MALAWI
IFPRI

STRATEGY SUPPORT PROGRAM | WORKING PAPER 31 DECEMBER 2019

Consumer Choices and Demand for Tilapia in Urban Malawi

What are the complementarities and trade-offs?

Christopher T. M. Chikowi, Dennis O. Ochieng, and Charles B. L. Jumbe

This Working Paper is an output of the Bunda Grant Scheme program of IFPRI-Lilongwe. This mentorship scheme provides selected MSc students from the Lilongwe University of Agriculture and Natural Resources (Bunda College) with opportunities to improve, publish, and disseminate the research that they undertake during their MSc training by working with a seasoned researcher from IFPRI. The Bunda Grant Scheme program is made possible by the support of the American people through the United States Agency for International Development (USAID). The views expressed in this working paper imply no endorsement by IFPRI-Malawi, USAID, or anyone except the authors.

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

GDP	gross domestic product
IHS	Integrated Household Survey
Kg	kilogram
Km	kilometer
LUANAR	Lilongwe University of Agriculture and Natural Resources
MVP	Multivariate probit
NSO	National Statistical Office of Malawi
Ny	Oreochromis (Nyasalapia) spp.
Os	Oreochromis shiranus
SUTR	Seemingly unrelated truncated regression

ABSTRACT

Despite concerted efforts to develop the fisheries sector in many developing countries, fish demand remains poorly understood due to weak and fragmented domestic markets, particularly in Africa south of the Sahara. An important area that affects the development of the fishery sector is limited understanding of how the choice between different fish products is affected by the socioeconomic characteristics of consumers, marketing factors and fish-specific attributes. Previous studies in Malawi have assessed consumer choice and demand for fish in general, without considering species-specific consumer choices. This paper analyzes consumer choices and demand for two species of tilapia, Lake Malawi *Oreochromis (Nyasalapia) spp.* (*Ny*) and *Oreochromis shiranus* (*Os*), in unprocessed and processed form in urban Malawi. We use data collected from a sample of 584 urban households in Malawi's two major cities, Blantyre and Lilongwe. Multivariate probit and seemingly unrelated regression models are employed to analyze the correlates of consumer choice and demand for tilapia products. Even though most consumers chose farmed tilapia (*Os)* over the wild tilapia (*Ny)*, our results indicate trade-offs in choice but complementarities in demand for unprocessed and processed tilapia products. We find that the correlates of choice are not the same as correlates of demand for tilapia products. This is explained by heterogenous consumer profiles, market conditions, and tilapia trait descriptors. Developing robust tilapia value chains requires exploiting these complementarities and trade-offs, policy support to boost tilapia production, and reducing its relative caloric price to consumers. These measures will contribute to increased consumer demand. More generally fish breeding programs should also link breeding objectives to consumer choices and demand for fisheries' products, particularly considering rarely examined fish attributes such as nutritive value and body texture.

Key words*:* Fisheries*,* aquaculture, tilapia, consumer choice, complementarities and trade-offs

1 INTRODUCTION

In many developing countries, the fisheries sector has transformed rapidly in the last 50 years and contributed to the significant growth of fisheries output and development of fish value chains (FAO 2018). This has far reaching implications on economic development, poverty reduction, food security and nutrition (Belton and Thilsted 2014; Béné et al. 2016). First, the sector contributes about 1.25 percent to global Gross Domestic Product (GDP) growth (AUC-NEPAD 2014). Second, it supports rural livelihoods through employment in fish farming, catch fisheries and other value chain activities (Funge-Smith and Bennett 2019; Rashid and Zang 2019; Rashid et al. 2019; Steenbergen et al. 2019). Third, fish products contribute about 16 percent of global consumption of low cholesterol animal products, from which high-quality fatty acids, proteins, calcium, iron, iodine and potassium vital for human body development are sourced (Tacon and Metian 2013; Kobayashi et al. 2015; Cai and Leung 2017). Hence, fish consumption contributes to the reduction of the prevalence of micronutrients malnutrition given that fish is the main animal-source food in low income countries (Bogard et al. 2017). Recent global statistics show a growth in annual consumption of fish from 9 kilograms (kg) per capita in 1961 to 20.5 kg per capita in 2017 (FAO 2018). It is predicted that, with relatively stable fish prices and consumer preferences, per capita consumption is likely to increase to 25 kg by early 2020 (Cai and Leung 2017). Hence, fisheries contribute to the achievement of sustainable development goal number 1 and 2 (UN 2015).

Transformation of the sector has also been facilitated by the innovations to cope with the fish production and demand challenges occasioned by growing population, climate change and dwindling fish stocks. This has led to rapid growth of aquaculture in many developing countries in what is described as a “blue revolution”. Aquaculture contributes about 47 percent of global food fish production and generates significant earnings from fish exports (FAO 2018). It is also a major source of employment and income to fish producers and other value chain actors (Shava and Gunhidzirai 2017; Hernandez et al. 2018; Rashid et al. 2019). The circular economy around aquaculture in rural spaces contribute significantly to rural transformation (Arthur et al. 2013; Pinstrup-Andersen and Cheng 2018). Lastly, aquaculture also contributes to resilience building of global food systems alongside crop and livestock production (Kristofersson and Anderson 2006; Troell et al. 2014; Shava and Gunhidzirai 2017).

The onset of the blue revolution was characterized by intensive production of mainly carps, but aquaculture production has since transformed with increased diversification and specialization in the production of other fish species including tilapia and catfish (Hernandez et al. 2018). Recent statistics show that tilapia ranks second to carps in terms of global food fish production (FAO 2018). However, tilapia is still one of the most widely bred and adapted fin food fish worldwide (Mehar et al. 2019).

Despite concerted efforts to develop the fisheries sector in Africa south of the Sahara, sector productivity remains low with inconsistent fish marketing and consumption trends of between 5–14 kg per capita, particularly in low income countries (FAO 2018). This reinforces the argument that besides food availability and affordability, consumer food choices are also pivotal in increasing food consumption (Dimitri and Rogus 2014). Existing aquaculture studies mainly focus on the role of fish producers in aquaculture and the resulting welfare impacts, and the value chains in terms of structure, conduct and performance (Hernandez et al. 2018). Most value chain studies focus on export markets for a few commercial fish species such as trout, catfish, salmon, and shrimp in developed countries and not domestic markets, particularly in developing countries (Goss et al. 2000; Belton and Bush 2014).

Little is known about the dynamics of domestic fish value chains in developing countries, particularly on how consumer choice of and demand for fish and fish products are affected by fish attributes (or traits), consumer characteristics and market factors. Yet this is important in developing fish value chains, especially in the context of rapid urbanization, rising middle class, and changes in tastes and preferences of consumers (Tschirley et al. 2015; Lu and Reardon 2018; Ruel et al. 2018; Khonje and Qaim 2019) and realization of the immense nutrition benefits of fish consumption (Oken et al. 2012). Besides, analysis of species-specific consumer choice of and demand for fish and fish products is lacking. There may also be choice and demand complementarities and trade-offs of fish products that are important for fish marketing in general. Further, consumer choice and demand for fish is influenced by fish traits and therefore analyzing influence of the traits on consumer choice and demand is critical for fish breeding programs and fish processing technologies. So far, fish breeding programs do not report on consumer choices in the fish-profile designs (Mehar et al. 2019). While previous studies have more generally analyzed the influence of fish traits such as size, color, smell, taste and appearance, other traits such as nutritive value and body texture are largely ignored yet equally important (Mehar et al. 2019). Using cross-sectional data for urban fish consumers in Malawi, this paper categorically analyzes consumer choice of and demand for processed and unprocessed products from Lake Malawi *Oreochromis (Nyasalapia) spp.* (*Ny*) and *Oreochromis shiranus* (*Os*).[1]

This paper contributes to the body of knowledge on consumer choice and demand for fish in four ways. First, while most studies focus on export markets, this paper focuses on the domestic fish market in Malawi's two major cities, Lilongwe and Blantyre. Second, we analyze the correlates of species-specific consumer choice and demand for fish and fish products, together with complementarities and trade-offs between processed[2] and unprocessed[3] tilapia products using *Lake Malawi Oreochromis (Nyasalapia) spp.* hereafter referred to as *Ny* and *Oreochromis shiranus* hereafter referred to as *Os*. Third, when analyzing the drivers of urban consumer choices and demand, we consider other fish traits (such as nutritive value, appearance in terms of body texture, and easiness to cook) whose influence on consumer choices of fish products have rarely been explored in the literature. Lastly, except for hatchery and nursery operators, studies on the influence of tilapia traits on consumer choice and demand focus on users in general and not on user-specific traits preferences as we do in this paper. We descriptively analyze consumer choice between *Os* and *Ny* and then simultaneously analyze correlates of choice and demand for the products using multivariate probit (MVP) and seemingly unrelated truncated regression (SUTR) models, respectively.

The three research questions the study addresses are: (1) What are the correlates of choice for *Os* and *Ny* products? (2) What are the correlates of demand for *Os* and *Ny* products? (3) What are the complementarities and trade-offs in the choice and demand for *Os* and *Ny* products?

The paper is organized as follows. The next section gives an overview of the fisheries sector in Malawi. Section 3 details the data and methods used. Section 4 present results and discussion, and section 5 concludes with policy implications.

[1] Lake Malawi *Oreochromis (Nyasalapia) spp.*, locally called Chambo, is a collective name for three wild tilapia species namely *Oreochromis karongae* (also *Oreochromis saka*), *Oreochromis lidole* and *Oreochromis squamipinnis*. On the other hand, *Oreochromis shiranus*, locally called *Makumba*, is an endemic tilapia species to Lake Malawi basin but commercially and commonly farmed under aquaculture in the present era where it is branded as Maldeco Aqua *Chambo (MAC)*.

[2] Processed tilapia products in this study refer to smoked and dried products.

[3] Unprocessed tilapia products in this study refer to fresh and fresh-frozen products.

2 THE FISHERIES SECTOR IN MALAWI

Malawi's fisheries sector includes aquaculture, capture fisheries, and aquarium trade subsectors. The sector contributes about 4 percent to Malawi's GDP, employs about 60,746 people annually and supports livelihoods of about 1.6 million people (Malawi Government 2016). Aquaculture production mainly involves tilapia and catfish rearing in ponds or cages in the lakes. Even though capture fisheries contribute the largest proportion of fish produced in Malawi, aquaculture is rapidly growing due to rising demand for fish and dwindling fish stocks in open waters (Banda et al. 2005; Kasulo and Perrings 2006; Limuwa et al. 2018).

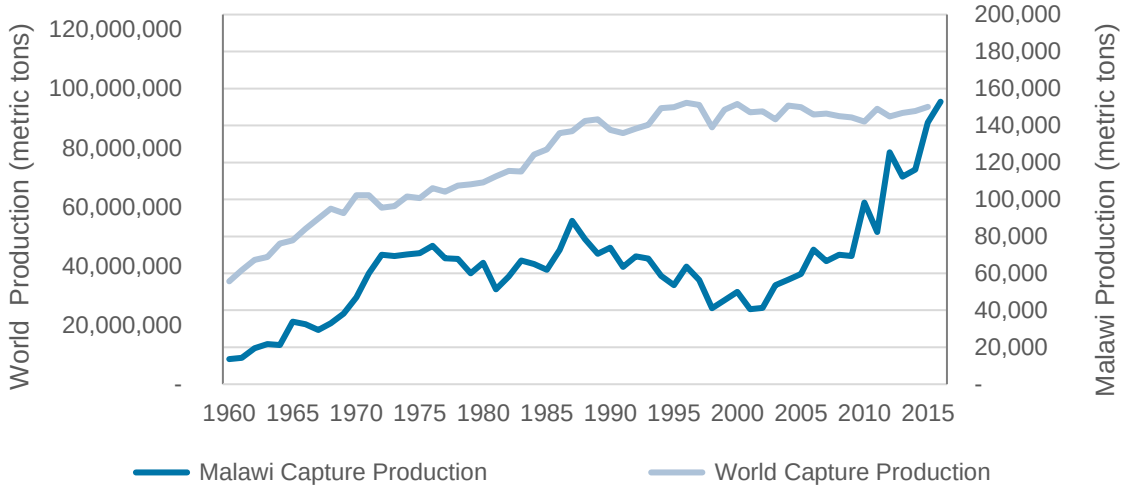
The Malawi fish market is mainly domestic except for ornamental fish exports (Malawi Government 2016). The demand for fish, especially tilapia, is growing with largely informal imports from neighboring countries such as Zambia and Tanzania to off-set the supply gaps. Per capita tilapia consumption was 8.12 kg per year in 2014 and is projected to reach 10 kg by 2020 (Malawi Government 2016). Fish is an important source of proteins, calcium, iron, iodine and potassium to many households in Malawi (Mumba and Jose 2005). It contributes about 40 percent of protein intake in general and 70 percent of animal protein intake in Malawi diets (Malawi Government 2016).

2.1 Trends in fish consumption in Malawi

While global fish production trends have been rising steadily, growth in Malawi's fisheries sector has been much more variable. Malawi's total fish production increased significantly in the first decade from 1960 and surpassed the global average production but fluctuated thereafter with a sharp decline between 1986 and 2000. Annual production rose sharply from 2002. This is attributed to the development of aquaculture in Malawi during this period, which contributed to total fish production. Annual production increased from13,600 metric tons in 1960 to 160,498 metric tons in 2016.

Figure 1 shows trends in capture fish production globally and in Malawi while Figure 2 plots global and national aquaculture production. Capture fisheries contribute the largest share of total fish production in the world and Malawi. Globally, capture fisheries production rose up to the mid-1990s and then stagnated (Figure 1). In contrast, Malawi's capture fish production accelerated from the 2000s onward, raising fears of overfishing and depletion of stocks.

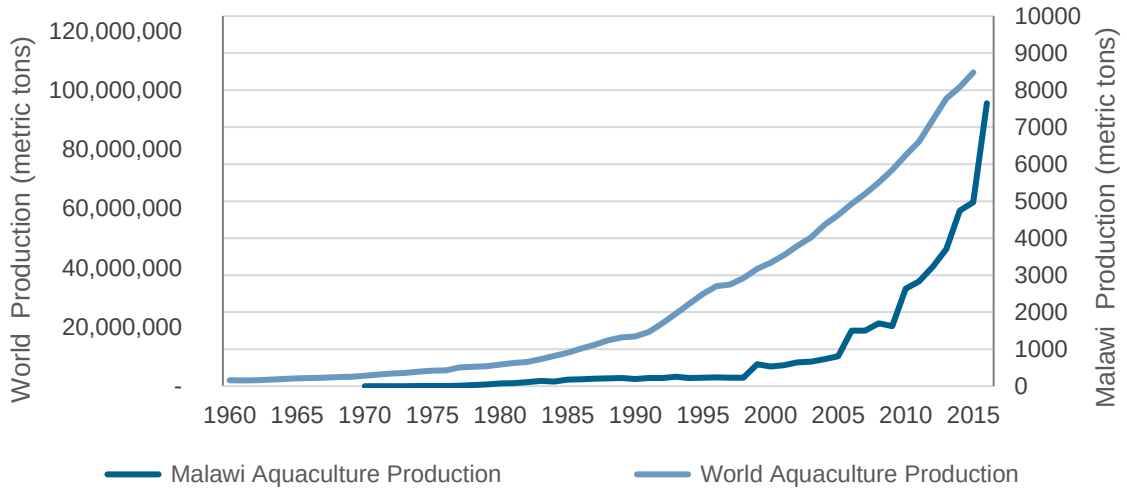
Figure 1: Capture fish production trends



Source: World Bank (2016a).

As shown in Figure 2, aquaculture production in both the world and Malawi has experienced substantial growth. Global aquaculture production started accelerating in the early 1980s, while Malawi's aquaculture production did not take off until the early 2000s. Aquaculture production in Malawi has grown from 6 metric tons in 1976 to 7,646 metric tons in 2016.

Figure 2. Aquaculture production trends



Source: World Bank (2016b).

2.2 Fish marketing in Malawi

Malawi's fish sector is largely underdeveloped. Fish is marketed in unprocessed form (e.g., fresh or frozen) and some is marketed in processed (e.g., smoked, canned or dried) form. About 75 percent of marketed fish is processed to prevent quantity and quality losses (Nagoli 2009). The key market players are small-scale fisherfolk, vendors, supermarkets, and aquaculture ventures. Most fisherfolk are unorganized and have limited processing capacities.

Unprocessed fish is usually stored for just a few hours after catching and seldom preserved. However, aquaculture ventures, such as The Foods Company Limited (TFCL), commonly known as 'Maldeco', have the capacity to store fish for longer periods due to their storage and cooling capacities. But as electricity and fuel costs are high in Malawi, and demand is limited, only a few of these ventures can thrive.

There is a dearth of studies on fish marketing in Malawi, particularly focusing on consumer choice and demand for farmed (mainly *Os*) and capture tilapia (mainly *Ny*) and their products. Existing studies focus on estimating demand for fish and fish products, in general. For example, Nankwenya et al. (2017) estimated demand for tinned, fresh, smoked, and dried fish products in Malawi using the third Integrated Household Survey (IHS3) data collected by the World Bank and the National Statistical Office (NSO). The study found that several socioeconomic and location factors influenced fish consumption. These include marital status; gender; education; expenditure; occupation; age; and distance to the market. The study concluded that demand for fish products outstripped supply, was inelastic to changes in prices, and increased with rising household incomes. Maganga et al. (2014) similarly found that the same socioeconomic factors influence demand for and consumption of foods including fish in Malawi. However, they found that fish demand was sensitive to price changes. These studies did not focus on species-specific consumer choice of fish and fish products.

This study specifically focuses on processed and unprocessed products from *Ny* and *Os*. The *Ny* species, *Oreochromis karongae, Oreochromis lidole,* and *Oreochromis squamipinnis*, as presented

in the Annex are closely related species of tilapine cichlids hence this study categorically treats them as one. Consumers in Malawi identify all these species as *Chambo* and treat them as one category. *Oreochromis karongae* is the dominant species among the three. *Os* is a distinct species in Malawi and has its own local name (*Makumba*). This species, unlike the *Ny,* is also promoted under aquaculture, hence most of its products available on the market come from the aquaculture subsector. This study purposefully chose these two categories of tilapia to assess consumer behavior: one species that is wild and faces extinction but is highly preferred by Malawians, and another that is gaining dominance in the aquaculture sector in the hope of mitigating low production levels from capture fisheries.

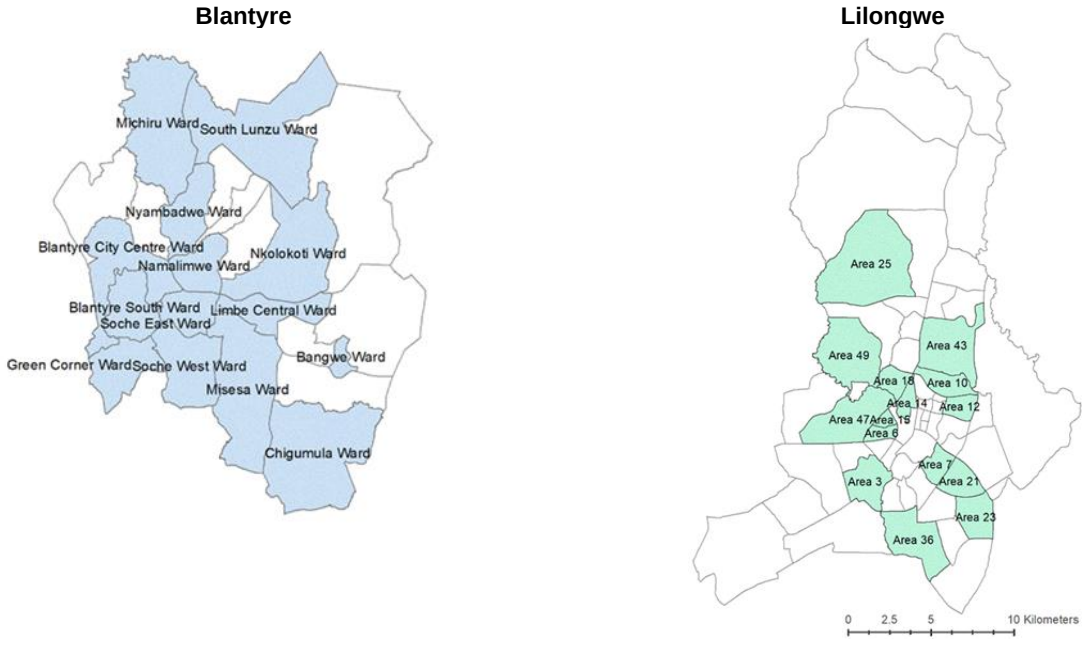
3 DATA AND METHODS

3.1 Study area and sampling protocol

The study uses data collected from urban households in the cities of Lilongwe and Blantyre in Malawi during November 2018. This provided a good setting for the study as the rapid modernization of food retailing in Malawi mirrors other developing countries with rapid urbanization, rising middle class and changes in tastes and preferences of consumers (Ruel et al. 2018; Khonje and Qaim 2019). Using the 2008 Malawi Population and Housing Census data (NSO 2009) and population data from UN-HABITAT (2011a, 2011b), we determined the populations in the two cities and used a multistage sampling procedure to build a representative sample of 310 and 274 households from Lilongwe and Blantyre, respectively.

Fifteen areas (administrative units) in Lilongwe and fourteen areas in Blantyre were randomly selected, with population proportionate to size sampling used to determine the number of households from the areas (Figure 3). Households were then sampled using systematic random sampling procedure. Respondents were either the household heads or spouses who were responsible for food purchases and preparation decisions. Interviews were conducted using a multi-module semi-structured questionnaire to capture data on households' socio-economic characteristics; food expenditures; fish purchase, consumption and attribute choices; and fish marketing environment.

Figure 3. Sampled areas in Blantyre and Lilongwe



Source: Constructed based on the 2018 census's enumeration area maps.

3.2 Ethical considerations

The study involved dealing with human subjects and all authors and survey team members underwent a training on research ethics. Respondents were informed about the objectives of the study before their written informed consent to be a respondent and to having their responses recorded was requested. The respondents were assured that the information provided would be treated confidentially and presented anonymously. Even though we used noninvasive approaches and measurements in the study, we still obtained permission to conduct the study from district authorities.

3.3 Data

Table 1 presents descriptive statistics for the 584 households' socioeconomic, market and location characteristics later controlled for in the MVP and SUTR models. The upper part of Table 1 presents the four tilapia products of interest while the middle part of the table summarizes the socioeconomic profiles of the households. The last part summarizes the location characteristics of the households.

Socioeconomic factors include age, gender, wealth, family size, and farm size that influence fish variety choices and demand (Maganga et al. 2014; Omasaki et al. 2016; Nankwenya et al. 2017; Mehar et al. 2019). In this study, we control for these factors in the model estimations. Most studies on adoption of new innovations (e.g., agricultural technologies) generally use demographic factors such as age and gender of the farmers or household heads as covariates in the model specifications. However, this may be inadequate for our analysis because there may be gender-specific differences in choices of fish and fish products which significantly influence household food security and nutrition (Ragot et al. 2018). Instead we consider gender, age, and nutrition knowledge (about nutritive value of fish) of the household's primary decision maker for food purchases. We also control for market factors such as access to markets and price information, location of the households and distance from dwelling place to the markets. Other influencers of choice and demand include fish product prices, household incomes and frequency of fish consumption. Incomes influence purchases and frequency of consumption of fish products.

Over the past twenty years, tilapia genetic improvement programs have increased the availability of tilapia selected for attributes or traits that improve production i.e., tilapia breeds with faster growth rates of between 7 and 10 percent are now used globally in more than sixteen countries (Ponzoni et al. 2012; Ansah et al. 2014). The breeds have unique attributes that influence consumer choice and demand for them. Breeding programs have primarily been defined by the economic value of consumers' preferences for fish traits (Dickerson 1970; Brascamp et al. 1985). However, just as in general agriculture, uptake of new technologies is defined by needs of users and therefore fish breeding is increasingly shifting towards incorporating diverse preferences (with both economic and non-economic value) of value chain actors (Byrne et al. 2012; Nielsen et al. 2014; Mehar et al. 2019). This has been fueled by the realization that adoption of new innovations is a function of user preferences, socioeconomic characteristics and context (Ragot el at. 2018).

On the fish attributes (or traits), we only considered two of the three broad categories of traits common in aquaculture literature namely: (1) productivity traits, i.e. size (a function of weight and length but loosely assessed visually by consumers); and (2) quality trait such as color, size, taste and appearance but excluded geographical traits, which influence breeding more than marketing of fish. In addition, related to the value of preferences, we include other fish traits that are hard to capture in terms of economic value such as ease to cook and nutritive value in analyzing consumer choice and demand for tilapia and tilapia products. These traits are hardly analyzed in existing literature (Mehar et al. 2019).

Table 1. Descriptive statistics (n=584)

Variable	Description	Mean	Std dev.
Tilapia and product dummies			
Lake Malawi ***Oreochromis (Nyasalapia) spp. (Ny)***	1 if household chose Lake Malawi *Oreochromis (Nyasalapia)* spp., 0 otherwise	0.68	0.47
Oreochromis shiranus (Os)	1 if household chose *Oreochromis shiranus*, 0 otherwise	0.79	0.41
Processed *Ny*[a]	1 if household chose processed *Ny*, 0 otherwise	0.25	0.44
Unprocessed *Ny*[b]	1 if household chose unprocessed *Ny*, 0 otherwise	0.58	0.49
Processed *Os*[a]	1 if household chose processed *Os*, 0 otherwise	0.14	0.35
Unprocessed *Os*[b]	1 if household chose unprocessed *Os*, 0 otherwise	0.75	0.43
Socioeconomic characteristics			
Male food decision maker[4]	1 if primary food decision maker is male, 0 otherwise	0.25	0.43
Age	Age of primary food decision maker in years	36.80	11.67
Education	Years of education for primary food decision maker	13.16	4.09
Marital status	1 if primary food decision maker is married, 0 otherwise	0.73	0.44
Household size	Number of household members	4.43	1.89
Household income	Annual household income in '000'Malawi Kwacha	841.21	1,195.95
Nutrition knowledge	1 if the decision maker has nutrition knowledge, 0 otherwise	0.87	0.34
Fish purchases	Ratio of expenditure on fish to meat products	0.50	0.26
Consumption frequency[c]	Frequency of fish consumption (percentage)		
	1 = More than twice a week, 0 otherwise	0.17	0.38
	1 = Twice times a week, 0 otherwise	0.47	0.50
	1= Once a week, 0 otherwise	0.28	0.45
	1= Less than once a week, 0 otherwise	0.09	0.28
Market factors			
Fish market information	1 if household accessed fish market information, 0 otherwise	0.60	0.49
Price information	1 if household accessed fish price information, 0 otherwise	0.51	0.50
Price of fish products (MWK)	Processed *Ny*	2,844.22	1,074.35
	Unprocessed *Ny*	2,348.65	1,066.79
	Processed *Os*	3,149.46	1,114.60
	Unprocessed *Os*	3,139.33	954.13
Distance to fish market (km)	Distance to the most frequented fish market	3.96	19.29
City dummies			
Blantyre City[d]	1 if household is in Blantyre, 0 otherwise	0.47	0.50
Lilongwe City[d]	1 if household is in Lilongwe, 0 otherwise	0.53	0.50

Source: Tilapia value chain survey, 2018. **Note**: The prices are average retail prices at purchase points. It is also influenced by fish attributes and market factors (Brummett 2000); [a] Base category: dried or smoked; [b] Base category: fresh or frozen; [c] Base category: less than once a week; [d]Base category: Lilongwe; MWK = Malawi Kwacha; Km = kilometer.

[4] Food decision makers are those household members primarily responsible in making food related decision such as the type and amount of food products to purchase, prepare and consume.

3.4 Empirical strategy

3.4.1 Correlates of consumer choice for tilapia products

In consumer (or household) choice analysis, probit models are widely used ─ particularly when products are assumed to be neither substitutes nor complements. However, in the context of our study, we consider choice of any of the four tilapia products (processed and unprocessed *Os* and *Ny*) is correlated with choice of the rest of the products, so using a simple probit model may yield biased estimates. We therefore employ a MVP model to analyze the correlates of consumer choice of the four tilapia products. The MVP model simultaneously analyzes the influence of household, market and location characteristics on the choice of each of the four tilapia products. The model assumes error term correlation (Cappellari and Jenkins 2003). We estimate four binary choice equations, corresponding to the four types of tilipia products that may be consumed, for household *i* while accounting for the same household, market, location and unobserved factors (X_{im}) that influence choice of product *m*. The binary dependent variable (observed) is q_{im} which equals to 1 if the household chooses a product and 0 otherwise. The m-dimensional MVP model is expressed as:

$$q_{im}^{*} = \beta_m' X_{im} + \varepsilon_{im}, \qquad m = 1, \dots 4 \tag{1}$$

$$q_{im} = \begin{cases} 1, & if\ q_{im}^{*} > 0 \\ 0, & otherwise \end{cases} \tag{2}$$

where the latent variable q_{im}^{*} captures unobserved household perception of the tilapia products and ε_{im} is the stochastic error term, each with a multivariate normal distribution and zero *(0) mean* and variance-covariance matrix *V*. The matrix has values of 1 on the leading diagonal and the correlations $\rho_{jk} = \rho_{kj}$ on the off-diagonals as shown in equation 3.

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_1 \\ \vdots \\ \varepsilon_M \end{pmatrix} \sim N_M \left[\begin{pmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1M} \\ \rho_{22} & 1 & \cdots & \rho_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{4M} & \rho_{4M} & \dots & 1 \end{pmatrix} \right] \tag{3}$$

Simulated maximum likelihood estimation was approximated using the Geweke-Hajivassiliou-Keane algorithm. This approach is widely used especially in studies analyzing consumer behavior (Geweke et al. 1996). We then used a likelihood ratio test for the hypothesis of equal correlation coefficients in assessing choice complementarity and trade-offs of the tilapia products.

3.4.2 Correlates of consumer demand for tilapia products

Seemingly unrelated truncated regressions are the most appropriate way to model the correlation of demand for tilapia product. The SUTR model specifies that the dependent variable assumes the value of either zero (for no consumption scenarios) or a positive and continuous value, and that the error terms between equations are assumed to be correlated (Baltagi 2011). We used a truncated instead of censored regression approach because we focused on a subsample of households that purchased at least one tilapia product. We estimated a system of equations (4), where the dependent variables are the quantities purchased (logged) denoted as q_1^{*}, q_2^{*}, q_3^{*} and q_4^{*} for unprocessed *Os*; processed *Os*; unprocessed *Ny;* and processed *Ny,* respectively.

$$\begin{bmatrix} q_1^* \\ q_2^* \\ q_3^* \\ q_4^* \end{bmatrix} = \begin{bmatrix} x_{j1} & 0 & 0 & 0 \\ 0 & x_{j2} & 0 & 0 \\ 0 & 0 & x_{j3} & 0 \\ 0 & 0 & 0 & x_{j4} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix} = x_{jm}\beta_m + \varepsilon_{jm} \quad (4)$$

The quantities *(q^*1-4)* demanded for one tilapia product was assumed to correlate with demand for any of the other three products so assessment of demand complementarity and trade-offs is important. x_j is the *j x j* matrix of the independent variables. *j* and *m* show the number of regressors and equations respectively. β_m is the vector of estimated parameters while ε_j are the stochastic error terms for the four equations having the following mean assumption

$$E\left[\varepsilon | x_1, x_{2,} x_3 \; and \; x_4\right] = 0 \quad (5)$$

$$E\left[\varepsilon\varepsilon' | x_1, x_{2,} x_3 \; and \; x_4\right] = \Omega, \quad \Omega = \Sigma \otimes I \quad (6)$$

and variance assumption

$$\Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} & \sigma_{34} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_{44} \end{bmatrix} \quad (7)$$

SUTR applies the feasible generalized least squares method when the covariance matrix of disturbance is unknown to estimate the necessary parameters and correlation coefficients simultaneously (Zellner 1962; Zellner 1963). However, the least squares estimation method can also be used to consistently estimate the elements of covariance matrix of disturbance (Greene 2000). The study used a likelihood ratio test of the hypothesis of equal correlation coefficients in assessing choice complementarity and trade-offs of the tilapia products demanded. Analysis was done using STATA version 15 (StataCorp).

4 RESULTS AND DISCUSSION

In this section, we present the study findings starting with descriptive statistics and empirical results from the regression models. From the data section, we established that most consumers chose *Os* over *Ny*. However, in terms of products, consumers consumed a variety of *Os* and *Ny* products, suggesting that consumer choice and demand are not mutually exclusive. Thus, there are interrelationships between choice and demand that influence consumption of tilapia products. By analyzing drivers of consumer choice and demand, we get to understand the similarities and differences in the correlates of choice and demand. This is important for the fisheries industry in terms of linking consumer choice with the fish breeding priorities and marketing strategies of chain actors and constraints in fish marketing.

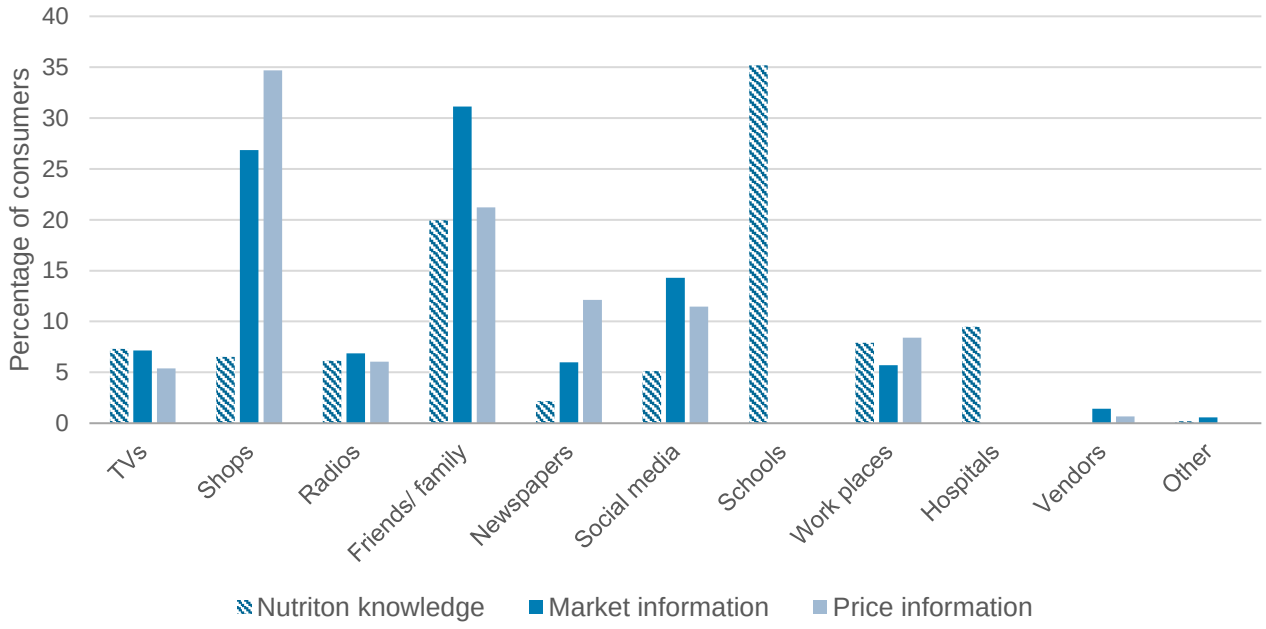
We discuss the empirical findings from MVP and SUTR regressions beginning with the correlates of consumer choice presented in Table 3, followed by the correlates of demand in Table 4, and then the complementarities and trade-offs in choice and demand for tilapia products in Table 5. We discuss the correlates of choice and demand together to relate the choices consumers make with the

quantities they demand. The marginal effects indicate the significance of the relationship between the dependent variable (choice or demand) and the independent variables (socioeconomic, market and tilapia characteristics). The marginal effects for dummy variables mean a change from 0 to 1. For the SUTR, the dependent variable is continuous and in log form so that the interpretation is a percentage change in quantities demanded as a result of a unit change in the independent variables. However, this depends again on the value of the independent variable, whether a dummy, categorical, continuous or in log form. The findings show significant and varied relationships between consumer profiles, market factors and tilapia trait descriptors and choice and demand for tilapia products.

4.1.1 Descriptive statistics

Figure 4 presents the sampled households' sources of information on tilapia market and price information, together with their sources of nutrition knowledge. It is notable that access to information on markets, prices and the nutrition benefits of tilapia was limited. Information on tilapia markets and prices was mostly obtained from shops, friends and family. This underscores the role of social networks in marketing of products and dissemination of nutrition-enhancing innovations, just as in the adoption of production technologies. Fewer households reported gaining knowledge about the nutrition benefits of tilapia from mainstream media sources.

Figure 4: Sources of information



Source: Tilapia value chain survey, 2018.

Table 2 provides a summary of the fish attributes consumers considered and preferred purchase points ranked in order of importance, together with the location of purchases of tilapia products. The values in column 1 are proportions of households that responded with a 'yes', while the values in columns 2–4 are proportions of household rankings of the three most preferred attributes. Most consumers considered several attributes in their choices of tilapia with taste, size, and form mentioned by more than half of the households, closely followed by nutritive value (47 percent). Ease of cooking and gill pigmentation were relatively unimportant to most households.[5]

[5] A red gill pigmentation is often associated with freshness of tilapia in Malawi.

In terms of location of purchase, most of the sampled households purchased tilapia products from vendors at designated fish markets (83 percent) followed by Maldeco outlets (69 percent). As noted in Section 2.1, Maldeco is one of the largest aquaculture ventures in Malawi and has a wide network of retail outlets in Malawi's cities. Interestingly, about 46 percent of the sampled households purchased from mobile vendors who often hawk fish in cooler boxes around urban estates. Some 29 percent of households also purchased from supermarkets. Most of the tilapia retailed by supermarkets, comes from aquaculture especially, *Os*, while *Ny* is largely produced from capture fisheries. These statistics underscore that there are multiple tilapia value chain actors at some marketing nodes.

Table 2: Tilapia attributes and purchase points

Variables	%Yes (1)	Ranking (%Yes) First (2)	Second (3)	Third (4)
General attributes				
Taste	62.67	29.45	13.15	12.13
Size	58.90	15.07	20.18	15.53
Form (processed, unprocessed)	51.88	18.49	14.41	13.40
Nutritive value	47.60	9.25	12.43	22.34
Smell	35.79	4.28	7.57	9.36
Health benefits	35.45	5.99	15.50	9.15
Appearance	30.82	3.60	8.11	5.53
Color (related to body texture)	29.62	8.73	5.95	6.81
Ease of cooking	18.66	4.79	2.70	5.53
Other (red gills)	0.51	0.34		0.21
Purchase points				
Market vendors	83.39	54.45	22.48	12.85
Maldeco outlets	69.01	24.14	28.49	26.54
Moving vendors	45.89	7.71	28.49	14.80
Supermarket	28.60	6.68	6.20	22.07
Private suppliers	15.07	4.45	5.81	7.54
Local butcher	13.18	0.17	2.13	9.78
Maldeco main shop	7.71	0.34	3.88	4.47
Fishermen	5.99	2.05	1.94	1.12
Aquaculture farm	1.54	-	0.58	0.84

Source: Tilapia value chain survey, 2018.

4.1.2 Consumer choice of and demand for tilapia products

Table 3 presents the results of our MVP modeling of the correlates of tilapia consumption. Socioeconomic characteristics, gender and level of education of the household decision maker, household income, frequency of consumption of tilapia products and knowledge about nutrition benefits of the products all positively influenced consumer choice and demand. The marginal effects columns show

the proportional change in the dependent variable (choice) associated with a unit change in the explanatory variables such as socioeconomic characteristics, market factors and tilapia attributes evaluated at their means. For example, households with male heads were 5.7 percent more likely to choose processed *Os* (Table 3, first row column 6) but this affected demand differently as they were likely to demand more of processed *Ny* by 32 percent (Table 4, column 7).

Number of years of formal education of the household food decision maker significantly influenced quantities demanded for most of the tilapia products but not choice of tilapia products. Additional years of schooling increased the demand for all unprocessed and processed tilapia (*Os*) and unprocessed tilapia (*Ny*) by 2.5, 4 and 2.6 percent, respectively (Table 3 columns 1, 3, 5). These findings show that formal education is associated with increased demand for processed tilapia despite its higher price. This finding is not surprising. Nankwenya et al. (2017) found that more educated people in Malawi had higher disposable incomes and propensity to purchase nutritious foods including fish, which is perceived to be more expensive than close substitute meat products such as beef, goat meat or pork. Herath and Radampola (2017) also argued that better educated household decision makers earned more and therefore could afford relatively expensive nutritious foods in Sri Lanka.

Ceteris paribus, higher household incomes increased the likelihood of choosing unprocessed *Os* and *Ny* by 4.1 percent and 5.5 percent, respectively (Table 3 columns 3 and 9). It also increased the quantities demanded for all tilapia products by between 15 and 25 percent (Table 4 columns 1, 3, 5 and 7). In Malawi as in other countries, more affluent and health-conscious urban populations are shifting to expensive yet nutritious foods including fish (Nankwenya et al. 2017; Herath and Radampola 2016). In Malawi, this is facilitated by increased availability of tilapia from the expanded markets and better networks of retail outlets for aquaculture ventures, which offer convenience to consumers. Greater access to refrigeration or cooling facilities, especially among richer households in the cities, increases the storability of perishable foods and this possibly explains urban households greater demand for both processed and unprocessed tilapia. Previous studies also show that food retailing has undergone rapid transformation to cope with the dynamic tastes and preferences of urban consumers who tend to purchase more of processed products (Demmler et al. 2018; Khonje and Qaim, 2019).

Our results show that nutrition knowledge of the decision maker in the household increased the overall likelihood of choosing unprocessed *Os* and processed *Ny* by 9.1 and 13.1 percent, respectively (Table 3 columns 3 and 12). The majority of the decision makers of food purchases and preparation were women as shown in Table 1 (75 percent) and women are usually the ones responsible for food preparations in the household. In contrast, nutrition knowledge reduces consumption of processed *Ny* and *Os* by 51.7 and 75.4 percent, respectively (Table 4 columns 3 and 7). Looking at the descriptive statistics on choice of tilapia products (Table 2), this is plausible given that most consumers chose unprocessed over processed tilapia. This is also closely associated with frequency of household tilapia consumption. Higher frequency of tilapia consumption was positively related with choice of unprocessed tilapia. The marginal effects on the consumption frequencies dummies, show that consumption of tilapia at least once a week increased demand for unprocessed *Os* and *Ny* by between 28 and 62 percent (Table 4 columns 1 and 5). Looking at the respective percentages across the consumption frequency categories, it is arguable that the frequency of consumption increases the likelihood of consuming more *Os* than *Ny* tilapia except for those who consumed the tilapia products more than twice a week. This can be explained by the fact that *Ny* products are cheaper than *Os* products (Table 1).

On market characteristics, the same correlates variedly influenced choice and demand. Access to market information increased the likelihood of choosing processed *Os* but reduced the likelihood of choosing unprocessed *Ny* (Table 3 columns 6 and 9) because the products are substitutes. In terms

of demand, access to market information generally reduced the likelihood of demanding tilapia products by at least 20 percent (Table 4 columns 4 and 9). Access to tilapia price information also increased the likelihood of choosing unprocessed *Os* but reduced the likelihood of choosing unprocessed *Ny*. These results are reinforced by the fact that consumers generally preferred *Os* to *Ny* tilapia despite the higher prices of *Os*. This is plausible given that consumers increasingly place premium on food quality, safety and traceability (Lusk and Marette 2010; Cecchini and Warin 2016), which is offered mainly by aquaculture ventures in Malawi marketing *Os* through retail outlets and supermarkets. These ventures label their fish products clearly and have cooling facilities in their retail outlets.

Table 3: Multivariate probit model results

	Unprocessed Tilapia (*Os*)			Processed Tilapia (*Os*)			Unprocessed Tilapia (*Ny*)			Processed Tilipia (*Ny*)		
	Coefficient	Std error	Marginal effect	Coefficient	Std error	Marginal effect	Coefficient	Std error	Marginal effect	Coefficient	Std error	Marginal effect
Covariates	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Socioeconomic characteristics												
Male decision maker (dummy)	0.144	0.145	0.041	0.275*	0.15	0.057*	-0.105	0.136	-0.036	0.0284	0.14	0.008
Age (years)	-0.008	0.006	-0.002	-0.001	0.006	0.0003	0.0002	0.006	0.00008	0.006	0.006	0.002
Marital status (dummy)	-0.079	0.16	-0.022	-0.279	0.175	-0.058	-0.024	0.152	-0.008	-0.0127	0.165	-0.004
Education (years)	-0.004	0.016	-0.001	-0.021	0.0166	-0.004	-0.014	0.015	-0.005	-0.01	0.016	-0.003
Household size (count)	-0.0004	0.036	-0.0001	0.031	0.039	0.006	-0.02	0.033	-0.007	0.019	0.035	0.006
Household income (log)	0.145**	0.072	0.041**	0.045	0.072	0.009	0.160**	0.066	0.055**	0.08	0.064	0.024
Nutrition knowledge (dummy)	0.322*	0.179	0.091*	-0.165	0.208	-0.034	-0.0271	0.187	-0.009	0.442**	0.204	0.131**
Consumption frequency (categorical variable where less than once a week is a base category)												
Once a week	-0.081	0.232	-0.021	0.729**	0.344	0.092***	0.597***	0.228	0.213***	0.158	0.254	0.044
Twice a week	-0.187	0.221	-0.051	0.827**	0.325	0.112***	0.662***	0.219	0.236***	0.227	0.246	0.065
More than twice a week	-0.317	0.247	-0.089	1.134***	0.345	0.189***	0.806***	0.245	0.287***	0.107	0.275	0.03

	Unprocessed Tilapia (*Os*)			Processed Tilapia (*Os*)			Unprocessed Tilapia (Ny)			Processed Tilapia (*Ny*)		
	Coefficient	Std error	Marginal effect	Coefficient	Std error	Marginal effect	Coefficient	Std error	Marginal effect	Coefficient	Std error	Marginal effect
Covariates	1	2	3	4	5	6	7	8	9	10	11	12
Institutional characteristics												
Market information (dummy)	0.127	0.159	0.036	0.389**	0.192	0.081**	-0.268*	0.153	-0.093*	-0.167	0.16	-0.05
Price information (dummy)	0.283*	0.165	0.080*	0.0371	0.185	0.008	-0.463***	0.149	-0.161***	-0.178	0.157	-0.053
Distance to fish market (km)	-0.002	0.002	-0.0005	0.002	0.003	0.0003	-0.0003	0.003	-0.0001	0.003	0.003	0.001
Blantyre city (dummy)	0.598***	0.122	0.169***	-0.230*	0.135	-0.048*	-0.218*	0.115	-0.076*	0.0003	0.122	0.0004
Tilapia attributes												
Color	-0.148	0.132	-0.042	0.17	0.141	0.035	0.0485	0.123	0.017	0.312**	0.127	0.093**
Size	0.176	0.131	0.05	-0.121	0.149	-0.025	0.149	0.12	0.052	0.059	0.128	0.017
Taste	0.302**	0.126	0.085**	0.173	0.155	0.036	-0.16	0.119	-0.056	0.389***	0.127	0.116***
Ease of cooking	-0.101	0.177	-0.029	0.293	0.182	0.061	0.0152	0.158	0.005	-0.406**	0.186	-0.121**
Appearance	-0.003	0.129	-0.001	0.127	0.146	0.026	0.104	0.125	0.036	0.357***	0.128	0.106***

Note: N = 584; Log likelihood = -1149.3747; Likelihood ratio test of rho chi^2 (76) = 234.62. ***, **, * significant at 1%, 5%, 10% level, respectively. Robust standard errors are clustered at household level. Km = kilometer.

Table 4: Seemingly unrelated truncated regression results

	Unprocessed tilapia (Os)		Processed tilapia (Os)		Unprocessed tilapia (Ny)		Processed tilapia (Ny)	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Covariates	1	2	3	4	5	6	7	8
Socioeconomic characteristics								
Male food decision maker (dummy)	0.11	0.077	-0.203	0.147	0.045	0.086	0.323***	0.11
Age (years)	0.003	0.003	-0.004	0.006	0.005	0.004	0.001	0.005
Married food decision maker (dummy)	-0.025	0.081	-0.123	0.127	0.028	0.096	0.136	0.118
Education (years)	0.025***	0.009	0.040***	0.014	0.026**	0.01	0.012	0.014
Household size (count)	0.090***	0.02	0.054	0.036	0.083***	0.019	0.086***	0.028
Household income (log)	0.161***	0.038	0.188***	0.07	0.152***	0.039	0.245***	0.053
Nutrition knowledge (dummy)	-0.08	0.1	-0.517***	0.195	-0.0513	0.113	-0.754***	0.174
Consumption frequency (categorical variable where less than once a week is a base category)								
Once a week	0.303**	0.132	-0.025	0.597	0.292*	0.163	-0.171	0.217
Twice a week	0.394***	0.129	-0.061	0.598	0.276*	0.155	0.022	0.216
More than twice a week	0.449***	0.144	0.114	0.604	0.616***	0.169	0.15	0.228
Market characteristics								
Market information access (dummy)	-0.206**	0.086	-0.410***	0.139	-0.215**	0.088	-0.06	0.147
Price information access (dummy)	0.202**	0.09	-0.058	0.128	-0.052	0.095	-0.095	0.140
Price (log) in Malawi Kwacha	-0.215**	0.084	-0.117	0.134	-0.031	0.081	-0.525***	0.122
Distance to fish market (km)	0.003	0.002	0.005**	0.002	0.001	0.002	0.001	0.003
Blantyre city (dummy)	-0.157**	0.068	-0.292**	0.125	-0.073	0.074	0.329***	0.105

	Unprocessed tilapia (Os)		Processed tilapia (Os)		Unprocessed tilapia (Ny)		Processed tilapia (Ny)	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Covariates	1	2	3	4	5	6	7	8
Tilapia attributes (dummies)								
Color	-0.072	0.073	-0.146	0.162	-0.142*	0.08	-0.145	0.104
Size	0.007	0.069	-0.383***	0.137	-0.017	0.08	0.061	0.109
Taste	0.074	0.072	-0.205	0.131	0.017	0.072	-0.104	0.108
Ease of cooking	-0.341***	0.089	-0.273*	0.163	-0.049	0.1	0.306**	0.134
Appearance	0.066	0.069	0.032	0.111	-0.052	0.08	-0.003	0.093

Note: N = 584. Log likelihood = -893.73; Likelihood ratio test of rho chi^2 (80) = 850.40. ***, **, * significant at 1%, 5%, 10% level, respectively. Robust standard errors are clustered at household level.

Household location significantly influenced consumer choices and demand for tilapia products. Table 3 shows that relative to Lilongwe consumers, Blantyre consumers were 16.9 percent more likely to choose unprocessed *Os* but 7.6 percent less likely to choose unprocessed *Ny*. Even though living in Blantyre increased the likelihood of consumers choosing unprocessed *Os*, it decreased the quantities demanded of unprocessed *Os* by 15.7 percent (Table 4). We see a clear disutility for processed *Os* among Blantyre consumers that is reflected in both their choice and demand. They were 4.8 percent less likely to choose processed *Os* and overall demand for Os decreased by 29.2 percent (Table 3 and 4). Instead, Blantyre consumers showed a 32.9 percent increased demand for processed *Ny* compared to Lilongwe consumers.

This finding is counterintuitive but not surprising and may be attributed to consumer desire for quality fish in three ways. First, the lengthy transportation time from distant production points to Blantyre affects the quality of fish supplied by vendors, except for the large aquaculture ventures that use refrigerated transportation. *Ny* is only produced around Lake Malawi which is further from Blantyre than Lilongwe. Hence, Blantyre consumers may demand more processed *Ny*. Second, the price per kg of *Os* products is higher in Blantyre than Lilongwe, so resource-constrained households may demand more of the relatively cheaper *Ny* products. Lastly, artisanal and small-scale fish production is not well regulated in Malawi, while sanitary standards are loosely enforced by local authorities, which might be of concern to affluent consumers. Aquaculture ventures brand their tilapia products to ensure food safety, quality and traceability but branding is hardly practiced by other traders. These aspects are important to health-conscious consumers in general (Kumar et al. 2008) and help to explain consumer general preference for *Os* over *Ny.*

We also examined the influence of product prices. Table 4 shows that a 1 percent increase in the price of unprocessed *Os* tilapia significantly reduced the quantities demanded by 21.5 percent while a 1 percent increase in the price of processed *Ny* reduced the quantities demanded by 52.5 percent. Hence, low prices increase demand for tilapia products. Headey and Alderman (2019) found that fish has been moderately expensive in many developing countries but very expensive and with high price variations across low income countries especially in Africa South of the Sahara. Unsurprisingly they also found that fish was more expensive in landlocked countries, such as Malawi, than in coastal countries. The study also indicated that for Eastern and Southern Africa countries, the mean relative caloric prices for fish was as high as 10.27 which is the highest among all other regions.

We found heterogenous influence of tilapia attributes on the choice and consumption of tilapia products. Ease of cooking, nutritive value, color, taste and appearance of tilapia products all influenced the choice of and demand for *Os* and *Ny* products. In Malawi, *Os* and *Ny* were distinguished by color and body texture. *Os* is darker than *Ny*. Nutritive value was important for consumers who were knowledgeable about the nutrition benefits of consuming tilapia. Such knowledge increased the likelihood of choosing unprocessed *Os* by 9.2 percent (Table 3 column 1). This could be explained in two ways. First, *Os* is mainly produced by aquaculture ventures that observe standard production practices and better feeding regimes compared to *Ny*, which is mainly from capture fisheries. Hence, urban consumers may choose more *Os* products because it assures them of quality, safety and traceability. Second, post-harvest management practices (gutting, cleaning and packaging) jointly influence the quality of products. *Os* producers often also market unprocessed *Os* in fresh or frozen form through a network of retail outlets so that city consumers prefer the conveniently accessible fresh products. There is less quality improvement and limited post-harvest management beyond cleaning and cooling by actors along the open capture *Ny* chain. This partly explains why most *Ny* tilapia is sold in processed form to reduce quality losses and why some attributes influenced choice of processed *Ny* more than others.

When consumers considered color, the likelihood of choosing processed *Ny* increased by 9.3 percent (Table 3) and demand for unprocessed *Ny* reduced by 14.2 percent (Table 4). The likelihood of choosing unprocessed *Os* and processed *Ny* increased by 8.5 and 11.6 percent when taste was considered (Table 3). Interestingly, during the interviews, respondents widely reported that *Ny* tasted better than *Os,* but this is not reflected in Table 4. The likelihood of choosing *Ny* reduced by 12 percent when ease of cooking was considered (Table 3). In contrast, it increased demand for processed *Ny* but reduced demand for *Os* products (Table 4).

4.1.3 Complementarities and trade-offs between tilapia products

So far, we have examined the correlates of choice and demand for tilapia products. However, consumer choice and demand are closely linked and there is no mutual exclusivity in the consumption of tilapia products. That is, the consumption of one tilapia product does not stifle consumption of the other three products. We examine the complementarity and trade-offs between choice and demand for *Os* and *Ny* products using covariance matrices from the MVP and SUTR models. The likelihood ratio test of equal correlation coefficients was rejected in both models thereby indicating that both models were most appropriate for the analysis and that the ordinary probit model would not suffice. The positive correlations imply complementarity of the products while negative correlations imply trade-offs and possible substitutability of the products.

In Table 5, the MVP correlation matrix show choice substitutability between unprocessed *Os* and *Ny* products, meaning that consumers view the two products as substitutes (columns 1 and 2). Similarly, there is a negative correlation between unprocessed *Os* and processed *Ny*, suggesting that the two products are substitutable. This is plausible given that consumers generally chose more unprocessed than processed tilapia products. However, this relationship cannot be strictly interpreted as such because we found heterogenous effects of the tilapia attributes correlates of choice. Interestingly, even though most consumers preferred *Os* to *Ny*, the positive correlation between processed *Os* and *Ny* indicate choice complementarity between the products. This is important for tilapia value chain development where the complementarities of these products have not been fully explored. *Os* products are generally branded and promoted by aquaculture ventures whereas there is limited branding of *Ny* products. Much of the *Ny* production and restoration efforts in lake Malawi are solely overseen by the Malawi government with limited or no interventions to market *Ny*. For the same reason, awareness of the nutrition benefits of the products remains low, particularly for *Ny*. It is noted in Figure 2 that access to information on tilapia market, price and nutrition was limited, and few households reported gaining knowledge of the nutrition benefits of tilapia from mainstream media sources. Information on tilapia markets and prices was mostly obtained from vendors in visited markets (shops), friends, and family. This underscores the role of social networks in dissemination of market information.

The SUTR correlation matrix in Table 5 shows a striking finding of only positive correlations between the tilapia products, suggesting complementarity in consumer demand for all the products (columns 1–3). Again, this reinforces our argument of the need to develop tilapia value chain while looking at the choice and demand complementarities and trade-offs between tilapia products. The big question is why such choice and demand complementarities are hardly observed. This is explained by the highlighted limitations in tilapia marketing. The mismatch between consumer choice of and demand show that drivers of choice are not necessarily drivers of consumer demand for tilapia products.

Table 5: Correlation matrices for the MVP and SUTR models

Tilapia products	Oreochromis shiranus (Os)		Lake Malawi *Oreochromis* (Ny-asalapia) spp. (Ny)	
	Unprocessed (1)	Processed (2)	Unprocessed (3)	Processed (4)
Choice of fish products (MVP model matrix)				
Unprocessed *Os*	1			
Processed *Os*	-0.113	1		
	(0.085)			
Unprocessed *Ny*	-0.433***	-0.043	1	
	(0.069)	(0.081)		
Processed *Ny*	-0.269***	0.276***	-0.043	1
	(0.075)	(0.079)	(0.074)	
Quantities demanded (SUTR model matrix)				
Unprocessed Os	1			
Processed Os	0.687***	1		
	(0.100)			
Unprocessed *Ny*	0.496***	0.640***	1	
	(0.053)	(0.104)		
Processed *Ny*	0.542***	0.845***	0.721***	1
	(0.067)	(0.057)	(0.038)	

Note: N = 584: standard errors in (parentheses). The LR test of equal correlation coefficients is rejected (p<0.001). ***, **, * significant at 1%, 5%, 10% level, respectively.

5 CONCLUSION AND POLICY IMPLICATIONS

In this study, we analyzed consumer choice between two tilapia species: *Os*, which is mostly farmed and *Ny*, which is mostly caught wild from the lake. We investigated the correlates of consumer choice and demand for tilapia products and the complementarities and trade-offs between consumption of various tilapia products in Blantyre and Lilongwe, Malawi's two major cities. This is one of the few studies to have examined species-specific complementarities and trade-offs in consumer choice and demand for fish products.

There are four important findings from this study. First, we find that most consumers generally choose farmed *Os* over the wild *Ny*. However, this choice should not be interpreted as indicating that consumers do not prefer *Ny, as* our MVP regression results show a heterogenous relationship between household choice (and demand) of tilapia products and households' location and socioeconomic characteristics, together with the attributes of the tilapia products purchased. Though less researched, we find that tilapia attributes such as nutritive value and ease of cooking significantly influence urban consumers' choice and demand for tilapia. Thus, just as with other fish types, the growth of the tilapia market will depend on the general availability of tilapia with attributes that appeal to a wide range of consumers.

Second, since prices significantly influence consumer choice and demand for tilapia products, lower prices are likely to increase demand for fish products, especially among resource-constrained households in Malawi. The finding that high tilapia prices reduce the likelihood of its consumption among households has important implications for food security and nutrition. Lower relative food prices tend to be associated with better dietary and nutrition outcomes. Lower prices increase affordability and consumption of nutrient rich foods such as fish and therefore reduce the prevalence of micronutrient malnutrition and non-communicable diseases (Headey and Alderman 2019). Further, our MVP correlation results show complementarity between processed tilapia products but trade-offs between unprocessed products, with more consumers choosing unprocessed *Os* despite their higher prices. These complementarities and trade-offs have important implications for the development of tilapia value chains in Malawi, since they show the potential for increased demand for tilapia products. Hence, reducing the relative caloric prices of fish will be beneficial to consumers. For landlocked Malawi where cost of fisheries inputs is high, this could be achieved through policies that facilitate public-private sector partnerships for greater investment in the nascent fisheries sector to widen accessibility and affordability of aquaculture inputs to lower the unit costs of fish production, thereby reducing consumer prices.

Third, our SUTR results indicate a heterogenous relationship between household, market and location factors, tilapia attributes, and the choice and demand for tilapia products. There is a mismatch between the correlates of choice and the quantity demanded of tilapia, suggesting that the determinants of choice are not the same as the determinants of demand. Furthermore, it should be noted that limited access to market information and low awareness of the nutrition benefits of fish consumption among consumers influence the frequency of tilapia consumption. *Ny* is mainly promoted by the Government of Malawi under a variety of capture fishery programs, while *Os* is promoted by aquaculture ventures through extensive advertisements to increase consumer awareness. Increased investment in developing both *Ny* and *Os* value chains and increasing consumers' access to information about the markets for and nutrition benefits of fish consumption is necessary to increase the demand for tilapia.

Lastly, our SUTR correlation results show complementarity in demand for tilapia products and diversity in choice and demand for various tilapia products. This finding is important for developing the tilapia value chain. As the value chain for wild tilapia is largely unorganized in Malawi, such complementarities are yet to be fully explored. Furthermore, aquaculture ventures should not only elicit consumer choice but also examine their demand for tilapia products. More generally, fish value chain actors need to consider the dynamics of consumer tastes and preferences, particularly among the rising middle-class in cities. There is need for greater investment in product branding and labelling in line with consumer preferences, particularly for *Ny* products. Furthermore, greater institutional support is required to regulate fish value chains and enforce food safety and quality standards in Malawi. Aquaculture ventures and other value chain actors need to expand their retail outlets to increase accessibility to farmed fish by city consumers who prioritize convenience shopping. Breeding programs should also consider consumer choice and demand for fish products in their product-profile designs, particularly for less commonly examined attributes such as nutritive value.

We argue that improving the fisheries sector especially the aquaculture sub-sector in Malawi to meet the growing urban demand for fish at affordable prices is a necessary but not sufficient condition for developing the tilapia value chains. Consumer choices and demand for fish products must also be considered. While our study was limited to four tilapia products in Malawi's two major cities, it nonetheless provides insights into the possible correlates of choice and demand for fish in general, and the complementarities and trade-offs in demand for fishery products. Future studies should examine the choices and demand for tilapia and other species of fish by value chain actors such as traders, feed mills, and food processors.

ABOUT THE AUTHORS

Christopher T. M. Chikowi is a MSc student in the Department of Agricultural and Applied Economics at the Lilongwe University of Agriculture and Natural Resources (LUANAR).

Dennis O. Ochieng is an Associate Research Fellow at IFPRI Malawi and leads the Strengthening Agricultural Markets and Institutions theme within the Malawi Strategy Support Program (MaSSP).

Charles B. L. Jumbe is a Professor of Economics at the Centre for Agricultural Research and Development at the Lilongwe University of Agriculture and Natural Resources (LUANAR).

ACKNOWLEDGMENTS

This Working Paper is an output of the Bunda Grant Scheme program of IFPRI-Lilongwe. This mentorship scheme provides selected MSc students from the Lilongwe University of Agriculture and Natural Resources (Bunda College) with opportunities to improve, publish, and disseminate the research that they undertake during their MSc training by working with a seasoned researcher from IFPRI. The Bunda Grant Scheme program is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The views expressed in this working paper imply no endorsement by IFPRI-Malawi, USAID, or anyone except the authors.

The authors acknowledge financial support for data collection from AquaFish - Africa Center of Excellence (ACE) at the Lilongwe University of Agriculture and Natural Resources. The authors also thank Bob Baulch for helpful comments on the penultimate draft of this paper, Todd Benson for creating the maps of Blantyre and Lilongwe, and Sandra Froebe for editorial and formatting assistance.

REFERENCES

Ansah, Y. 2014. “Enhancing Profitability of Pond Aquaculture in Ghana through Resource Management and Environmental Best Management Practices.” PhD Dissertation. Virginia Polytechnic Institute and State University, Blacksburg (USA).

Arthur, R., C. Béné, W. Leschen, and D. Little. 2013. Fisheries and aquaculture and their potential roles in development: an assessment of the current evidence. Marine Resources Assessment Group Limited (MRAG). London, UK.

AUC-NEPAD. 2014. *The policy framework and reform strategy for fisheries and aquaculture in Africa*. Nairobi, Kenya: African Union – Interafrican Bureau for Animal Resources.

Baltagi, B. H. 2011. “Seemingly Unrelated Regressions.” *Econometrics*: 241–256. https://doi.org/10.1007/978-3-642-20059-5_10.

Banda, M., D. Jamu, F. Njaya, M. Makuwila, and A. Maluwa, eds. 2005. “The Chambo Restoration Strategic Plan.” Proceedings of the national workshop Mangochi, May 13–16, 2013. *WorldFish Center Conference Proceedings*, Vol. 71, 112p.

Belton, B., and S. R. Bush. 2014. “Beyond Net Deficits: New Priorities for an Aquacultural Geography.” *Geographical Journal* 180 (1): 3–14. https://doi.org/10.1111/geoj.12035

Belton, B., and S. H. Thilsted. 2014. “Fisheries in Transition: Food and Nutrition Security Implications for the Global South.” *Global Food Security* 3 (1): 59–66. https://doi.org/10.1016/j.gfs.2013.10.001

Béné, C., R. Arthur, H. Norbury, E. H. Allison, M. Beveridge, S. Bush, L. Campling, W. Leschen, D. Little, D. Squires, and S. H. Thilsted. 2016. “Contribution of Fisheries and Aquaculture to Food Security and Poverty Reduction: Assessing the Current Evidence.” *World Development* 79: 177–96. https://doi.org/10.1016/j.worlddev.2015.11.007

Bogard, J. R., S. Farook, G. C. Marks, J. Waid, B. Belton, M. Ali, K. Toufique, A. Mamun, and S. H. Thilsted. 2017. ”Higher fish but lower micronutrient intakes: Temporal changes in fish consumption from capture fisheries and aquaculture in Bangladesh.” *PloS ONE*: 12 (4): e0175098. https://doi.org/10.1371/journal.pone.0175098

Boulenger, G. A. 1897a. Descriptions of new fishes from the upper Shiré River, British Central Africa, collected by Dr. Percy Rendall, and presented to the British Museum by Sir Harry H. Johnston, K.C.B. Proceedings of the Zoological Society of London 1896 (part 4): 915–920 & Plate 47.

———. 1897b. “Description of a new fish from Lake Nyassa.” *Annals and Magazine of Natural History* 6 (19): 155.

Brascamp, E. W., C. Smith, and D. R. Guy. 1985. “Derivation of economic weights from profit equations.” *Animal Science* 40 (1): 175–179. https://doi.org/10.1017/S0003356100031986

Brummett, R. E. 2000. “Factors influencing fish prices in Southern Malawi.” *Aquaculture* 186 (3-4): 243–251. https://doi.org/10.1016/S0044-8486(99)00383-X

Byrne, T. J., P. R. Amer, P. F. Fennessy, P. Hansen, and B. W. Wickham 2012. “A preference-based approach to deriving breeding objectives: applied to sheep breeding.” *Animal* 6 (5): 778–788. https://doi.org/10.1017/S1751731111002060

Cai, J., and P. Leung, P. 2017. Short-term projection of global fish demand and supply gaps. In *FAO Fisheries and Aquaculture Technical Paper*.

Cappellari, L., and S. P. Jenkins. 2003. "Multivariate Probit Regression using Simulated Maximum Likelihood." *The Stata Journal: Promoting Communications on Statistics and Stata* 3 (3): 278–294. https://doi.org/10.1177/1536867x0300300305.

Cecchini M., and L. Waren. 2016. "Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analyis of randomized studies." *Obsetiy Reviews* 17(3): 201–210. https://doi.org/10.1111/obr.12364

Demmler, K. M., O. Ecker, and M. Qaim. 2018. "Supermarket shopping and nutritional outcomes: A panel data analysis for urban Kenya." *World Development* 102*:* 292–303. https://doi.org/10.1016/j.worlddev.2017.07.018

Dickerson, G. 1970. "Efficiency of animal production—molding the biological components." *Journal of Animal Science* 30 (6): 849–859. https://doi.org/10.2527/jas1970.306839x

Dimitri, C., and S. Rogus. 2014."Food choices, food security, and food policy." *Journal of International Affairs* 67 (2): 19–31.

FAO (Food and Agriculture Organization of the United Nations). 2018. The State of World Fisheries and Aquaculture 2018 – Meeting the sustainable development goals. Rome.

Funge-Smith, S., and A. Bennett. 2019. "A fresh look at inland fisheries and their role in food security and livelihoods." *Fish and Fisheries* 20 (6): 1176–1195. https://doi.org/10.1111/faf.12403

Geweke, J. 1996. "Bayesian reduced rank regression in econometrics." *Journal of Econometrics* 75 (1): 121–146. https://doi.org/10.1016/0304-4076(95)01773-9

Goss, J., D. Burch, and R. E. Rickson. 2000. "Agri-food restructuring and third word transnationals: Thailand, the CP Group and the global shrimp industry." *World Development* 28 (3): 513–530. DOI: 10.1016/S0305-750X(99)00140-0

Greene W. H. 2000. Econometric Analysis. Fourth Edition. Macmillan, London.

Günther, A. 1864. Report on a collection of reptiles and fishes made by Dr. Kirk in the Zambesi and Nyassa regions. Proceedings of the Zoological Society of London 1864: 303–314.

Headey, D. D., and H. H. Alderman. 2019. "The relative caloric prices of healthy and unhealthy foods differ systematically across income levels and continents." *The Journal of Nutrition* 149 (11): 2020–2033. https://doi.org/10.1093/jn/nxz158

Herath, T. N., and K. Radampola, K. 2017. "Fisheries education in Sri Lanka: current status, constraints and future outlook." *Journal of Fisheries* 5 (3) 535. https://doi.org/10.17017/jfish.v5i3.2017.162

Hernandez, R., B. Belton, T. Reardon, C. H, X. Zhang, and A. Ahmed. 2018. The "quiet revolution" in the aquaculture value chain in Bangladesh. *Aquaculture* 493: 456–468. https://doi.org/10.1016/j.aquaculture.2017.06.006

Kasulo, V., and C. Perrings. 2006. "Fishing down the value chain: Biodiversity and access regimes in freshwater fisheries—the case of Malawi." *Ecological Economics* 59 (1): 106–114. https://doi.org/10.1016/j.ecolecon.2005.09.029

Khonje, M. G., and M. Qaim. 2019. "Modernization of African Food Retailing and (Un)healthy Food Consumption." *Sustainability* 11 (16): 4306. https://doi.org/10.3390/su11164306

Kobayashi, M., S. Msangi, M. Batka, S. Vannuccini, M. M. Dey, and J. L. Anderson. 2015. "Fish to 2030: the role and opportunity for aquaculture." *Aquaculture Economics and Management* 19 (3): 282–300. DOI: 10.1080/13657305.2015.994240

Kristofersson, D., and J. L. Anderson. 2006. "Is there a relationship between fisheries and farming? Interdependence of fisheries, animal production and aquaculture." *Marine Policy* 30 (6): 721–725. https://doi.org/10.1016/j.marpol.2005.11.004

Kumar, G., K. Quagrainie, and C. Engle. 2008. "Factors that influence the frequency of purchase of catfish by U.S. households in selected cities." *Aquaculture Economics and Management* 12 (4): 252–267. https://doi.org/10.1080/13657300802494297

Limuwa, M., W. Singini, and T. Storebakken. 2018. Is Fish Farming an Illusion for Lake Malawi Riparian Communities under Environmental Changes? *Sustainability* 10 (5): 1453. https://doi.org/10.3390/su10051453

Lusk, J. L., and S. Marette. 2010. "Welfare effects of food labels and bans with alternative willingness to pay measures." *Applied Economic Perspectives and Policy* 32 (2): 319–337. https://doi.org/10.1093/aepp/ppp013

Lu, L., and T. Reardon, T. 2018. "An economic model of the evolution of food retail and supply chains from traditional shops to supermarkets to e-commerce." *American Journal of Agricultural Economics* 100: 1320–1335. https://doi.org/10.1093/ajae/aay056

Maganga, A. M., M. A. R. Phiri, L. D. Mapemba, G. G. Gebremariam, and J. K. Dzanja. 2014. "A Food Demand System Estimation for Rural Malawi: Estimates Using Third Integrated Household Survey Data." Conference Paper. Annual Meeting, July 27-29, 2014, Minneapolis, Minnesota. Agricultural and Applied Economics Association.

Malawi Government. 2016. *National Fisheries and Aquaculture Policy*.

Mehar, M., W. Mekkawy, C. McDougall, and J. Benzie. 2019. "Fish trait preferences: a review of existing knowledge and implications for breeding programmes." *Reviews in Aquaculture.* https://doi.org/10.1111/raq.12382

Mumba, P. P., and M. Jose. 2005. "Nutrient Composition of Selected Fresh and Processed Fish Species from Lake Malawi: A Nutritional Possibility for People Living with HIV/AIDS." *International Journal of Consumer Studies* 29 (1): 72–77. https://doi.org/10.1111/j.1470-6431.2005.00377.x

Nagoli, J., E. M. Phiri, E. Kambewa, and D. Jamu. 2009. Adapting integrated agriculture aquaculture for HIV and AIDS-affected households: the case of Malawi. WorldFish Center Working Paper 1957. The WorldFish Center, Penang, Malaysia.

Nankwenya, B., E. Kaunda, and S. Chimatiro, S. 2017. "The demand for fish products in Malawi: An almost ideal demand system estimation." *Journal of Economics and Sustainable Development* 8 (16): 63–71.

Nielsen, J. R., K. Kristensen, P. Lewy, and F. Bastardie. 2014. A Statistical Model for Estimation of Fish Density Including Correlation in Size, Space, Time and between Species from Research Survey Data. *PLoS ONE* 9 (6): e99151. https://doi.org/10.1371/journal.pone.0099151

NSO (National Statistical Office). 2009. Malawi 2008 Population and Housing Census: *Main Report*, 1–23. Zomba: NSO.

Oken. E., A. L. Choi, M. R. Karagas, K. Mariën, C. M. Rheinberger, R. Schoeny, E. Sunderland, and S. Korrick. 2012. "Which fish should I eat? Perspectives influencing fish consumption choices." *Environmental Health Perspectives* 120 (6): 790–798. https://doi.org/10.1289/ehp.1104500

Omasaki, S. K., J. Arendonk, A. K. Kahi, and H. Komen. 2016. “Defining a breeding objective for Nile tilapia that takes into account the diversity of smallholder production systems.” *Journal of Animal Breeding and Genetics* 133 (5): 404–413. https://doi.org/10.1111/jbg.12210

Ponzoni, R.W., N. H. Nguyen, H. L. Khaw, and B. M. Rodriguez. 2012. Considerations about effective dissemination of improved fish strains. WorldFish Working Paper: 2012–47. The WorldFish Center Penang, Malaysia.

Pinstrup-Andersen, P., and F. Cheng. 2018. Case Studies in Food Policy for Developing Countries: Domestic Policies for Markets, Production, and Environment. Cornell University Press.

Ragot, M., M. W. Bonierbale, and E. Weltzien. 2018. From market demand to breeding decisions: a framework. CGIAR Gender and Breeding Initiative Working Paper 2. Lima (Peru): CGIAR Gender and Breeding Initiative. https://hdl.handle.net/10568/91275

Rashid, S., and X. Zhang, eds. 2019. *The Making of a Blue Revolution in Bangladesh: Enablers, Impacts and the Path Ahead for Aquaculture.* Washington, DC: International Food Policy Research Institute. https://doi.org/10.2499/9780896293618

Rashid, S., N. Minot, and S. Lemma, S. 2019. “Does a “Blue Revolution” help the poor? Evidence from Bangladesh.” *Agricultural Economics* 50 (2):139–150. https://doi.org/10.1111/agec.12472

Ruel, M., A. Quisumbing, and M. Balagamwala. 2018. “Nutrition-Sensitive Agriculture What Have We Learned and Where Do We Go from Here?” *Journal of Global Food Security* 17:128–153. https://doi.org/10.1016/j.gfs.2018.01.002

Shava, E., and C. Gunhidzirai. 2017. “Fish farming as an innovative strategy for promoting food security in drought risk regions of Zimbabwe.” *Jàmbá: Journal of Disaster Risk Studies* 9 (1): 491. https://doi.org/10.4102/jamba.v9i1.491.

Steenbergen, D. J., H. Eriksson, K. Hunnam, D. J. Mills, and N. Stacey. 2019. “Following the fish inland: understanding fish distribution networks for rural development and nutrition security.” *Food Security* 11 (6): 1417–1432. https://doi.org/10.1007/s12571-019-00982-3

Tacon, A., and M. Metian. 2013. “Fish Matters: Importance of Aquatic Foods in Human Nutrition and Global Food Supply.” *Reviews in Fisheries Science* 21: 22–38. https://doi.org/10.1080/10641262.2012.753405

Trewavas, E. 1935. A synopsis of the cichlid fishes of Lake Nyasa. *Annals and Magazine of Natural History* (10) 16: 65–118.

———. 1941. Nyasa fishes of the genus *Tilapia* and a new species from Portuguese East Africa. *Annals and Magazine of Natural History* 11: 294–306.

———. 1949: The origin and evolution of the cichlid fisches [sic] of the Great African lakes, with special reference to Lake Nyasa. *Comptes Rendus 13th Congrès International de Zoologie 1948*: 365–368.

———. 1983. “Tilapiine Fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*,” Bulletin of the British Museum (Natural History). London and Cornell & University Press, Ithaca, New York: 583.

Troell M., R. L. Naylor, M. Metian, M. Beveridge, P. H. Tyedmers, C. Folke, K. J. Arrow, S. Barrett, A. S. Crépin, P. R. Ehrlich, Å. Gren, N. Kautsky, S. A. Levin, K. Nyborg, H. Österblom, S. Polasky, M. Scheffer, B. H. Walker, T. Xepapadeas, and A. de Zeeuw. 2014. “Does aquaculture add resilience to the global food system?” *Proceedings of the National Academy of Sciences of the United States of America* 111 (37): 13257–13263. https://doi.org/10.1073/pnas.1404067111

Tschirley, D., T. Reardon, M. Dolislager, and J. Snyder. 2015. “The rise of a middle class in the east and southern Africa: Implications for food system transformation.” *Journal of International Development* 27 (5): 628–646. https://doi.org/10.1002/jid.3107.

United Nations. 2015. Transforming our World: The 2030 Agenda for Sustainable Development.

UN-HABITAT. 2011a. *Malawi: Blantyre Urban Profile insert Picture* Available at: http://www.zaragoza.es/contenidos/medioambiente/onu/issue06/1137-eng.pdf. [Accessed on 23 September 2018].

———. 2011b. Malawi Lilongwe Urban Profile. In *UN-Habitat Human Settlements Programme*.

World Bank. 2016a. *World Development Indicators*. Washington, DC: World Bank. http://api.worldbank.org/v2/en/indicator/ER.FSH.CAPT.MT?downloadformat=excel. [accessed on 29 June 2018].

———. 2016b. *World Development Indicators*. Washington, DC: World Bank. http://api.worldbank.org/v2/en/indicator/ER.FSH.AQUA.MT?downloadformat=excel. [accessed on 29 June 2018].

Zellner, A. 1962. “An efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias.” *Journal of the American Statistical Association* 57 (298): 348–368. DOI: 10.1080/01621459.1962.10480664.

———. 1963. “Estimators for Seemingly Unrelated Regression Equations: Some Exact Finite Sample Results.” *Journal of the American Statistical Association* 58 (304): 977–992. https://doi.org/10.1080/01621459.1963.10480681.

ANNEX: DESCRIPTIONS OF THE STUDIED TILAPIA PRODUCTS

Chambo species (Tilapia Nyasalapia), *Trewavas, 1983*

Oreochromis karongae (Trewavas, 1949)

O. karongae is distinguished from *O. lidole* by its smaller head and mouth, and heavier dentition, and from *O. squamipinnis* by its male breeding colors. *O. karongae* shows geographic variation in external and pharyngeal bone proportions and in the number of tooth rows in the jaws. However, although there are many statistically significant differences, most measurements show substantial degrees of overlap among the species.

Oreochromis lidole (Trewavas, 1941)

Oreochromis lidole is uniquely identified by its slender lower pharyngeal bone, which supports a small toothed area. In the field, it could be easily distinguished at sizes above 15 cm.

Oreochromis squimmipinis (Günther, 1864)

Oreochromis squamipinnis is distinguished from *O. lidole* and *O. karongae* by its distinctive male breeding colors. Morphologically, females and immature males are very similar to *O. karongae*: in Lake Malawi, fish below 20 cm were difficult to distinguish, while in Lake Malombe, only adult breeding fish could be reliably identified. Both external body proportions and pharyngeal bone shape show significant geographical variation between populations.

Pictorial comparison of the Nyasalapia species
(top down: Oreochromis squamipinnis, Oreochromis karongae, and Oreochromis lidole)

Table A 1. Identification of chambo species

	O. squampinnis[1]	*O. karongae*[2]	*O. lidole*[3]
Ripe Male Color	Blue or white head	Black	Black
Female/Juvenile Color	Silver Grey	Brownish (often yellow dorsal margin)	Dark Grey
Body Shape	Deep-bodied	Slim, except in Lake Malombe	Slim, big head
Jaws	Small-Medium	Small	Large
Teeth	3–7 rows	3–14 rows	3–4 (5) rows
Pharyngeal Toothed Area	medium	medium-large	small
Minimum Size for Accurate Identification	20 cm	20 cm	15 cm

Source: [1] Günther 1864; [2] Trewavas 1949; [3] Trewavas 1935.

Makumba (Oreochromis shiranus)

O. *shiranus* (Boulenger, 1987a, Boulenger, 1987b*)* is not a member of Lake Malawi's endemic tilapia "Nyasalapia" mini flock, being classified in a different subgenus. It differs from that species group in almost always having 4 anal fin spines (rarely 3 or 5), instead of 3 as in "Nyasalapia." Also, O. shiranus males lack a genital tassel (Trewavas, 1983). Females and immatures from the Lake Malawi catchment have a dark olive-colored body and are yellow-gold below. The horizontal stripes are often more prominent than the vertical bars; adult males develop very large jaws and a concave head profile, they are black, with red margins to the dorsal and caudal fins. Underwater or in aquaria, males show numerous white spots on the upper half of the flanks, but these fade quickly under stress, so that they appear uniformly black when removed from the water.

The Malawi Strategy Support Program (MaSSP) is managed by the International Food Policy Research Institute (IFPRI) and is made financially possible by the generous support of the American people through the United States Agency for International Development (USAID), and by the UK Department for International Development (DFID). This publication has been prepared as an output of MaSSP and has not been independently peer reviewed. Any opinions expressed here belong to the authors and are not necessarily representative of or endorsed by IFPRI, the US or the UK government's official policies.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

A world free of hunger and malnutrition

IFPRI Malawi, Area 14 Office, Plot 14/205, Lilongwe, Malawi | Mailing Address**:** PO Box 31666, Lilongwe 3, Malawi

T +265-1-771-780 | Email: IFPRI-Lilongwe@cgiar.org | http://massp.ifpri.info