Understanding Nutrient - Contaminant Tradeoffs in fish consumer demand: Evidence from Kenya

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Abstract

Fish consumers are often challenged by tradeoffs between nutritional benefits and contaminant risks, which increase due to environmental pollution. Health campaigns and labeling initiatives can guide decision-making by providing information both on contaminant risk and nutritional value of a product, but it is not well understood how consumers react to such complex dual labels. We use data from a stated choice experiment in Kenya's Lake Victoria region to study how consumers respond to dual labels on fish products, and how their responses to each label interact. We focus on the tradeoff between polyunsaturated fatty acids and contamination with microcystin, a toxin that accumulates in fish during harmful algae blooms. Our findings suggest that, faced with a dual information policy, consumers react rationally to dual health attribute labeling, and that nutrient labels and contaminant warnings can function concurrently, indeed even be mutually reinforcing, but pose a risk of inadvertently concentrating unhealthful consumption in less responsive subpopulations.

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Highlights:

- consumers must weigh nutrients against contaminants when purchasing fish
- consumers value dual information on microcystin risk and fatty acid benefits
- nutrient and contaminant preferences interact: consumers view them as complementary
- higher education, awareness, and income raise aversion to toxin contamination
- dual labels are promising, but may concentrate unhealthful choices in subpopulations

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1 Introduction

The trade-off between nutritional benefits and risks from contaminants has emerged as an important issue regarding fish consumption (Heilpern et al., 2025; Niederdeppe et al., 2019; Shimshack and Ward, 2010; Uchida et al., 2017). Fish is a valuable natural resource given nutrition benefits, such as from protein intake and polyunsaturated fatty acids (PUFA). However, consumers must increasingly weigh these benefits against contamination risks related to environmental pollution, such as from heavy metals or cyanotoxins due to harmful algae blooms (HABs) (Roegner et al., 2023; Shimshack and Ward, 2010).

Information — such as through labeling initiatives — can encourage healthier dietary patterns, including in the Global South (Balcombe et al., 2010; Cowburn and Stockley, 2005; Defago et al., 2020; Grunert and Wills, 2007; Lauber et al., 2018; Roosen et al., 2007). Labeling could also inform consumers' behavior in assessing and acting on nutrient-contaminant-tradeoffs, but information policies rely on balanced and judicious consumer responses, and can be complex or backfire in cases of complex trade-offs (Shimshack and Ward, 2010; Uchida et al., 2017). In some cases, the risk of contaminants has led consumers to avoid fish, crowding out nutritional benefits (Niederdeppe et al., 2019; Shimshack and Ward, 2010). This is especially salient where diets are commonly deficient in specific nutrients and/ or contamination risks are high. In this paper, we use data from Kenya to study consumer response to jointly provided contaminant and nutrient information.

We know little about consumers' response to joint contaminant-versus-nutrient labeling. The previous literature has either analyzed this tradeoff through the lens of health psychology (Rabia et al., 2006) or has analyzed the effect of subsequently introduced labels (Hu et al., 2004; Marette et al., 2008), where it remains unclear whether interaction results from interdependent preferences or from a change in the number of labels. Four sources of complexity arise. First, consumers may overemphasize messages on contamination risks over those highlighting nutritional benefits (Anabtawi et al., 2020; Hartmann et al., 2018; Marette et al., 2008; Shimshack and Ward, 2010; Uchida et al., 2017). Second, preferences for contamination risk versus nutritional benefits may be behaviorally interdependent due to higher or lower complementarity in generating well-being. A higher nutrition benefit label may for example strengthen or weaken the response to a contaminant label. Third, individual specific characteristics such as health conditions, pregnancy, presence of children in the household, or gender (Jones, 2019; Niederdeppe et al., 2019; Uchida et al., 2017), determine ideal risk-benefit-tradeoffs, a complexity often not reflected in information labels and unknown to the analyst. Fourth, preferences for the two labels may co-vary (Balcombe et al., 2010; Fonner and Sylvia, 2015) if consumers differ in a latent preference for healthy food overall, raising concerns that labeling may inadvertently concentrate health risks in less responsive groups.

Our research design generates novel estimates of consumer response to joint information on food-based health benefits and risks, that can shed light on these complexities. We use a choice experiment based on data from communities on the shore of Lake Victoria, Kenya. We focus on the tradeoff between PUFA and contamination with microcystin (MC), a cyanotoxin produced by bacteria during HABs (Brookes and Carey, 2011) that has been found in fish tissue in the region in harmful concentrations

(Roegner et al., 2023). MC contamination is an issue of global importance (Brookes and Carey, 2011) and a pressing matter in particular in the Global South (Abdallah et al., 2021; Borbor-Cordova et al., 2018; Roegner et al., 2023). Compared with more mature research on contamination, e.g., with heavy metals, cyanotoxin risks are newly being identified. Our main contribution lies in the explicit analysis of behavioral interactions between consumer preferences for contamination risk versus nutritional benefits. Our paper is also the first to examine consumers' valuation, and its individual heterogeneity, regarding MC contamination of fish.

We find that consumers show significant willingness to pay for PUFA rich fish, but this is often outweighed by their willingness to pay to avoid MC-contaminated fish. Moreover, preferences are interdependent. A statistically significant negative interaction effect shows that nutrients and low contamination partly complement each other. Each is more valued by consumers if the other is also at a more favorable level. In economic terms, richness in PUFA and low MC risk are non-separable, imperfect substitutes. This is consistent with a hypothesis of rational behavior regarding food and contaminant attributes: overall healthiness is a composite good dependent on many different nutritional aspects. At the individual level, preferences for low contamination co-vary with preferences for PUFA. That is, respondents with a high preference for PUFA also show a high preference to avoid MC, and vice versa. This contradicts the hypothesis of attention heuristics, whereby consumers focus on one attribute at the expense of attending to the other (Balcombe et al., 2010; Grunert and Wills, 2007). Higher income, higher education, and prior awareness of HABs, which govern the process behind toxin contamination, are associated with stronger preferences to avoid toxin contamination. This poses distributional challenges as labeling may inadvertently concentrate health risks in certain subpopulations who are less responsive to messaging about food contaminants.

2 The nutrient-contaminant-tradeoff for fish from Lake Victoria, Kenya

Our study is set in the Homa Bay and Kisumu regions, Kenya, close to Lake Victoria. The Lake Victoria basin is home to over 30 million people, and reliance on the lake for food and employment is very high (Simiyu et al., 2018). Fish is an integral part of lakeshore populations' diet, in particular regarding PUFA (Fiorella et al., 2016, 2018; Rasolofoson et al., 2025). PUFA are critical to brain development (Koletzko et al., 2008), and should be substituted for saturated fatty acids (SFA) or trans fatty acids to help prevent coronary artery diseases, a major cause of untimely deaths in many countries including Kenya (Government of Kenya, 2018). Gil and Gil (2015) find that the PUFA benefits from fish consumption regularly outweigh heavy metal contamination risks for healthy adults. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) recommend a PUFA intake of 6-11% of the overall energy intake, with fat on aggregate not exceeding 30% of energy intake (FAO, 2010, p. 15). Fish have favorable ratios of PUFA to SFA, ranging between 0.26 and 1.08 for Lake Victoria species (Fiorella et al., 2018). Even within favorable nutritional ranges, there is increasing recognition of the relative differences in nutritional composition across different fish and aquatic foods species (Byrd et al., 2021; Golden, 2021; Hicks et al., 2019) as well as the trade-offs in contaminant risks and nutritional benefits across species (Heilpern et al., 2025).

However, environmental pollution leads to contamination of fish with cyanotoxins, primarily MC, a toxin that may cause gastrointestinal symptoms, liver or kidney failure, low infant birth weight, as well as increased risk of liver or colorectal cancer and neurodegenerative disorders in humans (Chen et al., 2009; Greer et al., 2018; Ibelings and Chorus, 2007; Jones, 2019; Massey et al., 2018; Matsushima et al., 1992; Mello et al., 2018; Rastogi et al., 2015). MC is produced by bacteria during HABs (Mulvenna et al., 2012; Sitoki et al., 2012). Fishing communities around Lake Victoria report a range of negative impacts, including gastrointestinal, respiratory and dermal impacts (Ziegler et al., 2023). HABs result from increased water pollution with nutrients in combination with ever higher water temperatures (Ibelings and Chorus, 2007; Downing et al., 2021; Okechi et al., 2022; Sitoki et al., 2012). In freshwater environments of the Global South, HABs last for longer periods, and are associated with severe risks due to the greater reliance of populations on freshwater for drinking, fish, laundry, etc. (Abdallah et al., 2021; Olokotum et al., 2022; Roegner et al., 2023). In Lake Victoria, HABs are now present on and off throughout the year (Roegner et al., 2020), in particular in closed bays, such as Kisumu bay, which constitute the main nursery grounds for many fish stocks (Sitoki et al., 2012).

Humans are exposed to microcystin mainly through drinking water, fish consumption, or aerosols (Chen et al., 2009; Nyakairu et al., 2010; Poste et al., 2011; Roegner et al., 2020). WHO guidelines for intake of microcystin (MC) through drinking water were exceeded in 5 of 6 locations around Nyanza Gulf in Kenya (Olokotum et al., 2022). Specimens with WHO-guideline exceeding concentrations of MC were found among samples for each major fish species (Poste et al., 2011; Simiyu et al., 2018; Sitoki et al., 2012; Roegner et al., 2023). These results are prior to improved understanding of new congeners that may not be detected with some methods, and risk of background detection inflating other values (U.S. Environmental Protection Agency, 2021; Massey et al., 2020). Yet, they nonetheless suggest worrisome risks for fish consumers.

MC risk, similar to the risks of other contaminants, is likely to vary across observable characteristics, such as fish species, age, processing, and production methods (aquaculture or wild). MC contamination risk may systematically vary across fish species (Flores et al., 2018), as both uptake and depuration rates vary. Research on MC risk documents systematic variation based on traits observable to consumers, e.g., species, fish age, or processing method (Roegner et al., 2023; Silva et al., 2021), with the intention of providing systematic guidelines regarding MC risk avoidance during HABs. Systematic variation across observable traits could provide a basis to guide consumers' choices, since broadly testing individual fish is not feasible.[1] Drying fish as a processing method does not change MC contamination concentrations (Simiyu et al., 2018). Further systematic variation across observable traits may occur across fish age and between cage-farmed versus wild caught fish. Age matters as adult fish typically reside in deeper and more open waters and ingest less algae (Poste et al., 2011). Cage-farmed fish are fed might therefore ingest less contaminated algae than wild caught fish, but are on the other hand fixed in place where they can not adapt to algae blooms by relocation as wild fish might, both

[1] By contrast, fishing location - another trait likely to be a strong predictor for MC risk - is not easily verifiable for consumers.

factors that affect MC in fish tissue (Garita-Alvarado et al., 2025).

PUFA and MC are not known to be biologically or medically related. They each affect different health aspects, such that a high intake of PUFA and low MC intake should be complementary.

There is currently no label in place that informs Kenyan consumers either about PUFA benefits or MC risks of fish products, and none is planned to the best of our knowledge. In this study, we therefore use hypothetical labels to elicit consumers valuation for information regarding PUFA and MC content in fish.

3 Discrete choice experiment

3.1 Experimental design

We ran a labeled, discrete stated choice experiment (Nguyen et al., 2015; Rousseau and Vranken, 2013; Van Loo et al., 2020) with 402 consumers at six fish markets in the Lake Victoria bordering counties of Kisumu and Homa Bay, Kenya. The experiment was combined with a survey (see Appendix H for the questionnaire) to collect data on the participants' socio-economic characteristics, health, and preferences.

The experiment included the three most commonly consumed fish species around Lake Victoria: Nile perch (NP), dagaa (DG) (locally also known as omena), and tilapia (TP), with an additional opt-out option. This approach mirrors actual purchasing decisions and allows for the inclusion of species-specific attributes. Data from 2024 show that the cheapest, dagaa, was the most landed fish species from Lake Victoria, Kenya, by annual volume (30.5kt), followed by tilapia (11.2kt) and Nile Perch (7.1kt), out of total landings of 67kt (Ministry of Mining, Blue Economy & Maritime Affairs, 2025).

Participants were asked to choose as if they were purchasing fish for a single meal for their household, with all options reflecting locally sourced fish of similar freshness/ quality. Apart from the price, we included attributes that are observable, relevant to consumers, and according to the scientific literature may correlate with toxin and/ or PUFA share in fat (Roegner et al., 2023; Rombenso et al., 2016). This ensures inclusion of potential levers in a prospective actual information/labeling policy. For each species, we included one specific attribute with two levels, namely fresh (versus baseline dried) for dagaa, undersized (versus baseline medium sized) for Nile perch and aquaculture produced (versus baseline wild caught) for tilapia. These attributes are species specific as, for example, there exists no dagaa or Nile perch from aquaculture in this setting, and size is mainly an attribute for the relatively large Nile perch, but neither for dagaa nor tilapia.

Furthermore, we included six price levels (per kg) based on species-specific means based on market data (see Appendix B, Table 3), with additional levels above and below the mean ensuring to also cover ranges that accounted for the alternative-specific attribute variations, specifically price spans 119-759 KSh/kg for dagaa, 273-494 KSh/kg for Nile perch, and 309-572 KSh/ kg for tilapia.[2]

We asked each participant in the first part of the choice experiment to pick the favored alternative in six subsequent choice tasks. Next, we implemented an information treatment combined with two additional attributes for all alternatives: one for PUFA content and one for MC toxin content.

[2] The larger span for dagaa reflects greater observed market price variation.

We informed all consumers about the merits of unsaturated over saturated fatty acids to avoid heart problems and to improve children's development. We further informed consumers about potential liver damage and tumors following microcystin exposure, and named both drinking water and fish as potential channels of exposure. The information script is available in Appendix A. We asked participants to assume that the newly added labels were based on scientific quantification, making sure that consumers understood that the labels at this point were hypothetical.

The toxin attribute reflects average microcystin content in the fish tissue.[3] It was implemented as a traffic light label, where red indicated an unhealthy MC level; the WHO considers regular consumption of such a product as dangerous for adults. Yellow signified a medium, elevated but not unhealthy, level, and green represented a level of risk lower than the guideline value for vulnerable people, such as children.

We also labeled according to the ratio of PUFA to saturated fatty acids (SFA).[4] We considered a red label misleading, as even fish with the lowest PUFA to SFA ratio remains a generally recommendable choice. Instead, we conveyed PUFA content using a health star rating system (inspired by the Australian nutrient guidance (Russell et al., 2021)), where one star indicated a choice that did not comply with WHO recommendations in terms of the share of PUFA, and thus a less recommendable choice. Two stars represented a medium level which can be found in many fish species,

[3] WHO's recommended lifetime microcystin exposure limit is 0.04 μg per kg body weight, but they expect that up to 80% of exposure stems from drinking water, such that even small additional exposure via fish may be critical (WHO, 2017, 2020).

[4] This ratio has been extensively used in the literature to analyze fatty acid content in fish tissue (Chen and Liu, 2020). We used this ratio instead of absolute values to account for the fact that excessive total intake of fat could be detrimental, and that health benefits are particularly pronounced when PUFA replace SFA in the diet.

while three stars signified a highly recommendable choice. This mixed yet simple labeling approach allowed us to use an appropriate, non-misleading system for both MC toxin and PUFA. An example of the visualized choice task is presented in Appendix C, Figure 3.

Each respondent was asked to respond to several choice tasks, each time making a choice between the four available alternatives with varying characteristics (attribute levels). We used a design with six choice tasks out of a total of 36 in six blocks for part 1 (pre-information treatment), where each participant was randomly assigned to one of these blocks. We used a design with 12 choice tasks per participant in six blocks for a total of 72 choice tasks in part 2 (post-information treatment), again randomly assigning each participant one block. The design is orthogonal for part 2 - that is, the design ensures zero correlation among the attributes, letting each level of each attribute and every possible pair of attribute levels occur equally frequently. For part 1, while this design used the orthogonally designed 36 choice cards, the low number of choice cards per participants only allows for an almost orthogonal design at participant level. The total number of 18 choice tasks per participants is high for a choice experiment overall. However, given the one-to-one personal nature of our interviews, the relatively simple choice tasks in part 1, and positive results in the pilot, we determined the number to be appropriate.[5]

Similar to Uchida et al. (2014), fish choices were hypothetical given

[5] Survey and design were tested with 36 participants at a market away from the actual survey markets in Siaya county to avoid contamination, with 12 choice tasks per participants both in part 1 and part 2. Participants generally stated that the experiment was easy to understand, and no participants complained about the overall length of the experiment. However, given the generally high number of choice cards and the robust results based on the pilot, we decided to reduce the burden to participants by halving the number of choice cards in part 1 for the main survey.

that we can neither at this point measure fish level MC risk or PUFA, nor ensure availability of all fish types due to the stochasticity of HABs. Thus, it was not possible to use an incentive compatible design. This can introduce hypothetical bias(Lusk and Schroeder, 2004). A meta-study finds that hypothetical experiments overestimate willingness to pay (WTP) on average by 21% (Schmidt and Bijmolt, 2020). In our study, we were mainly interested in preference relationships rather than absolute WTP. Still, to mitigate this bias, we expressly communicated to the participants the relevance of truthful responses for future policies (see Appendix A), as such reminders have previously been found effective in reducing hypothetical bias(Penn and Hu, 2019).

3.2 Estimation Model

We estimated a Mixed Logit Model using the Apollo package in R (Hess and Palma, 2019). The model allows for random taste variation across individuals, and relaxes the Independence of Irrelevant Alternatives (IIA) assumption inherent in a multinomial logit model.[6] We let parameters continuously vary across individuals while assuming them to be constant within individual across different choice situations. To limit the number

[6] We also estimated a multinomial logit model for pre- and post-information treatment samples (BIC=5124 and BIC=9947), and average preference estimates are qualitatively very comparable with those for the mixed logit model. We favor the mixed logit model because a Hausman-McFadden test rejects the IIA null hypothesis assumed for the multinomial logit model (part 1, pre-info: chisq = [131.71, 13.71, 13.77] for exclusion of each of the fish alternatives, and for all three alternatives at the 5% level. Part 2, post-info: χ^2 = [2.23, 17.25, 25.66], such that we reject IIA for exclusion of two of the alternatives at the 5% level). An alternative nested logit model produced very similar results and indicated that Nile perch and tilapia are closer substitutes than dagaa, but the nest parameters were very close to 1 and we therefore concluded that substitution patterns should be relaxed at the individual level. Results can be reproduced from the available R codes.

of parameters to estimate, we estimate a restricted version of the model (Hess and Train, 2017) by restricting covariances to zero in parameter space. This means that WTP will co-vary across attributes. While we cannot test whether this specification is best with respect to goodness of fit, we have no theoretical reason to assume otherwise. Following Meas et al. (2015) and Fonner and Sylvia (2015), we relax this assumption for the health label attributes.

Individual n chooses among alternatives $j \in \mathcal{J}$ in choice situations $t = 1, \ldots, T_n$. The random utility of alternative j for individual n in choice situation t is given by:

$$U_{njt} = x_{njt}\beta_n + \varepsilon_{njt}, \tag{1}$$

where x_{njt} is a vector of observed attributes of alternative j in choice situation t, β_n is a vector of individual-specific taste coefficients (random parameters), and ε_{njt} is an i.i.d. extreme value type I error term. The elements in β_n follow a density function $f(\beta_n \mid \theta)$, where θ is a parameter vector describing the distribution.

Since all or some of the parameters in β_n are random variables, the unconditional mixed probability that individual n chooses alternative j in choice occasion t is obtained by integrating over their joint distribution:

$$P_{njt} = \int \left[\prod_{t=1}^{T_n} \frac{\exp(x_{njt}\beta_n)}{\sum_{k \in \mathcal{J}} \exp(x_{nkt}\beta_n)} \right] f(\beta_n \mid \theta)\, d\beta_n, \tag{2}$$

where $f(\beta_n \mid \theta)$ is the joint distribution of the random coefficients, parameterized by θ.

In our main specification, the utility function is:

$$
\begin{aligned}
U_{njt} = {} & asc_j + \beta_{price} price_{jt} + b_O Order && (3)\\
& + \beta_{tox1} tox1_{jt} + \beta_{tox2} tox2_{jt} + \beta_{FA} FA_{jt} + \beta_{int1} tox1_{jt} FA_{jt} + \beta_{int2} tox2_{jt} FA_{jt} \\
& + \delta_{freshDG,j} fresh_{jt} + \delta_{undersizedNP,j} undersized_{jt} + \delta_{aquacTP,j} aquaculture_{jt} \\
& + \varepsilon_{njt}, && (4)
\end{aligned}
$$

The main effect we are interested in is that of the toxin and PUFA attributes, as well as their linear interactions: β_{tox1} and β_{tox2} measure the effect of the toxin label for stage 1 (where $tox1_{jt}$ is 1 if the label is either yellow or red, and zero otherwise) and stage 2 (where $tox2_{jt}$ is 1 if the label is red, and zero otherwise). We modeled this effect stage-wise, given that the literature finds that with traffic light labels, consumers react particularly strongly to red labels (Balcombe et al., 2010). Parameter β_{FA} measures the effect of the PUFA label, with FA_{jt} coded as 0, 1 or 2 for a one, two, or three star label, respectively. That is, FA_{jt} increases linearly as the label indicates more favorable PUFA content. Modeling the PUFA attribute response as two separate parameters for the change from one to two and the change from two to three stars, analogous to the toxin label, did not improve model fit, and the two parameters were not significantly different, so we present the simpler version here. This means that, within the tested frame of 1-3 stars, consumers' response is roughly linear. Finally, we included two interaction effects, one between the first toxin label stage and the PUFA label, and another between the second toxin label stage and the PUFA label. A zero-estimated interaction coefficient would indicate that toxin and PUFA are perfect substitutes, given our additive utility function. Instead, conditional on finding the hypothesized positive preference for PUFA and negative preference for toxin contamination, a negative interaction effect would indicate that healthy labels are partly complementary (imperfect substitutes). The response to PUFA would be stronger when the toxin contamination risk was lower, and the response to toxin contamination risk would be stronger, when PUFA-content was more favorable. This is novel given that interaction terms are rarely taken into account in stated preference studies over multiple nutrient/ contaminant labels. Important exceptions are Marette et al. (2008) and Hu et al. (2004) who study the effect of the presence of contaminant and nutrient labels on each other.[7]

In both pre- (part 1) and post- (part 2) information samples[8], x_{njt} additionally includes the alternative specific constant asc_j, price, and the three alternative specific attributes. We chose baseline levels to reflect the commodities most traded in the market. Variable $fresh_{jt}$ is 1 if the commodity is fresh (as opposed to dried) dagaa, and zero otherwise. Variable $undersize_{jt}$ is 1 if the commodity is undersized (as opposed to mediumsized) Nile perch, and zero otherwise. Variable $aquaculture_{jt}$ is 1 if the commodity is cage-farmed (as opposed to wild-caught) tilapia, and zero otherwise. In addition, we included the question index to account for question order. The index numbers reach from -3 to 2 in part 1, such that the fourth question in the block of six questions is assigned zero. Likewise, the index numbers

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[7] All of the toxin and PUFA dependent parameters were restricted to zero for the estimation pre-information policy.

[8] To allow for a potentially differing scale effect between the part 1 and part 2 samples, we estimated each sample separately instead of pooling them.DeShazo and Fermo (2002) suggest that the addition of attributes may affect the size of the scale effect, which is an inverse measure of choice consistency or error variance. Choice consistency may improve reflecting that attributes that respondents previously made unobservable assumptions on are now observable. Choice consistency may also decline as higher complexity can adversely affect choice consistency.

reach from -6 to 5 in part 2, such that the seventh question in the block of twelve questions is assigned zero. This means that the alternative specific constants can be interpreted as the preference for each species roughly in the middle of each choice sequence, and the order coefficient controls for potential effects from learning and fatigue as the experiment progressed[9].

The alternative specific constants as well as the main health attribute parameters were modeled using normal distributions across individuals, where we estimated mean μ and standard deviation σ. The price parameter was modeled using a lognormal distribution (Hess and Train, 2017), with μ and σ representing the parameters for the underlying normal distribution. To restrict the number of estimation parameters, we estimated the parameters for alternative specific attributes (δ_{dried}, $\delta_{medsize}$, and δ_{AC}), the order effect, as well as the interaction effects across individuals, as fixed coefficients instead of distributions. That is, we fixed their standard deviations at zero. This choice was supported by goodness-of-fit measures.

To investigate possible systematic co-variation in health attribute preferences across individuals, we estimated an alternative model where the parameters for toxin stage 1, toxin stage 2 and PUFA could correlate, by specifying the coefficients as linear combinations of shared normal draws and estimating weights, which we then used to calculate correlation coefficients. Estimating a full correlation matrix across all parameters is infeasible given the sample size.

We used pseudo-Monte Carlo draws for maximum simulated likelihood estimation, with 2000-6000 draws depending on model complexity. Model selection and goodness-of-fit were assessed using the Bayesian Information

[9] Instead including one binary variable for each question number did not yield substantially better results in terms of model fit, such that we report this simpler design.

Criterion (BIC) and Akaike Information Criterion (AIC), as well as the percentage of correctly predicted observations (PCP).

We then analyze individual heterogeneity. As socioeconomic variables (see Table 4 in Appendix E for summary statistics), we included gross monthly income per household member, gender, education (having at most primary education), age, household size and whether there are children in the household. To account for differential vulnerability to MC and or nutrient demands, we included dummy variables for whether or not there are pregnant or lactating women in the household, household members with a heart condition, or household members with a liver condition. We also included a dummy variable for drinking water source, based on whether their reported water source was Lake Victoria or similar exposed source that might have a higher MC concentration.[10] We also included the number of days of reported illness in the household, relative to household size, as a continuous variable. Finally, we included a dummy variable for whether or not the participant was aware of HABs prior to our information.

We tested inclusion of the variables through their effect on the mean of the normal distributions of the health attribute effects. We included dummy variables as linear shifts, γVar, with γ as the estimated coefficient. We included continuous variables as inverse hyperbolic sine transformations (such as illness), $\gamma\, asinh(Var)$, again with γ as the estimated coefficient. For relative income, we chose instead a multiplicative specification,

$$\mu \left(\frac{Incomeperperson}{MeanIncomeperperson} \right)^{\lambda}, \tag{5}$$

[10] It is unclear, though, whether the alternative municipal water supply is actually lower in MC content, given that the water also usually stems from Lake Victoria and municipal and home-based treatment methods may have limited effects on microcystins in drinking water.

with λ as the estimated coefficient and μ the mean of the respective affected attribute. For income, we additionally included a similarly specified effect on the mean of the price parameter to verify that effects found on the health labels were not confounded with income-induced differential price sensitivity.

We initially ran separate mixed logit models to explore the effects of individual socioeconomic variables on the three health attributes. To assess the robustness of these findings in the context of multiple hypothesis testing, we applied the Benjamini-Hochberg procedure (Benjamini and Hochberg, 1995) to control for false discovery rate, correcting p-values from likelihood ratio tests based on joint significance of effects on the three health attributes. We then subsequently included variables jointly in our model based on corrected p-values, again using likelihood ratio tests and BIC to establish whether inclusion of further variables improved the model.

3.3 Data collection

During data collection, we randomly approached consumers at fish markets where all selected fish species are continuously on offer. We sampled from six markets, with sampling shares reflecting market size differences: Mbita (15.2%), Pier (22.4%) and Rodi (13.2%) in Homa Bay county and Dunga (17.7%), Kondele (17.4%) and Riat (14.2%) in Kisumu county. Conducting the study in a market setting ensures that respondents are in a purchasing mindset, enhancing the realism of the experiment, and simplified sampling of fish consuming participants. Respondents were offered a small lump sum financial compensation of 800 KSh as token of appreciation for their participation. Each respondent was interviewed by a trained enumerator using a tablet-based survey. The survey was available in English and two local languages (Dholuo and Kiswahili) to ensure accessibility. To maintain privacy, we offered to do the interview in private, for example in office spaces on site, and made sure that third parties could not overhear responses. In case an approached subject chose not to participate, we recorded the observed gender and approximate age in order to assess sample representativeness.[11]

The survey began with screening and general fish consumption questions to ease respondents into the process. Participants then completed the first part of the choice experiment, before receiving the information followed by two comprehension questions regarding the two newly introduced labels, which nearly all respondents were able to answer correctly, indicating that they comprehended well the information. The survey then proceeded to a second set of 12 choice cards that incorporated the MC and PUFA attributes. Afterwards, the survey concluded with a set of questions regarding socio-economics, health, fish consumption, and participants' perceptions regarding HABs

4 Results

4.1 Descriptive statistics

Of a total of 402 participants, 60% were female, the mean age was 33 years and 51% of the sample has at most secondary education, whereas 13% has at most primary education. Average household size, measured as

[11] In total, 46 participants, or 10% of the overall sample, refused to participate. Chi-square tests indicated no significant differences in age class or gender between participants and those that refused to participate.

the people that usually join together for meals, was 4.4 persons[12] and 72% of households included children below the age of 14, for an average share of children in the household, calculated as the number of children under 14 years of age divided by household size, of 30%. The average household earns 47,906 KSh of monthly income, equivalent to USD 369, but with a high standard deviation of 71,368 KSh. Household income includes fishing income for 14% of households.[13]

On average, 44% of households had consumed dagaa in the past seven days, compared with 39% for Nile Perch and 63% for tilapia, whereas 7% had not consumed any fish in the past seven days. Dagaa was consumed on average on 0.97 days during the past seven days, Nile perch on 0.78 days and tilapia on 1.32 days. Considering only those households that consumed the species, dagaa was consumed on average on 2.23, Nile perch on 2.03 days and tilapia on 2.09 days of the past week. Two thirds (67%) of respondents came to the market with the intention to buy fish on the day of the experiment. Relative to fish consumption frequency in other nations in sub-Saharan Africa (Robinson et al., 2025), our sample are frequent fish consumers, and thus purchasers.

Of the respondents, 65% stated that they were aware of HABs and more importantly, 44% of the respondents were aware of HAB implications, reporting, for example, that the water looks (86%) or smells (75 %) differently. A 14% share of households get their drinking water either from Lake Victoria directly (11%) or from streams or ponds (3%).

Pre-information treatment, respondents chose dagaa in 23%, Nile perch

[12] Average household size based upon the average number of people who usually live in the household was 4.5.

[13] Data on income is missing for 5% of the observations.

in 37% and tilapia in 38% of choice tasks. We also observed only 2% opt outs. Post-information treatment, those shares changed to 23%, 27%, 32% and 18%, respectively. Given the orthogonal design, this may mean that the information treatment and the inclusion of the health label attributes reduced consumer's overall utility from fish consumption, leading to a much higher share of opt outs. In particular, consumers chose a lower share of the higher priced options - tilapia and Nile perch. It could, however, also or alternatively reflect respondent fatigue, for which we control statistically with the order variable.

4.2 Preferences for fish consumption

	Pre-information		Post-information		Post-inf., incl. correl.	
Variable	Est	SE	Est	SE	Est	SE
asc DG (mean)	6.69***	0.58	1.92***	0.20	1.93***	0.20
asc DG (std. dev.)	1.10***	0.18	0.78***	0.12	0.83***	0.13
asc NP (mean)	7.29***	0.60	2.33***	0.19	2.38***	0.19
asc NP (std. dev.)	1.00***	0.16	0.83***	0.09	0.86***	0.09
asc TP (mean)	7.97***	0.61	2.71***	0.19	2.74***	0.19
asc TP (std. dev.)	1.64***	0.16	1.03***	0.11	1.01***	0.12
price (log mean)	-0.43***	0.08	-1.60***	0.13	-1.61***	0.13
price (log std. dev.)	0.60***	0.07	1.02***	0.08	1.02***	0.10
fresh (mean)	0.23*	0.14	0.20*	0.12	0.20*	0.12
aquaculture (mean)	-0.61***	0.13	-0.18**	0.09	-0.19**	0.09
undersized (mean)	0.04	0.10	-0.30***	0.09	-0.30***	0.10
Order (mean)	-0.01	0.11	-0.13***	0.02	-0.13***	0.02
Toxin, green to yellow (mean)			-1.13***	0.13	-1.25***	0.14
Toxin, green to yellow (std. dev.)			1.68***	0.12	1.76***	0.12
Toxin, yellow to red (mean)			-3.43***	0.28	-4.02***	0.31
Toxin, yellow to red (std. dev.)			1.85***	0.18	1.72***	0.24
PUFA, per step (mean)			1.38***	0.09	1.46***	0.10
PUFA, per step (std. dev.)			0.68***	0.08	0.74***	0.07
interact. PUFA-Toxin (green to yellow) (mean)			-0.50***	0.10	-0.50***	0.10
interact. PUFA-Toxin (yellow to red) (mean)			-0.34***	0.14	0.02	0.16
corr. coeff FA Toxin1					-0.31***	0.09
corr. coeff FA Toxin2					-0.50***	0.11
corr. coeff Toxin1 Toxin2					0.18*	0.12
BIC	4520.18		8615.93		8595.89	
PCP	0.52		0.59		0.58	

Table 1: Parameter Estimates Mixed logit model

Notes. The table shows parameter estimates and robust standard errors for the sample pre information treatment (Part 1), post information treatment (Part 2) and post information treatment with additional inclusion of parameters to estimate covariance among the health attribute parameters per equation 4. For random parameters, the table reports means standard deviations of the normal distribution. The lognormally distributed price parameter is described by the mean and standard deviation of the underlying normal distribution. Apollo computes Hubert-sandwich-standard errors, clustered by participant to correct for the panel nature of the data (Hess and Palma, 2025). DG=dagaa, NP=Nile perch, TP=tilapia, asc=alternative specific constant, corr. coeff.= correlation coefficient, BIC=Bayesian information criterion, PCP= percent correctly predicted.

Pre-treatment results (Table 1) show positive alternative specific constants for the baseline alternatives. Wild-caught tilapia is valued most, followed by medium-sized Nile perch and dried dagaa. Variation is substantial as indicated by significant estimates of the standard deviations (σ), but overall >99% of the participants have a positive preference for all three species. This means that, if the fish would cost nothing, nearly all participants would prefer to have the fish instead of not having the fish, as is to be expected. Respondents prefer wild-caught tilapia over cage-farmed. We furthermore find a positive, though only marginally significant, effect of fresh instead of dried dagaa. Interestingly, we do not find a significant effect for under-sized instead of medium-sized Nile perch pre-information treatment, but a significant negative effect for under-sized Nile perch post-information treatment. Question order has a significant negative effect only post-information treatment.

After the information treatment (Table 1), participants show the expected negative preference for MC and positive preference for PUFA. Due to the interaction effect, the main effects must be interpreted conditional on the respective other health attribute being 0, i.e., a green toxin label or a 1 star PUFA label. Comparing estimates for Toxin1 and Toxin2 reveals that the response to the toxin label is highly non-linear, and that respondents' reaction is stronger for a change from a yellow to a red label than the change from a green to a yellow label. According to the estimated normal distributions, 75% of participants experience disutility going from a green to a yellow toxin label (Toxin1), and 97% experience disutility going from a yellow to a red toxin label (Toxin2). This is in line with the literature finding that for traffic light labels, consumers react more to extreme label values than to intermediate values (Balcombe et al., 2010; Crosetto et al., 2019). Estimated normal distributions further show that 98% of respondents experience utility moving towards higher PUFA labels, i.e. 2 stars instead of 1 star or 3 instead of 2 stars.

We can compare the strength of consumers' reaction to the toxin label versus the PUFA label by means of the ratio of marginal effect sizes, i.e., the marginal rate of substitution (MRS). The average consumer would require 0.82 more units of the PUFA label to make up for the change from a green to a yellow toxin label when PUFA was formerly at 1 star. Given consumers' greater sensitivity to the red toxin label, the corresponding MRS of 2.5 implies that the PUFA label plays nearly no role for consumers when faced with a red label, which consumers avoid almost completely. Consumers may decide to focus on toxin avoidance, since they have no clear strategy to compensate for toxin once ingested, while they could compensate for low PUFA through other PUFA sources in their diets.

Both interaction effects between MC and PUFA labels are negative and significant. Thus, the two labels tend to reinforce each other. For example, the positive response to the PUFA label is lower if the product has a yellow instead of a green toxin label. The average consumer's MRS for the change from a green to a yellow toxin label increases from 0.82, for a 1 star PUFA label, to 1.49 if the PUFA label was already at its 2-star-level. We conclude that high shares of PUFA and low toxin are non-separable, imperfect substitutes.

In order to account for potential preference heterogeneity and correlation between unobserved taste components, we next include correlations between the main health label coefficients (Table 1, Part 2, rightmost two columns, and Figure 4 in Appendix D). Unsurprisingly, respondents who are willing to pay more to avoid the switch from the green to the yellow toxin label would also pay more to avoid the switch from a yellow to the red label. Moreover, we estimate a negative correlation between the preference parameter for PUFA and each of the preference parameters for MC toxin (-0.31 (green to yellow) and -0.50 (yellow to red)). Given the opposite signs of the main effects, this suggests that individuals who placed greater importance on avoiding food contamination tended to also value higher shares of PUFA in fish more. This relationship is stronger for the yellow-to-red toxin labels switch than for the green-to-yellow one. This pattern is consistent with the notion of individuals overall being either more or less interested in food's health attributes. It is inconsistent with the hypothesis that consumers use heuristics to make sense of multiple labels by focusing only on one of the two labels. Notably, when including these correlations, the interaction term between Toxin2 and the PUFA label is no longer significantly different from zero. It is still negative and significant for Toxin1 and PUFA. We do not observe meaningful changes in the other estimated parameters.

Correlation coefficients and interaction terms suggests that there are two channels by which low contamination and healthy high shares of PUFA in total fat are somewhat complementary. First, favorable values in one label strengthen WTP for favorable values of the other label, in other words, the two attributes are imperfect substitutes. Second, participants' with a strong preference for one health attribute tend to also have a stronger preference for the other. In the next section, we analyze whether some of this correlation is systematic and can be explained by consumer-level observables.

We computed the percentage of correctly predicted (PCP) observations as the share of observations where the alternative with the largest predicted probability coincides with the respondent's choice. Our models correctly predict 52-59% of observations, which illustrates that the models have substantial predictive power, as a random assignment would be expected to achieve only 25% correct predictions.

Our results are robust regarding respondent comprehension checks, inclusion of market-specific constants, and inclusion of the PUFA attribute stagewise, as two separate parameters for the change from one to two and the change from two to three stars (Appendix G).

4.3 Willingness to pay for fish products

We next report results in form of quantiles of the WTP distributions, as WTP is comparable across samples[14] (Table 2). WTP for an attribute is the monetary value a consumer would be willing to pay more for the product with that attribute relative to a product without that attribute, all else equal. We report median as well as 2.5th and 97.5th quantiles to describe these distributions which exhibit long tails, owing to dividing parameters estimated with a normal distribution by the log-normally distributed price parameter.

Median WTP for baseline products — 875 KSh/kg for dried dagaa, 1,083 KSh/ kg for medium sized Nile perch and 1,246 KSh/ kg for wild caught tilapia— is far higher than average prices, that generally lie around 300-450

[14] This is not true for parameter results, as those are identified only up to an overall scale effect, which may differ across samples due to complexity and due to inclusion of additional attributes(DeShazo and Fermo, 2002; Swait and Louviere, 1993). This is not an issue in WTP-space, where the scale parameter cancels out.

KSh/kg (see Appendix B). This is likely attributable partly to consumer surplus, but perhaps partly due to hypothetical bias, where participants opt out less often than they would if they actually had to spend the sum for an actual purchase. Wild caught tilapia has a somewhat higher WTP than medium-sized Nile perch, which corresponds well with relative observed market prices.

	Pre-information			Post-information			Post-information, incl. corr.			pre-inf. - post-inf.	
Quantile	0.025	0.5	0.975	0.025	0.5	0.975	0.025	0.5	0.975	0.025	0.975
DG	2.98	10.12	34.13	0.70	8.75	18.55	0.59	8.85	18.98	-71.27	32.38
NP	3.31	11.08	36.92	1.09	10.83	22.59	1.10	11.17	23.45	-85.83	34.95
TP	3.39	11.98	41.33	1.15	12.46	26.19	1.22	12.83	26.96	-100.55	38.72
fresh (DG)	0.11	0.35	1.13	0.14	0.99	1.97	0.14	1.02	2.03	-7.20	1.00
under-sized (NP)	0.02	0.05	0.18	-11.03	-1.50	-0.76	-11.24	-1.51	-0.76	0.38	11.05
aquaculture (TP)	-3.04	-0.94	-0.29	-6.60	-0.90	-0.45	-7.10	-0.95	-0.48	-2.92	6.31
Order	-0.06	-0.02	-0.01	-4.55	-0.62	-0.31	-4.76	-0.64	-0.32	0.02	4.55
Toxin, green to yellow				-69.11	-4.02	0.02	-75.38	-4.53	-0.19		
Toxin, yellow to red				-141.45	-14.91	-6.27	-166.72	-17.99	-7.82		
PUFA				0.10	6.09	13.31	-0.24	6.45	14.37		
interact PUFA-Toxin (green to yellow)				-18.29	-2.49	-1.25	-18.83	-2.53	-1.27		
interact PUFA-Toxin (yellow to red)				-12.51	-1.70	-0.86	0.01	0.08	0.17		

Table 2: WTP Estimates (in 100 KSh per kg)

Notes. The table shows 2.5%, 50% and 97.5% quantiles of estimated WTP distributions. All results reported assuming toxin at green level, and PUFA at 1 star level, and order as 0 (i.e. midpoint of the experiment), unless otherwise reported. The first three rows detail the alternative specific willingness to pay for dagaa (DG), Nile perch (NP), and tilapia (TP), respectively. The following three rows detail the willingness to pay for alternative specific attributes, namely fresh (versus dried) dagaa, under-sized (versus medium) sized Nile perch, and aquacultured (versus wild capture) tilapia. *Order* is the change in willingness to pay based on the number of the choice questions (coded as ranging from -3 to 2 for part 1 and -6 to 5 for part 2), which is modeled as a shift in the three alternative specific constants, uniform across fish species. *Toxin* and *Toxin* is the willingness to pay to avoid a higher level of toxin. *PUFA* is the willingness to pay for an additional step in the PUFA label (1-3 stars).

The median participant is willing to pay 402 KSh per kg less for fish with a yellow toxin label compared to a green labeled alternative, a 32-46% markdown. Consumers' WTP is reduced by 1,460 KSh per kg of fish for a red instead of a yellow label, essentially indicating that most participants would rather not buy any fish than buy a red-toxin-labeled fish.

The hypothetical PUFA label increased baseline WTP by 609 KSh (49-70%) per step of the label, where one step could represent for example a shift from a fish product with average relative PUFA level (2 stars) towards fish products found in the upper margin of unsaturated fat ratios (3 stars). WTP results show substantial uncertainty, which is unsurprising given that they are computed as the ratio of two random variables.

The negative interaction effect between the PUFA attribute and preferences for the toxin label changing from green to yellow is economically significant at about 249 KSh per kg of fish and per label step, 20-28% of alternative-specific WTP. The interaction effect for the yellow-to-red toxin switch is negative but not robust to the inclusion of correlation among health attribute preferences, in line with parameter results.

We report the 2.5th and 97.5th quantiles of the difference in WTP between part 1 (pre-information) and part 2 (post-information) (without correlations) in the rightmost column in Table 2 to highlight significant differences between our samples pre- and post-information policy. We do not observe a strong overall deterrence effect of the information script in the alternative specific WTP, where intervals overlap 0, indicating that if all products were labeled green for low toxin and one star for low PUFA, we would not observe a significant change due to the information given. This is consistent with Uchida et al. (2017) who did not find spillover effects of information provision on overall fish consumption, whereas Shimshack and Ward (2010) did find spillover effects lowering overall fish consumption. Our non-result could be driven either by a balancing of positive and negative health messages, or signal that there are no spillovers.

A significant change is observable, though, for the Nile-perch-specific attribute "under-sized", indicating a shift from under-sized towards medium-sized Nile perch post-information policy. We hypothesize that the information script may remind consumers of further nutritional aspects, which they do not see as covered by the labels.[15] The only other significant

[15] An alternative explanation is that some consumers previously incorporated notions about MC toxin/ PUFA into their decisions, which they no longer incorporate after the two labels are introduced because the labels relieve them of the need to rely on their own assessment. For example, the higher WTP for medium- versus under-sized Nile perch after

change between pre- and post-information policy concerns choice task order: Post-treatment, WTP for the baseline products decreases over the course of the experiment.

The non-linearity in toxin preferences is apparent in the 1-star-line (lowest PUFA level) in Figure 1. For better PUFA levels (two or three stars), utility and WTP is higher. The PUFA preference may outweigh the preference to avoid toxin contamination at medium risk (yellow), but not for high contamination risk, as evident from the negative aggregate utility/ WTP. The positive PUFA effect is visibly reduced when the toxin label indicates medium risk (yellow label), due to the interaction effect, as visible in the vertical distance of the three lines. For a high risk (red) toxin label, the interaction effect is too small to alter results visibly, the dominant effect here is toxin avoidance.

4.4 Individual heterogeneity

We find systematic individual heterogeneity in the main effect size of the two health attributes, MC toxin and PUFA labels, with regard to income, education, and awareness of HABs (see Appendix F, Table 5).[16] Higher

the information treatment suggests that at least some consumers considered under-sized Nile perch a systematically better choice due to either PUFA or toxin concerns.

[16] Following the pre-analysis plan, we also tested for effects of age, gender, having children/ the share of children in the household, higher MC exposure due to drinking water source or liver health conditions in the household, stronger PUFA concerns due to pregnant/lactating women or heart health conditions in the household, and general illness in the household. These variables were excluded based on likelihood ratio tests corrected for multiple hypothesis testing by use of the Benjamini-Hochberg procedure (Benjamini and Hochberg, 1995), and subsequent one-by-one expansion of the model with further socio-economic variables until likelihood ratio tests and BIC indicated that no further improvement of the model was achieved. Moreover, none of these variables showed significant parameter effects separately for the toxin and PUFA attributes in singular testing, indicating that even if they might be jointly significant, that effect was not pronounced enough to be able to disentangle differential effects on the separate health attributes.

income is associated with a stronger toxin label response, but the response is small. For respondents with income 25% above the mean income, median WTP to avoid a change from a green to a yellow label is only 2% higher than that of the mean income respondent. For a respondent with income 25% below the mean income, WTP to avoid a change from a green to a yellow label is reduced by just 3%. We find no systematic significant effect of income on the price response, the yellow-to-red toxin response, nor the PUFA label response.

While heterogeneity by income is modest, that with respect to educational attainment (specifically, having more than secondary education) and awareness of HABs is quite strong, especially to avoid fish carrying the red toxin label (Figure 2). Only 90% of those without higher education show a negative response to the change from a yellow to a red toxin label, compared with 96% of those with higher education. Among respondents unaware of HABs pre-information treatment, 90% show a negative response to the change from a yellow to a red toxin label, compared with 97% with prior HAB awareness. Both the higher education and HAB awareness differences are statistically significant. This is interesting since, even though HABs were not mentioned in the information treatment as the process that mediates toxin contamination, consumers who are aware of HABs either explicitly or inadvertently make this connection. Median WTP to avoid that change is 50% higher on average in absolute terms for respondents with higher education than for respondents without higher education. Awareness of HABs increases average WTP to avoid that change by 64%. The rightmost graph shows that heterogeneity in higher education and HAB awareness is complementary, as the overlap between the two distributions is substantially reduced as compared to either of the other two panels.

We can confirm first-order stochastic dominance, in other words that education and HAB awareness leads to a distributional shift across the population, raising toxin aversion for every individual ceteris paribus. Graphically, the cumulative distribution function for educated/ HAB aware populations lies strictly above that for populations without higher education or HAB awareness. Test statistics for a formal one-sided Kolmogorov-Smirnov test yielded $D^+ = 0.196$ for higher education, $D^+ = 0.248$ for HAB awareness, and $D^+ = 0.429$ for combined HAB awareness and higher education, all of which let us reject the null hypothesis of no first-order stochastic dominance at the 1% level.

The main effects for both health labels, as well as the interaction effects remain robust. The effect of the toxin label is negative for nearly the whole sample, and the effect of the PUFA label is positive for nearly the whole sample, despite individual heterogeneity in effect sizes.

These results suggest that systematic information about MC contamination risk would lead to a particularly strong avoidance reaction by higher-income, more educated households. The effectiveness of the label is mediated by prior awareness of HABs. We hypothesize that awareness increases the salience of the red label, albeit it curiously does not affect the reaction to the change from a green to a yellow MC toxin label. Moreover, the group of people unaware of HABs likely consists in part of people who might have heard about HABs previously, but did not care enough to retain that information, and this low level of caring is reflected in the low effect size. Only HAB awareness can to some degree explain the previously established covariance between MC toxin and PUFA label responses, since we did not identify any other explanatory variable that simultaneously affects both health label responses. We do not find nuanced decision making among more or less vulnerable consumer groups, such as households with children, pregnant or lactating women, or water source.

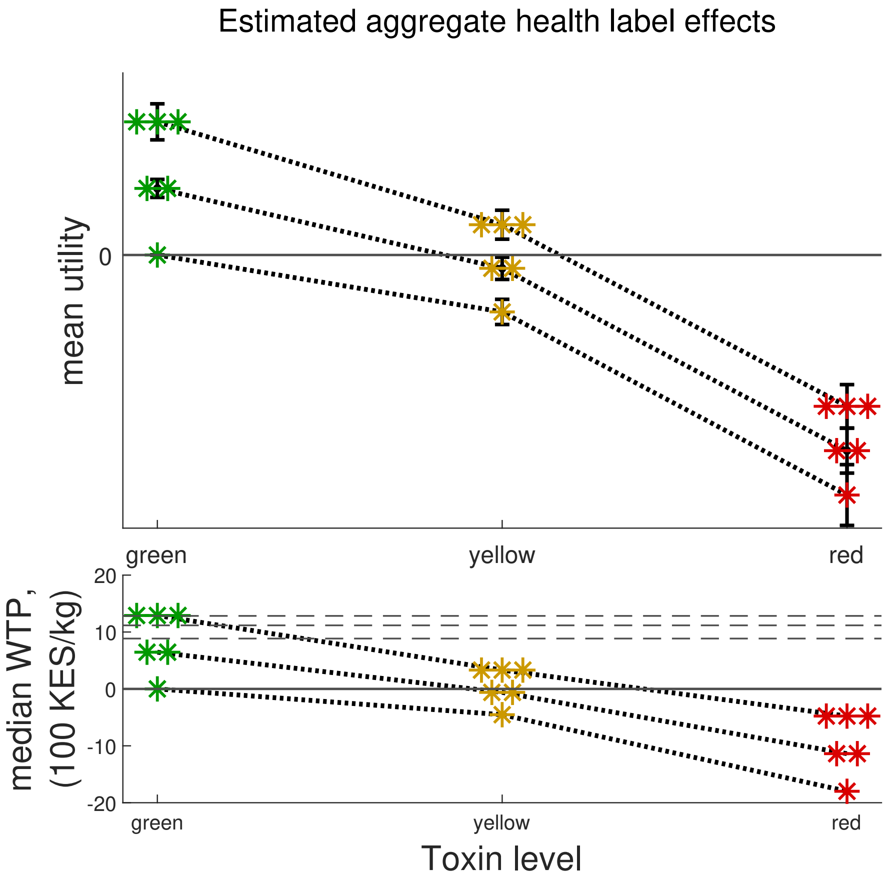

Figure 1: Graph visualizing the aggregate impact of health labels (sum over effects from the two health attributes, PUFA and MC toxin, and their interaction effect). Colors visualize the toxin label level (traffic light), and the number of stars visualizes the PUFA label level (1-3 stars). Upper panel: in utility space at the mean over participants, according to equation (4), based on estimates in the rightmost two columns of Table 1. Whiskers show the 95% confidence interval based on Apollo's delta method computation and robust standard errors. Lower panel: corresponding values in WTP space at the median over participants as shown in Table 2. Estimated baseline WTP for the three species, for comparison, is 8.85KSh/kg for dagaa, 11.17 KSh/kg for Nile perch and 12.83KSh/kg for tilapia, visualized for orientation as dashed horizontal lines. Not showing error bars for better visibility, given the wide amplitudes resulting from computing ratios of two random variables (cf. Table 2).

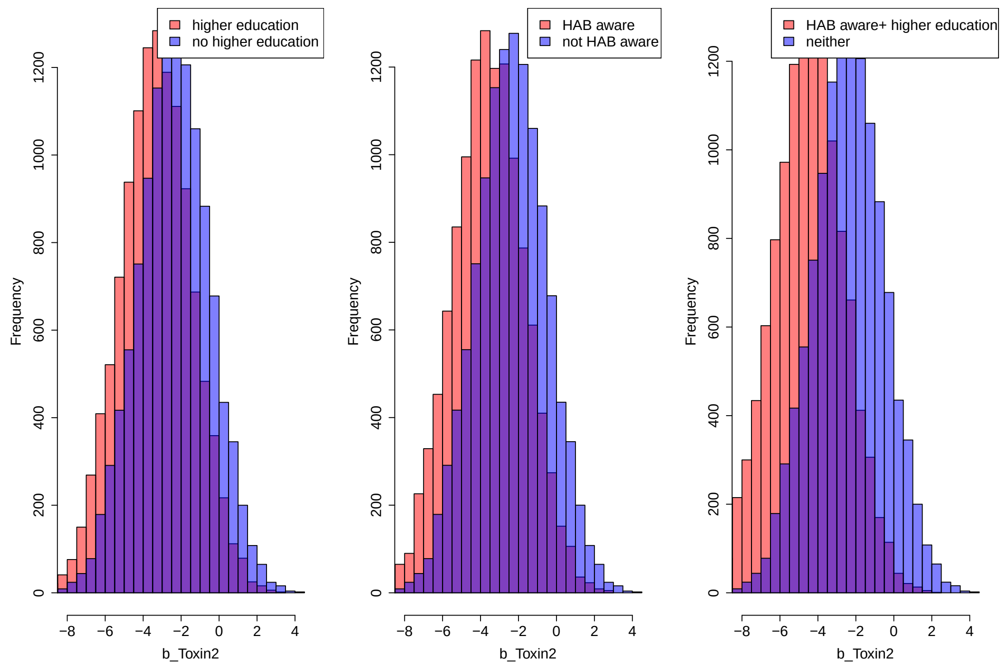

Figure 2: The graph shows the estimated parameter distributions quantifying the response of respondents to a change from the yellow to a red toxin label, separately for samples with and without higher education (left), with and without HAB awareness (middle), and with higher education and HAB awareness versus neither (right).

5 Policy implications

Despite their relatively low incomes, Kenyan consumers in markets near Lake Victoria place significant value on both the nutritional quality and safety of fish. They significantly favor fish labelled as containing a higher concentration of healthy fatty acids (PUFA) and strongly avoid products labeled as MC contaminated. Red toxin warning labels nearly fully curb demand. Faced with a trade-off of a cautionary yellow toxin label against different PUFA-benefits, however, consumers exhibit willingness to trade-off contaminants against nutritional benefits instead of fully abandoning fish with less-than-ideal health attributes. Estimated effect sizes are a bit higher than the 30% mean price premium for healthier food found in a recent review (Alsubhi et al., 2023), and substantially higher than estimated markups of 14% for non-genetically modified maize meal in Nairobi (Kimenju and De Groote, 2008) or 19% for an organic label in West African cities (Probst et al., 2012). The relatively large estimated effect sizes we find may partly reflect hypothetical bias due to the nature of the experiment. But this ordering also conforms with the relative strength of the scientific evidence on (un)healthful food attributes; MC is clearly harmful and PUFA clearly beneficial, while the relative healthfulness of non-GM or organic food remains, at best, uncertain (Smith-Spangler et al., 2012; of Sciences and Medicin, 2016).

Preferences for nutrients and contamination avoidance are interdependent. Consumers value each attribute more when the other attribute is favorable, making them imperfect substitutes. This is inconsistent with the hypothesis of compensatory health beliefs, whereby a consumer use healthy behaviors to compensate for unhealthy ones (Rabia et al., 2006), but instead consistent with the hypothesis of rational, composite decision-making. Since good overall health requires attention both towards nutrients supporting heart health and towards avoiding contaminants that cause, for example, liver and neural damage, it is rational to not fully trade-off either attribute against the other.

These results have clear policy implications. If the relative implied price premium for PUFA versus toxin reduction increases, say if options to reduce toxin risks suddenly became substantially cheaper relative to options to increase PUFA, this would temper changes in consumption that might inadvertently reduce dietary intake of PUFAs. If preferences did not interact, such a change might induce strong consumer switching to low toxin, low PUFA options. From a health perspective, this is a good thing, given likely diminishing marginal gains to healthful attributes. Further, this implies that multi-attribute labels could be mutually reinforcing rather than leading to consumer information overload that cancels out the independent effects of each label.

Preferences are also interdependent across individuals. Consumers who value either of the attributes more strongly also value the other attribute more strongly, and vice versa. This contradicts the attention heuristics hypothesis, which holds that consumers get overwhelmed by information on multiple health attributes and therefore tend to focus their attention on only one attribute, neglecting the other. It rather suggests that consumers prefer healthy food and synthesize multiple information sources from labels. This cautions against policies that promote single attribute labeling, assuming consumers cannot or will not effectively weigh the tradeoffs among distinct food attributes.

The fact that different people respond differently to label attributes raises two concerns. First, information policy might concentrate health risks among relatively non-reactive consumer subgroups, a group characterized by lower education, income, and HAB awareness. Higher income, more educated households' higher toxin sensitivity means they would be more likely to respond to effective toxin labeling by switching to healthier alternatives. If this effect is large enough to reduce aggregate demand and thereby market prices for less healthy fish products, toxin labeling might inadvertently induce lower income, less educated households to consume more unhealthy products, thereby concentrating toxin risk among households with less adaptation capacity and more nutrient-poor and contaminant-rich diets, for example, due to domestic water sources.

Second, after controlling for education, income and HAB awareness, we find no heterogeneity in label response with respect to vulnerability, such as prior health conditions or having children in the household. This is a concern because labels necessarily convey a population-average trade-off, not adapted to individual vulnerability. For example, contaminant warnings appropriate for vulnerable children might unduly shift the risk-benefit-tradeoff for adult men. If the studies used to design the standards that inform labeling are run primarily among adult men, perhaps the greater risk is that labels may mislead on risk-return health and nutrition tradeoffs for subpopulations at greater risk, e.g., children, pregnant or lactating women, those with compromised immune systems. Information policies must carefully consider such demographic heterogeneity in label design.

Labeling individual fish to inform consumers is infeasible in the coming few years. But researchers are actively working to link PUFA value and MC contamination risk systematically to observable fish traits, such as species. Our findings suggest that if such research succeeds, it might enable reliable reporting through labels or similar information policies to which consumers seem to respond reasonably rationally to advance their own health.

Our results also suggest that reducing environmental pollution and thereby lowering contamination risk would substantially increase consumer welfare, in particular for commodities that are rich in PUFA. A better understanding of consumer behavior could enhance fisheries resource management (Aura et al., 2019; Dube et al., 2025; Lancker and Bronnmann, 2022) by improving valuation methods, which currently assume no consumer response to contaminants.

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Appendix

A Scripts

The following script was read to study participants before the start of the choice experiment (for the full questionnaire, please see Appendix H): "I would now like to ask you a series of choice questions. In each question, you can choose between four options: You can buy dagaa, Nile perch, tilapia, or none of those. In each task, the alternatives differ in their characteristics and their prices. I would like you to choose the alternative that you, on a normal day, would most likely buy for your household. Think about a quantity that would be suitable for one meal for your household. Apart from the description given, please think about a typical purchase of that type of fish. If in any of the questions you think that your household would be best off buying none of the species, you can select "None". Please also assume that all of the varieties are readily available here on the market, even if right now is for example not the season for certain types. Please examine carefully each option before you make a decision, and please respond to each choice question as if it were a real buying decision, where you give up real money to purchase goods. The results of this studies are meant to inform food and health policies in the long run, and our study relies on collecting data here with you that best represents your actual buying decision. Thus, it is very important that you answer each question attentively and truthfully."

Information script The following script was read to study participants, after answering the six choice questions in part 1 and before answering 12 choice questions in part 2 of the choice experiment: "Fish are an excellent source of important nutrients that are good for our health. Yet people often don't consume enough of these nutrients. In particular, fish provide healthy unsaturated fat, which can reduce heart problems and improve children's development. It is recommended to have unsaturated fat, as one finds in fish or in liquid oils from plants, instead of unhealthy fat, called saturated fat.

However, fish can take up toxins from the environment, such as a toxin called "microcystin", which can cause liver damage and tumors. This toxin is found in freshwater lakes, such as Lake Victoria. Studies find that guideline values of both adults and children are exceeded in many households. Toxin exposure can occur through different channels, such as drinking water or contact with the Lake water. Fish may also contain the microcystin toxin, and thus add to your exposure. It is therefore recommendable to avoid fish that has high levels of toxin.

Studies are now being conducted to quantify both shares of PUFA, and risk from microcystin, such that consumers can be informed adequately on different fish products. Please imagine that this data was already available. Imagine that the information was given to you in the following form: For microcystin, a red light signifies that the option is unhealthy: the World Health Organization considers regular consumption of such a product as dangerous for adults. A yellow light a medium level of risk, and a green light indicates a low risk, lower than the guideline value even for vulnerable people, such as children.

For fatty acids, a single star signifies that the option is unhealthier than the World Health Organization recommends for adults: a too small share of the product's fat content consists of healthy, unsaturated fat. Two stars indicate a medium level of healthiness that you would find in many fish species, and three stars indicate that this is one of the healthiest options that you could choose.[17]

To summarize, the healthiest choices would be labeled in green for the toxin and three stars for the fatty acids. The unhealthiest choice would be labeled with one star for fatty acids and red for the toxin."

Guideline values and information on health benefits of PUFA are based on FAO (2010). Exposure levels, health implications, and MC guidelines are based on Chen et al. (2009); Codd et al. (2005); Massey et al. (2018); Mello et al. (2018); Nyakairu et al. (2010); Olokotum et al. (2022); Poste et al. (2011); Roegner et al. (2020), and WHO (2020).

B Overview of prices for fish commodities in Kenya

Table 3 reports summary statistics of prices reported in the electronic Catch Assesment Survey (eCAS) and Electronic Fish Market Information System (EFMIS) dataset (Aura et al., 2019) in August-October in the years 2023 and 2024. The markets used to collect this data partly serve for wholesale trade, and are likely a bit lower and a bit less variable than the prices consumers pay. However, they constitute the best available data source as basis for estimating consumer fish prices.

We infer the price differential for caged as opposed to wild caught tilapia from the Aquaculture Business Development Program (ABDP) survey dataset of 101 observations (Kenya Marine and Fisheries Research Institute,

[17] Nutritional parameters are often set as meeting requirements, where exceeding guidelines may not yield further benefits. The actual benefit depends on how the product is embedded in the overall diet.

2024) (mean price of 294 KSh/kg, standard deviation 48 KSh/kg). That translates into a markdown of about 120 KSh/kg (-29%). A price for under-sized as opposed to medium-sized Nile perch can be inferred from older EFMIS data (291 KSh/kg, -20%).

	N	mean	std. dev.	min	max
Dagaa Fresh	26	145	54	120	400
Dagaa Dried	100	410	116	250	643
Nile perch medium size	156	362	30	150	480
Tilapia wild caught	183	414	35	350	480

Table 3: Summary statistics of prices (KSh/kg) for different fish commodities in Kenya, Aug-Oct 2023 and Aug-Oct 2024. Markets: Kisumu, Migori, Gikomba, Eldoret main market, Awendo, Luanda, Kibuye Wholesale. Based on EFMIS data.

C Sample choice task (Part 2)

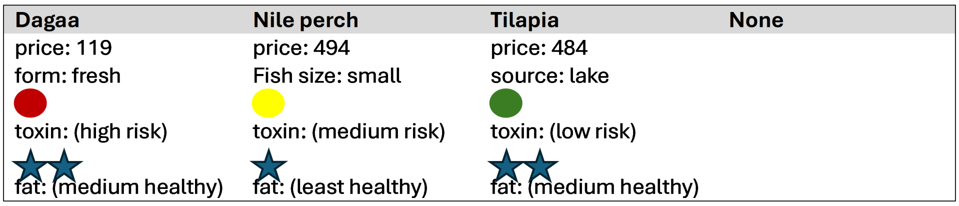

Figure 3: Sample choice task from part 2 (post information treatment)

D Correlation of health attribute parameter estimates

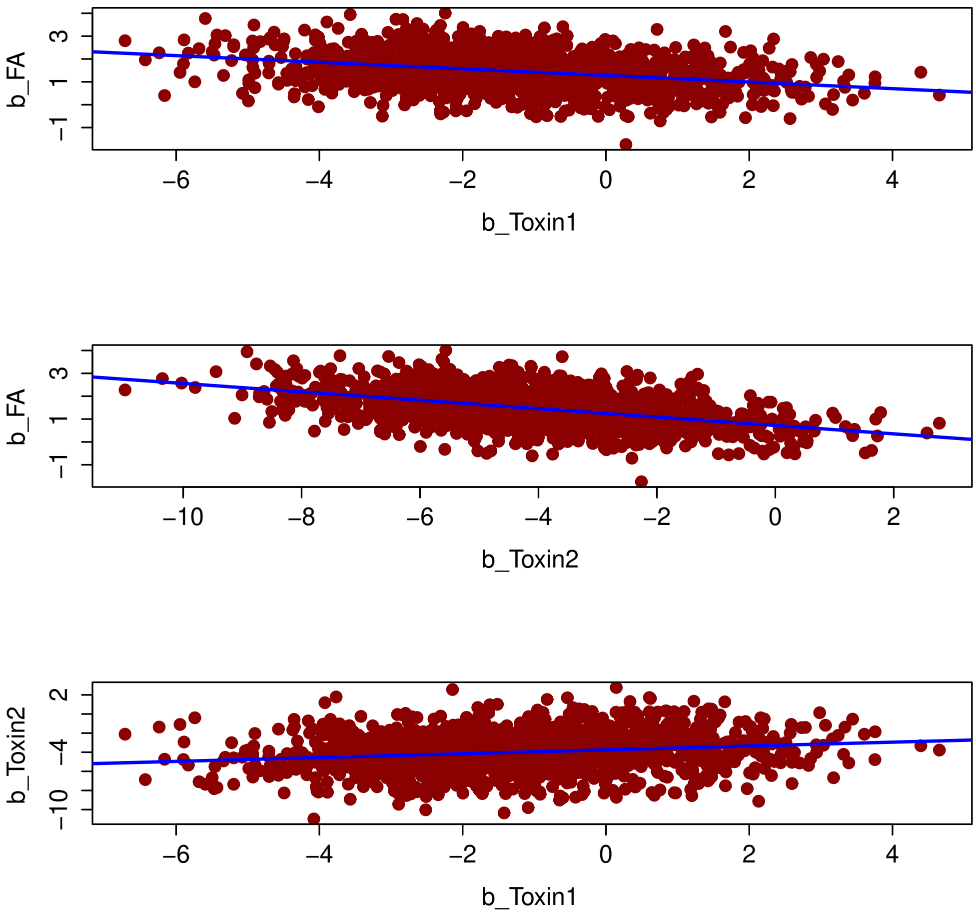

Figure 4: The graph shoes the distribution of health attribute parameter estimates and their correlation, based on Part 2, model with correlation (see Table 1).

E Descriptive statistics of additional variables

Table 4 reports descriptive statistics for variables discussed in section 4.1 and to study individual heterogeneity (section 4.4), as well as further variables used for robustness checks (Appendix G).

	N	Mean	SD	Min	Max
gross monthly HH income p.c. (KSH)	402.00	13594.48	22737.88	61.11	270000.00
higher education	402.00	0.49	0.50	0.00	1.00
gender	402.00	0.60	0.49	0.00	1.00
age	402.00	33.15	10.08	18.00	72.00
HH size	402.00	4.43	2.50	1.00	33.00
kids in household	402.00	0.72	0.45	0.00	1.00
kids share in HH	402.00	0.30	0.24	0.00	1.00
HH drinking water source lake	402.00	0.14	0.34	0.00	1.00
aware of HABs	402.00	0.68	0.46	0.00	1.00
person with heart condition in HH	402.00	0.08	0.27	0.00	1.00
person with liver condition in HH	402.00	0.03	0.18	0.00	1.00
pregnant/ lactating person in HH	402.00	0.22	0.42	0.00	1.00
last month' days of illness/HH member	402.00	0.65	2.18	0.00	30.00
Education: None	402.00	0.00	0.07	0.00	1.00
Education: Some Primary	402.00	0.03	0.16	0.00	1.00
Education: Primary	402.00	0.13	0.33	0.00	1.00
Education: Some Secondary	402.00	0.10	0.30	0.00	1.00
Education: Secondary	402.00	0.25	0.44	0.00	1.00
Education: Some College	402.00	0.03	0.18	0.00	1.00
Education: Certificate	402.00	0.06	0.24	0.00	1.00
Education: Diploma	402.00	0.18	0.38	0.00	1.00
Education: Degree	402.00	0.19	0.40	0.00	1.00
Education: Post Graduate	402.00	0.02	0.15	0.00	1.00
Education: Other	402.00	0.00	0.00	0.00	0.00
Market HB_Mbita	402.00	0.15	0.36	0.00	1.00
Market HB_Pier	402.00	0.22	0.42	0.00	1.00
Market HB_Rodi	402.00	0.13	0.34	0.00	1.00
Market KI_Dunga	402.00	0.18	0.38	0.00	1.00
Market KI_Kondele	402.00	0.17	0.38	0.00	1.00
Market KI_Riat	402.00	0.14	0.35	0.00	1.00
fishing income in HH	402.00	0.14	0.34	0.00	1.00
Days of DG cons. last 7 days	402.00	0.97	1.35	0.00	7.00
Days of NP cons. last 7 days	402.00	0.78	1.21	0.00	7.00
Days of TP cons. last 7 days	402.00	1.32	1.43	0.00	7.00
here to buy fish	402.00	0.67	0.47	0.00	1.00
can read (by interviewer perception)	400.00	0.88	0.32	0.00	1.00

Table 4: Descriptive statistics for socioeconomic, health, and HAB perception variables.

Notes. The table shows descriptives statistics for the variables used in the individual heterogeneity analysis, to support dataset description, or in the robustness section. SD= standard deviation, N=number of non-missing observations, Min=minimum value observed, Max=maximum value observed, HH=household, KI=Kisumu county, HB=Homa Bay county. Gross monthly HH income is the sum over the following income sources in the survey: agriculture, fisheries, small business, support (in cash or in-kind), other. HH size based on the group of people for whom a joint meal would usually be prepared.

Figure 5 visualizes the correlation matrix across variables tested for individual heterogeneity as systematic impacts on health attribute preferences in section 4.4.

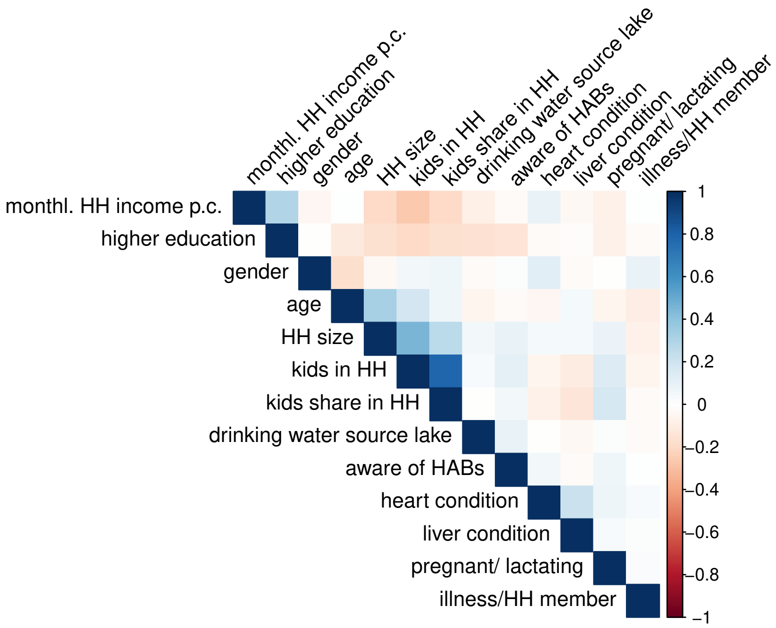

Figure 5: Visualization of the correlation matrix across variables tested for systematic impacts on health attribute preferences

F Individual heterogeneity estimates

Table 5 lists parameter estimates inclusive of potential individual-level heterogeneity. A Likelihood ratio test (p-value=0.000) confirms that there is value in the joint inclusion of the socioeconomic variables compared with the model without socio-economic variables, even though the BIC for this model is somewhat larger than for the model without socio-economic attributes.

	original		incl. socioecs.	
Variable	Est.	SE	Est.	SE
asc DG (mean)	1.92***	0.20	1.97***	0.20
asc DG (std. dev.)	0.78***	0.12	0.81***	0.13
asc NP (mean)	2.33***	0.19	2.39***	0.19
asc NP (std. dev.)	0.83***	0.09	0.86***	0.10
asc TP (mean)	2.71***	0.19	2.75***	0.19
asc TP (std. dev.)	1.03***	0.11	1.06***	0.11
price (log mean)	-1.60***	0.13	-1.52***	0.16
price (log std. dev.)	-1.02***	0.08	1.09***	0.12
fresh (mean)	0.20*	0.12	0.20*	0.12
aquaculture (mean)	-0.18**	0.09	-0.18**	0.09
undersized (mean)	-0.30***	0.09	-0.30***	0.09
Order (mean)	-0.13***	0.02	-0.13***	0.02
Toxin, green to yellow (mean)	-1.13***	0.13	-1.32***	0.24
Toxin, green to yellow (std. dev.)	1.68***	0.12	1.71***	0.11
Toxin, yellow to red (mean)	-3.43***	0.28	-2.42***	0.37
Toxin, yellow to red (std. dev.)	-1.85***	0.18	-1.88***	0.19
PUFA, per step (mean)	1.38***	0.09	1.20***	0.14
PUFA, per step (std. dev.)	0.68***	0.08	0.67***	0.07
interact. PUFA-Toxin (green to yellow) (mean)	-0.50***	0.10	-0.51***	0.10
interact. PUFA-Toxin (yellow to red) (mean)	-0.34***	0.14	-0.31**	0.14
HABaware on Toxin (green to yellow)			0.06	0.22
HABaware on Toxin (yellow to red)			-1.18***	0.30
HABaware on PUFA			0.17	0.12
higher education on Toxin (green to yellow)			0.02	0.23
higher education on Toxin (yellow to red)			-0.92***	0.32
higher education on PUFA			0.16	0.12
income on price			-0.06	0.05
income on Toxin (green to yellow)			0.14*	0.08
income on Toxin (yellow to red)			0.06	0.06
income on PUFA			0.00	0.04
BIC	8615.93		8650.98	
PCP	0.59		0.59	

Table 5: Parameter Estimates Mixed logit model: Individual heterogeneity

Notes. Parameter results and robust standard errors post information treatment. The first model reports reproduces original results for comparison (original), the second model reports heterogeneity results, including income, higher education and HAB awareness. For random parameters, the table reports means and standard deviations of the normal distribution. The lognormally distributed price parameter is described by the mean and standard deviation of the underlying normal distribution. DG=dagaa, NP=Nile perch, TP=tilapia. asc=alternative specific constant. Income is included as a multiplicative impact on the mean of the respective parameter distribution (λ in the specification $\mu \left(\frac{Incomeperperson}{MeanIncomeperperson}\right)^{\lambda}$) (see equation 5). Higher education and HAB awareness effects are modeled as linear shifts of the mean of the parameter distribution. BIC=Bayesian information criterion, PCP= percent correctly predicted.

G Robustness checks

G.1 Stagewise PUFA effect modeling

Here, in contrast to our main specification, we model the response to the PUFA attribute stagewise as two parameters, β_{FA1} and β_{FA2}, that measure the effect of the toxin label for stage 1 (where $FA1_{jt}$ is 1 if the label is either two or three stars, and zero otherwise) and stage 2 (where $FA2_{jt}$ is 1 if the label is three stars, and zero otherwise). This specification is analogous to the specification of the toxin attribute in the main model. The utility function is:

$$
\begin{aligned}
U_{njt} = {} & asc_j + \beta_{tox1} tox1_{jt} + \beta_{tox2} tox2_{jt} + \beta_{FA1} FA1_{jt} + \beta_{FA2} FA2_{jt} \\
& + \beta_{int1} tox1_{jt} FA1_{jt} + \beta_{int2} tox2_{jt} FA1_{jt} + \beta_{int3} tox1_{jt} FA2_{jt} + \beta_{int4} tox2_{jt} FA2_{jt} \\
& + \beta_{price} price_{jt} + \delta_{freshDG,j} fresh_{jt} + \delta_{undersizedNP,j} undersized_{jt} \\
& + \delta_{aquacTP,j} aquaculture_{jt} + b_O Order + \varepsilon_{njt}, \qquad \text{(A.6)}
\end{aligned}
$$

where β_{FA1} and β_{FA2} are estimated as the mean and standard deviations of the normal distributions, in line with the specification in the main model. For simplicity, we run the model with no correlation, which was also shown in the main results (Table 1, central two columns).

Results are shown in Table 6. T-tests fail to reject the null hypothesis that $\beta_{FA1} = \beta_{FA2}$ both for the mean ($p = 0.130$) and the standard deviation ($p = 0.570$). T-tests for equality of the interaction terms do reject the hypotheses that $\beta_{int1} = \beta_{int3}$ ($p = 0.012$) and $\beta_{int2} = \beta_{int4}$ ($p = 0.015$), however, the results confirm a negative interaction effect when both PUFA and toxin attributes are at medium levels (2 stars and yellow) and a significantly increased negative interaction effect when both are at their highest level (3 stars and red) (cf. Table 1). In contrast to the main model results presented, we do not see the interaction effect become larger in absolute terms when either toxin stays at yellow level and PUFA increases to three stars, or when toxin increases to its red level and PUFA remains at two stars, which would however net still trigger the negative interaction effect β_{int1}.

Given that qualitative insights don't change, that all other estimates remain remarkably robust, that neither BIC nor PCP indicate relevant gains in model fit and the much higher complexity of the model with an additional four parameters, we proceed to use the simpler model in the main results.

	Post-information	
Variable	Est	SE
asc DG (mean)	1.82***	0.20
asc DG (std. dev.)	0.86***	0.14
asc NP (mean)	2.25***	0.20
asc NP (std. dev.)	0.89***	0.10
asc TP (mean)	2.62***	0.19
asc TP (std. dev.)	1.00***	0.12
price (log mean)	-1.58***	0.13
price (log std. dev.)	0.92***	0.06
fresh (mean)	0.18	0.12
aquaculture (mean)	-0.18*	0.09
undersized (mean)	-0.30***	0.10
Order (mean)	-0.13***	0.02
Toxin, green to yellow (mean)	-0.89***	0.16
Toxin, green to yellow (std.dev.)	1.70***	0.10
Toxin, yellow to red (mean)	-3.83***	0.32
Toxin, yellow to red (std.dev.)	-1.89***	0.16
PUFA, 1 to 2 stars (mean)	1.71***	0.18
PUFA, 1 to 2 stars (std. dev.)	0.98***	0.19
PUFA, 2 to 3 stars (mean)	1.34***	0.15
PUFA, 2 to 3 stars (std. dev.)	1.10***	0.14
interact. PUFA (1 to 2)-Toxin (green to yellow) (mean)	-1.16***	0.27
interact. PUFA (1 to 2)-Toxin (yellow to red) (mean)	0.26	0.30
interact. PUFA (2 to 3)-Toxin (green to yellow) (mean)	-0.08	0.20
interact. PUFA (2 to 3)-Toxin (yellow to red) (mean)	-1.11***	0.34
BIC		8614.23
PCP		0.58

Table 6: Parameter Estimates Mixed logit model

Notes. The table shows parameter estimates and robust standard errors for the sample post information treatment per equation A.6. For random parameters, the table reports means and standard deviations of the normal distribution. The lognormally distributed price parameter is described by the mean and standard deviation of the underlying normal distribution. Apollo computes Hubert-sandwich-standard errors, clustered by participant to correct for the panel nature of the data (Hess and Palma, 2025). DG=Dagaa, NP=Nile perch, TP=Tilapia, asc=alternative specific constant, BIC=Bayesian information criterion, PCP= percent correctly predicted.

G.2 Markets

To test for important market specific level differences, we run the main models again, allowing for market specific effects to alter the alternative specific constant (Table 7).

Results remain robust, and even though the constants for some markets show a significnat negative constant, signifying a lower alternative specific constant than for baseline market (Kisumu), effects are largely small and neither BIC nor PCP suggest that model fit is improved by including the market constants.

	Pre-inf.		Post-inf.		Post-inf., incl. corr.	
Variable	Est	SE	Est	SE	Est	SE
asc DG (mean)	7.38***	1.11	2.70***	0.45	2.73***	0.45
asc DG (std. dev.)	1.09***	0.19	0.77***	0.11	0.81***	0.12
asc NP (mean)	7.97***	1.12	3.12***	0.45	3.19***	0.45
asc NP (std. dev.)	1.02***	0.15	0.82***	0.09	0.84***	0.09
asc TP (mean)	8.65***	1.13	3.49***	0.44	3.55***	0.45
asc TP (std. dev.)	1.64***	0.17	1.05***	0.11	1.04***	0.12
price (log mean)	-0.43***	0.08	-1.59***	0.13	-1.62***	0.13
price (log std. dev.)	0.61***	0.06	1.04***	0.08	1.04***	0.07
fresh (mean)	0.22	0.14	0.21*	0.12	0.21*	0.12
aquaculture (mean)	-0.61***	0.13	-0.19**	0.09	-0.19**	0.09
undersized (mean)	0.03	0.10	-0.30***	0.09	-0.30***	0.10
Order (mean)	-0.01	0.10	-0.13***	0.02	-0.13***	0.02
Homabay Mbita (constant)	-1.43	1.36	-1.12**	0.57	-1.14**	0.56
Homabay Pier (constant)	-0.53	1.15	-0.66	0.51	-0.680.52	
Homabay Rodi (constant)	0.03	1.41	-1.07*	0.59	-1.08*	0.58
Kisumu Dunga (constant)	-0.67	1.40	-1.41***	0.51	-1.44***	0.52
Kisumu Kondele (constant)	-0.78	1.06	-0.13	0.53	-0.23	0.55
Toxin, green to yellow (mean)			-1.16***	0.13	-1.26***	0.14
Toxin, green to yellow (std.dev.)			1.70***	0.11	1.78***	0.12
Toxin, yellow to red (mean)			-3.47***	0.28	-4.05***	0.31
Toxin, yellow to red (std.dev.)			1.86***	0.19	1.75***	0.24
PUFA, per step (mean)			1.39***	0.10	1.47***	0.10
PUFA, per step (std. dev.)			0.70***	0.08	0.75***	0.07
interact. PUFA-Toxin (green to yellow) (mean)			-0.50***	0.10	-0.50***	0.10
interact. PUFA-Toxin (yellow to red) (mean)			-0.34**	0.14	0.026	0.16
corr. coeff FA Toxin1					-0.30***	0.09
corr. coeff FA Toxin2					-0.50***	0.11
corr. coeff Toxin1 Toxin2					0.16*	0.12
BIC	4556.57		8629.14		8610.86	
PCP	0.52		0.58		0.58	

Table 7: Parameter Estimates Mixed logit model, incl. market effects

Notes. Robustness check with regard to market specific level differences in willingness to pay. The table shows parameter estimates and robust standard errors for the sample pre information treatment (Part 1), post information treatment (Part 2) and post information treatment with additional inclusion of parameters to estimate covariance among the health attribute parameters per equation 4. For random parameters, the table reports means and standard deviations of the normal distribution. The lognormally distributed price parameter is described by the mean and standard deviation of the underlying normal distribution. Apollo computes Hubert-sandwich-standard errors, clustered by participant to correct for the panel nature of the data (Hess and Palma, 2025). DG=Dagaa, NP=Nile perch, TP=Tilapia, asc=alternative specific constant, corr. coeff.= correlation coefficient, BIC=Bayesian information criterion, PCP= percent correctly predicted.

G.3 Comprehension

We first reran the main model for part 2 (post-information script) after dropping 15 observations where respondents had not correctly answered one or both of the test questions after the information script, which may indicate comprehension issues (Table 8). We do not observe relevant qualitative or quantitative differeneces in estimates compared to the main results.

We then re-ran the main models for part 1 (pre-information script) and part 2 (post-information script) after dropping 50 observations where

	Pre-inf.		Post-inf.		Post-inf., incl. corr.	
Variable	Est	SE	Est	SE	Est	SE
asc DG (mean)	6.49***	0.58	1.85***	0.20	1.87***	0.20
asc DG (std. dev.)	0.97***	0.20	0.87***	0.16	0.80***	0.12
asc NP (mean)	7.07***	0.59	2.29***	0.20	2.34***	0.20
asc NP (std. dev.)	1.07***	0.15	0.87***	0.10	0.87***	0.09
asc TP (mean)	7.76***	0.61	2.66***	0.20	2.70***	0.20
asc TP (std. dev.)	-1.65***	0.16	1.07***	0.12	1.07***	0.12
price (log mean)	-0.46***	0.08	-1.69***	0.14	-1.65***	0.13
price (log std. dev.)	0.57***	0.07	1.06***	0.08	1.01***	0.09
fresh (mean)	0.26*	0.14	0.22*	0.12	0.21*	0.12
aquaculture (mean)	-0.64***	0.14	-0.16*	0.10	-0.18*	0.10
undersized (mean)	0.04	0.10	-0.30***	0.10	-0.30***	0.10
Order (mean)	-0.02	0.11	-0.13***	0.02	-0.14***	0.02
Toxin, green to yellow (mean)			-1.10***	0.14	-1.25***	0.14
Toxin, green to yellow (std.dev.)			1.74***	0.11	1.81***	0.12
Toxin, yellow to red (mean)			-3.42***	0.29	-4.04***	0.32
Toxin, yellow to red (std.dev.)			-1.87***	0.23	1.70***	0.20
PUFA, per step (mean)			1.39***	0.10	1.47***	0.10
PUFA, per step (std. dev.)			0.67***	0.07	0.75***	0.07
interact. PUFA-Toxin (green to yellow) (mean)			-0.52***	0.10	-0.51***	0.10
interact. PUFA-Toxin (yellow to red) (mean)			-0.35***	0.14	-0.02	0.16
corr. coeff FA Toxin1					-0.29***	0.11
corr. coeff FA Toxin2					-0.48***	0.11
corr. coeff Toxin1 Toxin2					0.22**	0.14
BIC	4354.92		8275.6		8252.74	
PCP	0.52		0.58		0.58	

Table 8: Parameter Estimates Mixed logit model

Notes. Robustness check with regard to comprehension, excluding observations where respondents answered incorrectly to one or both of the comprehension test questions after the information script, which may inhibit effective choices in the experiment. The table shows parameter estimates and robust standard errors for the sample pre information treatment (Part 1), post information treatment (Part 2) and post information treatment with additional inclusion of parameters to estimate covariance among the health attribute parameters per equation 4. For random parameters, the table reports means and standard deviations of the normal distribution. The lognormally distributed price parameter is described by the mean and standard deviation of the underlying normal distribution. Apollo computes Hubert-sandwich-standard errors, clustered by participant to correct for the panel nature of the data (Hess and Palma, 2025). DG=Dagaa, NP=Nile perch, TP=Tilapia, asc=alternative specific constant, corr. coeff.= correlation coefficient, BIC=Bayesian information criterion, PCP= percent correctly predicted.

interviewers observed that participants were likely unable to read alongside the enumerator, which may make it harder to retain and process information and make informed decisions in the choice experiment (Table 9). Again, we do not observe relevant qualitative or quantitative differeneces in estimates compared to the main results.

	Pre-inf.		Post-inf.		Post-inf., incl. corr.	
Variable	Est	SE	Est	SE	Est	SE
asc DG (mean)	7.41***	0.81	1.92***	0.22	1.92***	0.22
asc DG (std. dev.)	1.19***	0.21	0.81***	0.13	0.86***	0.16
asc NP (mean)	8.04***	0.83	2.38***	0.21	2.40***	0.21
asc NP (std. dev.)	1.07***	0.18	0.80***	0.10	0.85***	0.10
asc TP (mean)	8.74***	0.85	2.77***	0.21	2.80***	0.21
asc TP (std. dev.)	1.77***	0.18	0.98***	0.12	0.96***	0.13
price (log mean)	-0.38***	0.09	-1.55***	0.14	-1.60***	0.14
price (log std. dev.)	0.60***	0.08	0.94***	0.08	0.98***	0.09
fresh (mean)	0.17	0.15	0.22*	0.13	0.23*	0.13
aquaculture (mean)	-0.65***	0.14	-0.24***	0.10	-0.26***	0.10
undersized (mean)	0.05	0.11	-0.31***	0.10	-0.32***	0.10
Order (mean)	-0.01	0.14	-0.11***	0.02	-0.12***	0.02
Toxin, green to yellow (mean)			-1.14***	0.14	-1.28***	0.15
Toxin, green to yellow (std.dev.)			1.75***	0.11	1.87***	0.13
Toxin, yellow to red (mean)			-3.68***	0.32	-4.27***	0.36
Toxin, yellow to red (std.dev.)			1.96***	0.22	1.71***	0.19
PUFA, per step (mean)			1.45***	0.10	1.56***	0.11
PUFA, per step (std. dev.)			0.70***	0.08	0.81***	0.08
interact. PUFA-Toxin (green to yellow) (mean)			-0.55***	0.10	-0.55***	0.11
interact. PUFA-Toxin (yellow to red) (mean)			-0.37**	0.15	0.02	0.18
corr. coeff FA Toxin1					-0.28***	0.09
corr. coeff FA Toxin2					-0.54***	0.09
corr. coeff Toxin1 Toxin2					0.19*	0.14
BIC	3843.49		7452.29		7445.27	
PCP	0.52		0.59		0.59	

Table 9: Parameter Estimates Mixed logit model

Notes. Robustness check with regard to comprehension, excluding observations where interviewers observed that participants were likely not able to read alongside the interviewers, which may inhibit effective choices in the experiment. The table shows parameter estimates and robust standard errors for the sample pre information treatment (Part 1), post information treatment (Part 2) and post information treatment with additional inclusion of parameters to estimate covariance among the health attribute parameters per equation 4. For random parameters, the table reports means and standard deviations of the normal distribution. The log-normally distributed price parameter is described by the mean and standard deviation of the underlying normal distribution. Apollo computes Hubert-sandwich-standard errors, clustered by participant to correct for the panel nature of the data (Hess and Palma, 2025). DG=Dagaa, NP=Nile perch, TP=Tilapia, asc=alternative specific constant, corr. coeff.= correlation coefficient, BIC=Bayesian information criterion, PCP= percent correctly predicted.

H Questionnaire

This questionnaire was also pre-registered in the OSF Registry (`https://doi.org/10.17605/OSF.IO/NC76M`) and is available as Excel download.

INTRODUCTION

Interviewer ID, Market name, Date

Upon approaching potential participant, please note the following, if the attempt to recruit the participant was unsuccessful:

Gender: (0) Female, (1) Male.

Age class: (0) Young (likely <25), (1) middle aged (likely 25-60), (2) senior (likely >60).

Hello! My name is [your name] and I came to this market to learn a little more about you and your community as part of a research project led by KMFRI and Cornell university, funded by the U.S. National Science Foundation (NSF). If you agree, I would like to find out whether you could be a participant in our study. If so, I would then like to describe the activities we will do together and ask for your consent to participate.

What is your preferred language?
(1) Luo, (2) Swahili, (3) English

Screening:
What is your age?
If <18: " Thank you for your time!" Complete the interview.

Do you eat fish in your household? By household we mean all of the people who usually stay in the same house and eat some of their meals together.
(0) No ("Thank you for your time!" Complete the interview.) (1) Yes

Have you been interviewed by us as part of this study before?
(0) No (1) Yes ("Thank you for your time!" Complete the interview.)

Thank you. We would be happy to welcome you as our participant. I would now like to describe the activities we will do together and ask for your consent to participate.

We are asking you to participate in a research study titled "Consumer Choice Experiment in Fish Markets". We will describe this study to you and answer any of your questions. This study is being led by Dr. Kathryn Fiorella, Department of Public and Ecosystem Health at Cornell University. The research study is funded by the US National Science Foundation (NSF).

Before you decide whether you would like to be part of this study, it's important for you to understand why we're doing the research and what's involved. We will give you an opportunity to read this form (or have it read to you) carefully. It may contain some words which are not familiar to you, however, we will be happy to explain anything you do not understand. Your participation in any research is voluntary. You have the right to know about procedures, risks and benefits of the research study to you and/or your household so that you can make decisions about whether or not to participate. This is called informed consent. Please take time to make your decision.

The purpose of this research is to better understand how people living around Lake Victoria, understand and respond to information about the fish they purchase. As part of this study, we will implement a consumer choice experiment on fish purchases to examine the willingness of fish consumers to pay for fish based on risk/benefit information received.

If you agree to be part of this research, we will provide you with some information about the health risks and benefits of fish, collect information about what you choose to buy today, and ask you some questions about your purchases based on the information we have provided. In total, all activities will take approximately 35 minutes. We do not anticipate any risks from participating in this research.

You and other participants will not directly benefit from participating in this study. Information from this study however may provide us with information that may be helpful in understanding how health information on fish impacts fish consumer's willingness to pay for fish. We will provide a small token of appreciation (1000KSH) for your time participating in this study.

We will do our best to keep your participation in this research study confidential to the extent permitted by law; however, it is possible that other people may need to review the research records and may find out about your participation in this study. For example, the following people/groups may check and copy records about this research:

- The Office for Human Research Protections in the U. S. Department of Health and Human Services
- The research study sponsor, US National Science Foundation
- Cornell University's Institutional Review Board (a committee that reviews and approves research studies) and the Office for Research Integrity and Assurance

Your participation in this research is entirely voluntary. You are free to join this study or not. If you decide to join, you are also free to change your mind and refuse to be in the study at any time for any reason and are free to skip any questions that may make you feel uncomfortable. Choosing not to participate in this study will not affect you in any way.

The main researcher conducting this study is Dr. Kathryn Fiorella, a professor at Cornell University. Please ask any questions you have now. If you have questions later, you may contact Dr. Kathryn Fiorella at kfiorella@cornell.edu or at 001-856-889-9184. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at 607-255-5138 or access their website at `http://www.irb.cornell.edu`. You may also report your concerns or complaints anonymously through Ethicspoint online at `www.hotline.cornell.edu` or by calling toll free at 1-866-293-3077. Ethicspoint is an independent organization that serves as a liaison between the University and the person bringing the complaint so that anonymity can be ensured.

Do you have any questions before we start?

Supervisor: Answer any question that is asked to the best of your ability and honestly. If you can not answer a question, the participant is always welcome to contact us (using the contact info on the debriefing sheet)

Do you agree to do the interview and participate in the study?

(0) No ("Supervisor: Thank you for your time!" Complete the interview.)

(1) Yes

Did you come here today with the intention to purchase fish?

(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

CHOICE EXPERIMENT

I would now like to ask you a series of choice questions. In each question, you can choose between four options: You can buy Dagaa, Nile perch, Tilapia, or none of those. In each task, the alternatives differ in their characteristics and their prices. I would like you to choose the alternative that you, on a normal day, would most likely buy for your household. Think about a quantity that would be suitable for one meal for your household. Apart from the description given, please think about a typical purchase of that type of fish. If in any of the questions you think that your household would be best off buying none of the species, you can select "None". Please also assume that all of the varieties are readily available here on the market, even if right now is for example not the season for certain types.

Please examine carefully each option before you make a decision, and please respond to each choice question as if it were a real buying decision, where you give up real money to purchase goods. The results of this studies are meant to inform food and health policies in the long run, and our study relies on collecting data here with you that best represents your actual buying decision. Thus, it is very important that you answer each question attentively and truthfully.

We will now start with the tasks and note down your answers.

(Choice tasks part 1, 1-6 implemented at this point)

(Information script) Fish can provide important nutrients, such as minerals and vitamins that are often consumed in too low quantities in this region, and in particular unsaturated fat. This essential part of any diet reduces the risk of coronary heart disease and related premature deaths. In Kenya, as in many other countries, more and more people suffer from heart diseases, which is one of the major causes for premature deaths. It is recommended to replace intake of unhealthy fat, called saturated fat, by intake of this unsaturated fat.

However, fish can also exacerbate health risks from a toxin called “microcystin”, which can cause liver damage and tumors. Microcystin is a toxin that results from bacterial processes in the Lake Water. Studies find that guideline values for lifetime exposure of both adults and children are exceeded in most households that use untreated drinking water from Lake Victoria, and that chlorination of water won’t reduce toxin levels sufficiently. Fish may also contain the microcystin toxin, and thus add to your exposure. It is therefore recommendable to avoid fish that has high levels of toxin.

Studies are now being conducted to quantify both benefits from fatty acids, and risk from microcystin, such that consumers can be informed adequately on different fish products. Please imagine that this data was already available, and that the fish would be labeled according to the results in form of colors and stars. For microcystin, a red light signifies that the option is unhealthier than minimum guideline values by the World Health Organization for adults: the World Health Organization considers regular consumption of such a product as dangerous for adults. A yellow light a medium level of risk, and a green light indicates a low risk. For fatty acids, a single star signifies that the option is unhealthier than minimum guideline values by WHO for adults: a too small share of the product’s fat content consists of healthy, unsaturated fat. Two stars indicate a medium level of healthiness, and three stars indicate that this is one of the healthiest options that you could choose. To summarize, the healthiest choices would be labeled in green for the toxin and three stars for the fatty acids. The unhealthiest choice would be labeled with one star for fatty acids and red for the toxin.

According to the text I just read out loud, which of the options below would be the healthiest choice regarding microcystin toxin?

(0) Fish with low microcystin toxin levels (three star label).

(1) Fish with medium microcystin toxin levels (two star label).

(2) Fish with high microcystin toxin levels (one star label).

(9999) Don't know/ prefer not to say.

(Correct as needed.)

According to the text I just read, which of the options below would be the healthiest choice regarding fatty acids?

(0) Fish with a low ratio of unsaturated to saturated fats (one star label).

(1) Fish with a medium ratio of unsaturated to saturated fats (two star label).

(2) Fish with a high ratio of unsaturated to saturated fats (three star label).

(9999) Don't know/ prefer not to say.

(Correct as needed.)

(Choice tasks part 2, 1-12 implemented at this point)

When you normally buy fish, what attributes are particularly important for you when you buy fish?

(0) Price

(1) Size/ age of the fish

(2) Origin (e.g. imported, local wild capture, aquaculture)

(3) form(e.g. dried, fried, fresh,. . .)

(4) nutritional/ health attributes

(5) freshness

(6) quality

(7) other (please specify)

(9999) Don't know/ prefer not to say.

When you were asked about your choice of fish today in this survey, which attributes did you find important?

(0) Price

(1) Size/ age of the fish

(2) Origin (e.g. imported, local wild capture, aquaculture)

(3) form(e.g. dried, fried, fresh,...)

(4) nutritional/ health attributes: toxin risk

(5) nutritional/ health attributes: fatty acid benefits

(9999) Don't know/ prefer not to say.

INCOME AND SOCIODEMOGRAPHICS

Next, we would like to know a little more about yourself and your household.

What is your gender?

(0) Female, (1) Male, (2) Other, (9999) Don't know/ prefer not to say.

How many people usually live in your household (including yourself)? By household we mean all of the people who usually stay in the same house and eat some of their meals together.

Number:

(9999) Don't know/ prefer not to say.

Please think about the group of people for whom you would usually prepare this meal, or for whom fish that you are buying is intended. How many people are in this group in total?

Number:

(9999) Don't know/ prefer not to say.

Of all those, how many are children below the age of 14?

Number:

(9999) Don't know/ prefer not to say.

What is the highest level of school you completed?

(0) None

(1) Some primary

(2) Primary

(3) Some secondary

(4) Secondary

(5) Higher degree than secondary school.

(9999) Don't know/ prefer not to say.

We would now like to know about your household's income during the past month. This includes activities such as agriculture, teaching, small businesses, fishing, charcoal selling, etc, and it also includes regular gifts from institutions or family and friends. Please list the overall income for your household, i.e. income from all persons from the household.

How much was the total amount of money earned last month by the total household for agricultural income-generating activities?

GROSS (KSH):

(9999) Don't know/ prefer not to say.

How much was the total amount of money earned last month by the total household for fisheries-related income-generating activities?

GROSS (KSH):

(9999) Don't know/ prefer not to say.

How much was the total amount of money earned last month by the total household for small-business income-generating activities (e.g. charcoal selling, vendor, tailoring...)?

GROSS (KSH):

(9999) Don't know/ prefer not to say.

Over the last month, how much support (in cash or in-kind) did your household receive in total from any source (Individuals/family/institutions) outside your household? GROSS (KSH): GROSS (KSH): (9999) Don't know/ prefer not to say.

Please state the total amount of any other income any member of your household received NOT already mentioned elsewhere e.g. pension, alimony, royalties in the past month?

GROSS (KSH):

(9999) Don't know/ prefer not to say.

FISH CONSUMPTION I would next like to ask you some questions about any fish you ate in the last several days.

Which of these fish types did you or any member of your household eat in the past 7 days?

(0) None of the below.

(1) Dagaa

(2) Nile perch

(3) Tilapia

(4) Other

(9999) Don't know/ prefer not to say.

How many days in the last 7 days did you or any member of your household eat Dagaa? (if mentioned in previous question)

Number of days:

How many days in the last 7 days did you or any member of your household eat Nile perch? (if mentioned in previous question)

Number of days:

How many days in the last 7 days did you or any member of your household eat Tilapia? (if mentioned in previous question)

Number of days:

HARMFUL ALGAE BLOOMS

Sometimes the lake is affected by algae blooms. Locally, people refer to these blooms as [Orwengu, Opirou, Otwodo, Osikonyodha]. Others refer to them as [Tuoro, Yugni, Pusi, Twodo, Othinyo or Onyoungi].

Have you heard or read anything about algae blooms before today?
(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

Have you heard or read anything about harmful implications of algae blooms before today? (if yes in previous question)
(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

Do you remember the last time the lake was affected by these blooms? (if yes in awareness question)
(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

If yes, please tell me about the time frame.
(open ended)

During harmful algae blooms, have you perceived or experienced any of the following things regarding Lake Victoria that you think may be related to the bloom?
(0) None of the below.
(1) Lake Water smells differently
(2) Lake Water looks differently
(3) Lake Water tastes differently
(4) Other. Please specify
(9999) Don't know/ prefer not to say.

During harmful algae blooms, have you perceived or experienced any of the following things regarding fish and fish markets that you think may be related to the bloom? (0) None of the below.

(1) Different prices for fish in these periods.

(2) Different availability of fish in these periods.

(3) Different quality/ taste of fish in these periods.

(4) Other.

(9999) Don't know/ prefer not to say.

If yes: What have you noticed regarding ...?

(open ended)

During harmful algae blooms, have you perceived or experienced any of the following health symptoms that you think may be related to the bloom?

(0) None of the below.

(1) Skin problems (itchiness, dryness, change in color, rashes, etc)

(2) Gastrointestinal/stomach problems

(3) General pain and discomfort

(4) Other

(9999) Don't know/ prefer not to say.

Have the blooms impacted you in any way that we haven't yet discussed?

(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

Please tell me about other ways in which you have been impacted by the blooms.

(open ended)

In times of algae bloom, do you change the way you consume fish?

(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

(if no, skip the rest of the HAB part)

How do you change the way you consume fish when there is an algae bloom?

(0) consume in a different form than usual (e.g. dried, fried, fresh,. . .)

(1) consume from a different production type (e.g. aquaculture)

(2) consume different size/ age of fish at meals

(3) purchase fish from different market or different vendor than usual

(4) consume less fish per week

(5) consume more fish per week

(6) other (please specify):

(9999) Don't know/ prefer not to say.

What is the main reason for you to change your fish consumption when there is an algae bloom?

(0) economic reasons (e.g. prices)

(1) health reasons

(2) due to changed availability

(3) due to changed quality/ taste

(4) other (please specify):

(9999) Don't know/ prefer not to say.

HEALTH AND WATER CONSUMPTION

What is the main source of water for your household?

(0) Private faucet (own or neighbors)

(1) Public tap

(2) Protected well

(3) Unprotected well

(4) Lake water

(5) River

(6) truck service/ water seller

(7) Other (please specify)

(9999) Don't know/ prefer not to say.

How do you usually treat your water at home before drinking?

(0) no treatment

(1) Chrlorine (e.g., watergueard)

(2) filtration

(3) decantation

(4) boiling

(5) other (please specify)

(9999) Don't know/ prefer not to say.

Does anybody in your household suffer from coronary heart diseases? (0) No, (1) Yes, (9999) Don't know/ prefer not to say.

Does anybody in your household suffer from known liver problems?

(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

Are there any pregnant or lactating women in the household, including yourself?
(0) No, (1) Yes, (9999) Don't know/ prefer not to say.

Overall, how many days in the last month did anybody in your household have to miss work/ school due to illness during the last 30 days? (on average)
Number:
(9999) Don't know/ prefer not to say.

INTERVIEWER PERCEPTION

Did other people besides the respondents follow the interview?
(0) No, (1) Yes

If yes, approximately how many people observed the interview?
Number:

How do you find the respondent's general understanding of the questions?
(0) The respondent understood everything well.
(1) The respondent understood most things well.
(2) The respondent understood some things well.
(3) The respondent understood few things well.
(4) The respondent understood almost nothing.
If >2, continue to next question.

Please indicate difficult parts
(open ended)

Do you think that the respondent was able to read the choice question tables alongside you?
(0) No, (1) Yes

DEBRIEFING

Thank you very much for your time - your participation was very helpful for our research. If you like, we have prepared a one page summary with information about what the research is about, data handling, and contact information for you to take home with you.

We also would like to thank you for your time with this promised small amount of 800 Kenyan shillings to compensate you for the time you dedicated to our survey.