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Innovating out of the fishmeal trap

The role of insect-based fish feed in consumers' preferences for fish attributes

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Abstract

Purpose – The purpose of this paper is to examine the potential market impacts of the use of insect-based protein for fish feed as an innovative approach out of the fish-meal trap.

Design/methodology/approach – An online questionnaire was used to elicit information on fish consumption choices among 610 German consumers using a discrete choice experiment. Mixed logit and latent class logit models were used to model consumers' preference heterogeneity.

Findings – Results show that consumers' preferences for fish attributes such as filets, freshness, ecolabelling and domestic production are heterogeneous and important in consumption choices. The minor share of the respondents is sensitive, while the remaining is indifferent regarding the use of insect based protein as feed in trout production. For this sensitive segment, consumption would be expected to be reduced unless the price is reduced or other attributes such as convenience aspects are improved.

Research limitations/implications – The implication is that firms can substitute without a significant impact on the market demand given that the majority of consumers are indifferent regarding feed sources for trout production. As a result, it provides an innovative way to ensure sustainable use of resources and reduces the threat of fish meal trap while reducing pressure on the already over-exploited marine life.

Originality/value – The results provide first insights into the market impact of using insects in the animal protein value chain. It is important especially with Europe's recent lift of the ban on using insect-based protein in the animal food industry.

Keywords Aquaculture, Sustainability, Choice modelling, Fish-meal trap, Insect as feed

Paper type Research paper

1. Introduction

Global population growth and changing consumer preferences are driving increased demand for animal protein including eggs, meat, fish and dairy. This trend will create a pressure to produce more animals which will lead to a significant increase in demand for resources used in animal production. This includes feed sources especially soymeal and fishmeal which present important environmental challenges. For instance, the cultivation of soy has been linked to deforestation, high water consumption and high utilization of pesticides and fertilizers (Stamer, 2015). Fish meal has been linked to overfishing of ocean resources, and furthermore, since it is a resource dependent on catch, its production is variable both quantitatively and qualitatively (Sánchez-Muros *et al.*, 2014). Moreover, global capture fishery production remains relatively static over longer time periods (FAO, 2016) and hence, it is unlikely to support the expanding aquaculture sector as a major component of fish feed. The resulting volatility in price linked to soymeal and fishmeal poses risks for economic viability of the livestock sector (Kobayashi *et al.*, 2015). According to Lang *et al.* (2009), 1 kg of farmed fish is produced from 2–5 kg of wild caught fish. With stagnating fishery production, there is a need for partial replacements of traditional animal feed such as fishmeal to ensure continued farmed fish production.

Insect-based feed presents a viable protein alternative for animal feed, and a means to innovating out of the "fishmeal trap," a term coined decades ago (Wijkstrom and New, 1989). The Fishmeal trap has become a common term in aquaculture expressing the concern that future growth in aquaculture could be constrained by limited marine resources. Five major insect species including the black soldier fly, common housefly, mealworm, locusts and silkworm have attracted interest in academic and industry research. Constraints associated with insect as feed include the possibility that insects may contain anti-nutrient properties, food safety concerns (Dobermann *et al.*, 2017), pathogen carriers or contain residues of pesticides (Makkar *et al.*, 2014). Black soldier fly (*Hermitia illucens*), on the other hand, has been identified to be the most promising in terms of food-waste recycling; it is neither a pest nor disease vector, and its larvae are omnivorous and robust against insect diseases (Stamer, 2015). The use of insects as feed source is known to reduce economic and environmental costs because they can be fed by-products (Sealey *et al.*, 2011) and require little infrastructure or resources. Stadtlander *et al.* (2017) demonstrate that substantial replacement of fishmeal by insect meal is possible without compromising growth, feed conversion and product quality. However, lower production efficiency might result from decreased protein utilization when applied over a whole production cycle. In the quest for sustainable feed for aquaculture which currently represents more than half of the World's fish supply, insects may be seen as a substantial part of the answers to the feed supply challenge.

Despite the potential of insect feed in the animal protein food value chain and the recent change in EU legislation for animal-based feed (Commission Regulation (EU) 2017/893, 2017), which has opened an avenue for acquisition of significant investment sums for mass production of insects, the impact of insect feed on the value of animal products when used as a substitute or partial replacement for the standard feed (fishmeal and soymeal) has not been researched. This paper produces first insights into consumer preferences for farmed fish fed with insect-based feed by evaluating the impact on the overall product value considering that feed source is only one of the many product attributes.

The direct consumption of insects (i.e. insect as food) has been documented to be traditional among some cultures in the developing countries (Ramos-Elorduy *et al.*, 1997), typically harvested from the wild (Van Huis *et al.*, 2013) but commonly not part of the conventional food chain (Alemu, Olsen, Vedel, Pambo and Owino, 2017). Alemu, Olsen, Vedel, Pambo and Owino (2017) study consumers' preferences for insect-based food products and show that most consumers in Kenya react positively when termite-based food products are introduced whole or as a processed component of a typical staple food. Alemu, Olsen, Vedel, Kinyuru and Pambo (2017) incorporate a sensory experience in an incentivized discrete choice experiment (DCE) approach and find positive effects for cricket-flour-based buns. The evidence is expected given that Kenya is a developing country where termite consumption is traditionally accepted.

In western societies, edible insects have long been gone from traditional diets. Evidence on western consumers' preferences is lacking. Studies such as Tan *et al.* (2015; 2016), Hartmann *et al.* (2015) and Caparros Megido *et al.* (2014) provide evidence of sensory likings among consumers in countries such as Germany, Belgium and the Netherlands where neophobic attitudes are identified. However, insects are perceived to be disgusting, dirty and dangerous for human consumption (Tan *et al.*, 2015), posing a serious challenge for consumer acceptance. Markets for insect-based food in the developed world are, however, coming up as they can currently be found in some retail shops. So while insects as food has been studied; only little is known about consumer preferences for insects in the food value chain.

Regarding the use of insect as feed source, an EU-wide poll on consumers' liking suggests that consumers would be "comfortable" eating livestock fed on insect protein since consumers did not show to be overly resistant to the idea of insect protein use in feed

(Byrne, 2015). Despite the attempt, the economic valuation of consumers' preferences and market impacts has not been examined. The successful development of insect-based feed as a viable substitute for fishmeal or soy-based feed depends on consumers' preferences and their willingness to pay for the end-products in the market. Hence, for the market to be driven by demand, developing effective marketing and policy strategies is of paramount importance, and this requires a thorough understanding of consumer purchasing behavior. The current paper contributes to this gap in the literature by assessing German consumers' preferences for portion sized farmed rainbow trout fed from black soldier fly protein among other important product attributes by use of the DCE approach.

Insect as a source of feed especially in aquaculture production is just one of several attributes that may affect consumers' purchase decisions when buying fish for consumption. So to investigate this single attribute, it is important to look at it in the context of the multiple attributes. Consumer preferences for seafood quality attributes have been analyzed in several studies based on the Lancaster (1966) theory of product characteristics. According to Carlucci et al. (2015), the characteristics of fish that emerge as the most relevant for consumers in the seafood literature include: country of origin, production method, preserving method (chilled, frozen, canned, smoked, salted, etc.), product development, packaging and ecolabelling. Consumers' preferences for the country of origin and the production method (wild and farmed) have received the greatest attention. For instance, Jaffry et al. (2004) and Loose et al. (2013) show that domestic products are perceived to be superior in terms of quality, safety and freshness. This trend is explained by reduction in perishability from reduced distance between production and consumption markets, perception of insufficient regulation in some countries of origin (Birch et al., 2012), environmental values and sense of patriotism to support the local economy (Stefani et al., 2012). Besides investigating preferences for insect fed fish, the current paper also contributes to the literature by considering consumer preferences for a range of other quality attributes in fish. These are consumer preferences for varying degrees of fish filleting, preferences for the newly introduced general Aquaculture Stewardship Council (ASC) label, the well-established organic labeling and the country of origin.

The remainder of the paper is organized as follows: the next section presents the method which includes the experimental design and analytical framework, Section 3 presents the results and discussion and section five the conclusion.

2. Method
A DCE was conducted among German consumers to examine the role of the feed source among other quality attributes in the demand for portion size rainbow trout. The gain in popularity in the use of DCEs is tied to the resemblance of real market decision-making settings, its foundation on Lancastrian consumer theory (Lancaster, 1966) that enables estimation of preferences based on attribute characteristics; and on the random utility theory (RUT) (McFadden, 1974) that provides a plausible theoretical behavioral framework to model individual's probabilistic choices. The design of DCEs involves: determining the product attributes and their levels, deciding on the experimental design, designing and testing the questionnaire and choice tasks, collecting the data and analyzing it (see e.g. Hensher et al., 2005).

2.1 The choice experiment design and data collection
While the core focus of this study is on the use of insects (black soldier fly larvae) as a source of feed, the literature suggests other important attributes that may influence consumers' choices (Carlucci et al., 2015). Based on literature and focus group discussions, the fish attributes and levels included in this study were: product form (whole fish, filet with skin and bone, filet with skin but no bone, filet without skin and bone), storage form

(frozen, smoked and fresh/chilled conditions), place of purchase (grocery store and specialized fish store), production method (conventional, organic and ASC certified), country of origin (Turkey, Germany, Denmark and other EU country), feed source (standard feed and insect-based feed) and price (€2.99, €4.49, €5.99, €7.49, €8.99, and €10.49 per 350 g trout)[1].

The combination of these attributes and levels results in $4 \times 3 \times 2 \times 3 \times 4 \times 2 \times 6 = 3{,}456$ possible combinations. Since showing all combinations to respondents was expected to cause fatigue, an efficient experimental design was used instead. The Ngene software was used to construct a D-efficient Bayesian experimental design, using priors from the literature. The priors were updated with priors estimated using a multinomial logit model to explain choices in a pilot survey with 100 German consumers. In total, 36 choice sets were generated and divided into 3 blocks of 12 choice sets. Each scenario consisted of three alternatives and an opt-out/no-buy option with a sample presented in Figure 1.

Which of the following will you buy (choose only one)?

The questionnaire development involved two focus groups in Denmark and Germany and one online pilot survey in Germany before the final administration. The questionnaire commenced with a number of background, behavioral and attitudinal questions. The choice tasks were then introduced with information on the implication of how "using insects (Black Soldier fly) as a component of fish feed might help reduce pressure on overfishing and competition on protein sources from other livestock and human population growth" and a description of each of the attributes. Follow-up questions were introduced and lastly, the socioeconomic profile of respondents.

The questionnaire was set up and implemented by Userneeds A/S and Research Now through an online consumer panel in July, 2016. The participants were sampled from the German regions: Schleswig-Holstein/Hamburg, Brandenburg/Berlin and Bayer so as to cover some regional diversity. They were then stratified by gender, age class, family structure and income in order to be representative for the population. The members of the panel were originally recruited to the panel to represent the German population and with the intention to answer various questionnaires. Thus, it is not a panel where members are expected to have any particular interests in relation to the topic. That being said, participants are selected and they can chose to participate or not and hence the representation could differ from the German population.

With a response rate of 12 percent, data from a total of 610 completed and usable questionnaires were extracted for analyses. The summary statistics of the sociodemographic profile of respondents are presented in Table AI. For example, about 60 percent of the sample was females and the mean age was 42 years (median = 40.5). Compared to the German population of 51 percent females and average age of

Figure 1.
Sample choice card

44 (median = 45) years (Destatis, 2017), this would be misrepresentation of females. The age statistics as well are slightly under estimated. Hence, caution should be drawn on general conclusions.

2.2 Discrete choice modeling and empirical specification

The RUT of McFadden (1974) serves as the theoretical foundation for analysis of data from DCEs. The basic assumption of the RUT is established on the premise that individuals act rationally, and they select the alternative product that yields the highest utility to them. Thus, when purchasing a given good, they will choose the product among the possible ones that maximizes their utility. If none provide sufficient utility for the price, they will not purchase anything (as they can spend the money and obtain higher utility somewhere else). Consider N consumers who are faced with J alternatives at T choice situations. Each choice situation is assumed independent from the previous. The utility (U_j) obtained for choosing alternative $j \in J$ at choice situation $t \in T$ can be analyzed as a multinomial logit (MNL) model with separable parts; the systematic (V_j) and random (ε_j) components:

$$U_{jt} = V_{jt} + \varepsilon_{jt} = \beta' x_{jt} + \varepsilon_{jt}, \tag{1}$$

where the systematic part consists of a vector of observed additive attributes, x_j. The unobserved term ε_j reflect factors that are known to the decision maker but unknown to the researcher. The MNL model has, however, been identified to suffer from the independent and irrelevant alternatives (IIA) assumption. To overcome the IIA property and also to allow for heterogeneity in people's preferences, the random parameter/mixed logit model has been developed. Because we suspect that people differ in their preferences for fish products, this is the model applied here. In the random parameter logit (RPL) model, the taste parameter β is allowed to vary over individuals such that individual n taste parameter is now β_n. In this case Equation (1) can be written as (Hess and Train, 2017):

$$U_{njt} = V_{njt} + \varepsilon_{njt} = \beta'_n x_{njt} + \varepsilon_{njt}. \tag{2}$$

The error term ε_{njt} is assumed to be extreme value distributed over individuals, alternatives and choices by the same individual. Under the assumptions in Equation (2), the probability that person n chooses alternative i at time t, conditional on β_n is the logit formula (Revelt and Train, 1998):

$$L_{nit}(\beta_n) = e^{V_{ni}(\beta)} / \Sigma_j e^{V_{nj}(\beta)}, \tag{3}$$

and the choice probabilities can be expressed in the following form:

$$P_{nit} = \int L_{nit}(\beta_n) f(\beta|\theta) d\beta. \tag{4}$$

$V_{ni}(\beta)$ is the observed portion of the utility which depends on β, and $f(.)$ is the density function that could be discretely or continuously distributed. In the case of mixed logit models, a continuous distribution is assumed. Following the assumption of a normal distribution, $f(\beta|\theta)$ would be a normal density function, $f(\beta|b,W)$, with mean b and standard deviation W. The researcher estimates b and W. The choice of estimating the RPL model over the multinomial logit model is embedded in the flexibility for random taste variation (β_n), unrestricted substitution patterns and correlation in unobserved factors due to repeated choices.

In the RPL model, preference heterogeneity is modeled as continuous, typically by describing the distributions, like the normal distribution – or more flexible distribution. However, to interpret heterogeneity, it may be easier to look at discrete groups, especially if preferences are very distinct. Within food choices such segmentation of the consumers is often appropriate. Therefore, we also estimate a latent class (LC) logit model, where heterogeneity is modeled by a number of distinct classes (i.e. discrete distribution of $f(.)$). The probability of alternative i being chosen by person n at time t subject to segment s is given by:

$$P_n(i) = \sum_{s=1}^{S} L_{ni|s} H_{ns},$$ (5)

where $L_{ni|s}$ is the expression for the probability within the classes, which is a multinomial logit model; and H_{ns} is the probability of person n belonging to class s (i.e. the class membership function) determined by a standard logit formulation respectively as (Greene and Hensher, 2003):

$$L_{ni|s} = \frac{\exp(\beta_s' x_{nit})}{\sum_{j=1}^{J} \exp(\beta_s' x_{njt})} \quad s = 1, \ldots, S \text{ and } H_{ns} = \frac{\exp(\gamma_s' Z_n)}{\sum_{s=1}^{S} \exp(\gamma_s' Z_n)}$$ (6)

The vector of segmentation variables consisting of individual socioeconomics and consumption characteristics or attitudes is indicated by Z_n; γ_s is a vector of parameters for class s and β_n is the class specific taste parameter. The determination of the optimal number of classes relies on a combination of statistical information criteria, model parsimony and researcher's judgement on interpretability of coefficients based on theoretical foundations (Ruto *et al.*, 2008; Scarpa and Thiene, 2011). Often, consumption attitudes are captured with a lot of Likert scale type questions. In this case, the standard principal component analysis (PCA) can be used to reduce the dimension of these attitudinal variables and they can be incorporated into the class membership function. This is the approach adopted in this study (detailed analytical descriptions available in Abdi and Williams, 2010).

3. Results and discussion
3.1 RPL results
The results of the RPL model are presented in Table I. With the exception of price, shop type and the alternative specific constant (no-buy option), the remaining parameters were assumed to be random following a normal distribution. Two models were estimated – a basic model, and a model with interaction between insect feed and ASC Ecolabelling (insect feed interaction with organic label was dropped since no significant effect was identified). In the interpretation of results, we will focus on the model with insect feed interaction. The marginal willingness to pay (MWTP) estimates is computed as the ratio of the attribute parameter to the price parameter, and standard errors are computed by the Delta method. These are presented in the last column of Table I.

The normally distributed random parameters show standard deviations that are statistically significant at the 1 percent level. This confirms that taste preferences of the respective attribute levels are heterogeneous across respondents. Price is statistically significant and negative, which is in agreement with expectations of economic theory. The statistically significant negative no-buy option parameter indicates that most consumers would prefer a choice of one of the fish alternatives regardless of the attribute levels rather

Estimation results Attributes	Model without interaction (1) Mean Coeff	SE	SD Coeff	SE	Model with interaction (2) Mean Coeff	SE	SD Coeff	SE	MWTP (2) (Delta) Ratios
Random parameters									
Filet with skin and bone	0.158***	0.051	0.201**	0.093	0.149***	0.051	0.212**	0.090	3.70***
Filet with skin, no bone	0.513***	0.059	0.855***	0.064	0.514***	0.059	0.849***	0.065	12.75***
Filet without skin and bone	0.419***	0.091	1.458***	0.104	0.435***	0.091	1.463***	0.102	10.80***
Fresh chilled	0.251***	0.060	0.959***	0.068	0.270***	0.060	0.967***	0.068	6.71***
Smoked	0.101*	0.061	0.912***	0.075	0.077	0.061	0.921***	0.073	1.90
ASC Ecolabel	0.214***	0.053	0.601***	0.071	0.404***	0.074	0.609***	0.072	10.03***
Organic	0.176***	0.057	0.827***	0.091	0.183***	0.058	0.846***	0.089	4.54***
Germany	0.690***	0.082	1.441***	0.083	0.703***	0.082	1.454***	0.084	17.44***
Denmark	0.343***	0.071	1.251***	0.100	0.364***	0.072	1.248***	0.103	9.03***
Other EU country	0.251**	0.098	1.543***	0.107	0.293***	0.099	1.564***	0.111	7.28***
Insect Feed	−0.098**	0.049	0.688***	0.080	0.036	0.061	0.682***	0.089	0.89
Fixed Parameters									−
Price	−0.038***	0.003			−0.040***	0.003			−
Specialized shop	0.122***	0.042			0.126***	0.042			3.11***
ASC Ecolabel × insect feed					−0.386***	0.105			−9.58***
No-buy option	−0.686***	0.097			−0.642***	0.098			−15.92***
Log likelihood	−8,528.5				−8,521.7				
McFadden. R^2	0.160				0.160				
Number of respondents	610				610				
Number of choice observations	7,320				7,320				

Notes: *,**,***Indicate statistical significance at 1, 5, and 10 percent levels, respectively

Table I.
Random parameter
logit model

than opting out of the choice scenario. The positive and significant sign for purchasing fish in a specialized shop may indicate a belief in better fish or a better shopping experience, all other things equal, and hence a MWTP estimate of about €3/Kg.

The marginal utilities associated with filets are higher than whole fish and increases further when the filets have bones and or skin removed. These results can be explained with intuition from previous literature in that consumers tend to appreciate and demand convenient fish products given that the original product characteristics do not undergo significant alterations to affect quality (Carlucci *et al.*, 2015; Debucquet *et al.*, 2012). Compared to the somewhat limited available literature, the evidence contrasts Cardoso *et al.* (2013) and Arvanitoyannis *et al.* (2004), who found the majority of consumers to prefer whole (unprocessed) fish or portioned fish to fillets among Portuguese and Greece consumers. However, in Germany it reflects what can be observed in supermarkets: the share of filets is quite high (European Union, 2014).

Moreover, results show that most consumers prefer fresh (chilled) fish to frozen fish. For smoked fish the mean does not significantly differ from zero but the standard deviation is significant, indicating that it matters for some consumers but while some have positive preferences for this, others have negative. Similar conclusions are reached at the 5 percent significance level in the model without interaction effects. This result follows the findings of Cardoso *et al.* (2013) and Arvanitoyannis *et al.* (2004) for Portuguese and Greece consumers. As indicated by (Carlucci *et al.*, 2015), this marked preference toward fresh fish is motivated by the perceived loss in quality, safety, nutritional value, naturalness and negative changes in taste, odor and texture.

The country of origin has been highlighted to be one of the most important fish attributes affecting consumers' choice with a clear convergence toward preference for domestic fish products (Carlucci *et al.*, 2015). As shown in Table I, the highest marginal utility and MWTP estimate (€17/Kg) is associated with domestically (German) produced trout, followed by Denmark and then other EU countries relative to a trout produced in Turkey[2]. Turkey (second largest producer of portion sized trout in the world) is included as a strong non-EU competitor to Denmark (the most important trout supplier on German market). Denmark shares border with Germany and together with other EU countries have a common aquaculture policy plan that might enhance consumer trust in fish products from these countries. Previous literature have found that domestic fish products are perceived to be superior in terms of quality, safety, freshness (Loose *et al.*, 2013; Jaffry *et al.*, 2004; Birch *et al.*, 2012) and reduced carbon foot-prints (Onozaka and McFadden, 2011) from transportation. The relative values of the country of origin levels might be attributed to consumers' perception and image about sufficiency of food regulations in countries where food is imported. Other determinants include consumer beliefs resulting from incorrect information, stereotypes, emotions and sense of patriotism (Birch *et al.*, 2012; Mauracher *et al.*, 2013).

Regarding sustainability and environmental attribute preferences, the use of ecolabels including organic label and ASC label are preferred relative to the conventional production principles. The results show that consumers have higher preferences for organic over conventional produced portion size trout. The results presented on the organic ecolabel follow Mauracher *et al.* (2013), who show that more than half of the respondents analyzed were willing to pay a price premium for organic sea bass. Stefani *et al.* (2012) show a positive median willingness to pay in Italy for the same product. Organic and ASC ecolabelling in aquaculture are still in the early stages of development and hence, not much evidence exists. However, in a revealed preference study, Ankamah-Yeboah *et al.* (2016) found that a segment of consumers are willing to pay a price premium for organic salmon.

The results shows that respondents' preferences for insect-based feed and ASC label are heterogeneous, but also that they are correlated. While the majority of consumers prefer the ASC label, this almost diminishes when an interaction with insect feed is incorporated. However, allowing for this interaction hardly affects the standard deviation, indicating that there is huge heterogeneity on this attribute, maybe even distinct grouping. Consequently, an LC model is used to segment consumer preferences in the following section to provide a deeper understanding.

3.2 LC logit results

To link preferences to attitudes, an LC modeling approach is utilized combined with PCA. The behavioral attitudes were obtained using Likert scale questions and analyzed by PCA. PCA is applied in this paper for dimensionality reduction. The groups of distinct questions analyzed have their average varimax factor rotation loadings and descriptions reported in Table AII.

Having created factor variables of consumption attitudes of the respondents, these are incorporated together with the socioeconomic factors as variables in the class membership function of the LCM. Combining statistical information criteria, interpretability of parameters, economic theory and parsimony, a three consumer segment model is estimated and results are presented in Table II. Despite improvement in model selection criteria with higher classes, a three class model was selected because higher number of classes produces segments with the similar utility preferences and with further increments, the standard errors become larger. For example, high standard errors, common class segments and significant positive price parameters were observed in class segments higher than 3 for this data. Class 1 is used as the normalized class for the class membership model identification. The log likelihood estimates show that the LCM has lower fit than the RPL estimates

Attributes	Class 1 Coefficients	SE	Class 2 Coefficients	SE	Class 3 Coefficients	SE
Filet with skin and bone	0.166***	0.052	0.256*	0.150	0.212	0.144
Filet with Skin, no bone	0.359***	0.052	0.789***	0.138	0.272*	0.154
Filet without skin and bone	0.341***	0.072	1.040***	0.168	0.187	0.251
Smoked	0.273***	0.050	0.127	0.134	0.063	0.162
Fresh chilled	0.319***	0.049	0.421***	0.125	0.273	0.176
Specialized shop	0.149***	0.041	0.183*	0.106	−0.205	0.134
ASC ecolabel	0.204***	0.046	0.196	0.121	−0.237	0.173
Organic	0.021	0.048	0.041	0.123	0.298*	0.158
Germany	0.435***	0.061	0.485***	0.152	0.761***	0.185
Denmark	0.026	0.056	0.186	0.136	0.565***	0.171
Other EU country	4x10^{-4}	0.078	−0.074	0.194	0.513***	0.202
Insect feed	−0.035	0.041	−0.202**	0.102	−0.189	0.139
Price	−0.005	0.003	−0.045***	0.008	−0.165***	0.020
No-buy option	−2.258***	0.133	0.862***	0.170	−3.431	0.371
Class shares	0.597		0.233		0.170	
Class membership covariates						
Intercept			−0.949	0.300	−1.111	0.395
Male			−0.715***	0.238	0.069	0.283
Berlin			0.254	0.276	−0.453	0.331
Hamburg			0.363	0.284	−0.467	0.341
Inc2			−0.007	0.322	−0.885**	0.420
Inc3			−0.020	0.287	−0.726**	0.342
Inc4			−0.008	0.339	−1.278***	0.440
Fam w/child			−0.096	0.251	−0.146	0.318
Age 35–49			−0.373	0.281	0.594	0.394
Age 50–65			0.476*	0.283	1.313***	0.394
Factor 1			0.279***	0.120	0.125	0.138
Factor 2			−0.344***	0.117	−0.049	0.140
Factor 3			0.202	0.124	0.230	0.147
Factor 4			−0.091	0.111	0.276**	0.140
Factor 5			−0.086	0.121	0.091	0.148
Factor 6			−0.312***	0.121	−0.418***	0.145
Log likelihood	−8,507.643					
R^2	0.196					
Number of respondents	610					
Number of choice observations	7,320					

Notes: *,**,***Indicate statistical significance at 1, 5 and 10 percent levels, respectively

Table II.
Latent class model
estimation results

presented earlier yet it may reveal a different understanding of the heterogeneity. At the
bottom of Table II the size of each class is indicated. Though one cannot compare attributes
across classes due to scale effects, ratios can be compared (like MWTPs), and as is seen, the
classes are quite distinct in their preferences.

The utility model for class 1 shows that respondents have strong preferences for
convenient innovative fish products such as filets, and the marginal utilities are higher for
filets with the bones removed. They are also interested in other attributes such as smoked,
fresh chilled, buying from specialized fish shops, ASC ecolabel. The strongest preferences
are associated with domestic (German) produced portion size trout but respondents appear
to be unconcerned about trout from other countries. Generally, class 1 can be characterized
to be concerned about attributes rather than the price of the fish. However, they do not
exhibit a significant preference for fish fed with insect-based protein feed. This indicates

that for the use of insect-based protein in trout farming, they are indifferent toward it. The significant and negative "no-buy option" parameter estimate indicates that this is a segment which prefers to buy fish rather than other products. As they constitute 60 percent of the sampled consumers, these two observations indicate the potential of using insect-based feed.

The marginal utility of the attributes in class 2 also indicate high preference for convenient innovative filleted fish products. In addition, they are identified with preference for fresh chilled products, have preferences for buying from specialized fish shops and also show an affinity for domestic produced fish products. Class 2 exhibits a significantly negative preference for fish fed with insect-based feed. With a significant positive "no-buy option" parameter, this segment of consumers can be described as people who see fish as an option, but easily substitute it with other products if the attributes of the fish are not satisfactory. The class membership model indicates that this class is more likely associated with females and likely to be among the age cohort, 50–65 years.

In terms of behavioral and attitudinal variables, the class 2 members are more likely to agree with the self-efficacy components. Thus, they agree to the statements that fish is expensive, fish has odor that deters them from eating, fish preparation is difficult and time consuming, and has too many bones. The latter two statements have higher weights in terms of factor loadings. It is hence, not surprising that they have much higher marginal utilities for filets than class 1. Relative to class 1, class 2 members are less likely to be pro-organic (factor 2) or active in environmental protection events and donations. This might explain the decreased marginal utility associated with insect-based fed fish products. The group consists of approximately 23 percent of the sample analyzed as indicated by the class share. This is the only group with a significant and negative preference for insect feed.

The third class has the least interest in the number of product attributes. The price and the extrinsic attributes of the fish product appear to be the attributes of importance. They have preferences for organic but not ASC Ecolabel. The country of origin is the most important attribute for them; such that, domestic (German) produced trout has the highest marginal utility, followed by Denmark and then other European countries. Given that both classes 2 and 3 have significant price coefficients, we can conclude that class 3 is the only segment willing to pay for organic labeled trout. Also the valuation of domestic products for class 2 is more than twice that of class 3.

Class 3 identifies with the lowest income quartile and they are more likely to be among the aged cohort. Regarding attitudinal and behavioral factors, they agree to the statement that organic products are expensive, and they are less likely to participate in environmental protection events and donate than others. The standard errors for this class are relatively large. It may be due to unclear preferences, or due to non-modeled preference heterogeneity within the class.

Putting things in perspective, the general observation regarding the choices of insect fed fish products in the presence of other important attributes is that when choosing fish products only 23 percent of the respondents analyzed are actually sensitive to what the fish has been fed. The remaining 77 percent are indifferent as to whether standard or insect-based feed has been used. This looks promising for the future development of the aquaculture industry when considering innovations out of the fish meal trap and the development of the insect based feed market as a whole. Black soldier fly has no known risks. Hence, given that positive but limited information was given to all respondents prior to the choice tasks, this could have have influenced the realized outcome. The major share of consumers indifferent to the source of feed can therefore be thought of as open to this innovation (or at least not opposing it).

4. Conclusion and policy implications
The application of the EU's acceptance of the use of insect processed animal proteins for livestock from the 1st of July, 2017 may mark a significant step toward ensuring a more

sustainable utilization of resources in the production of animal protein, and in the process, alleviating some environmental concerns. However, for successful development of a market for insect-based feed and proper integration into the food value chain, it is crucial to acquire knowledge about if and how consumers might react to what is essentially a new production method. This paper presents first insights into the demand for insect protein fed portion sized farmed rainbow trout among German consumers using an online questionnaire-based DCE survey.

Based on stated choice data from 610 respondents sampled from online panel, random parameter and LC logit models are estimated to determine heterogeneity in preferences for fish attributes, where insect feed is just one of several attributes affecting consumers' purchase decisions. Results indicate that the preferences for fish attributes vary widely among respondents. The majority of the respondents have preferences for filleted fish rather than whole fish. This appears to be driven by the demand for convenience and low self-efficacy in fish food preparation. Fresh chilled fish products appear to attract consumers more than smoked and frozen products, and most consumers state they are willing to pay more for ecolabeled than conventional fish products. Moreover, consumers generally prefer to buy fish from specialized fish shops, and they clearly prefer domestic production above imported fish products. All these observations are in line with findings in revealed and stated preference consumer studies.

Regarding the demand for insect protein fed fish products, the majority of consumers are not concerned about the type of feed when buying fish. However, there is a considerable segment of consumers, approximately 23 percent, who exhibit negative preferences for fish fed with insects rather than standard feed. This group is also not affected by organic or ASC ecolabeled products. Thus, in particular for these labeled products, the use of insect feed should not be sought. The consumers in this segment, however, also appear to have very strong preferences for convenience when buying fish products. Hence, to maintain market shares in this segment, producers using insect-based feed may want to develop fish products that are perceived as relatively convenient to prepare.

The fact that the majority of consumers sampled are indifferent to the fish being fed on insect-based feed appears to potentially hold promising perspectives for fish producers, *ceteris paribus*. Since insect-based feed is considered to become a cheaper alternative than standard feed once large-scale production is in place, switching to insect-based feed could pose a potential for increased profits due to a reduced feed input cost. It should, however, be noted that the extent of the expected economic benefits attributed to insect-based protein feed would be dependent on the development of both the cost of insect-based protein feed and alternative fishmeal-free sources such as plant based materials. More importantly, the results seem to point out that innovating out of the fish meal trap through for example insect-based meals present a way to increase production significantly to help ensure food for the growing population without significantly having any adverse effect on the market. While caution should be taken in drawing generalizations due to skewness in sampling representation, the results might indeed reflect market conditions.

Regarding the small group who have a negative attitude toward insect feed, strategic provision of information through public campaigns and marketing could potentially bring a shift in preference structure toward more positive preferences for insect-based feed. As has been shown in literature (see e.g. Wichman, 2017), information provision can be used to shape consumer preferences, though the effectiveness of the information depends on the type of good and information itself. Hence, arousing consumers' consciousness or awareness of sustainability and the environmental friendly nature of the use of insect as feed could potentially vertically differentiate fish products and shift preferences. However, further research is needed to determine the extent to which specific types and amounts of information about insect-based feed might indeed be a way to shift consumer preferences in a positive direction.

Notes

1. Attribute levels are indicated in parentheses and the italized levels are the reference levels used in modeling.

2. It is unknown to what extent the political tension between Turkey and Germany around the time of the data collection could have influenced the results. The result is, however, in line with expectations.

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Appendix

Characteristics	Percent	Mean	SD
Gender			
Male	39.67		
Female	60.33		
Age (years)		41.63	12.33
18–34	33.61		
35–49	35.41		
50–65	30.98		
Region			
Bayern	31.64		
Berlin/Brandenburg	36.07		
Hamburg/Schleswig-Holstein	32.30		
Household size		2.39	1.11
1 person	21.80		
2 persons	40.16		
3 persons	19.02		
4 persons	15.25		
Above 5 persons	3.77		
Employment status			
Part time	19.67		
Full time	56.56		
Other	23.77		
Household monthly income			
< €2,000	34.59		
€2,000 to < €3,500	39.84		
> €3,500	25.57		
Family status			
Single	25.90		
Married/registered partner	45.90		
Live together	18.36		
Separated/widow/divorce	9.84		
Education level			
Basic education	9.18		
Secondary school	31.31		
Higher secondary school	11.15		
Post-secondary Education	19.34		
Tertiary education	28.20		
Other	0.82		
Total observations	610		

Table AI.
Sample distribution
by socio-economic
characteristics (%)

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Factors	Description of respondents agreement to constructs	Average score of constructs
Factor 1	Agrees with negative perception of fish: being expensive, preparation difficulty, odor deters and many bones	0.648
Factor 2	Agrees with positive perception of organic fish: being environmental friendly, healthier, no chemical residue, higher quality, abundance in shop	0.671
Factor 3	Agrees with negative organic fish perceptions: taste no better, less appealing and high price premium	0.735
Factor 4	Agrees with organic fish products being more expensive	0.806
Factor 5	Agrees with attitudes such as: prefer recyclable packages, choosing ecolabels if price is not too high, avoids, environmentally harmful products, able to follow ecological issues on media, willing to sacrifice to protect environment for future generation	0.664
Factor 6	Agrees with attitudes: taking part in environmental protection events and donation to ecological organizations	0.787

Notes: constructs agreement Likert scaled as: $1 =$ Strongly Disagree, $2 =$ Disagree, $3 =$ Neutral, $4 =$ Agree and $5 =$ Strongly Agree

Table AII.
PCA – Factor rotation loadings and component description

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