements while women focused relatively more on traits related to the use of fish as food and as a consumer rather than a producer. The present work showed thatongoing genetic improvement programs focused on faster growth may address the reducing fish feed costs,identified by the respondentsthrough more efficient feed use of the improved strains. The work confirms the relevance of ongoing efforts in breeding program, but highlights the need for more specific information of feed efficiency of different breeds to be able to provide product performance data relevant to market needs – and so perhaps aid adoption. Other preferred characteristics of size or shape were identified that could advise breeding program goals but more research is required to unpack and specify these consumer market traits more clearly. The work also highlights the need for a greater clarity by policy makers and industry planners and breeders of the particular needs of different value chain actors, which may be conflicting, and how then to integrate those. Not all the solutions will be best achieved through genetic improvement programs. These can only effectively deal with and relatively small number of heritable traits and the ability to optimize their prioritization depends of better information on the tradeoffs between traits across the value chain and different user types.

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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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Appendix A. Supplementary data

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