Aquaculture 525 (2020) 735042

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aquaculture

Selective breeding trait preferences for farmed tilapia among low-income women and men consumers in Egypt: Implications for pro-poor and gender-responsive fish breeding programmes☆

Seamus Murphy[a,b,*], Harrison Charo-Karisa[b], Surendran Rajaratnam[c], Steven M. Cole[d], Cynthia McDougall[c], Ahmed Mohamed Nasr-Allah[b], Diaa Kenawy[b], Mohamed Y. Abou Zead[b], Martin L. van Brakel[e], Lauren K. Banks[c,f], Nabil Ibrahim[b]

[a] Bangor University, United Kingdom
[b] WorldFish, Egypt
[c] WorldFish, Malaysia
[d] International Institute of Tropical Agriculture, Tanzania
[e] WorldFish, Bangladesh
[f] Western University, Canada

ARTICLE INFO

Keywords:
Farmed tilapia preferences
Low-income consumers
Gender-responsive breeding
Food and nutrition security, Egypt

ABSTRACT

A number of studies have highlighted the promising growth of Egyptian tilapia aquaculture and the role of genetically improved strains in this development, such as the Abbassa Nile tilapia (*Oreochromis niloticus*, Linneaus, 1758). However, few studies have explored the link between aquaculture development and changes in fish demand among low-income consumers. This study combines household budgeting questionnaires and morphometric tilapia trait rankings conducted in the peak market season of 2017 to examine patterns of tilapia consumption and preferences among low-income women and men consumers across Egypt. Analysis of variance tests and a hierarchical logistic regression model were employed to determine effects of sex, age, educational status, household size, presence of children, food dependency ratio and location on tilapia consumption and trait preferences. Results showed significant differences in tilapia consumption between Lower and Upper Egypt. Greatest heterogeneity in tilapia trait rankings was found in preferences for total body weight, as well as for body width, body length and tilapia head traits. Models predicted that younger women consumers with children in Lower Egypt were more likely to consume smaller tilapia sizes and prefer larger tilapia head traits. This study offers the first evidence base of tilapia trait preferences of low-income consumers to genetic selection programmes considering the adoption of pro-poor and gender-responsive breeding objectives.

1. Introduction

Since 2000, Egypt's annual aquaculture yield has more than doubled, while tilapia farming has increased by 497% in the same period (Fig. 1).[1] Including all species, fish farming (1,370,660mt) now constitutes 69.6% of per capita fish supply (1,969,529mt) and 80.3% of

☆ Declaration to Editors: The submitted article does not contain any work which was previously published, nor work which is under consideration for publication elsewhere. This publication is approved by the authors. If accepted, this work will not be published elsewhere in the same form in English, nor in any other language without the consent of the copyright holder. This work was commissioned by WorldFish, the Swiss Development Cooperation and the Deutsche Gesellschaft für Internationale Zusammenarbeit

* Corresponding author.
E-mail address: seamusrobertmurphy@gmail.com (S. Murphy).

[1] Figures were compiled by author from four different sources:
General Authority for Fish Resources Development (2016) 'Fish Statistics Year Book', Ministry of Agriculture and Land Reclamation, Arab Republic of Egypt, Cairo.
General Authority for Fish Resources Development (2005) 'Fish Statistics Year Book', Ministry of Agriculture and Land Reclamation, Arab Republic of Egypt, Cairo.
FAO FishStatJ 'Global Aquaculture Summary Information 1950 – 2015', http://www.fao.org/figis/servlet/static?dom=collection&xml=global-aquaculture-production.xml&xp_detail=med, last accessed 08-02-18
FAO (2010) 'Fisheries and Aquaculture Profiles, Arab Republic of Egypt', Fisheries and Aquaculture Dept., Rome.

https://doi.org/10.1016/j.aquaculture.2020.735042
Received 28 April 2019; Received in revised form 18 January 2020; Accepted 29 January 2020
Available online 04 February 2020

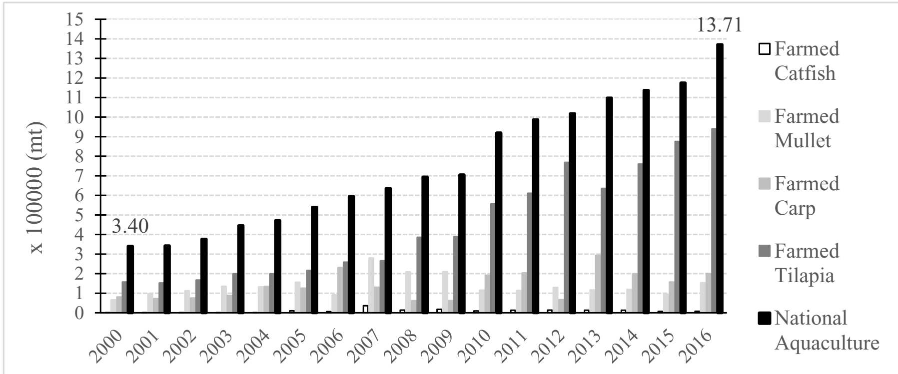

Fig. 1. National aquaculture production trends, 2000–2016 (compiled by author from annual fishery statistics yearbooks: GAFRD, 2000–2016).

the country's fish production (1,706,273mt). Tilapia aquaculture alone (940,309mt) now accounts for 47.7% of per capita fish supply, 55.1% of the country's fish production and 68.6% of total aquaculture production. Egyptian aquaculture is sustained by approximately 6000 pond- and cage-based fish farms, with the average farm estimated to be 20.8 ha in size. Fish farms are concentrated mainly in the Lower Delta districts that surround the coastal lagoons (GAFRD, 2016). Due to this geographic concentration, the bulk of farmed tilapia is produced in only four northern governorates: Kafr el Sheikh (486,502mt), Port Said (151,267mt), Sharkhia (113,873mt), and Beheira (113,440mt). Together, they accounted for 92.0% of the country's 2016 tilapia harvest.

The growth of tilapia production accelerated markedly in the last four years, following the release of the genetically improved Nile tilapia strain to Egyptian farmers. Farm trials comparing performance of improved strains and commercial strains recorded a 28% superior harvest weight and a 30% faster growth rate (Dickson et al., 2016; Ibrahim et al., 2013; Marjanovic et al., 2016). Reports suggest the rapid growth in production has contributed to tilapia farming becoming a strategic food sector, as fish plays an increasingly larger role than other meats in the diets of low-income consumers (Wally, 2016). Wally indicates per capita fish consumption [21.64kgs] is now almost double that of poultry [13.6kg] and almost three times that of beef [9.3kgs] (2016, p. 6).

However, value chain studies have cautioned that market pressures and tilapia farming developments are encouraging farmers to target higher value markets by producing larger, higher grade tilapia products that fetch a higher price per kilogram.[2] Combined with increased adoption of new generations of improved strains, these developments will likely lead to continued growth in fish production but may also reduce access to farmed tilapia by low-income consumers who rely on supply of more affordable smaller grades of tilapia (Eltholth et al., 2015; Macfadyen et al., 2012; El Mahdi et al., 2015). This comes at a time when fish demand has been affected by high food price inflation, which was reported at an annual rate of 16.6% since the Tahrir revolution.[3]

The shifts in both supply and demand have produced knock on effects in the price trends of different tilapia products. According to records from the national El-Obour wholesale fish market, the price of smaller tilapia grades has increased at a faster rate than larger tilapia grades. Between 2011 and 2016, the price of grade I tilapia increased by only 27.4%, while the price of grade III increased by 58.5%.[4]

Due to limited supply chain capacity, these price differentials are even more noticeable at the local level. Comparing retail markets between Lower Egypt and Upper Egypt, studies found significant variation in volume and price of tilapia sold by traders on a daily basis (Kantor and Kruijssen, 2014, 42–45). With traders in Upper Egypt selling smaller volumes of tilapia, more distant markets have been characterized by poorer fish availability and affordability. In these areas, consumers reportedly purchase tilapia less frequently and at a higher cost (El Mahdi et al., 2015, 20–22). These studies indicate that Egypt's farmed tilapia markets have become highly diversified with different grades of product sold at a range of prices according to size, quality, location and market.

Globally, the nutritional importance of micronutrient rich foods, such as fish, to maternal women and infants has been well documented (Andersen et al., 2013; Beveridge et al., 2013; Kawarazuka and Béné, 2010; Longley et al., 2014; Mori et al., 1999; Mulder et al., 2014). While there has been considerable aquaculture development (Fig. 1), the country continues to suffer from high rates of child stunting [22.3%], maternal obesity [32%] and maternal anemia [22.6%] (WHO, 2017). More significantly, studies have found higher rates of double burden malnutrition[5] occurring in areas far from fish farms, such as Upper Egypt [21.5%] and Metropolitan Egypt [26.9%] (Ecker et al., 2016a, 18),

Globally, limited research is available regarding the links between expanding aquaculture and fish consumption patterns among low-income consumers (Belton et al., 2018; Beveridge et al., 2013). Even fewer studies are available that have examined socially differentiated preferences for farmed fish (Murphy et al. *under review*). In response to this research gap, this study explored tilapia consumption patterns and trait preference of low-income consumers in Egypt, taking into account salient factors not considered in the literature to date. The study's main research questions included:

1. What is the current pattern of tilapia consumption among low-income consumers, and do these differ by sex or location?
2. What tilapia traits do low-income consumers prefer, and do they differ by sex or location?

2. Theoretical framework

This study adopts a gender lens to examine sex-differentiated fish

[2] According to Egypt's central fish wholesale market, El-Obour auction house, tilapia products are commonly graded in four sizes: grade IV (< 100 g), grade III (100-250 g), grade II (250-375 g) and grade I (375–600). Across Egypt, value chain studies have found even greater price differentials between tilapia products with grade III tilapia and grade II tilapia retailed at 47% at 20% lower than grade I in price per kilogram (Nasr-Allah and Dickson, 2017, pp. 185; Macfadyen et al., 2012).

[3] http://www.cbe.org.eg/en/pages/Search.aspx?k = inflation

[4] http://www.oboormarket.org.eg/prices_today.aspx

[5] According to the World Health Organization, the double burden of malnutrition is characterized by the 'coexistence of undernutrition along with overweight and obesity, or diet-related non-communicable diseases, within individuals, households and populations, and across the life course' (http://www.who.int/nutrition/double-burdenmalnutrition/en/).

preferences of low-income consumers and the social factors that shape them. It follows theoretical frameworks laid out by gender and development research on consumption behaviour and food preferences in food scarce and low-income environments (Bennett, 2013, 583; Duflo and Udry, 2004; Falkingham and Baschieri, 2009; Katz, 1997). Among this body of work, researchers have called for collection of more detailed household-level data that better explain differences in food consumption and preferences between family members of different sex (Cantillon and Nolan, 2001; Carletto et al., 2013; Carletto and Zezza, 2006; Lanjouw and Ravallion, 1995; Pradhan and Ravallion, 2000). Specifically, these studies have called for cross-referencing of data with socioeconomic variables such as sex, age, education, household (HH) size, presence of children, food and non-food expenditure, and location (Patil, 2013a). This study selected these seven indicators as independent variables in its descriptive analysis and predictive modelling.

This study also considers literature on the nutritional importance of micronutrient rich foods, such as fish, to maternal mothers and infants in the first 1000 days of pregnancy and infancy (Andersen et al., 2013; Beveridge et al., 2013; Kawarazuka and Béné, 2011; Longley et al., 2014; Mori et al., 1999; Mulder et al., 2014). With high rates of maternal and child malnutrition reported in Egypt (WHO, 2017), the role of farmed fish supply in addressing double-burden malnutrition[6] in areas further from aquaculture zones has been promoted as public concern in policy discussions (Kavle et al., 2016; Rashad, 2016). Research of fish consumption and food security have highlighted the importance of affordable tilapia products to low-income Egyptian consumers, especially maternal women and children (Eltholth et al., 2015, 138–39). In their assessment of fish consumption, El-Mahdi et al. reported that a majority of low-income consumers (96%) cited nutritional value of smaller and cheaper tilapia products. In particular, they reported that maternal women discussed such preferences in relation to the dietary requirements of their different household members and young children (El Mahdi et al., 2015, 34–35).

Literature on food and nutrition security in Egypt has also highlighted location as a key factor to consumption patterns. In particular, reports have highlighted poorer levels of employment, poverty, food security and malnutrition rates, as well as lower levels of women's education and women's labour participation in Upper Egypt (Assaad and Rouchdy, 1999; Ecker et al., 2016a; Hopkins and Saad, 2004; Megahed and Lack, 2011; Yount and Li, 2010). National reports also point to differences in fertility rates and household size that are higher in Upper Egypt, followed by lower rates in Cairo and lowest rates in Lower Egypt (Ministry of Health and Population, 2015, 36–45).

It is important to note certain limitations in this study's inquiry. While we recognized the significance of gender norms in driving food preferences and consumption patterns in Egypt, the study did not examine intra-household relations in decision-making processes. Instead, data collection and analyses were limited to consumers' individual and household characteristics and the intersection of these variables with tilapia preferences.

3. Methods

3.1. Sampling framework

During peak months of October and November of 2017, the study surveyed 739 low-income consumers (474 women, 265 men) who were identified as key respondents capable of answering questions on total household expenditure, fish consumption and tilapia trait preferences. A purposive sampling strategy was employed to target low-income consumers. Adapted from previous studies of low-income, Egyptian fish consumers (CAPMAS 2014; El Mahdi et al., 2015), the study's screening index was scored using nine asset-, education-, expenditure- and employment-based indicators. A household was considered ‘low-income’ if they meet at least five of the nine characteristics:

- Household head does not have social security
- Ratio of workers within household is less than 25%
- Share of members per room is less than 25%
- Share of members possessing a mobile phone is less than 25%
- Absence of telephone landline
- Absence of private bathroom
- Absence of motorised vehicle
- None of the household members attend private schooling
- Electricity consumption is less than E£150/month
- Household structure has no concrete or tiled floors

The geographic distribution of consumers was spread evenly with approximately 100 consumers from each of the seven governorates selected: three in Upper Egypt (Aswan, Menia, Fayoum), three in Lower Egypt (Kafr el Sheikh, Sharkhia and Beheira) and one in Metropolitan Egypt (Cairo) (Fig. 2).

3.2. Data collection: four staged questionnaire

All four stages of the questionnaire were presented to one key respondent from each household (474 women, 265 men). Stages 1 and 2 of the questionnaire conducted weekly and monthly recalls to inquire about their total household characteristics, food and non-food expenditure. Stages 3 and 4 inquired about the personal preferences of tilapia among key respondents. We note here limitations to the study's sampling. As consumption and expenditure data relied on weekly and monthly recalls, these questionnaires captured snapshots of peak market season activity. This was chosen to reflect seasonal pressures of high fish prices on household food security. Nonetheless, further research is needed to better understand the seasonal fluctuations Egypt's food markets and the economic importance of cultural events such as marriages on household budgets.

In stage 1, non-food expenditures were reported as monthly recalls, including expenditures on clothing, education, health, maintenance, transport, fuel, house rental and loan payments, land purchases, livestock, agricultural inputs and farming equipment, festivals and marriages, cosmetics and cleaning materials. In stage 2, food expenditures were reported as 7-day recalls, including expenditures on rice, grains, bread and pasta, sheep, beef, chicken, fish, dairy, eggs, oil and butter, fruits, vegetables, sugar and spices. A separate set of questions was asked regarding fish expenditures of different species, including tilapia (*Oreochromis niloticus*, Linneaus, 1758), mackerel (*Scomberomorus* spp., Lacepède, 1801), mullet (*Mugil* spp. Linnaeus, 1758), lizardfish (*Synodus variegatus,* Lacépède, 1803), sardines (*Sardinella* spp., Valenciennes, 1847), catfish (*Clarius gariepinus,* Burchell, 1822; *Heterobranchus bidorsalis,* Saint-Hilaire, 1809; *Schilbe mystus,* Linnaeus, 1758; *Bagrus* spp., Bosc, 1816) or herring (*Spratelloides gracilis,* Temminck & Schlegel, 1846).

Stages 3 and 4 inquired about key respondents' personal preferences for tilapia and tilapia traits. Here, the focus was on revealing respondents' stated preferences for tilapia products given their considerations of household constraints and patterns of consumption discussed above. As such, we aimed to identify gender-differentiated preferences for farmed tilapia among the sample of low-income households. These sections were conducted as a ranking exercise. Key respondents were asked to first rank their general tilapia preferences from among ten morphometric and organoleptic ‘priority tilapia traits’. These included six morphology traits: ‘size’ (total body weight), ‘body

[6] According to the World Health Organization, the double burden of malnutrition is characterized by the ‘coexistence of undernutrition along with overweight and obesity, or diet-related non-communicable diseases, within individuals, households and populations, and across the life course’ (http://www.who.int/nutrition/double-burden-malnutrition/en/).

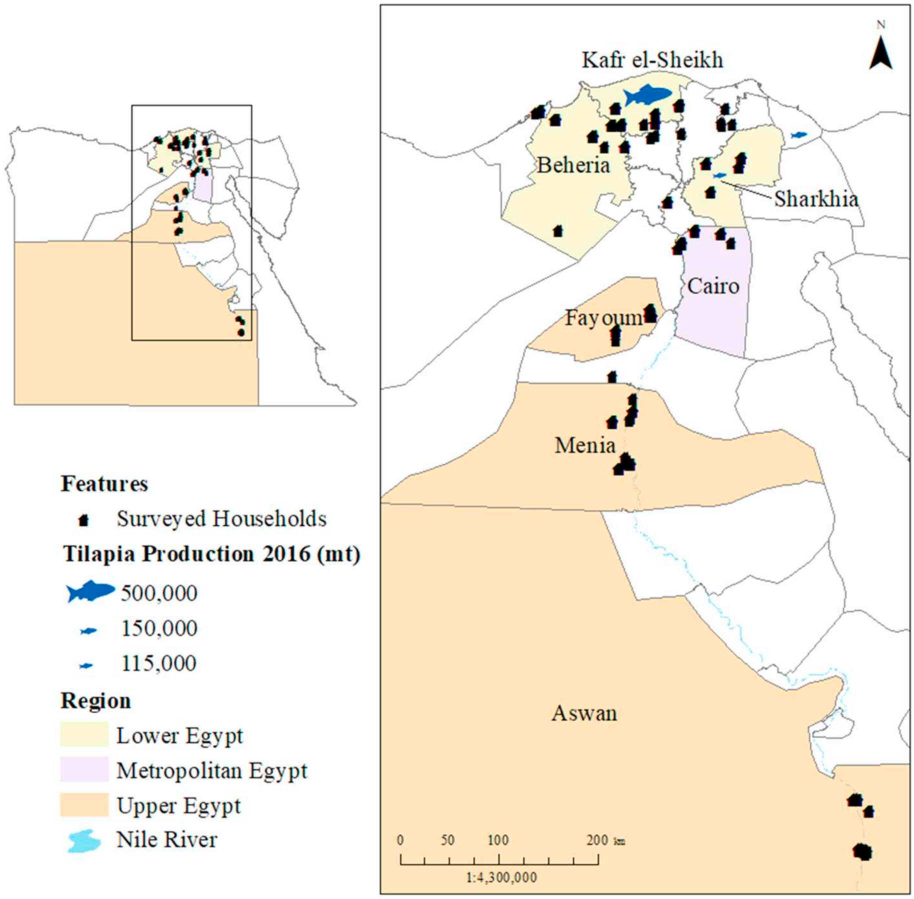

Fig. 2. Distribution of sampled consumers.

Table 1
Measurement of morphometric trait variables.

Morphometric variables	Description
1. Size	Measured as total weight including gut and gonads
2. Width	Measured with callipers at the first ray of the dorsal fin
3. Length	Measured from middle of upper lip of mouth to end of caudal fin
4. Head size	Measured from cranial point of upper lip to rear of operculum
5. Tail size	Measured with callipers along fin edge from front to rear of caudal fin
6. Bone:fillet ratio	Reported as presence of bones by touch and filleting

width', 'body length', 'head traits', 'tail traits' and 'bone to fillet ratio' (Table 1); and four organoleptic traits: 'flesh', 'taste', 'cooking' and 'fin' preferences. For the purpose of this study, we considered results specific to Nile tilapia morphology that were cited as actionable breeding traits in literature regarding existing selective breeding programmes (Charo-Karisa et al., 2006; Marjanovic et al., 2016). In these rankings, highest preferences were given a score of 10 and lowest preferences were given a score of 1.

Key respondents were then asked to rank their five preferred morphometric characteristics. In this questionnaire, consumers were presented with four morphometric measurements for each of the 6 morphology traits, providing a total of 24 morphometric variables to choose from (Table 2). Measurement categories of the 24 morphometric variables were estimated following the conventional approach outlined by González et al. (2016). This involved a random sampling of the four commonly graded tilapia products, which was conducted in two retail markets of Zagazig and Abou Hammad cities. Ten samples were measured of each grade to calculate averages and standard deviation in centimetres and kilograms. To avoid artificial error, lineal morphometric measurements were taken on the left hand side of the carcass by the same person using a measuring board, mechanical callipers and an electronic weighing scale (Fig. 3). To assist accurate estimation of these measurements, interviewers presented consumers with life-size picture aids of the four grades of Nile tilapia carcasses and a diagram indicating parts of the fish being measured (Fig. 4). In these rankings, highest preference was given a score of 1 and lowest preference was given a score of 5.

3.3. Data analysis

Statistical analyses were performed using version 21 of SPSS software. Analysis of variance was conducted using one-way ANOVA Welch *t*-test and the Games Howell post-hoc function. The Welch robust test of means was chosen due to homogeneity of variance and sample size violations. To determine vulnerability of low-income households to food price shocks and supply chain developments, a household dependency ratio was calculated based on the conventional methods of Engel and Bennett's Laws (Engel, 1857; Timmer et al., 1983, 23). These equations assessed the ratio of household food and fish expenditure to total household expenditure. In order to evaluate these ratios in relation to non-food expenditure, weekly food purchases were transformed into monthly expenditure.

Results of trait preference rankings that expressed greatest heterogeneity across sub-groups were used to identify response variables for

Table 2
Morphometric trait dictionary.

Variable label	Trait measurement	Variable label	Trait measurement
1.1. Size – Grade I	Body weight μ 441.50 g ± 54.50	1.2. Size – Grade II	Body weight μ 298.50 g ± 37.94
1.3. Size – Grade III	Body weight μ 184.50 g ± 32.01	1.4. Size – Grade IV	Body weight μ 51.50 g ± 24.50
2.1. Width – Fat	Body width μ 4.12 cm ± 0.20	2.2. Width – Medium	Body width μ 3.85 cm ± 0.16
2.3. Width – Slim	Body width μ 2.81 cm ± 0.21	2.4. Width – Skinny	Body width μ 1.92 cm ± 0.20
3.1. Length – Long	Total length μ 26.97 cm ± 0.99	3.2. Length – Medium	Total length μ 23.66 cm ± 0.80
3.3. Length – Short	Total length μ 21.14 cm ± 0.96	3.4. Length – Stumpy	Total length μ 13.46 cm ± 1.97
4.1. Head size – Large	Head length μ 6.89 cm ± 0.32	4.2. Head size – Medium	Head length μ 6.04 cm ± 0.30
4.3. Head size – Small	Head length μ 5.60 cm ± 0.31	4.4. Head size – Very Small	Head length μ 3.71 cm ± 0.52
5.1. Tail size – Large	Caudal fin μ 4.88 cm ± 0.33	5.2. Tail size – Medium	Caudal fin μ 4.52 cm ± 0.21
5.3. Tail size – Small	Caudal fin μ 3.96 cm ± 0.24	5.4. Tail size – Very Small	Caudal fin μ 2.75 m ± 0.36
6.1. Bones:fillet ratio	'I love bones'	6.2. Bones:fillet ratio	'Bones are okay'
6.3. Bones:fillet ratio	'I dislike bones'	6.4. Bones:fillet ratio	'I prefer fillet only'

logistic regression, which was employed to determine effects of seven independent variables on four response variables (Table 3). To develop these response variables, morphometric trait variables were transformed using a two-step process. Firstly, morphometric trait rankings were transformed from ordinal into discrete variables to represent 'preferred' responses (1/0). Secondly, for each morphometric trait, the four morphometric measurements were collapsed into two. That is, preferences for larger grades I and II tilapia were included into one new variable: 'larger tilapia preference' (1/0). Similarly, preferences for smaller grades III and IV were included into one variable: 'smaller tilapia preference' (1/0).

In total four models were employed to test preference against preference for smaller sized tilapia, larger sized tilapia, thicker sized tilapia and longer sized tilapia. Models were checked for goodness-of-fit using the Hosmer and Lemeshow test ($p > .10$). The Nagelkerke test provided estimates of variance explained in the dependent variables of the four models ($R^2 = 2.9$–8.3%), which correctly classified between 59.9% and 73.2% of the cases.

4. Results

4.1. Household characteristics and expenditure

Household and consumer characteristics, including food and non-food expenditures, are presented below in Table 4. Average household size was 4.5 ± 1.5. Higher percentages of women (31%) than men (18%) reported no formal education [$F(1, 738) = 13.631$, $p = .000$]. Meanwhile more men (11%) than women (4%) reported completing secondary or attending higher education [$F(1,739) = 10.761$, $p = .001$]. A significant number of consumers reported having children (60%).

Average monthly household expenditure was E£1614.6 ± 927.4 (95% CI = 1547.6, 1681.5). Average monthly household expenditure differed significantly by location and sex. The Welch t-test observed statistically significant effect of governorate on average monthly household expenditure [$F(6, 733) = 11.079$, $p = .000$]. It also observed significant effect of region [$F(2, 737) = 5.936$, $p = .003$], and sex [$F(1, 738) = 4.553$, $p = .033$] on same response variable. Across governorates, the highest average monthly household expenditure was reported in Fayoum of Upper Egypt (μ E£1880.7 ± 927.7, 95% CI = 1705.4, 2056.0) and the lowest was reported Menia of Upper Egypt (μ E£1302.4 ± 571.2, 95% CI = 1199.2, 1405.7). By sex, we found that men reported higher average monthly household expenditure (μ E£1716.6 ± 1003.8, 95% CI = (1591.8, 1841.4) than women (μ E£1557.3 ± 857.8, 95% CI = 1479.9. 1634.7).

Average monthly food expenditures was E£964.9 ± 462.3 (95% CI = 931.6, 998.3). Average monthly food expenditure differed significantly by location and sex. The Welch t-test observed significant effect of governorate [$F(6, 733) = 7.896$, $p = .000$] and sex on monthly food expenditure [$F(1, 738) = 5.202$, $p = .023$]. By location, highest average monthly food expenditure was reported in Fayoum of Upper Egypt (μ E£1161.9 ± 527.8, 95% CI = 1062.2, 1261.6) and lowest was reported in Aswan of Upper Egypt (μ E£822.2 ± 442.6, 95% CI = 738.6, 905.9). By sex, men reported higher average monthly food expenditure (μ E£1012.0 ± 490.8, 95% CI = 958.7, 1077.2) than women (μ E£935.1 ± 443.2, 95% = 895.1, 975.1).

Average monthly fish expenditure was E£83.2 ± 106.8 (95% CI = 75.5, 90.9). Average monthly fish expenditure differed significantly by location but not by sex. By location, the Welch t-test observed statistically significant effect of governorate [$F(6, 733) = 34.800$, $p = .000$] and region [$F(2, 737) = 61.811$, $p = .000$] on monthly fish expenditure. Highest average fish expenditure was reported in Kafr El Sheikh of Lower Egypt (μ E£154.0. ± 116.9, 95% CI = 130.8, 177.2), while the lowest monthly fish expenditure was reported in Menia of Upper Egypt (μ E£21.7 ± 72.7, 95% CI = 8.5, 34.8).

Calculating household food dependency ratio and specific food expenditure ratios, we found average monthly food expenditure accounted for 63.3% and average monthly fish expenditure accounted for 8.3% of average total monthly household expenditures. Compared to other foods, fish expenditure ratio was much lower to that spent on red meat (30.0%), vegetables (19.5%), and dairy and eggs (13.8%).

Fig. 3. Market-based sampling of tilapia morphology.

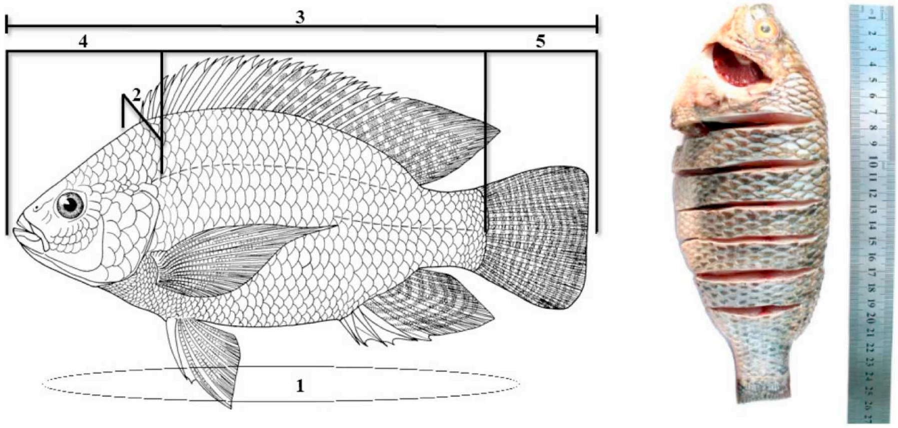

Fig. 4. Interview picture aids (source: adapted by author from Hassanien et al., 2011; Kosai et al., 2014; Rocha et al., 2012; Bogard et al., 2018).

Table 3
Variables used in the logistic regression models.

Variable	Type	Measure	Definition
Tilapia preference	Dependent	Dichotomous	1 for consumers citing binary characteristics in top 5 preferences
Sex	Independent	Dichotomous	1 for female consumers, 0 for male consumers
Age	Independent	Continuous	Age of consumers reported in increment of years
Education	Independent	Continuous	Education of consumers reported in increment of years of schooling
HH size	Independent	Continuous	Number of household members residing within same residence
Children	Independent	Dichotomous	1 for consumers with children under age of 12
HH dependency	Independent	Continuous	Household dependency calculated as % of total household expenditure spent on food
Location	Independent	Categorical	Regional location of consumers between Lower, Metropolitan and Upper Egypt

Both household food dependency ratios and fish expenditure ratios differed significantly by location but not by sex. By location, the Welch *t*-test observed significant effect of governorate [$F(6, 733) = 6.643$, $p = .000$] and region [$F(2, 733) = 4.612$, $p = .011$] on household food dependency ratio. Highest household food dependency ratio was reported in Menia of Upper Egypt (68.1%) and the lowest was reported in Kafr El Sheikh of Lower Egypt (54.7%). For fish expenditure ratio across locations, the Welch *t*-test observed significant effect of governorate [$F(6, 733) = 15.852$, $p = .000$] and region [$F(2, 733) = 87.064$, $p = .000$]. Highest fish expenditure ratio was reported in Kafr El Sheikh of Lower Egypt (17.3%) and the lowest was reported in Menia of Upper Egypt (1.9%).

Across the aggregate sample, only 356 consumers reported buying fish (48.2%). We refer to these as 'fish-consuming consumers'. Between regions, the share of fish-consuming consumers differed significantly [$F(2, 739) = 11.910$, $p = .000$], which was lowest in Upper Egypt (24.4%), slightly higher in Cairo (39.0%) and highest in Lower Egypt (78.3%). Between governorates, this differed more significantly [$F(6, 722) = 44.322$, $p = .000$]. Highest shares found in Sharkhia (83%) and Kafr El-Sheikh (82%). Lowest shares were found in Menia (10.0%) and Aswan (11.8%).

In terms of species purchased, tilapia was by far the most popular fish, which was purchased by 83.2% of fish-consuming consumers. In Aswan, fish-consuming consumers reported purchasing tilapia only, compared to 91.7% in Menia, 86.6% in Kafr El Sheikh and 85.7% in Beheira. Responses regarding which tilapia products were purchased by women and men during their previous market visit indicated most frequently purchased tilapia sizes were smaller grades III and IV. Eighty per cent of women while 80.1% of men reported buying one of these two smaller grades.

4.2. Selection trait preferences of consumers by sex and location: 'Priority tilapia traits'

Results found that women and men ranked their priority tilapia traits in similar order of preference, with both groups scoring highest tilapia size (total body weight). In descending order of preference rankings, body width, body length and head traits followed (Table 5). However, consumers' priority trait rankings differed significantly when disaggregated by sex, location, and by sex within locations.

Across the aggregate sample, analysis observed a statistically significant effect of sex on body length preferences [$F(1, 737) = 4.38$, $p = .032$] and head traits preferences [$F(1, 737) = 7.56$, $p = .006$]. Results showed that men ranked body length traits higher (μ 6.77 ± 2.23) than women (μ 6.39 ± 2.43). Conversely, women ranked head traits higher (μ 4.75 ± 2.16) than men (μ 4.31 ± 2.03). Within regions, greatest heterogeneity of trait rankings was found in Lower Egypt between women and men's preferences for body length traits [$F(1, 298) = 5.377$, $p = .021$] and head traits preferences [$F(1, 298) = 6.719$, $p = .010$). Results showed that in Lower Egypt, men ranked body length traits higher (μ 6.84 ± 2.12) than women (μ 6.22 ± 2.33), while women ranked head traits higher (μ 5.42 ± 2.14) than men (μ 4.75 ± 2.16).

Across the aggregate sample, analysis observed a statistically significant effect of sex on preferences for body length traits [$F(1, 737) = 4.38$, $p = .032$] and head traits [$F(1, 737) = 7.56$, $p = .006$]. Results showed that men ranked body length traits higher (μ 6.77 ± 2.23) than women (μ 6.39 ± 2.43). Conversely, women ranked head traits higher (μ 4.75 ± 2.16) than men (μ 4.31 ± 2.03). Within regions, greatest heterogeneity in sex-disaggregated trait rankings was found in Lower Egypt between women and men's preferences for body length traits [$F(1, 298) = 5.377$, $p = .021$] and head traits preferences [$F(1, 298) = 6.719$, $p = .010$). Results showed men ranked body length traits higher (μ 6.84 ± 2.12) than women (μ 6.22 ± 2.33), while women ranked head traits higher (μ 5.42 ± 2.14) than men (μ 4.75 ± 2.16).

Across the aggregate sample, analysis by location found a significant effect of region on preferences for head traits [$F(2, 736) = 21.99$, $p = .000$], tail traits [$F(2, 736) = 3.29$, $p = .016$] and bone-to-fillet ratio [$F(2, 736) = 43.10$, $p = .000$]. Results showed consumers preferences for head traits differed most significantly between Lower Egypt

Table 4
Sample characteristic.

	Lower Egypt (n = 300)				Cairo (n = 100)				Upper Egypt (n = 339)				Total N = 739				
	Female	Male	All	Wp	Female	Male	All	Wp	Female	Male	All	Wp	Female	Male	All	Wp	All/region
Variable	*198*	*102*	*300*		*53*	*47*	*100*		*223*	*116*	*339*		*474*	*265*	*739*		
Unemployed (%)	**0.94**	0.11	**0.66**	***	**0.87**	**0.09**	0.50	***	**0.96**	0.10	**0.66**	***	**0.94**	0.10	0.64	***	*
Education (years)	7.77	7.72	7.75		5.09	**8.28**	6.59	**	6.61	**8.82**	7.37	***	6.92	**8.30**	7.42	***	
Age (years)	32.2	**41.4**	35.3	***	34.6	**39.2**	36.8	**	31.3	**38.0**	33.6	***	32.1	**39.5**	34.7	***	*
HH size	4.2	4.3	4.2		4.6	4.8	**4.7**		4.8	4.6	**4.7**		4.6	4.5	4.5		***
HH's with children (%)	0.61	0.54	0.59		0.64	0.74	0.69		0.62	0.51	0.58		0.62	0.56	0.60		
HH total exp. (E£/month)	1650.0	**1953.2**	**1753.1**	*	1477.9	**1773.4**	1616.8	**	1493.9	1487.5	1491.7		**1716.6**	1557.3	1614.6	*	**
HH food exp. (E£/month)	919.2	**1038.8**	959.9	*	907.5	**1080.5**	988.8	**	955.8	974.8	962.3		935.1	**1018.0**	9964.9	*	
HH fish exp. (E£/month)	129.1	136.6	**131.6**		54.3	85.5	68.9		44.6	44.8	44.6		80.9	87.2	83.2		***
HH dependency (%)	0.61	0.61	0.61		0.65	0.64	0.65		0.64	0.67	**0.65**		0.63	0.64	0.63		**
Fish exp. ratio (%)	0.14	0.13	**0.14**		0.06	0.07	0.06		0.04	0.05	0.04		0.08	0.08	0.08		***
Red meat exp. ratio (%)	0.19	0.22	0.20		0.19	0.24	0.21		0.35	0.35	0.35		0.26	0.28	0.27		
Vegetable exp. ratio (%)	0.21	0.20	0.21		0.19	0.19	0.19		0.18	0.19	0.19		0.19	0.19	0.19		
Dairy & eggs exp. ratio (%)	0.15	0.16	0.16		0.17	0.16	0.17		0.12	0.10	0.11		0.14	0.14	0.14		
Fish-consumers (%)	0.80	0.75	**0.78**		0.38	0.40	0.39		0.25	0.24	0.24		0.49	0.47	0.48		***
Fish-consumers buying tilapia (%)	0.81	0.87	0.83		0.85	0.95	0.90		0.75	0.93	0.81		0.80	0.90	0.83		

Welch t-test scores (Wp): mean values in bold are significantly higher than other sex and regions at the $<$0.05, 0.01, 0.001 levels for *, **, ***

(μ 5.19 ± 2.16) and Upper Egypt (μ 4.15 ± 1.96). Consumers' preferences for tail traits differed most significantly between Lower Egypt (μ 3.66 ± 1.60) and Metropolitan Egypt (μ 3.21 ± 1.63). Consumers' preferences for bone-to-fillet traits differed most significantly between Upper Egypt (μ 3.44 ± 2.38) and Lower Egypt (μ 1.98 ± 1.38).

4.3. Morphometric trait rankings

Consumers' rankings of their top five preferred morphometric characteristics are presented below (Table 6). Given that consumers were asked to choose five traits from 24 morphometric traits, the following results are presented in descending order of frequency of citations (f) in addition to average ranking scores. Traits that were scored by fewer than 99 consumers were not included in the analyses.

Across the aggregate sample, grades III and IV were cited in top five preferences more frequently than larger sizes (Grade I and II); while Grade IV was ranked second highest among all morphometric traits. Comparing preference rankings between women and men, the Welch t-test observed a statistically significant effect of sex on 'Width-Fat' traits [$F(2, 263) = 4.43$, $p = .034$] and 'Grade IV' size traits [$F(1, 197) = 5.09$, $p = .015$]. Results showed that women ranked 'Width-Fat' traits higher (μ 2.99 ± 1.21), while men ranked 'Grade IV' size higher (μ 4.28 ± 1.02).

Comparing preference rankings between Lower, Upper and Metropolitan Egypt, the Welch t-test found a significant effect of region on preferences for 'Grade IV' sizes [$F(2, 196) = 7.43$, $p = .001$]. As seen in Table 6, Grade IV size was ranked higher among consumers in Metropolitan Egypt (Cairo, μ 4.50 ± 0.82). Comparing preference rankings within Metropolitan Egypt only, heterogeneity of preferences was also observed between women and men for other traits. The Welch t-test found a statistically significant effect of sex on preferences for 'Head Medium' traits [$F(1, 11) = 9.88$, $p = .025$] and 'Grade III' size traits [$F(1, 34) = 5.29$, $p = .028$]. As seen in Table 6, women in Cairo ranked 'Head-Medium' traits higher (μ 3.33 ± 1.50) than men (μ 1.43 ± 0.53).

4.4. Logistic regression analysis of socioeconomic factors to tilapia preferences

To understand the independent effects of socioeconomic characteristics on trait preferences, the following logistic regression analysis was conducted.

Across the aggregate sample (Table 7), preferences for smaller sized tilapia were significantly associated with age, years of education, presence of children and location of residence [$\chi^2(8, 739) = 47.29$, $p = .000$]. The model observed strongest relationship between smaller tilapia preferences and location. Results predicted that consumers from Upper Egypt were least likely to consume smaller tilapia ($p = .000$). In comparison, the odds for consumers in Cairo consuming smaller tilapia increase by 51% ($R^2 = 1.509$, 95% CI = 0.95, 2.39, $p = .081$), while the odds for consumers from Lower Egypt increase by 139% ($R^2 = 2.387$, 95% CI = 1.71, 3.33, $p = .000$). A significant relationship was observed with the presence of children. Compared to households without children, the odds for this group increase by 99% ($R^2 = 1.988$. 95% CI = 1.30, 3.03, $p = .001$). Significant associations were also observed with age and educational years, with both expressing a negative correlation. That is, as age of consumers increases by one year, consumers' odds for consuming smaller tilapia decrease by 2.3%

Table 5
Differences between women and men's morphometric trait preference rankings by location and sex.

	Lower Egypt (n = 300)				Cairo (n = 100)				Upper Egypt (n = 339)				Total N = 739				
	Female	Male	All	Wp	Female	Male	All	Wp	Female	Male	All	Wp	Female	Male	All	Wp	All/Region
Variable	198	102	300		53	47	100		223	116	339		474	265	*739*		
Size	7.77	8.26	7.94		8.49	8.38	8.44		8.33	8.23	8.30		8.12	8.27	8.17		
Width	6.44	6.77	6.55		**7.17**	6.32	6.77	*	6.47	6.68	6.54		6.53	6.65	6.58		
Length	6.22	**6.84**	6.43	*	6.45	6.85	6.64		6.53	6.81	6.58		6.39	**6.77**	6.53	*	
Head size	**5.42**	4.74	**5.19**	**	4.57	4.04	4.32		4.20	4.04	4.15		**4.75**	4.31	4.60	**	**
Tail size	3.64	3.71	**3.66**		3.09	3.34	3.21		3.71	6.49	3.63		3.61	3.55	3.59		*
Bone:fillet ratio	2.00	1.93	1.98		2.55	2.36	2.46		3.54	3.24	**3.43**		2.78	2.58	2.71		**

Welch t-test p-values (Wp): mean values in bold are significantly higher than other sex and regions at the $<$0.05, 0.01, 0.001 levels for *, **, ***.

Table 6
Differences between women and men's morphometric trait rankings by location and sex.

	Lower Egypt (n = 300)					Cairo (n = 100)					Upper Egypt (n = 339)					Total N = 739					
	Female	Male	All	*f*	W*p*	Female	Male	All	*f*	W*p*	Female	Male	All	*f*	W*p*	Female	Male	All	*f*	W*p*	All/ region
Variable	198	102	300			53	47	100			223	116	339			474	265	*739*			
Length - Medium	2.65	2.66	2.65	*170*		2.66	2.71	2.68	*57*		2.97	2.70	2.87	*200*		2.80	2.69	2.76	*427*		
Width - Fat	2.89	2.62	2.79	*107*		2.95	2.35	2.67	*36*		3.10	2.85	3.02	*122*		**2.99**	2.67	2.88	*265*	*	
Width - Medium	2.78	2.61	2.72	*95*		2.83	2.71	2.79	*38*		2.46	**3.03**	2.66	*114*	**	2.64	2.81	2.70	*247*		
Size - Grade IV	3.42	**4.22**	3.68	*99*	***	4.70	4.17	**4.50**	*16*		4.26	4.37	4.30	*84*		3.86	**4.28**	4.01	*199*	*	***
Size - Grade III	3.55	4.00	3.71	*82*		3.33	**4.17**	3.75	*36*		4.15	4.07	**4.13**	*55*		3.73	4.06	3.85	*173*		
Head - Medium	2.59	2.38	2.54	*82*		**3.33**	1.43	2.31	*13*	*	2.05	2.52	2.22	*58*		2.44	2.31	2.40	*153*		
Size - Grade I	3.97	4.27	4.06	*52*		3.71	3.75	3.73	*11*		4.03	3.86	3.97	*111*		3.99	3.96	3.98	*174*		
Size – Grade II	3.85	4.20	4.00	*23*		4.21	3.93	4.07	*28*		4.25	3.75	4.04	*48*		4.15	3.91	4.04	*99*		

Welch *t*-test p-values (W*p*): mean values in bold are significantly higher than other sex or regions at the < 0.05, 0.01, 0.001 levels for *, **, ***. Frequency (*f*) showing number of citations in consumers' top five morphometric trait preferences.

(R^2 = 0.977, 95% CI = 0.90, 0.99, p = .009) and as educational years of consumers increases by one year, their odds of consuming smaller tilapia decrease by 4.1% (R^2 = 0.959, 95% CI = 0.93, 0.99, p = .016).

The model testing against preferences for thicker tilapia traits found statistically significant associations with educational status of consumer [χ^2 (8, 739) = 16.43, p = .037]. The model observed negative correlation between education and the dependent variable. As educational years increase by one year, the odds for consumers consuming thicker tilapia decrease by 4.6% (R^2 = 0.954, 95% CI = 0.99, 1.03, p = .005).

The model testing against preferences for longer tilapia traits found statistically significant association with sex [χ^2 (8, 739) = 15.72, p = .047]. The model predicted that women are 1.68 times more likely to prefer longer tilapia than men are (R^2 = 1.682, 95% CI = 1.16, 2.44, p = .006).

The model testing against preference for larger tilapia head traits found statistically significant associations with educational status, household food dependency ratio and location [χ^2 (8, 739) = 22.44, p = .004]. The model predicted that consumers from Lower Egypt were most likely to consume larger tilapia heads (R^2 = 1.499, 95% CI = 1.04, 2.16, p = .030), while consumers from Cairo were least likely to consume larger tilapia heads (R^2 = 0.948, 95% CI = 0.55, 1.65). For all consumers, as their household food dependency ratio increases by one percentile their odds for consuming larger tilapia heads decrease 1.1% (R^2 = 0.989, 95% CI = 0.98, 1.00, p = .032). Conversely, as educational years increase by one year, consumers' odds for consuming larger tilapia heads increase by 3.7% (R^2 = 1.037, 95% CI = 1.00, 1.07, p = .040).

5. Discussion

In the present study, we observed determinants of consumer demand for tilapia products and tilapia traits. For the first time, this study examined whether the demand for tilapia traits differed significantly by sex or location across Egypt. In order to do so, we extended the traditional approach of analysing fish demand, proposed by the Asia Fish Demand Model (Dey et al., 2005; Dey, 2000; Dey et al., 2008; Tran et al., 2017). Specifically, new variables were developed to assess heterogeneity of fish preferences not only in terms of fish demand for different species or product types but also in terms of differentiated demand for specific traits and their morphometric measurements.

Our analysis of food expenditures found that location had a significant effect on fish consumption. Results showed that the share of fish-consuming households in Lower Egypt (78.3%) far outweighed numbers in Upper Egypt (24.4%). Even greater geographic disparity was found at the more local level of governorates, both within administrative regions and between. Greatest disparity was found between numbers of fish-consuming households in Menia (10%) and Sharkhia (83%).

To examine vulnerability of these households and the role that fish plays in their food baskets, a household food dependency ratio (Engel, 1857; Timmer et al., 1983) and food expenditure shares were calculated (Fan et al., 1995; Holcomb et al., 1995). Again, these differed significantly between Upper and Lower Egypt. Highest food dependency ratio and greatest share of fish expenditures was observed among households in Menia (92.3%, 22%, respectively). Considering this geographic disparity in consumption, we support ongoing policy debates calling for development of supply and cold chain infrastructure (Eltholth et al., 2015; Goulding and Kamel, 2013; Kitinoja, 2013; Macfadyen et al., 2012). While the success of Egypt's tilapia fish farming presents a worthy model for aquaculture development, there remains further opportunity to tackle food security concerns while generating increased employment through market development and trade logistics.

These imperatives are made all the more pressing when comparing

Table 7
Results of the logistic regression analyses (total sample).

	Smaller tilapia preference				Thicker tilapia preference				Longer tilapia preference				Larger head preference			
	*e*β	*SE* β	Wald's χ^2	Sig.	*e*β	*SE* β	Wald's χ^2	Sig.	*e*β	*SE* β	Wald's χ^2	Sig.	*e*β	*SE* β	Wald's χ^2	Sig.
Female (1)	1.192	0.177	0.987		1.020	0.187	0.012		1.682	0.189	7.543	**	0.830	0.199	0.881	
Age (yrs)	0.977	0.009	7.722	**	1.008	0.009	0.715		0.996	0.009	0.252		0.989	0.01	1.319	
Education (yrs)	0.959	0.016	7.180	**	0.954	0.017	7.970	**	1.012	0.016	0.507		1.037	0.018	4.223	*
HH size	0.965	0.068	0.282		1.013	0.073	0.031		1.093	0.072	1.55		1.027	0.077	0.121	
Children (1)	1.988	0.216	10.141	***	1.070	0.228	0.087		0.858	0.224	0.469		0.909	0.238	0.162	
HH dependency	1.005	0.005	1.153		1.007	0.005	2.177		1.009	0.005	2.969		0.989	0.005	4.583	*
Upper Egypt (1)			26.024	***			0.693				0.215				5.689	
Lower Egypt (1)	2.387	0.171	26.02	***	0.944	0.178	0.104		1.053	0.176	0.086		1.499	0.186	4.734	*
Cairo (1)	1.509	0.235	3.076		1.178	0.262	0.390		1.116	0.253	0.190		0.948	0.282	0.036	

Statistically significant results are presented at the < 0.05, 0.01, 0.001 levels as *, **, ***. Exponentiated beta values (*e*β) represent odds ratio of consumers' preference groups according to independent variables.

consumption and expenditure results to previous national household surveys conducted in Egypt (CAPMAS, 2012; WFP, 2013), as we find significant increases in both food dependency and fish expenditure shares. In 2011, the central agency for public mobilisation and statistics reported that among lowest income quintile households, 51% of their household budget was spent on food, while the present study observed 86.6% of average household budget was spent on food. Similarly, expenditure shares for fish increased from 8.6% to 15.4%. This confirms claims by others that tilapia aquaculture has become a strategic pro-poor food sector for Egypt (Macfadyen et al., 2012; El Mahdi et al., 2015; Wally, 2016).

However, this also calls for future research to investigate the impact of recent economic developments and food price inflation on the food baskets of Egypt's low-income households. Given recent market fluctuations, we recommend that future methodological approaches to assessing consumption and preferences among low-income households would benefit from alternative sampling frameworks. Specifically, we recommend the use of Bennett's Law, which can be adapted to address the specific context of Egyptian food markets. While Bennett's Law has been used widely to examine nutritional shifts through economic development and the reduction of intake of starchy staples (Caballero, 2005; FAO, IFAD, UNICEF, WFP, 2018; Msangi and Rosegrant, 2009; Vonke, 2011), studies in Egypt have pointed instead to increases in consumption of starchy staples and decrease in consumption of micronutrient rich foods such as fish (Breisinger et al., 2013; Ecker et al., 2016a). Such methodological advances are called upon to address current debates regarding the importance of affordable fish to addressing food and nutrition security in Egypt (Ecker et al., 2016b, p. 35).

Several limitations to this study must be highlighted here. Firstly, this study's sampling of low-income households has been limited in its use of expenditure-, asset-, employment-, education-, and household-based indicators. Drawing from literature on food security in developing economies, a number of qualitative models, quantitative models and mixed methods sampling models offer alternative approaches. These models include, but not limited to, the Coping Strategy Index (Christiaensen and Boisvert, 2000; Wright and Gupta, 2015), Food Diversity and Food Consumption Indexes (Carletto et al., 2013, 32–35), the Multi-Development Poverty Index (Alkire et al., 2017; Alkire and Santos, 2014) and in particular the Gender Development Poverty Index (Schüler, 2006). Adapting these sampling frameworks to understanding fish consumption patterns is a particularly important field of research, when seeking to provide accurate findings of tilapia trait preferences. This not only applies to accurate morphometric measurement of locally available tilapia products, representation of local descriptions of such traits, but also to capturing of actual meal-time behaviour and intra-household allocation of fish and fish parts. Going beyond standard questionnaires may provide better insight to otherwise hidden and personally sensitive realities.

Previous studies using the Asia Fish Demand Model found price and income elasticities for fish to be higher among poorer populations in several Asian countries, implying that despite higher price fluctuations in fish markets, fish plays a more significant role in the food baskets of low-income populations than middle or high-income populations (Dey et al., 2005). The current study highlights a similar situation in Egypt. That is, while currency devaluations and food price inflations have placed pressure on the food baskets of the poor, the demand for farmed tilapia has not declined overall. Results suggested that fish now accounts for larger expenditure shares. National wholesale figures indicated a proportionally greater increase in demand and prices for cheaper and smaller tilapia compared to higher priced, larger tilapia grades. To understand comprehensively the importance of fish to food and nutrition security in Egypt, we recommend future research to consider tilapia consumption as part of a bundle of food costs and market preferences. Towards this end, we also recommend future research that examines tilapia demand for specific products grades, morphometric traits and their morphological measurements in the context of food market fluctuations.

In our analyses of tilapia preferences among low-income households, we found significant effect of sex on consumers' preferences for longer body length traits and significant effect of location on preference for smaller tilapia size (total body weight) and larger head traits. We also observed that women cited smaller tilapia sizes (Grade III and IV) more frequently in their top preferences, while women also preferred head traits and longer body length traits.

Logistic regression analysis added insights to these results, as significant relationships were observed between smaller tilapia preferences with the presence of children, suggesting that women considered household dietary requirements in their tilapia preferences.

These results offer methodological and empirical recommendations to future genetic selection programmes considering gender-responsive and pro-poor breeding objectives. Methodologically, these results contribute to gender research debates regarding the need to investigate the intersectionality of sex with other social and economic characteristics including age, education, household size, households structure, age of children, employment and location (Kabeer, 2015; Mangubhai and Capraro, 2015; Patil, 2013b). Empirically, these findings suggest that younger women from larger households with children are more likely to consume smaller tilapia grades. This suggests that tilapia selective breeding programmes considering food and nutrition security objectives, or gender-responsive breeding objectives may better reach such targets through selection of morphometric traits including size and total length traits. That is, if breeding programmes seek to reach bottom of pyramid markets and nutrition insecure consumers of Egypt, further research may be required to explore additional traits than those commonly reported in commercial tilapia breeding programmes (Gjedrem et al., 2012), which have tended to be limited to faster growth rate, disease resistance and feed conversion ratio.

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.

Appendix A. Fish production and supply trends in Egypt, 2000–2015

Year	National Production	Capture Fishieres Production	Aquaculture Production	Farmed Tilapia Production	Farmed Carp Production	Farmed Mullet Production	Farmed Catfish Production	Other (Capture/ Farmed)	Other (Farmed)	Net Imports
2000	724407	384314	340093	157425	80530	66231	654	35253		260156
2015	1518943.00	344112.00	1174831.00	875513	15179	94606	7455	151787	40078	276357

Egypt's Fish Production and Supply, 2000 & 2015 [tonnes] (GAFRD, 2002; 2015; FAO, 2017).

Appendix B. Farmed fish wholesale price trends; 2000–2015 (E£).[7]

Year	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Tilapia grade 1	8.8	8.4	7.7	7.7	8.5	8.2	8.7	8.4	9.2	10.0	9.0	9.5	11.1	10.8	12.7	12.1
Tilapia grade 2	5.9	5.6	5.3	5.6	5.9	5.7	5.8	6.4	7.1	8.1	7.2	8.1	8.8	8.9	10.5	9.7
Tilapia grade 3	3.1	3.0	3.0	3.0	3.4	3.3	3.7	4.1	5.1	6.1	4.8	4.1	5.2	5.2	5.4	6.5
Flathead grey Mullet grade 1	13.0	12.2	11.8	12.7	12.8	13.1	15.5	15.4	17.4	18.5	18.0	21.2	24.7	24.2	25.0	24.1
Flathead grey Mullet grade 2	9.9	9.8	9.2	9.4	9.5	9.5	12.2	11.6	13.6	13.9	13.5	15.1	15.5	14.6	15.7	16.3
Gilthead seabream	21.0	21.0	21.2	24.0	23.1	23.9	28.7	37.7	35.2	34.1	35.6	31.9	34.6	37.8	50.4	49.1
Red mullets grade 1	14.0	14.9	13.9	14.5	15.1	13.9	15.4	14.8	14.6	15.5	16.0	15.1	17.1	17.3	15.5	15.7
Red mullets grade 2	7.3	6.9	6.1	6.5	7.1	6.5	8.2	7.3	7.9	9.3	10.3	8.3	9.4	9.6	10.2	9.7
Catfish	4.2	4.2	4.1	4.4	4.8	5.2	5.5	5.4	6.9	6.8	7.3	8.1	10.7	12.4	12.6	11.4

References

Alkire, S., Apablaza, M., Chakravarty, S., Yalonetzky, G., 2017. Measuring chronic multidimensional poverty. J. Policy Model 39, 983–1006. https://doi.org/10.1016/j.jpolmod.2017.05.020.

Alkire, S., Santos, M.E., 2014. Measuring acute poverty in the developing world: robustness and scope of the multidimensional poverty index. World Dev. 59, 251–274.

Andersen, A.B., Thilsted, S.H., Schwarz, A.M., 2013. Food and Nutrition Security in Solomon Islands.

Assaad, R., Rouchdy, M., 1999. Poverty and Poverty Alleviation Strategies in Egypt. American University in Cairo Press Cairo.

Belton, B., Bush, S.R., Little, D.C., 2018. Not just for the wealthy: rethinking farmed fish consumption in the global South. Glob. Food Sec. 16, 85–92. https://doi.org/10.1016/j.gfs.2017.10.005.

Bennett, F., 2013. Researching within-household distribution: overview, developments, debates, and methodological challenges. J. Marriage Fam. 75, 582–597.

Beveridge, M.C.M., Thilsted, S.H., Phillips, M.J., Metian, M., Troell, M., Hall, S.J., 2013. Meeting the food and nutrition needs of the poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculturea. J. Fish Biol. 83, 1067–1084. https://doi.org/10.1111/jfb.12187.

Bogard, J.R., Marks, G.C., Wood, S., Thilsted, S.H., 2018. Measuring nutritional quality of agricultural production systems: application to fish production. Glob. Food Sec. 16, 54–64. https://doi.org/10.1016/j.gfs.2017.09.004.

Breisinger, C., Al-riffai, P., Ecker, O., Office, C., Abuismail, R., Waite, J., 2013. Tackling Egypt's Rising Food Insecurity in a Time of Transition.

Caballero, B., 2005. A nutrition paradox—underweight and obesity in developing countries. N. Engl. J. Med. 352, 1514–1516.

Cantillon, S., Nolan, B., 2001. Poverty within households: measuring gender differences using nonmonetary indicators. Fem. Econ. 7, 5–23.

CAPMAS Central Authority for Population Monitoring and Statistics, 2012. *Household Income and Expenditure Survey 2011*. Government of Egypt, Cairo, Egypt.

Carletto, G., Zezza, A., 2006. Being poor, feeling poorer: combining objective and subjective measures of welfare in Albania. J. Dev. Stud. 42, 739–760.

Carletto, C., Zezza, A., Banerjee, R., 2013. Towards better measurement of household food security: harmonizing indicators and the role of household surveys. Glob. Food Sec. 2, 30–40.

Charo-Karisa, H., Komen, H., Rezk, M.A., Ponzoni, R.W., van Arendonk, J.A.M., Bovenhuis, H., 2006. Heritability estimates and response to selection for growth of Nile tilapia (Oreochromis niloticus) in low-input earthen ponds. Aquaculture 261, 479–486. https://doi.org/10.1016/j.aquaculture.2006.07.007.

Christiaensen, L.J., Boisvert, R.N., 2000. Validating operational food security indicators against a dynamic benchmark. Am. Agric. Econ. Assoc. Tampa 372 (2016), 19367 Florida.

Dey, M.M., 2000. Analysis of demand for fish in Bangladesh. Aquac. Econ. Manag. 4, 63–81. https://doi.org/10.1080/13657300009380261.

Dey, M.M., Briones, R.M., Ahmed, M., 2005. Disaggregated analysis of fish supply, demand, and trade in Asia: baseline model and estimation strategy. Aquac. Econ. Manag. 9, 113–139. https://doi.org/10.1080/13657300590961555.

Dey, M.M., Garcia, Y.T., Praduman, K., Piumsombun, S., Haque, M.S., Li, L., Radam, A., Senaratne, A., Khiem, N.T., Koeshendrajana, S., 2008. Demand for fish in Asia: A cross-country analysis. Aust. J. Agric. Resour. Econ. 52, 321–338. https://doi.org/10.1111/j.1467-8489.2008.00418.x.

Dickson, M., Nasr-Allah, A., Kenawy, D., Kruijssen, F., 2016. Increasing fish farm profitability through aquaculture best management practice training in Egypt. Aquaculture 465, 172–178. https://doi.org/10.1016/j.aquaculture.2016.09.015.

Duflo, E., Udry, C., 2004. Intrahousehold Resource Allocation in Cote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices.

Ecker, O., Al-Riffai, P., El-Batrawy, R., 2016a. Nutrition and Economic Developmentl Exploring Egypt's Exceptionalism and the Role of Food Subsidies, Working Paper.

Ecker, O., Al-Riffai, P., Breisinger, C., El-Batrawy, R., 2016b. Nutrition and Economic Development: Exploring Egypt's Exceptionalism and the Role of Food Subsidies. International Food Policy Research Institute, Washington DC.

El Mahdi, A., Krstic, J., Abdallah, A., Abdullah, H., Kantor, P., Valpiani, N., 2015. The Role of Farmed Fish in the Diets of the Resource-Poor in Egypt. pp. 1–44.

Eltholth, M., Fornace, K., Grace, D., Rushton, J., H??sler, B., 2015. Characterisation of production, marketing and consumption patterns of farmed tilapia in the Nile Delta of Egypt. Food Policy 51, 131–143. https://doi.org/10.1016/j.foodpol.2015.01.002.

Engel, E., 1857. Die produktions-und konsumptionsverhältnisse des königreichs sachsen. Zeitschrift des Stat. Bur. des Königlich Sächsischen Minist. des Inn. 8, 1–54.

Falkingham, J., Baschieri, A., 2009. Gender and poverty: how misleading is the unitary model of household resources? An illustration from Tajikistan. Glob. Soc. Policy 9, 43–62.

Fan, S., Wailes, E.J., Cramer, G.L., 1995. Household demand in rural China: a two-stage LES-AIDS model. Am. J. Agric. Econ. 77, 54–62.

FAO, IFAD, UNICEF, WFP, 2018. The State of Food Security and Nutrition in the World 2017: Building Resilience for Peace and Food Security. United Nations Food and Agriculture Organisation.

GAFRD General Authority of Fisheries Resources Development, 2002. Report on National Fish Production. Ministry of Agriculture & Land Reclamation, Cairo, Egypt.

GAFRD General Authority of Fisheries Resources Development, 2015. Fish Statistics Yearbook No. 25. Ministry of Agriculture and Land Reclamation, Cairo, Egypt.

GAFRD General Authority of Fisheries Resources Development, 2016. Fish Statistics Yearbook No, 26. Ministry of Agriculture and Land Reclamation, Cairo, Egypt.

Gjedrem, T., Robinson, N., Rye, M., 2012. The importance of selective breeding in aquaculture to meet future demands for animal protein: a review. Aquaculture 350–353, 117–129. https://doi.org/10.1016/j.aquaculture.2012.04.008.

González, M.A., Rodriguez, J.M., Angón, E., Martínez, A., Garcia, A., Peña, F., 2016. Characterization of morphological and meristic traits and their variations between two different populations (wild and cultured) of Cichlasoma festae, a species native to tropical Ecuadorian rivers. Archiv fuer Tierzucht 59 (4), 435. https://doi.org/10.5194/aab-59-435-2016.

Goulding, I., Kamel, M., 2013. Institutional, Policy and Regulatory Framework for Sustainable Development of the Egyptian Aquaculture Sector. (WorldFish).

Hassanien, H.A., Kamel, E.A., Salem, M.A., Dorgham, A.S., 2011. Multivariate analysis of morphometric parameters in wild and cultured Nile tilapia Oreochromis niloticus. J. Arab. Aquac. Soc. 6, 424–440.

Holcomb, R.B., Park, J.L., Capps, O., 1995. Revisiting Engel's law: examining expenditure patterns for food at home and away from home. J. Food Distrib. Res. 26, 1–8.

Hopkins, N., Saad, R., 2004. The region of upper Egypt: identity and change. Up. Egypt Identity Chang. 1–24.

[7] El-Oboor Central Auction House, Cairo, Egypt, http://www.oboormarket.org.eg/prices_today.aspx

Ibrahim, N.A., Zaid, M.Y.A., Khaw, H.L., El-Naggar, G.O., Ponzoni, R.W., 2013. Relative performance of two Nile tilapia (Oreochromis niloticus Linnaeus) strains in Egypt: the Abbassa selection line and the Kafr El sheikh commercial strain. Aquac. Res. 44, 508–517. https://doi.org/10.1111/j.1365-2109.2012.03240.x.

Kabeer, N., 2015. Gender & Development Gender , Poverty , and Inequality : A Brief History of Feminist Contributions in the Field of International Development Gender , Poverty , and Inequality : a Brief History of Feminist Contributions in the Field of International Develo. 23. pp. 189–205. https://doi.org/10.1080/13552074.2015.1062300.

Kantor, P., Kruijssen, F., 2014. Informal Fish Retailing in Rural Egypt: Opportunities to Enhance Income and Work Conditions for Women and Men 1–25.

Katz, E., 1997. The intra-household economics of voice and exit. Fem. Econ. 3, 25–46.

Kavle, J.A., Flax, V.L., Abdelmegeid, A., Salah, F., Hafez, S., Ramzy, M., Hamed, D., Saleh, G., Galloway, R., 2016. Factors associated with early growth in Egyptian infants: implications for addressing the dual burden of malnutrition. Matern. Child Nutr. 12, 139–151.

Kawarazuka, N., Béné, C., 2010. Linking small-scale fisheries and aquaculture to household nutritional security: an overview. Food Secur. 2, 343–357. https://doi.org/10.1007/s12571-010-0079-y.

Kawarazuka, N., Béné, C., 2011. The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. Public Health Nutr. 14, 1927–1938. https://doi.org/10.1017/S1368980011000814.

Kitinoja, L., 2013. Use of cold chains for reducing food losses in developing countries. Population (Paris). 6, 5–60.

Kosai, P., Sathavorasmith, P., Jiraungkoorskul, K., Jiraungkoorskul, W., 2014. Morphometric characters of Nile tilapia (Oreochromis niloticus) in Thailand. Walailak. J. Sci. Technol. 11, 857–863.

Lanjouw, P., Ravallion, M., 1995. Poverty and household size. Econ. J. 1415–1434.

Longley, C., Thilsted, S.H., Beveridge, M., Cole, S., Nyirenda, D.B., Heck, S., Hother, A., 2014. The role of fish in the first 1 , 000 days in Zambia. Inst. Dev. Stud. 27–35.

Macfadyen, G., Nasr-Alla, A.M., Al-Kenawy, D., Fathi, M., Hebicha, H., Diab, A.M., Hussein, S.M., Abou-Zeid, R.M., El-Naggar, G., 2012. Value-chain analysis - an assessment methodology to estimate Egyptian aquaculture sector performance. Aquaculture 362–363, 18–27. https://doi.org/10.1016/j.aquaculture.2012.05.042.

Mangubhai, J.P., Capraro, C., 2015. 'Leave no one behind' and the challenge of intersectionality: Christian Aid's experience of working with single and Dalit women in India. Gend. Dev. 23, 261–277. https://doi.org/10.1080/13552074.2015.1054206.

Marjanovic, J., Mulder, H.A., Khaw, H.L., Bijma, P., 2016. Genetic parameters for uniformity of harvest weight and body size traits in the GIFT strain of Nile tilapia. Genet. Sel. Evol. 48, 41. https://doi.org/10.1186/s12711-016-0218-9.

Megahed, N., Lack, S., 2011. Colonial legacy, women's rights and gender-educational inequality in the Arab world with particular reference to Egypt and Tunisia. Int. Rev. Educ. 57, 397–418.

Ministry of Health and Population, 2015. Demographic and Health Survey, Egypt. Cairo.

Mori, T.A., Bao, D.Q., Burke, V., Puddey, I.B., Watts, G.F., Beilin, L.J., 1999. Dietary fish as a major component of a weight-loss diet: effect on serum lipids, glucose, and insulin metabolism in overweight hypertensive subjects. Am. J. Clin. Nutr. 70, 817–825.

Msangi, S., Rosegrant, M., 2009. World agriculture in a dynamically-changing environment. In: FAO Expert Meeting on How to Feed the World In.

Mulder, K.A., King, D.J., Innis, S.M., 2014. Omega-3 fatty acid deficiency in infants before birth identified using a randomized trial of maternal DHA supplementation in pregnancy. PLoS One 9, e83764.

Nasr-Allah, M., Dickson, M.W., 2017. Price setting in Markets for Egyptian Farmed Fish. Environ. Ecol. Res. 5, 184–194. https://doi.org/10.13189/eer.2017.050303.

Patil, V., 2013a. From patriarchy to intersectionality: a transnational feminist assessment of how far we've really come. Signs J. Women Cult. Soc. 38, 847–867.

Patil, V., 2013b. From patriarchy to intersectionality: a transnational feminist assessment of how far we've really come. Signs (Chic). 38, 847–867.

Pradhan, M., Ravallion, M., 2000. Measuring poverty using qualitative perceptions of consumption adequacy. Rev. Econ. Stat. 82, 462–471.

Rashad, A.S.S.M.F., 2016. Regional inequalities in child malnutrition in Egypt. Jordan. Work. Pap. - Dep. Econ. Univ. Alberta 2016.

Rocha, D.N., Simões, L.N., Paiva, G., Gomes, L.C., 2012. Sensory, morphometric and proximate analyses of Nile tilapia reared in ponds and net-cages. Rev. Bras. Zootec. 41, 1795–1799.

Schüler, D., 2006. The uses and misuses of the gender-related development index and gender empowerment measure: a review of the literature. J. Hum. Dev. 7, 161–181.

Timmer, C.P., Falcon, W.P., Pearson, S.R., Agriculture, W.B., Economics, R.D.D., Division, P., 1983. Food Policy Analysis. Johns Hopkins University Press Baltimore.

Tran, N., Rodriguez, U.P., Chan, C.Y., Phillips, M.J., Mohan, C.V., Henriksson, P.J.G., Koeshendrajana, S., Suri, S., Hall, S., 2017. Indonesian aquaculture futures: an analysis of fish supply and demand in Indonesia to 2030 and role of aquaculture using the AsiaFish model. Mar. Policy 79, 25–32. https://doi.org/10.1016/j.marpol.2017.02.002.

Vonke, D., 2011. The paradox of malnutrition in developing countries. African Res. Rev. 5.

Wally, A., 2016. Egypt the State and Development of Aquaculture in Egypt 1–14.

WFP, 2013. The Status of Poverty and Food Security in Egypt: Preliminary Summary Report.

WHO, 2017. Worldwide trends in body-mass index, underweight. In: Overweight and Obesity from 1975 to 2016; a Pooled Analysis and Population-Based Measurement Studies.

Wright, L., Gupta, P., 2015. Coping strategies adopted by urban poor to ameliorate food insecurity: case of United States, Belize and India. J. Food Secur. 3, 40–46.

Yount, K.M., Li, L., 2010. Domestic violence against married women in Egypt. Sex Roles 63, 332–347. https://doi.org/10.1007/s11199-010-9793-3.