Journal of Insects as Food and Feed, 2021 online **ARTICLE IN PRESS**

SPECIAL ISSUE: *Application of insect ingredients in sustainable aquaculture*

Consumer attitude and acceptance toward fish fed with insects: a focus on the new generations

L. Baldi[1], T. Mancuso[2], M. Peri[1], L. Gasco[2*] and M.T. Trentinaglia[1]

[1]Department of Environmental Science and Policy, University of Milan, Via G. Celoria 2, 20133 Milan, Italy; [2]Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Braccini 2, 10095 Grugliasco (TO), Italy; laura.gasco@unito.it

Received: 22 June 2021 / Accepted: 24 November 2021

RESEARCH ARTICLE

Abstract

Since global demand for aquaculture products is expected to increase dramatically in the near future, policymakers and companies are considering the adoption of insect-based feed, which is more economically viable and environmentally sustainable than fish or vegetable-based meals currently used. Nonetheless, fish farmed with insects are still perceived as innovative products by consumers, and further studies exploring these demand-side concerns must be conducted to make sure a market for such products exists. This study focuses on the factors that can favour the acceptance of farmed fish fed with insects of a sample of young Italians. In particular, within the theoretical framework adopted in this analysis, we let acceptance be expressed by different dimensions, each potentially influenced by individual factors, such as socio-economic characteristics, as the provision of information on the nutritional and environmental benefits of insect-based feed for aquaculture, and as consumer psychometric indicators. In this respect, we use the by-dimensional definition of environmental attitude proposed by environmental psychologists, that considers attitude toward environmental protection and toward nature. In this survey, we reached 482 consumers, aged less than 40, using social networks. A Factor Analysis was performed to identify the different dimensions of the acceptance process. We then applied the Rasch model on consumers' reported behaviours toward environmental protection or nature to retrieve their environmental attitudes. We performed a Seemingly Unrelated Regression to assess the importance of socio-demographic, information, and psychometric variables on the different dimensions of acceptance. Results indicate that the use of psychometric variables to study the acceptability of an innovative food product seems particularly appropriate. In addition to the role of environmental attitude, acceptance is also explained by some socio-demographic variables, with men and younger consumers being more inclined to accept the product. Acceptance is also higher among informed respondents, confirming the importance of reducing information asymmetries.

Keywords: aquaculture, insect-based feed, Rasch Model, young consumers, circular economy

1. Introduction

In order to keep up with the food demand of a relentlessly increasing global population, food systems and animal farms are being exposed to unsustainable production paces and challenges. One challenge is represented by the quest for more economically and environmentally sustainable feed. In particular, the aquaculture industry uses fish or vegetable meals as feed, tough both solutions are sub-optimal. To minimise the cost and environmental impact of fish feed for the whole industry, the European Union authorises the use of insects' proteins as fish feed and human food (Regulations 2017/893 and 2021/882 respectively; EU, 2017a,b).

In nature, many fish feed on insects. Therefore, a farmed fish fed with insects is natural, and respects fish requirements especially for carnivorous species; insect meals, with their reduced environmental footprint, are also resource efficient. This breeding practice should be appreciated by end-users, who are increasingly aware of the nutritional opportunities presented by insects as feed (e.g. Van Huis, 2020, and references therein); the review by Sogari *et al.*

(2019a) concludes in fact that 'consumer acceptance will not be a barrier towards the development of the insect protein industry for feed'. Nonetheless, the inspection of consumer acceptance has revealed that there are still some concerns from the demand side that deserve further study. In particular, the consumer analysis conducted in Italy by Mancuso *et al.* (2016) reveals the existence of a behavioural gap (see, for sustainable food consumption in general, Trentinaglia De Daverio *et al.*, 2021; Vermeir and Verbeke, 2006), i.e. despite the generally positive attitude reported by most respondents, not all of them (25%) are actually ready to purchase it. An even higher share (53%) of reluctant Italian consumers emerges in Laureati *et al.* (2016), even when consumers' care for environmental issues is considered. A particular aversion to insects as feed emerges in Ankamah-Yeboah *et al.* (2018), where a share of German respondents (23%) displays negative preferences for farmed fish fed with insects. In a survey conducted in France by Bazoche and Poret (2021), information on the nutritional and environmental benefits encourages acceptance. Other acceptance drivers have been examined in the literature: for instance, Onwezen *et al.* (2019) find that affective factors can improve consumer acceptance of insects especially as food. In Brazil, consumers acceptance for insect-based feed is higher for fish than for poultry, cattle, and pigs (Domingues *et al.*, 2020), and acceptance seems to be positively affected by the attitude consumer have towards insect farms and insect-based feed. A part from consumer acceptability and preferences, other analyses based on contingent valuation have retrieved consumers' willingness to pay for insects as food or feed: the analysis conducted by Giotis and Drichoutis (2021) on Greek consumers a negative Willingness to Pay for direct entomophagy, implying that consumers require a discount in order to purchase the product, and a higher acceptance for indirect consumption of insects; willingness to pay for insects as feed is also higher in the analysis of Ferrer Llagostera *et al.* (2019), even though taste expectations are low. Interestingly enough, the Greek survey conducted by Rumbos *et al.* (2021) considered both demand and supply-side perspectives. Their analysis shows that individuals are indeed aware of the environmental spillovers of insect-based feed, and display a positive attitude and willingness to consume fish fed with insects. As for firms, half of the interviewed companies declared to be in favour and ready to implement this innovation in their production process.

Despite the conspicuous research efforts, most studies do not emphasise the role of consumer environmental attitude, that can be instead an important predictor of acceptability (Byrka *et al.*, 2017). Following the recent advancements proposed by environmental psychologists, environmental attitude can be decomposed into attitude toward environmental protection and toward nature (Kaiser *et al.*, 2013; Martin and Czellar, 2017; Thompson and Barton, 1994). More specifically, environmental protection is defined as a measure of a person's attitude toward environmental issues, and consists of more cognitive items, whereas connection to nature is seen as a measure of the person's affective, cognitive, and experiential aspects of her relation with nature (see also Kaiser *et al.*, 2013). These two measures can be also promising explanators of consumer behaviour in the food domain (e.g. Baldi *et al.*, 2021).

In the context of insect-based feed, the two distinguished psychometric characteristics of environmental attitude could be perfectly reconciled with the naturalness and sustainability features of the product examined. Hence, to make the use of insect feed as profitable and widespread as possible, it is relevant to understand if consumers that care about the environment and that can connect with nature are actually more open and inclined to accept the product. Also, the provision of information can reassure consumers about the sustainability and safety of the production process. This has been proved crucial for other food related innovations, such as GMO products (e.g. Hobbs and Plunkett, 2007), for aquaculture products (e.g. Pieniak *et al.*, 2013) and for insects as food (Mancini *et al.*, 2019) and feed (e.g. Sogari *et al.*, 2022).

This work has two aims: first, it wants to improve the comprehension of consumer acceptance, a prerequisite for ensuring enough market opportunities for fish farmers switching to insect-based feed (Ssepuuya *et al.*, 2019), not only in terms of examining the individual traits, such as attitude, that could favour acceptance, but also to see how the provision of information could reduce consumption barriers (Popoff *et al.*, 2017). The second contribution of this paper is a methodological one: it uses the Item Response Theory, and the Rasch model in particular (Rasch, 1993), to estimate psychometric consumer attributes. This methodological approach, based on past behaviours rather than on self-reports, allows for an indirect and objective measurement of attitude, whereas self-reports may be subjectively measured (De Houwer *et al.*, 2013) and lead to erroneous inference (Fraley *et al.*, 2000). Even though the introduction of consumer attitude is not new in the field of entomophagy, existing studies used traditional attitude measurement methods, i.e. based on self-reports, to predict intentions to eat insects or food products containing insects. In particular, the measure proposed by La Barbera *et al.* (2020) was based on self-reports and considered positive and negative attitudes for direct and indirect entomophagy. This instrument, validated on a Danish representative sample and cross-validated on an Italian convenience sample, turned out to be a more accurate predictor than existing alternative instruments, such as disgust and neophobia. Within the theoretical framework of the Theory of Planned Behaviour, Menozzi *et al.* (2017) elicited beliefs related to attitude, subjective norms and Perceived Behavioural Control (PBC), and observed that attitude and PBC predict intention of eating a novel food containing insect flour.

We expect that the method adopted in our study, based on past behaviours, could improve the measurement of individual environmental attitude and better predict food consumer behaviour.

Our study focuses on young consumers and their acceptance of farmed fish fed with insects. Young consumers are in fact pivotal in the adoption of sustainable lifestyles (e.g. Bollani *et al.*, 2019), and are also friendly with Social Networks, that can be fruitfully used to share and divulgate sustainability messages (Sogari *et al.*, 2017). Still, there are only few contributions relating youngsters and insects, and these generally focus on insects as food (e.g. Fasanelli *et al.*, 2020; Sogari *et al.*, 2019c), not as feed.

This paper is structured as follows: Section 2 describes the benefits for the environment and human nutrition related to using insects as feed; Section 3 develops the Theoretical Framework; Section 4 discusses the Materials; Section 5 presents the results; Section 6 discusses and concludes.

2. Insects in feed for fish: benefits for the environment and human nutrition

In the past two decades, food demand has increased at a faster pace than population growth, reflecting therefore not only the people growth, but also a general increase in per capita consumption (EU Agricultural Market Brief, 2019). The global demand for animal products is expected to more than double in the future, and in the case of aquaculture production, even to triplicate. To face this increase, a consequent increase in fodder and feeds is needed. About two thirds of the global soya beans production is crushed to obtain oil and soybean meals (SBM). SMB represents the most used plant protein source in animal feed.

The last FAO report on the state of world fisheries and aquaculture (FAO, 2020), indicates a global aquatic animal production of 178.5 million tons, of which, aquaculture accounts for 46% (82.1 million tons). Global captures being limited by wild-fish stocks (Shepherd and Jackson, 2013), aquaculture is the only solution to meet the increasing demand of fish products. In the past 30 years (from 1990 to 2018), aquaculture registered a +527% of increase (compared to an only +14% of the wild-capture fisheries) (FAO, 2020), and the increase is expected to continue. To comply with the Agenda for Sustainable Development (SDG), the adoption of sustainable fish production systems and in particular, of new and more sustainable feeds, is required.

The farming of carnivorous fish species, such as salmons, trout, seabass or seabream, requires large quantities of proteins, and in the wild, requirements are covered by small fish or crustaceans. In the past, aquaculture feeds largely used fishmeal (FM) produced using wild fish caught and not intended for human consumptions. With the rapid aquaculture development, great research effort has been spent to find alternatives to FM, and nowadays, FM often only represent a small percentage of the fish feed. Currently, aquafeeds use large quantities of plant and land-based processed animal proteins (Hua *et al.*, 2019; Parisi *et al.*, 2020). Among plant proteins, SBM is likely the most used one but aquafeeds also use other sources such as gluten from wheat or corn, and pea, rapeseed or sunflower meals. Plant proteins contain anti nutritional factors that may induce negative effects on feed palatability, growth or fish health and need to be eliminated or at least reduced to avoid major issues (Hua *et al.*, 2019; Krogdahl *et al.*, 2010). Moreover, from a nutritional point of view, they do not perfectly fit the fish requirements, in particular when carnivorous species are concerned, as they lack in some essential amino acid. Moreover, from and ethic point of view, in carnivorous species, the use of plant proteins is a clear 'jump' out of their normal feeding behaviour. The increasing use of plant protein in aquafeed also rises concerns due to the pressure on land and environment it implies (Hua *et al.*, 2019).

Processed animal proteins are more adapted to carnivorous species requirements, as they present a higher protein content and a better-balanced amino acid profile compared to plant protein sources. However, their use in aquafeed is sometimes limited by legislation (in particular in the European Union) and rise some issues about social acceptability.

Recently, great attention has been paid to processed proteins derived from insects and stakeholders agree considering them as one of the most promising alternatives to FM or to conventional protein sources (i.e. SBM) in livestock and aquaculture feeds (Gasco *et al.*, 2019; Lock *et al.*, 2018; Sogari *et al.*, 2019a). Insect meals are rich in proteins of high biological value, they contain good amount of fat, vitamins and energy (De Souza *et al.*, 2019; Gasco *et al.*, 2020a). Insects are sustainable as they can be produced using low land, low (or no) water input and have low greenhouses gas emission. Some insects perfectly apply the circular economy principles as the easily bio-convert low value organic substrates into high value (Gasco *et al.*, 2020b; Smetana *et al.*, 2019; Van Huis and Oonincx, 2017). In addition, as far as carnivorous fish are concerned, insects are part of their natural diet (Henry *et al.*, 2018a,b). So far, the global insect meal market is limited due to limited production capacity, high production costs and, in EU countries, also to legislative constrains (IPIFF, 2019; Pippinato *et al.*, 2019). However, the sector is expanding and prices are expected to decrease (Pippinato *et al.*, 2019). Moreover, insect also contain bioactive compounds (chitin, anti-microbial peptides, specific fatty acids) able to modulate the fish microbiota, to boost the immune system, to positively impact the gut health and, therefore, to undoubtedly contribute to the global fish health status (Gasco *et al.*, 2018, 2020c; Henry *et al.*, 2018a,b).

3. Theoretical framework

As research on insect breeding for feed or food advanced, a number of studies on the demand and market side gradually appeared (see the review by Dagevos, 2021, for consumers studies on edible insects in Western countries). In fact, even if consumers do not consume insects directly, they are increasingly attentive to the entire food chain, especially in terms of food safety and sustainability of production processes (Kher *et al.*, 2013; Mol, 2015; Van Rijswijk and Frewer, 2008).

Fish raised with insect meal represents to the consumer a product with a built-in innovation, the technology of which is not yet known. Existing literature has thoroughly analysed the relationship between new technologies and food consumption highlighting consumer scepticism and increased risk perception (Chaudhry *et al.*, 2010; Giordano *et al.*, 2018; Sodano *et al.*, 2016). Therefore, it is of great relevance to investigate further consumer acceptance of food related innovations and products, and its determinants.

According to the integrated framework proposed by Albertsen *et al.* (2020), consumer acceptance of food innovations follows a real process involving several dimensions. It starts from the perception linked to the existence of the innovation, including its benefits and risks. Then, there is the intentions dimension, when the consumer decides whether to adopt or reject the innovative product, a decision that will subsequently lead to the possibility of purchasing and consuming the product (Rogers, 2003). This last stage, representing the behavioural component, is connected to an implementation step, during which consumers decide whether to consume the product regularly and to integrate it into everyday life or not.

Albertsen *et al.* (2020) identify cause-and-effect relationships existing between these dimensions, highlighting that the initial perception is among the main determinants of consumer acceptance of new food technology, as already found in Ronteltap *et al.* (2007) and Gupta *et al.* (2012). According to other studies, personal attitude appears to be one of the key factors determining consumer acceptance (Byrka *et al.*, 2017; Frewer, 2003). In particular, Byrka *et al.* (2017) develop their studies in the environmental field by highlighting how acceptance of a situation that is beneficial to the environment but requires effort for consumers is primarily determined by attitude toward the environment. Attitude can thus compensate for the effort required to incur a sustainable behaviour towards the environment. In the context of accepting an innovation, this effort can be seen as having to deal with the risk and uncertainty involved in a new product or production process.

Following this idea, in our work we use the theoretical framework in Figure 1, which takes a version adapted to our context of the Tripartite Model of Attitude conceived by Rosenberg and Hovland (1960) and revised by Kaiser and Wilson (2019). In this framework, we focus on attitudes as determinants of the acceptability process, as in Byrka *et al.* (2017). According to this view, a higher level of environmental attitude should translate into a better perception related to the existence of the innovation, as well as an incentive to the intentions of dealing with the new product, up to the confirmation of acceptance through specific behaviours (purchase, consumption, loyalty).

To give substance to attitude, which is clearly a latent variable, we use the Campbell Paradigm (Campbell, 1963; Kaiser *et al.*, 2010), a theoretical framework in which attitudes are inferred from environmentally suitable behaviours in order to measure them objectively. Furthermore, following the idea of some works (Kaiser *et al.*, 2013; Martin and Czellar, 2017; Thompson and Barton, 1994), we divided environmental attitude into two components: protection towards the environment and appreciation of nature. As for the measure of acceptance dimensions, we assume that these could be latent variables,

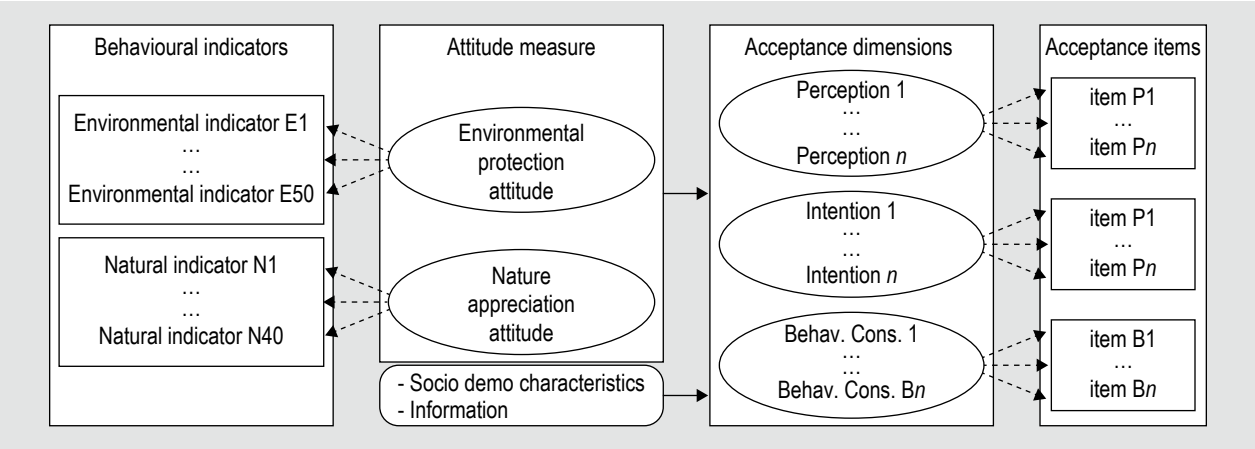

Figure 1. Adapted conceptual framework (adapted from Kaiser and Wilson (2019), Byrka *et al.* (2017) and Kaiser *et al.* (2013)).

obtained by specific magnitudes of perception, intentions, and behaviour toward innovatively farmed fish fed insect meal. To complete the picture, we add some socio-demographic variables.

4. Materials

Environmental attitude scales

In order to measure respondents' attitude toward environment and toward nature, we use two scales proposed by the environmental psychological literature. The first scale (Kaiser, 1998; Kaiser and Wilson, 2004) includes 50 questions grouped in six domains: energy conservation (e.g. owning energy efficient devices, solar panel); mobility and transportation (e.g. being a member of a carpool); waste avoidance (e.g. reusing shopping bags); consumption behaviour (e.g. buying seasonal produces); recycling behaviour (e.g. collecting and recycling used paper) and lastly social behaviours toward conservation (e.g. being a member of an environmental organisation.

The attitude related to connection with nature is measured using the scale by Brügger *et al.* (2011), that inspects reports of past bonding activities with nature, and of statements that indirectly reflect a person's connection with nature, such as the appreciation of experiences involving natural situations or lived in nature. This attitude measure is the result of responses to up to 40 different questions, related to the behaviours toward animals (e.g. talking to them); toward the vegetable world (e.g. enjoying gardening), and enjoying natural surroundings (e.g. crossing meadows barefoot).

On either attitude measurement, the authors calibrated the items of each scale so as to rank behaviours by the implicit cost, or difficulty, of performing them. The more difficult a behaviour, the higher the attitude toward environmental protection or connection with nature.

It is worth stressing that the resulting measures of attitude are indirectly obtained from behavioural and evaluative statements, and not from a direct exploration of the personal disposition. In this way, the measures of attitude are not affected by subjective measurement issue. Also, these scales are constructed in such a way that respondents are not aware of what is being measured and how, so that their answers are a representation of their behaviours.

The consumer survey

To analyse the characteristics and determinants of consumer acceptability of insect-fed fish, we launched a nationwide sample survey from February to May 2021. As the focus was on young people, we used Social Networks, and in particular Instagram and Facebook, and disseminated the questionnaire through popular influencers. The questionnaire was built using the Qualtrics platform. A target variable was initially included to select only those respondents who consume fish on a regularly basis. A total of 482 interviews was collected from respondents aged less than 40.

The questionnaire consists of seven different sections (Table 1). The first one gathers socio-demographic information, such as gender, age, and education. The questionnaire proceeds with the two scales for measuring attitude toward environmental protection (Kaiser, 1998; Kaiser and Wilson, 2004, Kaiser *et al.*, 2010) and towards nature (Brügger *et al.*, 2011). All the questions are either dichotomic (yes/ no, approve/disapprove) or based on a 5-point Likert scale (never, seldom, occasionally, often, very often); a 'not applicable' option was also available.

Upon the completion of the attitude section, a concise text was randomly proposed to respondents to inform them about the current issues and challenges of aquaculture from an environmental and social perspective; the naturalness of feeding fish with insects; the environmental sustainability of insect meal production; and the positive effect of insect meal on fish health. This treatment was randomised, and only half of the sample received this information.

The third, fourth and fifth sections are dedicated to measure consumer acceptability of insect-farmed fish following the work of Bazoche and Poret (2021). In particular, the third section includes seven questions related to consumers' perceptions on farmed fish diet; the fourth section consists of five questions on consumer perception on eating insect-fed fish; the fifth section is made of seven questions measuring purchase intentions surrounding insect aquafeeds. Finally, in the last section, we use six questions from the work of Albertsen *et al.* (2020) that measure the conative component and the implementation of the consumer acceptance process.

5. Methodological aspects

To achieve our goal, the methodological steps of the conceptual framework of Figure 1 were implemented: first, we performed a Rasch model (Bond and Fox, 2007; Kaiser, 2021; Rasch, 1993) to characterise individuals in terms of their attitude towards environmental protection and toward nature. We then developed a Factor Analysis to identify the latent factors expressing the dimensions of the acceptance process; last we ran a Seemingly Unrelated Regression to explore the relationships between consumer acceptance and attitudes.

The original idea of Campbell Paradigm can be expressed as a function of environmental or nature attitude and the cost of the specific behaviour and can be appropriately implemented with Rasch's model. In this model the natural

Table 1. Items used in the questionnaire and their descriptive characteristics.

Variable name	Item	Type	Scale / categories	Mean	Standard deviation	Valid cases
Socio-demo						
age	Age	Ordinal	1-4	1.32	0.47	485
gender	Gender	Categorical	0-1	n.a.	n.a.	485
educ	Education	Ordinal	1-4	3.40	0.52	485
income	Income	Ordinal	1-4	2.89	0.85	485
Attitude						
Env.att	Attitude toward Environmental protection (50 items)[1]	Dichotomic/ ordinal	1-2/1-5	see Table 3 for a deeper analysis		
Nat.att	Attitude toward Nature (40 items)[1]	Dichotomic/ ordinal	1-2/1-5			
Info						
Information	Short text to inform about the topic	Dummy	0-1			
Perceptions on farmed fish diet						
natins	I find natural for fish to feed on insects	Ordinal	1-5	3.87	1.23	485
natfish	I find natural for fish to feed on other fish	Ordinal	1-5	3.93	1.08	485
natinsba	I find normal for farmed fish to be fed on insect-based feed	Ordinal	1-5	3.57	1.21	485
natfishba	I find normal for farmed fish to be fed on fish-based feed	Ordinal	1-5	3.23	1.20	485
natplant	I find normal for farmed fish to be fed on plant-based feed (grains and pulses)	Ordinal	1-5	3.39	1.21	485
negenv	Fish farming can have negative knock-on effects on the environment	Ordinal	1-5	3.15	1.15	485
concerfed	I am concerned about how farmed fish are fed	Ordinal	1-5	3.33	1.26	485
Eating insect-fed fish						
eatinsba	For me, eating fish fed on insect-based feed is reasonable in the scheme of things	Ordinal	1-5	3.19	1.24	485
eatdisg	For me…is just disgusting	Ordinal	1-5	-2.20	1.27	485
eathealth	For me…is good for my health	Ordinal	1-5	2.95	0.97	485
eatenv	For me…is good for the environment	Ordinal	1-5	3.29	1.15	485
eatnovel	For me…is a novel experience	Ordinal	1-5	3.30	1.33	485
Intentions surrounding insect aquafeeds						
readyeat	I would be ready to eat farmed fish fed on insect-based feed	Ordinal	1-5	3.55	1.34	485
readysafe	I would…as long as the foods were safe and fit to eat	Ordinal	1-5	4.14	1.14	485
readytaste	I would…as long as the foods did not taste like insect	Ordinal	1-5	3.92	1.31	485
readylabel	I would…as long as the food label clearly flags the fact	Ordinal	1-5	3.84	1.28	485
readyrisk	I would…as long as all insect farming-related risks are controlled	Ordinal	1-5	4.31	1.08	485
readyexpens	I would…as long as the food is not more expensive than another product in the same category	Ordinal	1-5	3.61	1.26	485
insectfarm	I would see no problem having an insect farm near my home	Ordinal	1-5	2.72	1.40	485
Conative and implementation component of acceptance						
buyfish	I intend to buy the product in the future	Ordinal	1-5	3.43	1.22	485
faithfish	I am very faithful to the product	Ordinal	1-5	3.17	1.17	485
highprice	The product is worth a higher price than other products	Ordinal	1-5	2.98	1.09	485
friends	I would recommend the product to my friends	Ordinal	1-5	3.09	1.15	485
usefish	How willing would you be to use the product?	Ordinal	1-5	3.37	1.23	485
integrate	How likely is it that you will integrate the product into your everyday life?	Ordinal	1-5	3.14	1.21	485

[1] To improve the questionnaire design, we created three sub-sets of question, each containing a selection of 36 questions regarding the environment and nature preserving, at the same time, the balance between the two types of items included (56% regarding environmental protection and 44% regarding connection with nature). These three blocks, randomly displayed to consumers, were created in such a way to be of similar difficulties and to ensure sufficient latent drift in each block. The procedure is reported in Baldi *et al*. (2021).

logarithm of the ratio of the probability ($p_{n\omega}$) of person n's engagement relative to the probability of non-engagement ($1 - p_{n\omega}$) in a specific behaviour w (i.e. its odds) is the result of the difference between n's attitude (θ_n) and the costs of behaviour w (δ_ω):

$$ln\left(\frac{p_{n\omega}}{1-p_{n\omega}}\right) = \theta_n - \delta_\omega \quad (1)$$

Thus, the Rasch model describes the probability of engaging in a specific behaviour as the difference between the strength of a person's attitude and the difficulty of the specific behaviour in question.

As discussed previously, the different spheres of consumer acceptance are evaluated separately. Since variables belonging to each section are inevitably correlated one another, a Factor Analysis is a suitable instrument to reduce the number of variables by modelling the covariation among a set of observed variables as a function of one or more latent construct. Hence, it is then possible to find the main factors expressing an overall measure of acceptance. By extracting a few and independent common factors, the common information and correlation of the original variables are well preserved (Rummel, 1988).

In this study, we performed four Factor Analyses for 25 variables, one for each dimension of consumer acceptance, and obtained 7 different factors, thoroughly described in Section 6.3, and used as dependent variables in a seemingly unrelated regression model (SUR) (Zellner, 1963), that represents a system of linear equations with errors terms correlated across equations for a given individual but uncorrelated across individuals. Since the dependent variables share the same error structure, we can simultaneously estimate the effects of attitudes and socio-economic variables on the acceptance dimensions retrieved from the Factor Analysis. The general specification of the model is:

$$Y_{nk} = \sum_{s=1}^{7} X_{nks}\theta_{ns} + \varepsilon_{nk} \quad (2)$$

where Y_{nk}, with k=1,...7, is precisely one of the 7 factor load identified from the Factor Analysis of individual n. X_{nks}, with s=1,...7, is the individual attitude score towards environmental protection or connection with nature and other five variables; θ_{ns} is the regression coefficient; ε_{nk} is the error term on individual n in regression equation for Factor k.

Specifically, for each of the seven factors of consumer acceptance, the following regression specification was performed:

$$Y_k = f(X_{nat.att}, X_{env.att}, X_{age}, X_{gender}, X_{educ}, X_{income}, D_{information}) \quad (3)$$

Where: $X_{env.att}$ and $X_{nat.att}$ respectively denote the scores for attitude toward environment protection and connection with nature; X_{age}, X_{gender}, X_{educ}, X_{income} are the socio-demographic characteristics, and $D_{information}$ is a dummy variable that is equal to 1 when the respondent was asked to read the information and 0 otherwise.

6. Results

Sample description

As stressed earlier, we targeted only individuals aged less than 40: 68% of respondents is aged between 18 and 25, and the remaining 32% is represented by millennials, i.e. individuals that at the time of taking the questionnaire were aged between 25 and 40, in line with the definition of Dimock (2019).

Considering gender, the sample appears well balanced (Table 2). As for education, no respondent had an elementary level of education; only 1.6% have a middle school diploma, while 57% are represented by respondents with a high school diploma and almost 42% a university degree. Finally, with regard to their perception of the adequacy of the economic conditions in which they live, around 68% of respondents state that their income (or, in any case, that of the family in which they live) is adequate or more than adequate to match their budgets.

Table 2. Socio-demographic characteristics.

Category	%
Age	
18-25	67.6
26-40	32.4
Total	100.0
Gender	
Male	47.4
Female	52.6
Total	100.0
Education	
Primary	-
Lower/ secondary	1.6
Upper/ secondary	56.7
University degree/PhD	41.6
Total	100.0
Income	
Not adequate	4.9
Almost adequate	27.6
Adequate	41.0
More than adequate	26.4
Total	100.0

Rasch estimation results

The Rasch model discussed earlier was applied to compute the two dimensions of attitude for each respondent. For both scales, i.e. environmental protection and connection with nature, the model was calibrated on the whole set of items and obtained item difficulties and individual attitude scores. Prior to the model calibration, all the behaviours that originally had a five-point polytomous response format were dichotomised so as to prevent excessive measurement error, particularly in attitude research (DeCoster *et al.*, 2009). We re-coded responses as negative (i.e. the options 'never', 'seldom', and 'occasionally') and positive (i.e. 'often' and 'always') as in Kaiser *et al.* (2020). All the missing values (i.e. the 'not applicable' option in all the responses) were handled as negative responses.

Results show that environmental items are scored from -3.9 to +4.3, i.e. from the least to the most difficult to engage with. Similarly, the difficulty of nature items ranges from -4.6 to 4.8, indicating whether the item reflects a less or more care towards nature. It is worth stressing that these item scores are endogenous; in fact, they depend on how respondents answer and, in particular, on how many respondents engage in a certain behaviour, as expected from the Item Response Theory. Based on item scores, one can retrieve individual scores to understand if that person tends to engage in easy or difficult behaviours (Smolders *et al.*, 2012). Table 3 below reports the average item descriptive statistics for each type of attitude, which both have 0 mean item difficulty by construction. Table 3 also reports mean Infit MS and Outfit MS, to indicate how productive for measurement the items considered are. Following Linacre (2002, 2010), Bond and Fox (2007) we removed one misfitting item from the environment scale. All reliability coefficients are greater than 0.50, proving the reliability of the two scales in measuring attitudes. The full list of items, with their scores and statistics is available upon request.

Table 4 shows the summary results of the respondents' scores. It can be seen that, on average, the attitude towards the environment is slightly higher than the attitude towards nature. Moreover, the latter shows a greater variability and a much higher range than the former. Also, in terms of asymmetry, attitude towards nature shows a negative value, a sign of a higher proportion of negative scores.

Factor analysis results

As anticipated, we ran four different Factor Analyses, one for each dimension of consumer acceptance. The summary results displayed in Table 5 indicate that the Kaiser-Meyer-Olkin (KMO) test is greater than 0.6 in most cases, with the exception of Factor Analysis 1 where it is borderline. Rotation was not performed in Factor Analyses 2 and 4, since only one factor was extracted. From this step, we retrieved seven different factors that are well explanatory of the dimensions of the acceptance process (due to lack of space, component matrix values useful for the factor identification are provided upon request). In particular, factor 1 expresses respondents' perception of the naturalness of the insect-based feed for fish, and it can thus be interpreted as a first step of the acceptance process. Factor 2 focuses on how fish-based nutrition in aquaculture is perceived. Factor 3 is identified by questions regarding the negative effects of fish farming on the environment and the concern about the diet of farmed fish. The fourth factor expresses the positive attitude of eating farmed fish fed with insects, while the fifth factor expresses the various reasons that may prevent respondents from eating this product (e.g. as long as the product does not taste like insect; as

Table 3. Item descriptive statistics.[1]

Items	Mean item scores	Infit MS min	Infit MS max	Outfit MS min	Outfit MS max	Separation reliability
Environmental attitude	0.000	0.712	1.188	0.299	1.732	0.545
Nature attitude	0.000	0.671	1.243	0.221	1.879	0.657

[1] MS = mean squared value. The reported 'Separation' reliability is the Rasch separation reliability coefficient.

Table 4. Respondents' environmental attitude descriptive statistics.[1]

Items	Min	Max	Mean	SD	Asymmetry
Environmental attitude	-2.67	3.48	0.1707	0.92240	0.219
Nature attitude	-3.57	3.40	0.1318	1.18221	-0.097

[1] The attitude means are statistically different at 3% significance with a one-tail t-test, and at 7% significance with a two-tail t-test.

Table 5. Synthesis of factor analyses results.

	Factor analysis 1	Factor analysis 2	Factor analysis 3	Factor analysis 4
No. of variables involved	7	5	7	6
No. factor extracted	3	1	2	1
KMO test[1]	0.54	0.82	0.78	0.88
Bartlett's test significance	1%	1%	1%	1%
Explained variance	69.4%	61.0%	66.3%	72%
Rotation	yes	no	yes	no

[1] KMO = Kaiser-Meyer-Olkin.

long as all insect farming-related are controlled). Factor 6 captures positive intentions toward eating the product examined and the NIMBY effect (Not-In-My-Back-Yard) regarding an insect farm close to home. Finally, factor 7 is the synthesis of all the questions linked to the final phases of the process of consumer acceptance, such as the willingness to buy, the possible frequency of purchase, the suggestion to friends, etc. The interpretation of the seven factors is summarised also in Table 6.

Seemingly unrelated regressions results

Table 7 reports the results of the SUR analysis performed using Stata v. 16 (StataCorp LLC, College Station, TX, USA). The null hypothesis of the Breusch-Pagan test, which assumes the independence of errors across the equations considered, is rejected. Hence, this model is superior to its Ordinary Least Square counterpart (Breusch and Pagan, 1980). Also, the residuals obtained from each of the seven equations are significantly correlated one another and there is a high correlation of the error terms across the equations representing the latent variable obtained from the Factor Analysis. In other words, the different dimensions of acceptability examined in this analysis are related one another. As for the general model, the results of the chi-square indicate that all the equations, with the exception of the second one (PERCFISHD) are statistically significant.

Table 6. Factors' identification.

Factor name	Identification
PERCINSD	Consumer perception of the naturalness of insect-based feed for farmed fish
PERCFISHD	Consumer perception of the naturalness of fish-based feed for farmed fish
PERCFARM	Negative consumer perception of fish farms and general concern for fish feed
EATING	Positive attitude toward the idea of eating farmed fish fed with insects
WORREAT	General concern toward eating farmed fish fed with insects
INTENT	Positive intentions toward eating the product and NIMBY effect
CONIMPL	Favourable propensity in terms of concrete action

Table 7 reveals that, as expected, the two measures of attitude have a significant role in influencing alternative dimensions of consumer acceptability. In particular, the coefficient of attitude toward the environment is significant for most dimensions of acceptance. Obviously, it is significant and negative in the WORREAT equation, that captures consumers' concerns toward eating the product: the more environmental consumers are, the less they are concerned. Also, the coefficient of attitude toward nature reveals interesting results, even though it is lower in magnitude than the environmental coefficient: this result suggests that consumer acceptance is driven more by the more 'altruistic' component of attitude. i.e. toward environmental protection.

Among the socio-demographic factors, gender is one of the most significant drivers of acceptability, and men seem to be more favourable to the product, in line with the analysis on people of all ages by Bazoche and Poret (2021). Interestingly enough, age, when statistically significant, is always negative: consumer acceptability is thus higher among younger consumers (18-25 years old) than among Millennials. Income is significant in two equations, and always negative. This is no surprise, as young respondents are generally not budget constrained. Finally, education is not particularly relevant, as young respondents have not completed their educational cycle yet. Finally, the information dummy is often positive and statistically significant, a result that confirms how information can play a fundamental role in favouring the acceptance of a new product (Bazoche and Poret, 2021; Laureati *et al.*, 2016).

By looking at the single equations individually, it emerges that the different dimensions of consumer acceptance process are influenced by different variable combinations. The perception of the naturalness of insects as feed (PERCINSD) is explained by age (younger consumers have higher perceptions), by gender and by information. The PERCFARM variable is affected by the two measures of attitude, by low-income levels and by information. We argue that low levels of income, when combined with people sensibility to environmental issues and ability of establishing a connection with nature, can make consumers think that fish farms are harmful for the environment, an aversion that goes against aquaculture.

Table 7. Seemingly unrelated regressions results.[1]

	PERCINSD	PERCFISHD	PERCFARM	EATING	WORREAT	INTENT	CONIMPL
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Nature attitude	-0.010	-0.033	0.117***	-0.007	-0.068*	0.072*	0.011
	0.80	*0.41*	*0.00*	*0.86*	*0.08*	*0.07*	*0.79*
Environmental attitude	0.070	-0.030	0.175***	0.030	-0.114**	0.123**	0.122**
	0.17	*0.55*	*0.00*	*0.56*	*0.02*	*0.01*	*0.02*
Age	-0.183*	-0.183*	0.118	-0.169*	-0.291***	-0.083	-0.112
	0.06	*0.06*	*0.20*	*0.08*	*0.00*	*0.38*	*0.24*
Gender	-0.210**	-0.085	0.104	-0.292***	0.297***	-0.481***	-0.347***
	0.03	*0.37*	*0.24*	*0.00*	*0.00*	*0.00*	*0.00*
Education	0.059	0.122**	0.063	0.065	0.138**	0.010	0.047
	0.33	*0.04*	*0.27*	*0.28*	*0.02*	*0.87*	*0.43*
Income	0.025	-0.005	-0.191***	0.024	-0.085*	0.072	0.029
	0.62	*0.92*	*0.00*	*0.63*	*0.09*	*0.14*	*0.55*
Information	0.148*	-0.171*	0.142*	0.178**	0.074	0.182**	0.142
	0.10	*0.06*	*0.10*	*0.05*	*0.40*	*0.04*	*0.11*
n	482	482	482	482	482	482	482
Chi[2]	12.95	10.99	63.34	16.66	34.61	44.23	23.68
	0.0733	*0.1393*	*0.000*	*0.0197*	*0.000*	*0.000*	*0.0013*
BP test	1,379.49						
	0.000						
LR test[2]	1,243.93						
	0.00						

[1] Regression *P*-values are reported in italic. *, **, *** denote 10, 5, 1% statistical significance. GLS estimator is used. BP stands for Breusch-Pagan LM diagonal covariance matrix test for independent equations and tests the suitability of running the seemingly unrelated regression instead of the single ordinary least squares.

[2] LR test is the likelihood ratio LR test for heteroscedasticity.

A positive opinion toward eating farmed fish fed with insects (EATING) can be explained by environmental protection attitude, and by being younger, male and more informed. The equation WORREAT, gathering all possible concerns related to eating farmed fish fed with insects, reveals interesting results: this factor is negatively affected by both dimension of environmental attitude, as one may expect: environmental and naturalist consumers raise less concerns toward eating this particular fish. Moreover, differently from other factors, these concerns rise in young consumers and in women. The education coefficient predicts instead that a higher educational attainment increases concerns, whereas income tends to reduce them. As we move along the acceptance process, the real intention of purchasing the product (INTENT) still depends on the two attitude measures, on gender and information; CONIMPL, that captures the final stages (conative and of implementation) of acceptance, is influenced by attitude toward environmental protection, and is higher among men and among informed consumers.

7. Discussion and conclusion

The present study contributes to the literature by examining the relationship between different dimensions of young consumers' environmental attitudes and the acceptance of an innovative product, which is fish fed with insects. The focus of the work is of great interest for other reasons, as it combines two relevant areas of investigation: the young people of today, who will influence tomorrow's consumption patterns, and the context of 'circular economy', which sees the feeding of fish bred with insects that were in turn grown and fed by enhancing the production wastes of the agri-food chain.

Some clear evidence emerges from the results. First of all, the introduction of psychometric variables to study the acceptability of an innovative food product seems more appropriate and indispensable than ever: the two dimensions of attitude (toward environmental protection and toward nature) make a notable contribution to the empirical model, and in particular it appears that it is

the more 'altruistic' component, i.e. that towards the protection of the environment, that is decisive for a greater responsibility and awareness of the usefulness of insects for issues related to sustainability. Individual psychometric characteristics have been found suitable for explaining individual choices, such as voting behaviour, as in Kaiser and Wilson (2019), and energy-saving behaviour, as in Starke *et al.* (2020). Their introduction in the food domain has only been sporadic, and limited to investigate barriers to sustainable purchase behaviour (Yamoah and Acquaye, 2019) and to study waste behaviour (Bortoleto, 2014). The importance of psychometric indicators should encourage researchers to consider more frequently attitude as a predictor of consumer decision in the food domain and with regards to new products, as recently done by Baldi *et al.* (2021). Moreover, what appears relevant is also the role of information, which is fundamental for the acceptance of a new food product characterised by different aspects, from sustainability to food safety. Therefore, the reduction of information asymmetries must be pursued through appropriate communication strategies, mainly aimed at reassuring about the wholesomeness of the final product and the sustainability of farms. Several studies have stressed the importance of providing transparent information to increase consumers' awareness of farming practices in aquaculture (e.g. Altintzoglou *et al.*, 2010; Pieniak *et al.*, 2013) and to increase their acceptance of insects as food (Mancini *et al.*, 2019; Sogari *et al.*, 2019b) and feed (Menozzi *et al.*, 2021; Sogari *et al.*, 2022; Spartano and Grasso, 2021). The reduction of information asymmetries is even more important when psychometric indicators reveal those traits that are more vulnerable or sceptical towards a new product. In our setting, attitudes in fact may encourage people to buy and eat insect-fed fish, but they also raise concerns about the sustainability of fish farms in general and their diets. If we consider that 47% of the sample declared themselves to be very worried about the diet of farmed fish, and 35% believe that fish farms have a very negative effect on the environment, then it is clear that it is necessary in the next few years to try to change the image of fish farming in Italy. Otherwise, any innovation in this field will not find favourable feedback in the market and therefore will be destined to fail in economic terms.

Lastly, the importance of reducing information asymmetries and of digging into personality traits is even more important when it comes to young consumers, whose engagement in sustainable behaviour is promising but contrasting. In our analysis, we observe that very young consumers are more open to the innovative product than Millennials, just like Sogari *et al.* (2019c) observe in young Australians and insects as food, but also more concerned toward eating farmed fish fed with insects. This is a result to be considered carefully, on the one hand positively, since new generations represent the future; on the other hand, as a challenge, since novel consumption goods must meet young consumers' rising expectations for healthy and sustainable food products.

Broadly speaking, consumers of all ages and origin will soon have to face directly climate change. To adapt, people will be asked to change their eating habits and switch to more sustainable dietary patterns. Circular economy initiatives, such as the food waste cycle, insect breeding, and fish farming, must be supported and promoted to make them accepted by consumers.

This study represents a step to comprehend even more consumer acceptance of a new product, such as fish raised with insects, introducing psychometric variables and targeting, at the same time, future consumers. Future studies on young and future consumers could be devoted to the comprehension of the psychological traits driving their consumption choices; further research could use also more appropriate techniques (such as neural networks or Structural Equation Models) to examine the cause-effect relationships among the dimensions of acceptability.

Acknowledgements

The authors would like to thank the editor and three anonymous referees for the valuable comments. The project has received funding by the European Union's Horizon 2020 research and innovation programme under grant agreement no. 861976. This document reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains.

Conflict of interest

The authors declare no conflict of interest.

References

Albertsen, L., Wiedmann, K.P. and Schmidt, S., 2020. The impact of innovation-related perception on consumer acceptance of food in food innovations – development of an integrated framework of the consumer acceptance process. Food Quality and Preference 84: 103958. https://doi.org/10.1016/j.foodqual.2020.103958

Altintzoglou, T., Verbeke, W., Vanhonacker, F. and Luten, J., 2010. The image of fish from aquaculture among Europeans: impact of exposure to balanced information. Journal of Aquatic Food Product Technology 19: 103-119. https://doi.org/10.1080/10498850.2010.492093

Ankamah-Yeboah, I., Jacobsen, J.B. and Olsen, S.R.B., 2018. Innovating out of the fishmeal trap: the role of insect-based fish feed in consumers' preferences for fish attributes. British Food Journal 120(10): 2395-2410. https://doi.org/10.1108/BFJ-11-2017-0604

Baldi, L., Trentinaglia, M.T., Mancuso, T. and Peri, M., 2021. Attitude toward environmental protection and toward nature: how do they shape consumer behaviour for a sustainable tomato? Food Quality and Preference 90: 104175. https://doi.org/10.1016/j.foodqual.2021.104175

Bazoche, P. and Poret, S., 2021. Acceptability of insects in animal feed: a survey of French consumers. Journal of Consumer Behaviour 20: 251-270. https://doi.org/10.1002/cb.1845

Bollani, L., Bonadonna, A. and Peira, G., 2019. The millennials' concept of sustainability in the food sector. Sustainability 11: 2984. https://doi.org/10.3390/su11102984

Bond, T.G. and Fox, C.M., 2007. Applying the Rasch model: fundamental measurement in the human sciences, 2nd edition. Psychology Press, New York, NY, USA, 360 pp. https://doi.org/10.4324/9781410614575

Bortoleto, A.P., 2014. Waste prevention policy and behaviour new approaches to reducing waste generation and its environmental impacts, 1st edition. Routledge, London, UK, 218 pp. https://doi.org/10.4324/9781315817941

Breusch, T.S. and Pagan, A.R., 1980. The Lagrange multiplier test and its applications to model specification in econometrics. Review of Economic Studies 47: 239-253. https://doi.org/10.2307/2297111

Brügger, A., Kaiser, F.G. and Roczen, N., 2011. One for all? European Psychologist 16: 324-333. https://doi.org/10.1027/1016-9040/a000032

Byrka, K., Kaiser, F.G. and Olko, J., 2017. Understanding the acceptance of nature-preservation-related restrictions as the result of the compensatory effects of environmental attitude and behavioral costs. Environment and Behavior 49: 487-508. https://doi.org/10.1177/0013916516653638

Campbell, D.T., 1963. Social attitudes and other acquired behavioral dispositions. In: Koch, S. (ed.) Psychology: a study of a science. McGraw-Hill, New York, NY, USA, pp. 94-172. https://doi.org/10.1037/10590-003

Chaudhry, Q., Watkins, R. and Castle, L., 2010. Nanotechnologies in the food arena: new opportunities, new questions, new concerns. In: Chaudhry, Q., Castle, L. and Watkins, D.R. (eds.) Nanotechnologies in food, Royal society of chemistry, London, UK, pp. 1-17. https://doi.org/10.1039/9781847559883-00001

Dagevos, H., 2021. A literature review of consumer research on edible insects: recent evidence and new vistas from 2019 studies. Journal of Insects as Food and Feed 7: 249-259. https://doi.org/10.3920/JIFF2020.0052

De Houwer, J., Gawronski, B. and Barnes-Holmes, D., 2013. A functional-cognitive framework for attitude research. European Review of Social Psychology 24: 252-287. https://doi.org/10.1080/10463283.2014.892320

De Souza-Vilela, J., Andrew, N.R. and Ruhnke, I., 2019. Insect protein in animal nutrition. Animal Production Science 59: 2029-2036. https://doi.org/10.1071/AN19255

DeCoster, J., Iselin, A.M.R. and Gallucci, M., 2009. A conceptual and empirical examination of justifications for dichotomization. Psychological Methods 14: 349-366. https://doi.org/10.1037/a0016956

Dimock, M., 2019. Defining generations: where millennials end and generation Z begins. Pew Research Center, Washington, DC, USA. Available at: https://tinyurl.com/2p8wxedj

Domingues, C.H.D.F., Borges, J.A.R., Ruviaro, C.F., Gomes Freire Guidolin, D. and Rosa Mauad Carrijo, J., 2020. Understanding the factors influencing consumer willingness to accept the use of insects to feed poultry, cattle, pigs and fish in Brazil. PLoS ONE 15: e0224059. https://doi.org/10.1371/journal.pone.0224059

EU Agricultural Market Brief, 2019. Agriculture markets and prices. Available at: http://ec.europa.eu/agriculture/markets-and-prices/index_en.htm

European Union (EU), 2017a. Commission Implementing Regulation (EU) 2017/892 of 13 March 2017 laying down rules for the application of Regulation (EU) No 1308/2013 of the European Parliament and of the Council with regard to the fruit and vegetables and processed fruit and vegetables sectors. Official Journal of the European Union L 138: 57-91. Available at: http://data.europa.eu/eli/reg/2017/892/oj.

European Union (EU), 2017b. Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein. Official Journal of the European Union L 138: 92-116. Available at: http://data.europa.eu/eli/reg/2017/893/oj.

Fasanelli, R., Galli, I., Riverso, R. and Piscitelli, A., 2020. Social representations of insects as food: an explorative-comparative study among millennials and X-generation consumers. Insects 11: 656. https://doi.org/10.3390/insects11100656

Ferrer Llagostera, P., Kallas, Z., Reig, L. and Amores De Gea, D., 2019. Use of insect meal as a sustainable feeding alternative in aquaculture: current situation, Spanish consumers' perceptions and willingness to pay. Journal of Cleaner Production 229: 10-21. https://doi.org/10.1016/j.jclepro.2019.05.012

Food and Agriculture Organisation (FAO), 2020. The state of world fisheries and aquaculture 2020. Sustainability in action. FAO, Rome, Italy. https://doi.org/10.4060/ca9229en

Fraley, R.C., Waller, N.G. and Brennan, K.A., 2000. An item response theory analysis of self-report measures of adult attachment. Journal of Personality and Social Psychology 78: 350. https://doi.org/10.1037/0022-3514.78.2.350

Frewer, L., 2003. Societal issues and public attitudes towards genetically modified foods. Trends in Food Science & Technology 14: 319-332. https://doi.org/10.1016/S0924-2244(03)00064-5

Gasco, L., Acuti, G., Bani, P., Dalle Zotte, A., Danieli, P.P., De Angelis, A., Fortina, R., Marino, R., Parisi, G., Piccolo, G., Pinotti, L., Prandini, A., Schiavone, A., Terova, G., Tulli, F. and Roncarati, A., 2020a. Insect and fish by-products as sustainable alternatives to conventional animal proteins in animal nutrition. Italian Journal of Animal Science 19: 360-372. https://do.org/10.1080/1828051X.2020.1743209

Gasco, L., Biancarosa, I. and Liland, N.S., 2020b. From waste to feed: a review of recent knowledge on insects as producers of protein and fat for animal feeds. Current Opinion in Green and Sustainable Chemistry 23: 67-79. https://doi.org/10.1016/j.cogsc.2020.03.003

Gasco, L., Biasato, I., Dabbou, S., Schiavone, A. and Gai, F., 2019. Animals fed insect-based diets: state-of-the-art on digestibility, performance and product quality. Animals 9: 170-201. https://doi.org/10.3390/ani9040170

Gasco, L., Finke, M. and Van Huis, A., 2018. Can diets containing insects promote animal health? Journal of Insects as Food and Feed 4: 1-4. https://doi.org/10.3920/jiff2018.x001

Gasco, L., Józéfiak, A. and Henry, M., 2020c. Beyond the protein concept: health aspects of using edible insects on animals. Journal of Insect as Food and Feed 7 (5): 715-741. https://doi.org/10.3920/JIFF2020.0077

Giordano, C., Piras, S., Boschini, M. and Falasconi, L., 2018. Are questionnaires a reliable method to measure food waste? A pilot study on Italian households. British Food Journal 120: 2885-2897. https://doi.org/10.1108/BFJ-02-2018-0081

Giotis, T. and Drichoutis, A.C., 2021. Consumer acceptance and willingness to pay for direct and indirect entomophagy. Q Open 1(2): qoab015. https://doi.org/10.1093/qopen/qoab015

Gupta, N., Fischer, A.R. and Frewer, L.J., 2012. Socio-psychological determinants of public acceptance of technologies: a review. Public Understanding of Science 21: 782-795. https://doi/10.1177/0963662510392485

Henry, M., Gasco, L., Chatzifotis, S. and Piccolo, G., 2018a. Does dietary insect meal affect the fish immune system? The case of mealworm, *Tenebrio molitor* on European sea bass, *Dicentrarchus labrax*. Developmental and Comparative Immunology 81: 204-209. https://doi.org/10.1016/j.dci.2017.12.002

Henry, M.A., Gai, F., Enes, P., Peréz-Jiménez, A. and Gasco, L., 2018b. Effect of partial dietary replacement of fishmeal by yellow mealworm (*Tenebrio molitor*) larvae meal on the innate immune response and intestinal antioxidant enzymes of rainbow trout (*Oncorhynchus mykiss*). Fish and Shellfish Immunology 83: 308-313. https://doi.org/10.1016/j.fsi.2018.09.040

Hobbs, J.E. and Plunkett, M.D., 2007. Genetically modified foods: consumer issues and the role of information asymmetry. Canadian Journal of Agricultural Economics 47: 445. https://doi.org/10.1111/j.1744-7976.1999.tb00442.x

Hua, K., Cobcroft J.M., Cole, A., Condon, K., Jerry, D.R., Mangott, A., Praeger, C., Vucko, M.J., Zeng, C., Zenger, K. and Strugnell, J.M., 2019. The future of aquatic protein: implications for protein sources in aquaculture diets. One Earth 1: 316-329. https://doi.org/10.1016/j.oneear.2019.10.018

International Platform of Insects for Food and Feed (IPIFF), 2019. The European insect sector today: challenges, opportunities and regulatory landscape. IPIFF vision paper on the future of the insect sector towards 2030. Available at: https://tinyurl.com/ypjvky4v

Kaiser, F.G. and Wilson, M., 2004. Goal-directed conservation behavior: the specific composition of a general performance. Personality and Individual Differences 36: 1531-1544. https://doi.org/10.1016/j.paid.2003.06.003

Kaiser, F.G. and Wilson, M., 2019. The Campbell paradigm as a behavior-predictive reinterpretation of the classical tripartite model of attitudes. European Psychologist 24: 359-374. https://doi.org/10.1027/1016-9040/a000364

Kaiser, F.G., 1998. A general measure of ecological behavior. Journal of Applied Social Psychology 28: 395-422. https://doi.org/10.1111/j.1559-1816.1998.tb01712.x

Kaiser, F.G., 2021. Climate change mitigation within the Campbell paradigm: doing the right thing for a reason and against all odds. Current Opinion in Behavioral Sciences 42: 70-75. https://doi.org/10.1016/j.cobeha.2021.03.024

Kaiser, F.G., Byrka, K. and Hartig, T., 2010. Reviving Campbell's paradigm for attitude research. Personality and Social Psychology Review 14: 351-367. https://doi.org/10.1177/1088868310366452

Kaiser, F.G., Hartig, T., Brügger, A. and Duvier, C., 2013. Environmental protection and nature as distinct attitudinal objects: an application of the Campbell paradigm. Environment and Behavior 45: 369-398. https://doi.org/10.1177/0013916511422444

Kaiser, F.G., Henn, L. and Marschke, B., 2020. Financial rewards for long-term environmental protection. Journal of Environmental Psychology 68: 101411. https://doi.org/10.1016/j.jenvp.2020.101411

Kher, S.V., De Jonge, J., Wentholt, M.T., Deliza, R., De Andrade, J.C., Cnossen, H.J., Luijckx, N.N.L. and Frewer, L.J., 2013. Consumer perceptions of risks of chemical and microbiological contaminants associated with food chains: a cross-national study. International Journal of Consumer Studies 37: 73-83. https://doi.org/10.1111/j.1470-6431.2011.01054.x

Krogdahl, Å., Penn, M., Thorsen, J., Refstie, S. and Bakke, A.M., 2010. Important antinutrients in plant feedstuffs for aquaculture: an update on recent findings regarding responses in salmonids. Aquaculture Research 41: 333-344. https://doi.org/10.1111/j.1365-2109.2009.02426.x

La Barbera, F., Verneau, F., Videbæk, P.N., Amato, M. and Grunert, K.G., 2020. A self-report measure of attitudes toward the eating of insects: construction and validation of the Entomophagy Attitude Questionnaire. Food Quality and Preference 79: 103757. https://doi.org/10.1016/j.foodqual.2019.103757

Laureati, M., Proserpio, C., Jucker, C. and Savoldelli, S., 2016. New sustainable protein sources: consumers' willingness to adopt insects as feed and food. Italian Journal of Food Science 28: 652-668. https://doi.org/10.14674/1120-1770/ijfs.v476

Linacre, J.M., 2002. What do infit and outfit, mean square and standardized mean? Rasch Measurement Transactions. Available at: https://www.rasch.org/rmt/rmt162f.htm

Linacre, J.M., 2010. When to stop removing items and persons in Rasch misfit analysis? Rasch Measurement Transactions. Available at: https://www.rasch.org/rmt/rmt234g.htm

Lock, E.J., Biancarosa, I. and Gasco, L., 2018. Insects as raw materials in compound feed for aquaculture. In: Halloran, A., Flore, R., Vantomme, P. and Roos, N. (eds.) Edible insects in sustainable food systems. Springer International Publishing AG, Cham, Switzerland, pp. 263-276. https://doi.org/10.1007/978-3-319-74011-9_16

Mancini, S., Sogari, G., Menozzi, D., Nuvoloni, R., Torracca, B., Moruzzo, R. and Paci, G., 2019. Factors predicting the intention of eating an insect-based product. Foods 8: 270. https://doi.org/10.3390/foods8070270

Mancuso, T., Baldi, L. and Gasco, L., 2016. An empirical study on consumer acceptance of farmed fish fed on insect meals: the Italian case. Aquaculture International 24: 1489-1507. https://doi.org/10.1007/s10499-016-0007-z

Mancuso, T., Pippinato, L., Gasco L., T., 2019. The European insects sector and its role in the provision of green proteins in feed supply. Quality– Access to Success 20: 374-381

Martin, C. and Czellar, S., 2017. Where do biospheric values come from? A connectedness to nature perspective. Journal of Environmental Psychology 52: 56-68. https://doi.org/10.1016/j.jenvp.2017.04.009

Menozzi, D., Sogari, G., Mora, C., Gariglio, M., Gasco, L. and Schiavone, A., 2021. Insects as feed for farmed poultry: are Italian consumers ready to embrace this innovation? Insects 12: 435. https://doi.org/10.3390/insects12050435

Menozzi, D., Sogari, G., Veneziani, M., Simoni, E. and Mora, C., 2017. Eating novel foods: an application of the theory of planned behaviour to predict the consumption of an insect-based product. Food Quality and Preference 59: 27-34. https://doi.org/10.1016/j.foodqual.2017.02.001

Mol, A.P., 2015. Transparency and value chain sustainability. Journal of Cleaner Production 107: 154-161. https://doi.org/10.1016/j.jclepro.2013.11.012

Onwezen, M.C., Van den Puttelaar, J., Verain, M.C.D. and Veldkamp, T., 2019. Consumer acceptance of insects as food and feed: the relevance of affective factors. Food Quality and Preference 77: 51-63. https://doi.org/10.1016/j.foodqual.2019.04.011

Parisi, G., Tulli, F., Fortina, R., Marino, R., Bani, P., Dalle Zotte, A., De Angeli, A., Piccolo, G., Pinotti, L., Schiavone, A., Terova, G., Prandini, A., Gasco, L., Roncarati, A. and Danieli, P.P., 2020. Protein hunger of the feed sector: the alternatives offered by the plant world. Italian Journal of Animal Science 19: 1204-1225. https://doi.org/10.1080/1828051X.2020.1827993

Pieniak, Z., Vanhonacker, F. and Verbeke, W., 2013. Consumer knowledge and use of information about fish and aquaculture. Food Policy 40: 25-30. https://doi.org/10.1016/j.foodpol.2013.01.005

Popoff, M., MacLeod, M. and Leschen, W., 2017. Attitudes towards the use of insect-derived materials in Scottish salmon feeds. Journal of Insects as Food and Feed 3: 131-138. https://doi.org/10.3920/JIFF2016.0032

Rasch, G., 1993. Probabilistic models for some intelligence and attainment tests. MESA Press, Chicago, IL, USA.

Rogers, E.M., 2003. Diffusion of innovations. New York Free Press, New York, NY, USA, 551 pp.

Ronteltap, A., Van Trijp, J.C.M., Renes, R.J. and Frewer, L.J., 2007. Consumer acceptance of technology-based food innovations: lessons for the future of nutrigenomics. Appetite 49: 1-17. https://doi.org/10.1016/j.appet.2007.02.002

Rosenberg, M. and Hovland, C.I., 1960. Research on communication and attitude coated. In: Triandis, H.C. (ed.) Attitude and attitude change. John Wiley Publisher, New York, NY, USA, 232 pp.

Rumbos, C.I., Mente, E., Karapanagiotidis, I.T., Vlontzos, G. and Athanassiou, C.G., 2021. Insect-based feed ingredients for aquaculture: a case study for their acceptance in Greece. Insects 12: 586. https://doi.org/10.3390/insects12070586

Rummel, R.J., 1988. Applied factor analysis. Northwestern University Press, Evanston, IL, USA, 617 pp.

Shepherd, C.J. and Jackson, A.J., 2013. Global fish meal and fish-oil supply: inputs, outputs and markets. Journal of Fish Biology 83: 1046-1066. https://doi.org/10.1111/jfb.12224

Smetana, S., Schmitt, E. and Mathys, A., 2019. Sustainable use of *Hermetia illucens* insect biomass for feed and food: attributional and consequential life cycle assessment. Resources, Conservation and Recycling 144: 285-296. https://doi.org/10.1016/j.resconrec.2019.01.042

Smolders, K.C., De Kort, Y.A., Tenner, A.D. and Kaiser, F.G., 2012. Need for recovery in offices: behavior-based assessment. Journal of Environmental Psychology 32: 126-134. https://doi.org/10.1016/j.jenvp.2011.12.003

Sodano, V., Gorgitano, M.T., Verneau, F. and Vitale, C.D., 2016. Consumer acceptance of food nanotechnology in Italy. British Food Journal 118: 714-733. https://doi.org/10.1108/BFJ-06-2015-0226

Sogari, G., Amato, M., Biasato, I., Chiesa, S. and Gasco, L., 2019a. The potential role of insects as feed: a multi-perspective review. Animals 9: 119. https://doi.org/10.3390/ani9040119

Sogari, G., Bogueva, D. and Marinova, D., 2019c. Australian consumers' response to insects as food. Agriculture 9: 108. https://doi.org/10.3390/agriculture9050108

Sogari, G., Menozzi, D. and Mora, C., 2019b. The food neophobia scale and young adults' intention to eat insect products. International Journal of Consumer Studies 43: 68-76. https://doi.org/10.1111/ijcs.12485

Sogari, G., Menozzi, D., Mora, C., Gariglio, M., Gasco, L. and Schiavone, A., 2022. How information affects consumers' purchase intention and willingness to pay for poultry farmed with insect-based meal and live insects. Journal of Insects as Food and Feed. https://doi.org/10.3920/JIFF2021.0034

Sogari, G., Pucci, T., Aquilani, B. and Zanni, L., 2017. Millennial generation and environmental sustainability: the role of social media in the consumer purchasing behavior for wine. Sustainability 9: 1911. https://doi.org/10.3390/su9101911

Spartano, S. and Grasso, S., 2021. UK consumers' willingness to try and pay for eggs from insect-fed hens. Future Foods 3: 100026. https://doi.org/10.1016/j.fufo.2021.100026

Ssepuuya, G., Sebatta, C., Sikahwa, E., Fuuna, P., Sengendo, M., Mugisha, J., Fiaboe, K.K.M. and Nakimbugwe, D., 2019. Perception and awareness of insects as an alternative protein source among fish farmers and fish feed traders. Journal of Insects as Food and Feed 5: 107-116. https://doi.org/10.3920/JIFF2017.0056

Starke. A.D., Willemsen, M.C. and Snijders, C.C., 2020. Beyond 'one-size-fits-all' platforms: applying Campbell's paradigm to test personalized energy advice in the Netherlands. Energy Research & Social Science 59: 101311. https://doi.org/10.1016/j.erss.2019.101311

Thompson, S.C.G. and Barton, M.A., 1994. Ecocentric and anthropocentric attitudes toward the environment. Journal of Environmental Psychology 14: 149-157. https://doi.org/10.1016/S0272-4944(05)80168-9

Trentinaglia De Daverio, M.T., Mancuso, T., Peri, M. and Baldi, L., 2021. How does consumers' care for origin shape their behavioural gap for environmentally friendly products? Sustainability 13: 190. https://doi.org/10.3390/su13010190

Van Huis, A. and Oonincx, D.G.A.B., 2017. The environmental sustainability of insects as food and feed. A review. Agronomy for Sustainable Development 37: 43. https://doi.org/10.1007/s13593-017-0452-8

Van Huis, A., 2020. Insects as food and feed, a new emerging agricultural sector: a review. Journal of Insects as Food and Feed 6: 27-44. https://doi.org/10.3920/JIFF2019.0017

Van Rijswijk, W. and Frewer, L.J., 2008. Consumer perceptions of food quality and safety and their relation to traceability. British Food Journal 110: 1034-1046. https://doi.org/10.1108/00070700810906642

Vermeir, I. and Verbeke, W., 2006. Sustainable food consumption: exploring the consumer 'attitude-behavioral intention' gap. Journal of Agricultural and Environmental Ethics 19: 169-194. https://doi.org/10.1007/s10806-005-5485-3

Yamoah, F.A. and Acquaye, A., 2019. Unravelling the attitude-behaviour gap paradox for sustainable food consumption: insight from the UK apple market. Journal of Cleaner Production 217: 172-184. https://doi.org/10.1016/j.jclepro.2019.01.094

Zellner, A., 1963. Estimators for seemingly unrelated regression equations: some exact finite sample results. Journal of the American Statistical Association 58: 977-992. https://doi.org/10.1080/01621459.1963.10480681