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An empirical study on consumer acceptance of farmed fish fed on insect meals: the Italian case

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Abstract Aquaculture is assuming ever more importance in diminishing the pressure on wild stocks in the seas and to satisfy the demand of fish worldwide. Prices of feed used in farming fish are increasing, due to the rise in demand. Research on sustainable sources of feed was recently intensified, and insects as meal to substitute soybean and fish meals and fish oils seems a promising field. In particular, only very few papers have explored consumer interest in fish feed. The objective of this study is to explore the attitude and behavior of Northern-Italian consumers of farmed fish fed on insects considering the different phases of the purchasing process: from a general claim to interest in sustainability about the use of marine resources to the attitude in to eating finfish products if fed on insect meals and finally to the decision to purchase. In particular, the study utilizes a quantitative research methodology to explore factors affecting the gap between consumer intention and consumer behavior. Results indicate almost 90 % of consumers have a positive attitude to insect meal as feed and most of the respondents intend to purchase and eat farmed fish even though fed with insect meals. Moreover, interest is mainly affected by socioeconomic variables, knowledge of the issue and the interest attributed to origin and certification. Positive attitude is mainly influenced by interest in this issue and variables linked to appearance and price, whereas the willingness to buy fish fed on insect meals is closely linked to the importance of price and expected price for this kind of fish.

Keywords Aquaculture · Consumer · Feed · Fish · Insect · Sustainability · Willingness to buy

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Motivation and background

In recent years, finfish production in Europe has increasingly become the subject of attention from an environmental and economic sustainability perspective. Intensive current finfish farming practices and consumption patterns in high-income countries are associated with ecological pressure and marine over-exploitation. Aquaculture has achieved 42 % of global fish supplies by weight (FAO 2014), and the continued increase in the demand for fish products has caused a rise in feed prices, such as fish meals, fish oil, soybean meals. The EU has proven to be the major consumer market of seafood products in the world, with 12.3 million tons, equal to € 52.2 billion in 2011. It is the primary importer of seafood products, purchasing 24 % of total world exchanges in value (EU Commission-EUMOFA 2014). At the same time, the interest of European consumers in healthy and affordable products such as fish is increasing (Menrad 2003; Frewer et al. 2007; Niva and Mäkelä 2007; Verbeke 2011). Moreover, in the European Union the dependence on the importation of fish products is growing, so it is urgent to verify both the cost and the advantage for aquaculture companies to introduce innovations in feeding practices. At the present time, one of the more interesting solutions to feeding fish is the use of insect meal to substitute fish and soybean meal (Van Huis 2013). Several studies have been conducted from a farming and nutritional point of view (Van Huis 2015). Scientists consider the insect meals a valid alternative source of animal protein and have studied the nutritional characteristics, in terms of amino-acid profile and composition of fatty acid (Barroso et al. 2014; Gasco et al. 2014a, b, Sánchez-Muros et al. 2014; Schiavone et al. 2014).

European Union policy supports these issues by financing dedicated projects; however, at present, ambiguous and restrictive European laws concerning the use of insects in feed and food are a major barrier to potential development (FAO 2013).

In this perspective, it is essential to know the opinion of consumers in order to provide support to policy makers and producers in taking into consideration whether to adopt insect meals as feed for fish in the future. However, there is little knowledge on this issue (Smith and Pryor 2014); consequently, it is necessary to obtain more information in order to set up policy and commercialization strategies (Van Huis 2013, 2015).

The first online survey results from the EU project Proteinsect.eu indicate that 88 % of respondents ask for more information about the use of insects as feed and food; 66 % said that the larvae of flies are a suitable source of protein for use in animal feed; 52 % feel they do not know enough about the matter, so they refuse to eat meat from fish, pork or chicken fed on insect meals (AllAboutFeed 2014).

Another study on the acceptance of insects in animal feed comes from Verbeke et al. (2015) that reports the results of a survey of farmers, agricultural sector stakeholders and the general public and finds that attitudes to the idea of using insects for animal feed are generally favorable, most notably for fish and poultry.

However, these studies focus attention on consumer attitude without taking into consideration consumer behavior. The transition from intention to purchasing behavior is weakly analyzed for this issue, and in our work we try to investigate this presumed gap between favorable attitude toward sustainable behavior and intention behavior to purchasing sustainable food products.

The objective of this study is to explore the attitude and behavior of Northern-Italian consumers of farmed fish fed on insects considering the different phases of the purchasing process: from an interest in marine ecology and awareness of limited resources for fish farming to the attitude into eating finfish products if fed on insect meals and finally to the

decision to purchase. In particular, the study utilizes a quantitative research methodology to explore the gap between consumer intention and consumer behavior identifying those consumer characteristics and factors affecting interest in the sustainability issue and the behavior to purchase and eat this kind of fish. A clearly revealed consumer opinion and behavior for sustainable fish consumption will help motivate and reinforce appropriate activities of companies, as well as impact the activities of political institutions that define regulatory frameworks and play an influential role in attaining sustainability goals (Balderjahn et al. 2013).

The literature review

In the literature, fish consumption has been extensively studied and recently a comprehensive review was carried out (Carlucci et al. 2015). In several papers analyzed, the authors identify the main drivers of fish consumption in the sensory appreciation perception to eating fish, like taste, smell and texture as well as the health and nutritional believe. Other important drivers discovered are the fish-eating habits that can be reinforced from accumulated past experiences or generated from high fish consumption during childhood. Conversely, the main barriers to fish consumption are represented by the sensory lack of appreciation of fish, health risk issues, high price perception, and lack of knowledge in selecting and preparing fish.

Carlucci et al. also report consumers' preferences with regard to the attributes of fish products. In particular, they cite a number of studies highlighting the country of origin as one of the most important attributes. Specifically, consumers show a clear preference for domestic fish perceived as superior to imported fish (Mauracher et al. 2013, Stefani et al. 2012); moreover, consumers can be influenced by a specific country of origin image (Claret et al. 2012). Furthermore, in terms of production methods several papers demonstrate that for the majority of consumers wild-caught fish is perceived as better than farmed fish (Verbeke et al. 2007a). However, very few papers have explored consumer interest in fish feed.

One of the main studies is that proposed by Stefani et al. (2012) which analyzed Italian consumer preferences for farmed sea bream, as well as focused on the type of feed (fish and vegetables or only fish) used in farming. In their survey, results indicate the feed type does not particularly influence purchasing choices. Similar conclusions are found by Pieniak et al. (2007). In their work, they consider the aspect "feed used during farming" and "fed with genetically modified feed," but it seems that these issues do not matter to consumers. Claret et al. (2012) underline that consumers recognize their limited knowledge on aquaculture methods and animal feeding, whereas Pieniak and Verbeke (2008) discovered that of five European countries only Danes indicated a strong interest in information cues related to the origin of fish and sustainability issues, such as fish welfare, feed used during farming and fed with genetically modified feed. Thus, the feed issue seems to be of interest to consumers only when it is associated with the sustainability issue.

In the last twenty years, attention to sustainability and sustainable consumption has increased at all levels of the food chain. Reaching sustainable development embraces policies to achieve economic, social and environmental goals (World Bank 2003). In the literature, sustainable food consumption has been extensively studied (Verain et al. 2012), but it is no easy matter to obtain reliable information on consumer preferences and behavior for environmental/ethical products introduced in the market. In fact, several

Table 1 Italian indicators of marine fish and aquaculture (2005–2014)

Indicators	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	var. 2013–2014/ 2005–2006 (%)
Total fishery products (t live weight)	475,177	485,626	463,690	390,071	410,338	383,647	376,857	333,035	313,787	325,620	−33.5
Marine catches (t live weight)	294,076	312,047	282,699	232,206	248,013	230,021	212,730	195,996	172,907	177,019	−42.3
Aquaculture (t live weight)	181,101	173,579	180,991	157,865	162,325	153,626	164,127	137,039	140,880	148,601	−18.4
Aquaculture/total products (%)	38	36	39	40	40	40	44	41	45	46	22.6

Source: Eurostat database

Table 2 Trade, per capita consumption, self-sufficiency rate for fishery products in Italy (2003–2012)

Indicators	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	var. 2011–2012/ 2003–2004 (%)
Imports (t)	830,000	843,000	872,000	901,000	915,000	913,000	913,000	923,000	961,330	903,038	11.4
Exports (t)	119,000	124,000	132,000	141,000	141,000	133,000	133,000	138,000	126,225	117,232	0.2
Imports (mln €)	3153	3113	3382	3681	3777	3655	3565	n.a.	4416	4207	37.6
Exports (mln €)	414	434	475	556	556	528	494	n.a.	557	501	24.8
Per capita consumption (kg per year)	21.4	21.6	21.4	22.1	21.9	20.9	20.8	20.9	20.8	19.8	−5.6
Self-sufficiency rate (%)	42.3	42.9	41.1	41.6	40.4	37.3	37.8	37.8	33.3	333	−21.8

Source: ISMEA (2008, 2009, 2013)

authors have demonstrated that although public interest in sustainability has increased, consumers value sustainable products and their attitude are mainly positive (Carrigan and Attala 2001; Crane and Matten 2004; Connolly and Shaw 2006); however, their buying behavior is frequently inconsistent with this (Alwitt and Pitts 1996; Bech-Larsen 1996; Thøgersen 1999, 2004; Thøgersen and Ölander 2003; Vermeir and Verbeke 2006; Moisander 2007), thus creating a gap between intention and behavior.

Few studies have analyzed fish consumption in a sustainable issue context. The focal contribution comes from Verbeke et al. (2007b) who analyze the importance Flemish consumers attach to sustainability issues related to seafood. Their results show that consumers indicate that the sustainability issue is important even if this interest is not related to attitude and behavior. Other contributions mainly investigate the sustainable issue in terms of the role of eco-labeling (Johnston et al. 2001 and Jaffry et al. 2004), whereas analysis of the factors leading to the demand for green seafood products is carried out by Brécard et al. (2009).

In the case of Italy, two studies (Stefani et al. 2012 and Mauracher et al. 2013) have also investigated consumer behavior to fish also in terms of sustainability. The main finding of the first paper is that the country of origin appears as one of the most important aspects of consumer choice, followed by organic certification and fish farming in marine cages, considering this type of fishery to have a lower environmental impact. However, on average consumers show a moderate pro-environmentalism. Mauracher et al. 2013 focus their attention on organically farmed fish and discover that about half of their sample is willing to pay a premium price for this characteristic.

Finally, a recent study (Verbeke et al. 2015) utilizes a sample of farmers, agricultural sector stakeholders and citizens in Belgium to analyze attitudes to the idea of using insects in animal feed (fish, poultry, pigs, pets and cattle) as a possible way to improve the sustainability of animal diets. The main results show that opinions are generally favorable, in particular for fish and poultry feed. For citizens, results show that the strongest perceived benefits are that the use of insects may allow a better use of organic waste and lower dependence on foreign protein sources as well as improving the sustainability of livestock production, and lowering the ecological footprint of livestock to a lesser degree. No study has ever analyzed the gap between interest/attitude and behavior regarding the sustainability of fish consumption with particular reference to feed used. We intend to fill this gap because we feel that in the future the use of insects for feed could became a potential path to advance the sustainability of fish diets and meet the increasing demand for fish products.

Exploring the Italian finfish sector

In 2014, the Italian fishery sector obtained 325,620 t of total fishing production, of which 177,019 t from marine catches and 148,601 t from aquaculture activities (Table 1) (Eurostat database). Aquaculture has achieved 46 % of the total, in terms of production.

The Italian aquaculture sector is dominated by small enterprises with less than five employees each. There were 587 companies in 2012. The total workforce employed in the sector (number of people employed) in 2011 was 58,000 units (EU Commission-JRC 2014).

By ISMEA market analysis, in 2012 the Italy's self-sufficiency for seafood (i.e., the production relative to its internal consumption) was equal to 33 % (ISMEA 2013), Table 2. In fact, the imports were substantial, equaling 903,038 t and 4207 million of euros; exports

equaled 117,232 t or 501 million of euros, leading to a negative trade balance. The analysis of the commercial trade deficit for fish product categories shows that almost 80 % of the deficit was determined by processed fish products (frozen, dried, salted or in brine, smoked, prepared or preserved, fresh fish fillets), amounting to 3291 billion euros in 2012 (ISMEA 2013). The national imports are divided between suppliers from EU countries suppliers (57.4 % in value) among which Spain, the Netherlands and Denmark, and outside the non-EU countries (42.6 % in value) such as Ecuador and Thailand (ISMEA 2013).

From the analysis of dynamics of the other main variables, the situation of the fishery sector is in decline: Eurostat data for the period 2005–2014 show a decrease of 33.5 % of total production, −42.3 % for marine catches, and −18.4 % of aquaculture production (Table 1). In fact, the fishery sector in Italy has been in difficulties since the year 2000, as also shown by all ISMEA indicators for 2011–2012 compared with 2003–2004 (Table 2). Italy's self-sufficiency for seafood (i.e., the production relative to its internal consumption) diminished by 9 point (from 42 to 33 %) in the period analyzed. Imports have increased, in terms of quantity (+11 %) and value (+38 %).

However, the number of companies has decreased: 826 in 2007, 754 in 2010, a result partly due to a process of vertical integration and concentration led by mollusk companies which have reorganized into consortiums, multiregional enterprises and POs (Producers Organizations); however, another factor is that many companies have closed (EU Commission-JRC 2012, 2014).

Per capita consumption amounted to 19.8 kg in the year 2012. Consumption per capita was down compared to the past: It decreased by 5.6 % between the two periods considered (ISMEA 2008, 2009, 2013). The health benefits associated with fish consumption (EFSA 2014) require maintaining or increasing domestic consumption. Since the marine life caught in the Mediterranean cannot grow (Vasilakopoulos et al. 2014), sustainable aquaculture is identified as a means of tackling the problems of the fishery sector and of meeting the demand (EU Commission 2013).

The JRC-STECF suggests overcoming the stagnation of the European aquaculture sector, with the introduction of different types of innovations, among them feed ingredients (EU Commission-JRC 2012). The use of insect meals in aquaculture may be a process production innovation.

Use of insect meals in aquaculture

Several articles have highlighted how insect meals may provide a sustainable source for animal feed (Rumpold and Schluter 2013a; Sánchez-Muros et al. 2014; Barroso et al. 2014; Henry et al. 2015) as part of the natural diet of fish, poultry and pigs (Howe et al. 2014), being highly nutritious as well as having advantages from an efficiency and environmental point of view (Ramos-Elorduy 2008; Wilkinson 2011; Oonincx and De Boer 2012; Van Huis 2013).

In fact, insect meals have a high nutritional value. They are a protein-rich raw material, ranging from 40 to 75 % on a dry matter basis, taking into consideration species and stage in the life cycle (Rumpold and Schluter 2013b) with a greater concentration of essential amino acids (EAA) than soybean (Makkar et al. 2014); moreover, some insect meals cover the requirement for all EAA for fish (Henry et al. 2015).

Insect meals are high in fat, providing energy at levels comparable to or even higher than grains or legumes (from 10 % to up to 38 %, depending on the rearing substrate)

(Barroso et al. 2014). Moreover, degreasing the meal can further increase its level of protein as well as lead to valuable by-products that can be used in the animal feed industry or for other purposes (i.e., biodiesel) (Manzano-Agugliaro et al. 2012).

Besides being rich in nutrients, insect meals could also be a source of high value bioactive compounds, i.e., chitin, antimicrobial peptides, whose value has to be investigated further.

It has been estimated that insects (i.e., Hermetia illucens or Musca domestica) could convert the 1.3 billion tons of waste generated globally per year (Van Huis 2013), reducing the substrate mass by about 60 % thus dramatically decreasing disposal and transportation costs as well as the environmental footprint (Gustavsson et al. 2011; Veldkamp et al. 2012; Van Huis 2013).

Moreover, insects have the potential to yield 200 times the amount of protein per hectare per year as soy and do not require fertile or large areas of land or the use of large quantities of water (Manzano-Agugliaro et al. 2012).

Nevertheless, critical points on the use of insect meals in animal feed cannot be ignored. Under EC legislation (Regulations EC 1069/2009, EC 767 2009, EC 68/2013), only some substrates can be used to rear insects but even in that case, hygiene and the potential for disease carryover must be considered. Even if early evidence on that topic seems to indicate that insects are at low risk of transmitting zoonotic diseases, more information and the need for a Hazard Analysis of Critical Points (HACCP) is crucial and required by European legislators. Insect meals also need to be regularly tested for the risk of heavy metal concentration, pesticide presence or bacterial carry over. Moreover, special processing, storage and sanitation procedures must be carried out in order to ensure the safety of the product (Klunder et al. 2012).

The price of insect meal is also a matter of concern. At present, because of the lack of legislation in Europe, insect meals are produced in low quantities and the price is high when compared to other protein sources. European producers are waiting for clear legislation before shifting their production, currently focused on pet and novelty human foods, to large-scale production in order to supply the animal feed industry thus resulting in a decrease in the price of insect meal (Koeleman 2014; IPIFF 2014; Veldkamp et al. 2012). Moreover, the production of insect meals of a constant and defined quality is a mandatory point for the feed industry.

More investigation needs to be carried out on the quality and safety of products aimed at human consumption which are obtained using insect meals. Consumer acceptance must also be studied further. There is also a need for more investigation into the use of insect protein for livestock and aquafeed carried out together with economic analyses.

Materials and methods

To explore consumers' gap between attitude and behavior to fish farmed in aquaculture using insects as animal feed, we carried out a survey of Northern-Italian consumers of fish during summer-autumn 2014. A sample of 277 respondents was stratified by age and gender on the basis of the composition of the Italian population. The study is based on face-to-face interviews. We conducted the survey in three districts of the Piedmont region, in two different types of venue: 127 respondents were interviewed in local outdoor markets and 150 in supermarkets. We differentiated the type of market so as to include two kinds of fish consumers: more traditional in the first case and more evolved in the second one.

Table 3 Components used for questionnaire

Components	Demands	Scale/categories	*N*	Mean	SD
FP (fish-purchasing habits)	Interview site (category)	0–1	277	–	–
	Fish-purchasing frequency	1–5	277	3.97	1.08
	Type of fish purchased (categorical)	1–3	277	–	–
DC (drivers of fish consumption)	Reasons for purchasing fish (categorical)	1–3	277	–	–
	Importance of price	1–4	277	3.10	0.72
	Importance of origin	1–4	277	3.37	0.80
	Important if Italian or foreign origin	1–4	277	3.26	0.85
	Important if farmed or wild caught	1–4	277	2.88	0.88
	Importance of appearance	1–4	277	3.72	0.58
	Importance of nutritional aspects	1–4	277	2.86	0.97
	Importance of certification	1–4	277	2.94	1.03
	Importance of other factors	1–4	277	2.11	1.31
K (consumer knowledge)	Knowledge of over-fishing	1–2	277	1.07	0.25
	knowledge of feed provided (categorical)	1–5	277	–	–
I (interest in sustainability of fish farming)	Interest in research in sustainable feed	1–4	277	3.32	0.74
	Interest in type of fish feed	1–4	277	3.05	0.78
AT (consumer attitude toward finfish produced with insect meals)	Attitude toward use of insect meal	1–3	277	2.40	0.67
	Willingness to buy fish farmed on insect meal	1–3	277	2.69	0.61
	Negative factors: distaste	1–4	19	3.68	0.57
	Negative factors: quality	1–5	19	3.05	1.00
	Negative factors: trust	1–6	19	3.21	1.15
	Expected price for fish farmed on insect meals	1–3	277	1.93	0.75
	Willingness to pay more for fish farmed on insect meal	1–2	277	0.13	0.42
SE (socioeconomic–demographic factors)	Income	1–4	127	1.07	1.31
	Gender (categorical)	1–2	277	–	–
	Age	1–7	277	4.11	1.25
	Education	1–4	277	2.98	0.80
	Employment (categorical)	1–12	277	–	–
	Family size	1–4	277	2.43	0.70
	BMI	Continuos	277	23.28	3.36

Following Verbeke et al. (2007b) to reveal the interest that the consumer places on sustainability issues linked to marine ecology and the attitude toward finfish produced with insect meals, we consider six components relevant to food consumer science (Table 3).

The first component corresponds to consumers' fish-purchasing habits; the second to drivers of fish consumption; the third to consumer knowledge of marine over-exploitation and raw materials used for feeding farmed fish; the fourth to consumer interest in the sustainability of fish farming and the fifth to consumer attitude to insect meal as a feed substitute for fish and soybean meals. Finally, socio-demographic and economic characteristics were collected. A questionnaire was developed with these components using a multiple-choice format with rating or dichotomous scales.

Firstly, we carried out a descriptive analysis to study the characteristics of the sample and the frequencies of the answers. Subsequently, we used three ordinal logistic regression models (McCullagh 1980, 1998) to predict three different ordinal dependent variables given 24 independent variables. Between these, we utilized 20 ordinal variables and 4 categorical variables. The dependent variables with rating scale are listed below:

IS = consumer interest in research in sustainable feed for fish farming (score 1–4)
CA = consumer attitude to use of insect meal (score 1–3)
WB = Willingness to buy fish farmed on insect meal (score 1–3)

For the aim of our work, we considered the following functional relations:

$$\mathrm{I} = \mathrm{f}(\mathrm{FP},\ \mathrm{DC},\ \mathrm{K},\ \mathrm{I},\ \mathrm{AT},\ \mathrm{SE}) \tag{1}$$

$$\mathrm{CA} = \mathrm{f}(\mathrm{FP},\ \mathrm{DC},\ \mathrm{K},\ \mathrm{I},\ \mathrm{AT},\ \mathrm{SE}) \tag{2}$$

$$\mathrm{WB} = \mathrm{f}(\mathrm{FP},\ \mathrm{DC},\ \mathrm{K},\ \mathrm{I},\ \mathrm{AT},\ \mathrm{SE}) \tag{3}$$

We chose different dependent variables because we were interested in distinguishing general interest in this issue versus effective decision to purchase.

IS variable is selected to explore general interest, CA variable can be considered as a proxy of the intention to purchase, whereas WB variable measures the actual behavior of consumers in purchasing fish feed with insects.

Ordinal regression provides a useful extension of the binary logistic model in those situations where, precisely, a dependent variable is ordered. An ordinal logistic model takes the following form:

$$c_j(X_i) = \ln\left\{\frac{P(Y > j|X_i)}{P(Y \leq j|X_i)}\right\} = \beta_1 X_{i1} + \cdots + \beta_k X_{ik} - \alpha_{j+1}$$

In our empirical model: $i = 1, \ldots, 277$, corresponds to number of consumers interviewed; $j =$ score from 1 to 3 (or $j = 1, \ldots, 4$ for "IS" dependent variable); $k = 1, \ldots, 24$, corresponds to number of independent variables; $Y =$ response variable; $X_i =$ independent variables (answers for each consumer); $\beta =$ regression coefficients; $\alpha =$ parameter referred to as "cutpoints" between intervals of values of response variable. β coefficients represent the log odds ratio of scoring $>j$ versus $\leq j$ for a one unit change in X.

We ran ordinal regression using SPSS23 software with the exclusion of three variables from the set of independent variables (negative reasons for a negative attitude to fish fed on insects) due to the limited number of answers.

Provided that we use several independent variables that are highly correlated to each other, multicollinearity problems occurred. This led to difficulties with understanding which independent variable contributed to the explanation of the dependent variable and technical issues in calculating an ordinal regression. Therefore, we quantified the severity of multicollinearity by variance inflation factor (VIF). It provides an index that measures

how much the variance (the square of the estimate's standard deviation) of an estimated regression coefficient is increased because of collinearity.

Finally, considering that in a regression model the effect of an independent variable is thought to vary depending on the value of another independent variable, we also evaluate interaction effects between variables at second-order level (Jaccard 2001). Provided that we deal with several variables and interactions between each pair of variable produce too many relations, we decided to consider only interactions between significant independent variables. We start by specifying a full model that includes all two-way interactions. We then run the model with the main effects and all the two-way interactions, subsequently eliminating any non-significant two-way interaction terms.

Results

Descriptive results

An overview of the six groups of questions with means and standard deviations is presented in Table 3.

The sample analyzed includes 67.5 % of women and 32.5 % of men. 61.4 % were equally distributed between the ages of 45–54 and 55–64 years, and 15 % were in the 35–44 years old range. The level of education is medium high: 47.3 % of respondents have a high school diploma, and 27.1 % hold a university degree. For 39 % of the sample, monthly income amply covers expenses, whereas 45 % have to keep a close eye on spending. 16 % have highly limited purchasing power, and as a result, this group is often forced to do without. 54.5 % of respondents come from families with 3–5 members, 33.2 % come from 2-person families, and 11.9 % live alone. The BMI (biomass index, height x weight) shows that most respondents had a normal body weight (66.8 %), 28.2 % were overweight (of whom 4 % were obese), and 5 % were underweight.

Descriptive results show (Fig. 1) that almost 90 % of consumers are interested in research on more sustainable sources of feed used in aquaculture.

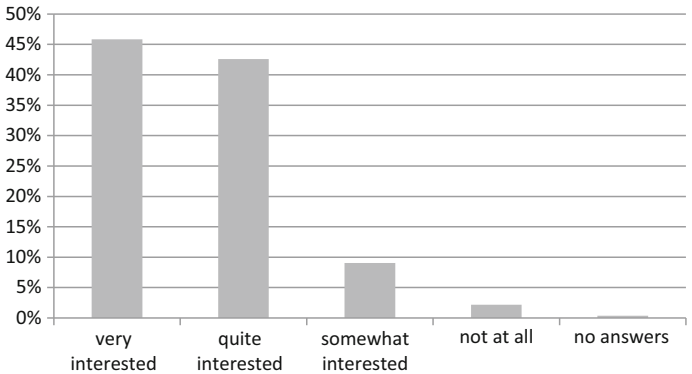

Fig. 1 Interest of respondents in international research on more sustainable feed for farmed fish (%). *Source*: Based on our survey

Likewise descriptive results show that almost 90 % of consumers have a positive attitude to insect meals as feed in fish farming (Fig. 2). In addition, almost 50 % of consumers are in full agreement, whereas 40 % are in partial agreement.

Most of the respondents (76 %, see Fig. 3) intend to purchase and eat farmed fish even though they are fed on insect meals, so long as the hygiene requirements are met.

A small group (7.6 %) stated it would not buy this type of fish product, 95 % of whom said they feel uncomfortable with the use of this new feed (Fig. 4); 74 % do not trust the production process; 42 % think that the quality (taste and other parameters) of the product could be highly compromised, while 32 % felt it could be somewhat damaged.

We then analyzed consumer opinion against the market price that a new product such as fish fed with insect meal could have. About half of the samples (46.2 %) believe that the price will be the same as traditional fish products; 29.2 % think that the product will have a lower price either because insect meal costs less than traditional feed or in order to promote it on the market. On the other hand, 23.8 % of people expect a higher price for three reasons: (1) because they do not think that plants that produce insect meals currently exist in the European Union and therefore they would have to be built. The respondents think they have to be built in the EU zone because they believe that hygiene is more regulated compared to non-EU countries; (2) because sustainable products have a higher price due to the intrinsic added value; and (3) because it is an innovative food that incorporates the cost of research.

Other interesting results tell us that 73 % of the samples purchase fish almost once a week and 70 % of those do so in a supermarket. Among factors affecting the purchasing decision, fish "appearance" emerges as most important (77 % of consumers state "it is very important") followed by origin (53 %), in line with the existing literature.

Thus descriptive results indicate a strong interest in, positive attitude to and willingness to buy this kind of fish and I-B gap seem to be quite small. However, our analysis aims to explore which factors may have an impact on the passage from interest to behavior with the result that a more in-depth analysis is required.

Regression results and discussion

Ordinal regression results for the three models are reported in Table 4. To solve multicollinearity problems, we had to remove some variables after checking *tolerance* and *VIF* (*variance inflation factor*) values for each predictor.

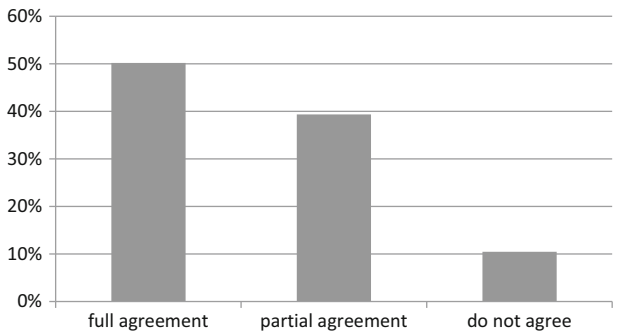

Fig. 2 Attitude of respondents to insect meals as feed in fish farming (%). *Source*: Based on our survey

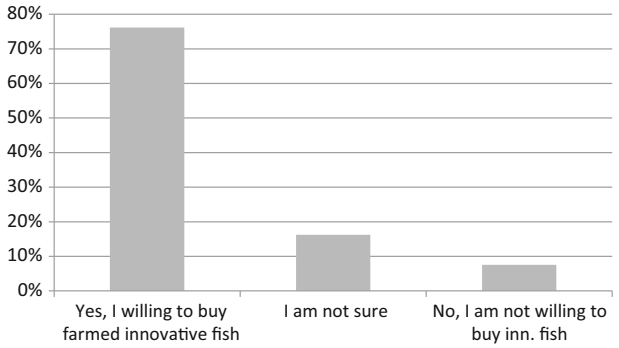

Fig. 3 Willingness of respondents to purchase and eat farmed fish fed on insect meals if presented on the market (%). *Source*: Based on our survey

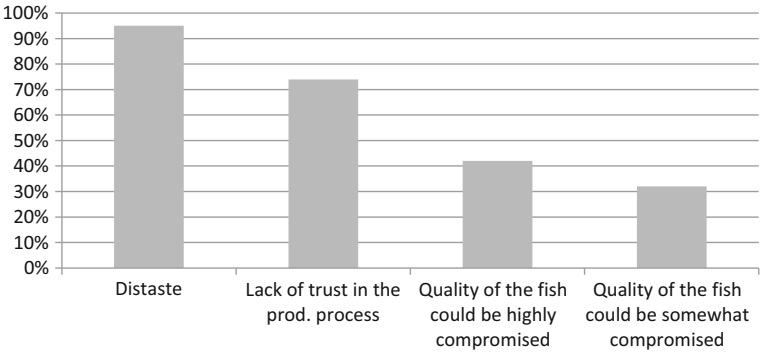

Fig. 4 A small group of respondents and their reasons for being unwilling to consume farmed fish fed on insect meals (%). *Source*: Based on our survey

The overall fit of the model is reasonably good with pseudo-R^2 measures ranging between 0.15 and 0.589. Equation (1) specifies consumer interest in research in sustainable feed for fish farming. All six components are significant at least for one variable. Coefficient of variable that expresses where consumers are interviewed appears significant and with high value so we can conclude this is an important predictor. The positive sign indicates that consumers who utilize outdoor markets are more likely to be interested in research in marine ecology and awareness of limited resources for fish farming. Interest is also affected by the frequency of fish purchase, origin, domestic/foreign provenance of the fish and the presence of certification. Nonetheless, those who have a greater knowledge of over-fishing issues are less interested in these topics. Moreover, all the socioeconomic variables show significant estimates. In particular, education, age and BMI result in predictors positively affecting consumer interest, whereas income, gender (female) and family size have a negative effect. Two-way interaction results provide more interesting aspects. In particular, the effect of the attitude toward use of insect meal on "interest" varies significantly based on the level of knowledge of over-fishing as well as fish-purchasing frequency.

Considering Eq. (2), we first note that between factors relating to fish-purchasing habits, only the "type of fish purchased (category: wild-caught fish)" affects consumer attitude in

Table 4 βs estimates of ordinal regression

	(Eq. 1) Interaction	(Eq. 2) Attitude	(Eq. 3) Willingness
α_1	10.071***	−0.697	5.137
α_2	11.943***	2.975	7.494*
α_3	14.764***		
FP			
Interview site (category = local market)	1.349**	−1.079	−1.609*
Interview site (category = supermarket)	0[a]	0[a]	0[a]
Fish-purchasing frequency	1.030**	−0.031	−0.206
Type of fish purchased (category = farmed fish)	0.256	0.124	−0.679
Type of fish purchased (category = caught fish)	0.364	−0.613*	0.021
Type of fish purchased (category = both)	0[a]	0[a]	0[a]
DC			
Reasons for purchasing fish (category = I like)	0.134	−0.287	0.478
Reasons for purchasing fish (category = healthy)	−0.402	0.082	0.024
Reasons for purchasing fish (category = both)	0[a]	0[a]	0[a]
Importance of price	−0.078	−2.810***	0.565**
Importance of origin	0.442*	−0.169	0.212
Important if Italian or foreign origin	−0.314	0.120	−0.152
Important if farmed or wild caught	0.062	−0.081	1.320
Importance of appearance	−0.188	0.599**	0.065
Importance of nutritional aspects	−0.061	0.049	−0.207
Importance of certification	0.233*	0.018	0.101
Importance of other factors	−0.043	0.130	−0.155
K			
Knowledge of over-fishing	1.965	0.635	−0.941
I			
Interest in research in sustainable feed	–	−1.661*	0.213
Interest in type of fish feed	0.447**	0.357*	−0.271
AT			
Attitude toward use of insect meal	3.457***	–	5.866***
Willingness to buy fish farmed on insect meal	0.381	2.565***	–
Expected price for fish farmed on insect meals	0.154	0.058	0.705**
Willingness to pay more for fish farmed on insect meal	0.371	2.621	−0.386
SE			
Income	−0.449**	0.334	0.483
Gender (category = F)	−0.816***	0.079	−0.050
Gender (category = M)	0[a]	0[a]	0[a]
Age	0.315***	−0.243*	0.128
Education	0.365**	−0.241	0.070
Family size	−0.341*	0.137	−0.030
BMI	0.103**	0.024	−0.128**
INTERACTION			
Fish-purchasing frequency*	−0.328*		
Attitude toward use of insect meal			

Table 4 continued

	(Eq. 1) Interaction	(Eq. 2) Attitude	(Eq. 3) Willingness
Knowledge of over-fishing*	−1.429**		
Attitude toward use of insect meal			
Interest in type of fish feed*		−0.854*	
Willingness to pay more for fish farmed on insect meal			
Importance of price*		0.693**	
Interest in research in sustainable feed			
Important if farmed or wild caught*			−0.947**
Attitude toward use of insect meal			
Pseudo-R^2			
Cox and Snell	0.266	0.443	0.414
Nagelkerke	0.305	0.589	0.55
McFadden	0.15	0.42	0.383

***, **, * denote 1, 5 and 10 % level of significance, respectively

[a] This parameter is set to zero because it is redundant

eating finfish products if they are fed with insect meals. This means that those consumers that usually buy wild-caught fish show a lower attitude.

Interestingly, price is both a significant and negative factor; this means that those who consider price an important driver for fish purchase are less likely to agree to the use of insect meals. However, considering two-way interaction price effect on attitude varies depending on the "interest in research in sustainable feed."

Fish appearance is a positive predictor of this attitude, and also highly significant is the willingness to purchase fish fed with insects and an interest in marine ecology. Conversely to Verbeke et al. 2015, age in this equation is significant and negative, that is, the younger the consumers, the higher the probability they agree with this innovation. Moreover, in Eq. 2 "interest in type of fish feed" effect on "attitude" varies depending on "willingness to pay more."

The predictors affecting the willingness to purchase this kind of farmed fish are analyzed in Eq. (3). The first interesting result is still the place where the interviews are conducted, that is, if consumers are at outdoor markets, they are less willing to buy this kind of fish. Price appears as a significant factor affecting the dependent variable in a positive manner as well as expected price for fish farmed on insect meals. This result tells us that the consumer that considers price an important aspect in the purchase of fish tends to be more willing to buy fish farmed on insect meals. Moreover, those who expect that this particular type of fish will be more expensive are the same ones who are more likely to buy it. We could justify this result by assuming that consumers more favorable to fish fed with insects consider it both as a sustainable product with a higher price due to the intrinsic added value and as an innovative food incorporating the cost of research. Obviously results of the "attitude to the use of insect meal" predictor are highly significant and positive. For "attitude" and "importance if farmed or wild-caught," we also find significant interaction term.

Contrary to the findings of some works in the literature (Claret et al. 2012, Agrawal and Kamakura 1999), the origin in this case is not a significant factor for the purchase but this may be justified by the fact that the focus is not placed on the fish in general but on a

specific product farmed with particular characteristics. Finally, BMI results appear significant and negative. This is not surprising considering that consumers more future and sustainability-oriented are more prone to take into account healthy aspects and more likely to have healthy BMI levels (Cavaliere et al. 2014).

For all three dependent variables, where the interviews were conducted turned out to be one of the most important factors. Actually putting their intentions into practice is more probable for consumers buying fish in a supermarket than for those shopping at a local outdoor market. This finding suggests the central role that the type of market assumes in influencing consumer attitude and behavior. Supermarkets assure uniform standards of safety, quality and "ethical" content of their food products. The price of fish fed on insect meals is a factor that underscores the distance between those who declare a positive attitude or interest and state that price has no importance and those consumers willing to purchase this specific product, who consider price a decisive factor.

Moreover, comparison between the results of these three models allows us to shed light on the factors explaining the gap between consumer attitude and behavior. First, I-B gap shrinks when consumers are in a less traditional and specialized place. Second, price represents a discriminating factor; that is, consumers who claim to be willing to purchase this specific product consider price an important factor, while those who have a positive attitude or interest do not.

Conclusions

As consumer interest in feed for fish is almost unknown, this is one of the first studies trying to empirically analyze attitudes to sustainable fish fed on insects and consumer interest in sustainability issues. In this work, we have analyzed the interest, attitude and willingness to buy of consumers regarding finfish products fed on insect meals.

We carried out a survey submitting a questionnaire to a sample of Northern-Italian consumers. Almost 90 % of consumers have a positive attitude to insect meal as feed, and most of the respondents intend to purchase and eat farmed fish even though fed with insect meals, so long as the hygiene requirements are met.

However, recent research shows that consumers claim to attribute importance to ethical and sustainable consumption, but when purchasing, they rarely translate their intentions into a concrete act.

In order to analyze this gap between intention and behavior, ordinal regressions were used to discover which factors are significant in affecting a) interest in research on sustainable feed for fish farming, b) consumer attitude to use of insect meal and c) willingness to buy fish farmed on insect meal.

In particular, *interest* is mainly affected by socioeconomic variables, knowledge of the issue and the interest attributed to origin and certification. *Positive attitude* is mainly influenced by interest in this issue and variables linked to appearance and price, whereas the *willingness to buy* fish fed on insect meals is closely linked to the importance of price and expected price for this kind of fish.

One of the most important aspects that emerges is that there is a marked difference in the results of the three equations of ordinal regression: The predictors that influence the three dependent variables are often different or have a different sign. This leads us to conclude that there is a difference between interest and actual willingness to buy.

The research has to overcome the critical points of insect production as insect meal used to feed fish which relates to the safety of an eventual industrial production process, distribution and use. The advantage of insect meals as both feed and protein source produced on an industrial scale must be demonstrated from an economic and environmental point of view as soon as possible.

As the European Union is the largest consumer of fish in the world and the largest importer, it is essential to increase internal production. The Italian fish and aquaculture sector is in difficulty. In order to reduce the pressure on the seas, both the European and Italian aquaculture industry need to be strengthened and re-launched.

Future research should check whether the use of insect meal feed is more expensive than that of conventional feed. This aspect may be a potential obstacle for investments to create a specialization of the European feed industry in an insect meals feed supply-chain. At the same time, all risks and measures to take excluding any sources of feeding contamination, if feasible, must be analyzed to construct a European regulation framework.

The findings of our work offer an image of the Italian consumer as sensitive to the sustainability of aquaculture; however, in purchasing they look at the price of fish fed on non-conventional feed with a watchful eye. Caution is in order, however, as our work is one of the first attempts to empirically examine the behavior of consumers with respect to a product that does not yet exist on the market. Thus, we could not measure the authentic behavior using data of actual purchase.

Note This paper is the result of the collaboration of the authors who are jointly responsible. The text is attributed as follows: sections "Motivation and background", "Exploring the Italian finfish sector", "Descriptive results" and "Conclusions" to T. Mancuso; sections "The literature review", "Materials and methods" and "Regression results" to L. Baldi; section "Use of insect meals in aquaculture" to L. Gasco.

References

Agrawal J, Kamakura WA (1999) Country of origin: a competitive advantage? Int J Res Mark 16(4):255–267

AllAboutFeed (2014) Consumers curious about using insects as feed. In www.Allaboutfeed.net, News, 05/16/2014

Alwitt LF, Pitts RE (1996) Predicting purchase intentions for an environmentally sensitive product. J Consum Psychol 5:49–64

Balderjahn I, Buerke A, Kirchgeorg M, Peyer M, Seegebarth B, Wiedmann K-P (2013) Consciousness for sustainable consumption: scale development and new insights in the economic dimension of consumers' sustainability. Acad Mark Sci Rev 3(4):181–192

Barroso G, de Haro C, Sánchez-Muros M-J, Venegas E, Martínez-Sánchez A, Pérez-Bañón C (2014) The potential of various insect species for use as food for fish. Aquaculture 422–423:193–201

Bech-Larsen T (1996) Danish consumers' attitudes to the functional and environmental characteristics of food packaging. J Consum Policy 19:339–363

Brécard D, Hlaimi B, Lucas S, Perraudeau Y, Salladarré F (2009) Determinants of demand for green products. An application to eco-label demand for fish in Europe. Ecol Econ 69(1):115–125

Carlucci D, Nocella G, De Devitiis B, Viscecchia R, Bimbo F, Nardone G (2015) Consumer purchasing behaviour towards fish and seafood products. Patterns and insights from a sample of international studies. Appetite 84(1):212–227

Carrigan M, Attala A (2001) The myth of the ethical consumer—do ethics matter in purchase behaviour? J Consum Mark 18:560–577

Cavaliere A, De Marchi E, Banterle A (2014) Healthy–unhealthy weight and time preference: is there an association? An analysis through a consumer survey. Appetite 83:135–143

Claret A, Guerrero L, Aguirre E, Rincón L, Hernández D, Martínez I, Benito Peleteiro J, Amàlia Grau F, Rodríguez-Rodríguez C (2012) Consumer preferences for sea fish using conjoint analysis: exploratory

study of the importance of country of origin, obtaining method, storage conditions and purchasing price. Food Qual Prefer 26:259–266
Connolly J, Shaw D (2006) Identifying fair trade in consumption choice. J Strateg Mark 14:353–368
Crane A, Matten D (2004) Business ethics: a European perspective. Oxford University Press, Oxford
EU COMMISSION (2013) Comunicazione della Commissione al Parlamento Europeo, al Consiglio, al Comitato Economico e Sociale Europeo e al Comitato delle Regioni. Orientamenti strategici per lo sviluppo sostenibile dell'acquacoltura nell'UE, Bruxelles, 29.4.2013, COM(2013) 229 final http://ec.europa.eu/fisheries/cfp/aquaculture/official_documents/com_2013_229_en.pdf
EU Commission-EUMOFA (2014) European market observatory for fisheries and aquaculture production, The EU Fish Market
EU Commission-JRC (2012) Economic performance of the EU aquaculture sector (STECF EWG 11-14). JRC Scientific and Technical Reports. Report JRC 70424. Edited by Jordi Guillen, Franca Contini, Hendrik Doerner
EU Commission-JRC (2014) The Economic Performance of the EU Aquaculture Sector (STECF 14-18). JRC Scientific and Policy Reports. Report JRC 93169. Edited by Rasmus Nielsen, Arina Motova
EUROPEAN FOOD SAFETY AUTHORITY (2014) Scientific Opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury. EFSA J 12(7):3761
EUROSTAT online database: http://ec.europa.eu/eurostat/data/database
FAO (2013) The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nation, Rome, Italy
FAO (2014) The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nation, Rome, Italy
Frewer L, Lyly M, Urala N (2007) Understanding consumers of food products. Woodhead, Cambridge
Gasco L, Belforti M, Rotolo L, Lussiana C, Parisi G, Terova G, Roncarati A, Gai F (2014a) Mealworm (Tenebrio molitor) as a potential ingredient in practical diets for rainbow trout (Oncorhynchus mykiss). In: Abstract book conference "Insects to Feed The World" The Netherlands, 14–17 May 2014, p 69
Gasco L, Gai F, Piccolo G, Rotolo L, Lussiana C, Molla P, Chatzifotis S (2014b) Substitution of fish meal by Tenebrio molitor meal in the diet of Dicentrarchus labrax juveniles. In: Abstract book conference "Insects to Feed The World" The Netherlands, 14–17 May 2014, p 70
Gustavsson J, Cederberg C, Sonesson U, van Otterdijk R, Meybeck A (2011) Global food losses and food waste: extent, causes and prevention. Food Agric. Organ, Rome
Henry M, Gasco L, Piccolo G, Fountoulaki E (2015) Review on the use of insects in the diet of farmed fish: past and future. Anim Feed Sci Technol 203:1–22. doi:10.1016/j.anifeedsci.2015.03.001
Howe ER, Simenstad CA, Toft JD, Cordell JR, Bollens SM (2014) Macroinvertebrate prey availability and fish diet selectivity in relation to environmental variables in natural and restoring north San Francisco bay tidal marsh channels. San Franc Estuary Waters Sci 12:1–46
IPIFF (2014) Insects food safety first—first time right. Regulatory roadmap for insect products in Feed and Food applications. http://www.protix.eu/wp-content/uploads/2014/07/IPIFF-Report-on-Regulatory-Barriers-related-to-insect-production.pdf
ISMEA (2008) I consumi ittici nei principali paesi europei. http://www.ismea.it
ISMEA (2009) Check up settore ittico http://www.ismea.it
ISMEA (2013) Check up settore ittico http://www.ismea.it
Jaccard J (2001) Interaction effects in logistic regression, vol 135. Sage, New York
Jaffry S, Pickering H, Ghulam Y, Whitmarsh D, Wattage P (2004) Consumer choices for quality and sustainability labelled seafood products in the UK. Food Policy 29(3):215–228
Johnston RJ, Wessells CR, Donath H, Asche F (2001) Measuring consumer preferences for eco-labelled seafood. An international comparison. J Agric Resour Econ 26(19):20–39
Klunder HC, Wolkers-Rooijackers J, Korpela JM, Nout MJR (2012) Microbiological aspects of processing and storage of edible insects. Food Control 26:628–631
Koeleman E (2014) Insects crawling their way into feed regulation. AllAboutFeed 22(6):18–21
Makkar HP, Tran G, Heuzé V, Ankers P (2014) State-of-the-art on use of insects as animal feed. Anim Feed Sci Technol 197:1–33
Manzano-Agugliaro F, Sanchez-Muros MJ, Barroso FG, Martínez-Sánchez A, Rojo S, Pérez-Bañón C (2012) Insects for biodiesel production. Renew Sustain Energy Rev 16:3744–3753
Mauracher C, Tempesta T, Vecchiato D (2013) Consumer preferences regarding the introduction of new organic products. The case of the Mediterranean sea bass (*Dicentrarchus labrax*) in Italy. Appetite 63:84–91
McCullagh P (1980) Regression models for ordinal data (with discussion). J R Stat Soc A B42:109–142
McCullagh P (1998) The proportional-odds model (in: Encyclopedia of Biostatistics). http://www.stat.uchicago.edu/~pmcc/prop_odds.pdf

Menrad K (2003) Market and marketing of Functional Food in Europe. J Food Eng 56:181–188
Moisander J (2007) Motivational complexity of green consumerism. Int J Consum Stud 31:404–409
Niva M, Mäkelä J (2007) Finns and functional foods. Socio-demographics, health efforts, notions of technology and the acceptability of health-promoting foods. Int J Consum Stud 31:34–45
Oonincx DG, De Boer IJ (2012) Environmental impact of the production of mealworms as a protein source for humans—a life cycle assessment. PLoS One 7(12):e51145
Pieniak Z, Verbeke W (2008) Consumer interest and marketing potential of information on fish labels. Paper presented at 12th Congress of the European Association of Agricultural Economists, EAAE. http://ageconsearch.umn.edu/bitstream/44235/2/544.pdf
Pieniak Z, Verbeke W, Scholderer J, Brunso K, Olsen SO (2007) European consumers' use of and trust in information sources about fish. Food Qual Prefer 18:1050–1063
Ramos-Elorduy J (2008) Energy supplied by edible insects from Mexico and their nutritional and ecological importance. Ecol Food Nutr 47:280–297
Rumpold BA, Schluter OK (2013a) Potential and challenge of insects as an innovative source for food and feed production. Innov Food Sci Emerg Technol 17:1–11
Rumpold BA, Schluter OK (2013b) Nutritional composition and safety aspects of edible insects. Mol Nutr Food Res 57:802–823
Sánchez-Muros M-J, Barroso FG, Manzano-Agugliaro F (2014) Insect meal as renewable source of food for animal feeding: a review. J Clean Prod 65:16–27
Schiavone A, De Marco M, Rotolo L, Belforti M, Martinez Mirò S, Madrid Sanchez J, Hernandez Ruiperez F, Bianchi C, Sterpone L, Malfatto V, Katz H, Zoccarato I, Gai F, Gasco L (2014) Nutrient digestibility of Hermetia illucens and Tenebrio molitor meal in broiler chickens. Abstract book conference "Insects to Feed The World" The Netherlands, 14–17 May 2014, p 73
Smith R, Pryor RE (2014) PROteINSECT—do European citizens accept the use of insects for animal feed & human food? Abstract book conference "Insects to Feed The World" The Netherlands, 14–17 May 2014, p 31
Stefani G, Scarpa R, Cavicchi A (2012) Exploring consumer's preferences for farmed sea bream. Aquac Int 20(4):673–691
Thøgersen J (1999) Spillover processes in the development of a sustainable consumption pattern. J Econ Psychol 20:53–81
Thøgersen J (2004) A cognitive dissonance interpretation of consistencies and inconsistencies in environmentally responsible behavior. J Environ Psychol 24(1):93–103
Thøgersen J, Ölander F (2003) Spillover of environment-friendly consumer behavior. J Environ Psychol 23:225–236
Van Huis A (2013) Potential of insects as food and feed in assuring food security. Annu Rev Entomol 58:563–583
Van Huis A (2015) Insects to feed the world. J Insects Food Feed 1:3–5
Vasilakopoulos P, Maravelias CD, Tserpes G (2014) The alarming decline of mediterranean fish stocks. Curr Biol 24:1–6
Veldkamp T, van Duinkerken G, van Huis A, Lakemond CMM, Ottevanger E, Bosch G, van Boekel MAJS (2012) Insects as a sustainable feed ingredient in pig and poultry diets—a feasibility study. In: Rapport 638—Wageningen Livestock Research
Verain M, Bartels J, Dagevos H, Sijtsema SJ, Onwezen MC, Antonides G (2012) Segments of sustainable food consumers: a literature review. Int J Consum Stud 36:123–133
Verbeke W (2011) 16-Communicating food and food chain integrity to consumers: lessons from European research. In: Hoorfar J, Jordan K, Butler F, Prugger R (eds) Food chain integrity. Woodhead Publishing Series in Food Science, Technology and Nutrition, Cambridge, pp 285–293
Verbeke W, Sioen I, Brunsø K, De Henauw S, Van Camp J (2007a) Consumer perception versus scientific evidence of farmed and wild fish: exploratory insights from Belgium. Aquac Int 15:121–136
Verbeke W, Vanhonacker F, Sioen I, Van Camp J, De Henauw S (2007b) Perceived importance of sustainability and ethics related to fish: a consumer behavior perspective. AMBIO 36(7):580–585
Verbeke W, Spranghers T, DeClercq P, DeSmet S, Sas B, Eeckhout M (2015) Insects in animal feed: acceptance and its determinants among farmers, agriculture sector stakeholders and citizens. Anim Feed Sci Technol. doi:10.1016/j.anifeedsci.2015.04.001
Vermeir I, Verbeke W (2006) Sustainable food consumption: exploring the consumer «attitude-behavioral intention » gap. J Agric Environ Ethics 19:169–194
Wilkinson JM (2011) Re-defining efficiency of feed use by livestock. Animal 5:1014–1022
World Bank (2003) World development report 2003. In: Sustainable development in a dynamic world, transforming institutions, growth and quality of life. Oxford University Press for World Bank, New York