Eating edible insects as sustainable food? Exploring the determinants of consumer acceptance in Germany

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Abstract

The potential use of insects as a novel food source has recently attracted a great deal of attention in Europe, as they have many environmental and nutritional advantages and thus present a promising and sustainable animal protein source. Yet despite insects being a highly appreciated food in many parts of the world, consumer aversion remains as the major barrier to successful implementation in Europe. This study examines prospects of edible whole insect and processed insect-based food in Germany and investigates determining factors for acceptance. It does so to better understand consumers' attitudes toward insects and to derive approaches for insect food to become more appreciated. An online survey was conducted within the German population with a final sample of 393 participants. Several explanatory variables were established, and their influence on the acceptance of whole and processed insect products was analyzed by applying ordinal regressions to compare the market potential and hurdles of either option. The main results show a low willingness to try insects amongst Germans and the prevalence of psychological and personality barriers to consumption, such as disgust and food neophobia. Focusing on processed insect products is shown to be the most promising strategy to implement entomophagy, as an essential barrier to consumption is the visibility of the insects. However, whether this strategy would diminish the rejection of any insect product requires further investigation.

Keywords: edible insects, consumer acceptance, novel food, entomophagy, alternative protein source, whole insect food, processed insect food

1. Introduction

Researchers estimate that by 2050, the world population will grow to approximately nine billion people (Food and Agricultural Organization of the United Nations [FAO], 2009; Van Huis et al., 2013). Consequently, present food production will have to double to meet the steadily growing food demand (FAO, 2009). Facing these problems, food production needs to be re-evaluated, with the introduction of sustainable and efficient food sources becoming indispensable (Ghosh et al., 2018; Rumpold & Schlüter, 2013). Chaalala et al. (2018) expect that by 2054, new alternative protein sources will claim up to one-third of the protein market.

In 2009, the FAO published a report on sustainable nutrition advocating for the potential of insects as a viable option. Insects have received increasing public attention in Europe, as they might constitute a solution to today's food and nutrition challenges, especially in the context of the growing demand for animal protein and food with healthy and environmentally friendly characteristics (Baker et al., 2018; Van Huis et al., 2013). In the first place, insects require far fewer natural resources such as water, feed, land than conventional livestock (Dunkel & Payne, 2016; Gamborg et al., 2018; Van Huis et al., 2013) and they also cause significantly less greenhouse gas and ammonia emissions (Halloran et al., 2016; Oonincx, 2017; Van Huis & Tomberlin, 2017b). They are cold-blooded and thus have a high feed conversion rate, which means that they are very efficient in the biotransformation of organic matter into insect biomass (Gamborg et al., 2018; Oonincx, 2017). Moreover, up to 80% of the mass of most insects can be consumed and digested; this is compared to around 55% of chicken and pork and only 40% of cattle (Heckmann et al., 2018; Van Huis et al., 2013). As the concept of circular economy becomes more prominent, insect production might play a significant role in the future since they can be reared on organic side streams and thus cost-efficiently transform and recycle agricultural and industrial by-products or waste into valuable protein (Jensen et al., 2017; Oonincx, 2017; Van Huis et al., 2013). As mini livestock, insects are especially suitable for industrial production, as they usually grow quickly, are highly reproductive, have a short lifespan with high survival rates, are efficient at nutrient conversion, and thrive at a high density, contributing to another beneficial attribute of animal welfare (Gahukar, 2016; Jensen et al., 2017). Taking into account the high nutritional value and resource efficiency in rearing insects, they are a more sustainable alternative to conventionally produced animal protein (FAO, 2009; Hartmann & Siegrist, 2017; Van Huis et al., 2013; Van Huis & Tomberlin, 2017a; Verbeke, 2015).

Despite insects being a highly appreciated food source in many parts of the world—an estimated two billion people integrate insects into their traditional diets, the majority of whom are located in Asia, South America, and Africa—most Western cultures do not consider them to be an appropriate food source, and negative attitudes prevail (Vantomme, 2017; Wilkinson et al., 2018). Moreover, for centuries, the rearing of insects has been an essential element of food acquisition in the Global South and subsequently plays an integral role in ensuring food security (Gahukar, 2016; Van Huis et al., 2013). However, as developing countries adapt to Western lifestyles, a decline up to a disappearance of insect consumption could be observed (Costa-Neto & Dunkel, 2016).

Achieving consumer acceptance remains the biggest challenge for the insect industry (Mancini et al., 2019; Van Huis et al., 2013; Verbeke, 2015). Nevertheless, researchers have perceived a change in consumer preferences and social attitudes toward entomophagy (the practice of eating insects) in Western societies, as people have begun to focus on healthier, natural, and more environmentally friendly diets and have sought new, more sustainable protein sources (Dunkel & Payne, 2016; Galati et al., 2019; Shockley et al., 2017; Van Huis et al., 2013). Within this context, new chances for insects to become a successful and viable food alternative are emerging (Alemu & Olsen, 2018; Costa-Neto & Dunkel, 2016).

Researchers expect the insect industry to become a rapidly emerging market in Europe (Costa-Neto & Dunkel, 2016; Derrien & Boccuni, 2018; Fitches & Smith, 2018). The global market value of edible insects in 2018 was USD 406.32 million; it is anticipated to nearly triple to USD 1181.6 million by 2023, implying a compound annual growth rate of 23.8%. Asia will remain as the leading and most expanding market. Europe follows with significant growth, from USD 92.2 million in 2018 to USD 261.5 million by 2023, surpassing Latin America (Sogari et al., 2019; Stull et al., 2018).

Although previous research in Europe was primarily carried out in the Netherlands and Belgium (Tan et al., 2015), Germany is an equally interesting market to analyze, as it has the biggest food market in Europe (Germany Trade and Invest, 2019). Moreover, numerous insect food companies were founded in Germany in the last few years, and they are constantly introducing new insect-based products to the market. Most start-ups in Germany focus on processed insect products such as protein bars with insect powder, reacting to the acknowledged presumption that the visibility of insect ingredients has a severe effect on consumers' reluctance to accept insects in their food (Caparros Megido et al., 2014; Tan et al., 2016b).

This work aims to provide new insights into the potential of novel insect food by investigating the parameters influencing acceptance in the German market. Special focus is placed on the analysis of potential differences between whole and processed insect-based products (powder or protein extracts). The research aims of this study find strong support in the stream of literature that investigates the factors influencing consumer intention to accept and consume insect-based food products. Its contribution to the stream relates to investigating German consumers by considering a comprehensive set of variables for both whole and processed food products. Indeed, there are still a limited number of studies conducted among German consumers (see Mancini et al., 2019), even if it is an important market for insect-based food. Moreover, only two studies have been conducted in Germany that investigated consumer preferences for insect-based foods. Piha et al. (2018) conducted an online survey to investigate the effect of subjective and objective knowledge on consumers' willingness to buy such products. Hartmann et al. (2015) compared consumers' food neophobic tendencies with different cultural exposure to insects (i.e., Chinese and German consumers). To the best of our knowledge, no studies have focused on a comprehensive evaluation of all-important predictors of German consumers' willingness to accept insect-based food. Also, this is the first attempt to simultaneously compare willingness to accept whole and processed insect-based products by considering all the different variables found in the literature that impact on consumers' predisposition toward such food products (i.e., food neophobia, disgust, environmental awareness, health consciousness, risk assessment, personal experiences, and familiarity).

2. Key determinants to acceptance

Concerning novel foods such as insects, acceptance or rejection does not primarily depend on product-related attributes (price, taste, etc.) and rational factors but on emotional and cultural beliefs (Hartmann & Siegrist, 2016; Meixner & Mörl von Pfalzen, 2018). This study summarizes the parameters influencing initial willingness to try insects as identified by recent studies in Europe; it uses these to derive a theoretical model for analysis.

2.1 Food neophobia

Food neophobia is the expression used to describe an individual's tendency to reject new, unknown food (Dossey et al., 2016; Hartmann & Siegrist, 2017). Hence, testing the level of food neophobia is included in the majority of studies investigating consumers' acceptance of insects (Hartmann et al., 2015; La Barbera et al., 2018; Monteleone et al., 2017; Verbeke, 2015; Wilkinson et al., 2018). According to current literature, there is a negative correlation between consumers' food neophobic tendencies and the probability to eat insects both as a whole and as an ingredient in food (Hartmann et al., 2015). Food neophobia is also found to be an important predictor of consumers' willingness to consume insects in Western countries when it is associated with other explanatory variables such as as perceived healthiness, convenience, gender, prior consumption, and disgust sensitivity (Schulp & Brunner, 2018; Verbeke, 2015; Hartmann & Siegrist, 2016). Empirical analysis has been found to be a superior predictor compared to other important variables, such as subjective and objective knowledge (Piha et al., 2018).

2.2 Disgust

European cultures perceive insects as dirty, disgusting, or dangerous pests; disease vectors; or sheer nuisances instead of as a nutritious food item (Costa-Neto & Dunkel, 2016; Shockley et al., 2017; Van Huis et al., 2013). Studies show a great negative impact of disgust on willingness to eat insects, resulting in their rejection even before actually tasting insect products (Gmuer et al., 2016; Hartmann et al., 2015; Hartmann & Siegrist, 2016; Meixner & Mörl von Pfalzen, 2018; Tan et al., 2015; Verbeke, 2015).

The sensation of disgust related to insect food often derives from culturally induced rejection and adverse taste expectations (Mancini et al., 2019). Studies show a great negative impact of disgust on willingness to eat insects (Hartmann et al., 2015; Hartmann & Siegrist, 2016; Tan et al., 2015; Verbeke, 2015). Caparros Megido et al. (2016) asked participants what prejudices or preconceptions they had about entomophagy, and 13% indicated disgust and nausea. Tan et al. (2015) observed that the feeling of disgust strongly influenced perception even before insect products were actually tasted.

The recent introduction of insects within certain European markets has demonstrated a slight increase in consumers' positive perceptions about insects as a source of protein in food products (Barsics et al., 2017; Schouteten et al., 2016). Van Thielen et al. (2019) and Adamek et al. (2018) confirmed this cultural trend;

they reported a more positive willingness to consume insects in Belgium and the Czech Republic, respectively. Moreover, several studies have demonstrated an increase in consumers' willingness to eat insects as a consequence of a taste activity (Sogari et al., 2017; Menozzi et al., 2017; Lensvelt & Steenbekkers, 2014). Such findings reveal that a positive tasting experience can help to reduce the sense of disgust toward insects in countries where they are not part of the gastronomic heritage.

Such a predictor reveals its explanatory power when associated with other variables such as appearance, taste, and odor (Balzan et al., 2016). La Barbera et al. (2018) demonstrated that the explanatory power of disgust at the intention to consume insects was even higher than the explanatory power of food neophobic tendencies. Moreover, the sensation of disgust can be rooted in irrational logic or wrong information (Dunkel & Payne, 2016). Presenting rational positive facts about food with cultural stigmas alone does not allow people to overcome their aversions (Shockley et al., 2017).

2.3 Environmental awareness

The potential to become an environmentally sustainable alternative food source arising from the low environmental impact of insect rearing is a significant advantage that is expected to positively influence acceptance of entomophagy (Hartmann & Siegrist, 2018; Menozzi et al., 2017; Tan et al., 2015). Several studies have found that individuals who pay attention to the environmental impact of their food choices and who are aware of the ecological benefits of insects are more open to entomophagy (Gamborg et al., 2018; Lensvelt & Steenbekkers, 2014; Schiemer et al., 2018; Tan et al., 2015; Verbeke, 2015). Consumer relevance assigned to the environmentally friendly properties of insects was supported by several studies conducted in Italy, Poland, and Belgium. Menozzi et al. (2017) highlighted that positive consumer beliefs in insects' contribution to the preservation of the environment positively affected consumers' attitudes toward the intention to eat insects in Italy. Kostecka et al. (2017) found that environmental awareness was one important factor in increasing consumers' probability to eat insects. Verbeke (2015) reported that consumers' likelihood to adopt insects into their diets was enhanced by the importance that consumers placed on the environmental impact of food production.

Other studies revealed how information increased consumers' environmental awareness and their acceptability of insects as an alternate protein source. Vernau et al. (2016) found that distributing information about the quality attributes of insects increased consumers' intention to eat them, and that such a behavioral predisposition persisted for almost one month. Lombardi et al. (2019) confirmed such findings by analyzing consumers' willingness to pay (WTP) for different insect-based foods when information on the benefits of insects was provided.

Even if most studies agree on the importance of environmental awareness for the acceptance of insects within Western diets, this is not sufficient to stimulate actual behaviors or to provide effective strategies to stimulate the consumption of such a protein source (Sidali et al., 2018; House, 2016).

2.4 Health consciousness

Due to their valuable nutritional profile, edible insects are undoubtedly a healthy and highly nutritional food source (Cavallo & Mateira, 2018). Ruby et al. (2015) observed the nutritional profile to be the most common perceived benefit, proving that the healthiness of insect-based food could be a convincing factor in changing food habits. People searching for a healthy, balanced, or functional diet (e.g., athletes) are therefore more likely to accept insects as food (Schiemer et al., 2018). Also, Hartmann et al. (2018) found that vegetarians evaluated insect alternatives as healthier than conventional meat. Moreover, Schlup and Brunner (2018) and Gere et al. (2017) stressed the expected food healthiness of insects as one of the main predictors of consumers' acceptance.

2.5 Risk assessment

Perceived risks play an important role in the acceptance of novel foods (Meixner & Mörl von Pfalzen, 2018). Feelings of disgust, distaste, or hesitation to try insects are often based on the miscalculation of insects being dirty, harmful, and dangerous to personal health (Costa-Neto & Dunkel, 2016). Baker et al. (2018) investigated the different elements of risk perception and their influence on willingness to try insects. Many consumers perceived entomophagy as an activity that involved a very high risk, which ultimately lead to rejection; this was a determinant of insect food acceptance (Baker et al., 2018). Furthermore, Hartmann et al. (2015), Hartmann and Siegrist (2017), and Ruby et al. (2015) confirmed consumers' risk perception as an important predictor limiting acceptance of edible insects.

2.6 Personal experiences

Most studies focusing on insects as human food have defined previous experiences of eating insects as an important factor in the acceptance of entomophagy (Caparros Megido et al., 2016; Hartmann et al., 2015; Hartmann & Siegrist, 2016; Piha et al., 2018; Tan et al., 2015; Verbeke, 2015). When insect products convince consumers in terms of taste, entry barriers are lower, and people are much more likely to eat insect food again (Tan et al., 2015). Caparros Megido et al. (2016) observed that 81% of study participants who had previously eaten insects connected positive memories with the experience and stated that they were open to considering insects as food. Lensvelt and Steenbekkers (2014) interviewed Dutch and Australian consumers and found that people who had previously eaten insects showed a more positive attitude toward entomophagy than those who had never tried them before. Meixner and Mörl von Pfalzen (2018) showed that most participants' attitudes toward entomophagy improved after tasting them, and that 68% of people were prepared to include insects in their diets. Verbeke (2015) showed that consumers' sensory experience of meat products had a negative effect on their probability to adopt insects as a meat substitute.

2.7 Familiarity

Familiarity and experience are closely related. Consumers are expected to be familiar with edible insects if they have tasted them before. However, consumer evaluation is not exclusively related to the associated sensory experience after the first tasting (Caparros Megido et al., 2018).

Researchers have found information and knowledge about entomophagy to considerably impact consumers' perceptions (Caparros Megido et al., 2016; Hartmann & Siegrist, 2016; Tan et al., 2016b; Verneau et al., 2014; Verneau et al., 2016). Familiarity with the advantages of edible insects becomes especially crucial in European countries, as people who come into contact with insect food products for the first time can only rely on information that does not derive from experimental experience (Caparros Megido et al., 2018; Tan et al., 2016b). Thus, the low demand for insect products is associated with the lack of knowledge about entomophagy and the consequential ignorance of its benefits (Costa-Neto & Dunkel, 2016).

Some studies have investigated whether preparation of familiar foods and familiarity with certain kinds of products could enhance consumer acceptability of insect-based products. Tan et al. (2015) found that the inclusion of insects as an ingredient in food that is typically considered of familiar preparation, such as meatballs or cookies, increased consumers' likelihood to taste insects. Van Thielen et al. (2018) suggested the invisible incorporation of insects into hamburgers for Belgian consumers to increase their willingness to eat insect-based food. Caparros Megito et al. (2016) considered hybrid insect-based hamburgers in their analysis, and they found a positive level of sensory-liking of such products.

2.8 Sociodemographic factors

According to several studies, gender has an effect on insect acceptance, as it is posited that men have a more positive attitude toward entomophagy than women (Schlup & Brunner, 2018; Menozzi et al., 2017; Hartmann et al., 2015; Ruby et al., 2015; Schösler et al., 2012; Tan et al., 2016a; Tan et al., 2016b; Verbeke, 2015; Verneau et al., 2016; Wilkinson et al., 2018; Sheppard & Frazer, 2015; Barsics et al., 2017). Only Hartmann et al. (2015) and de Boer et al. (2013) did not find an influence of gender on the acceptability of insect-based food.

Most studies have claimed that younger people are more willing to eat insects than older people (Caparros Megido et al., 2014; Hartmann et al., 2015; Tranter, 2013; Verbeke, 2015). In line with knowledge about entomophagy having an influence on acceptance, level of education might also be important. However, according to recent studies, the extent of education did not affect willingness to try insects (Hartmann et al., 2015; Tan, 2017; Tan et al., 2017b; Tan & House, 2018; Verbeke, 2015). Like meat, insects can be subject to dietary restrictions based on nutritional or animal welfare restrictions. It is generally expected that people living on a vegetarian or vegan diet would have a stronger aversion to eating insects (Costa-Neto & Dunkel, 2016).

3. Methodology

3.1. Data collection and sample

In order to examine consumers' attitudes toward insects and to operationalize the identified determining factors for acceptance, this study conducted an online survey in Germany between December 2018 and January 2019. A total of 402 people participated in the study. After a thorough check of the plausibility, reliability, conscientiousness, and completeness of the sample, very few answer sets were omitted. The final number can be accepted as a sufficient response quantity, as other online studies on the matter in Europe operated with similar or even lower numbers. For example, Verbeke (2015) used a sample of 368 Belgian participants, Verneau et al. (2016) used a sample of 264 Danish respondents, and Piha et al. (2018) carried out a study with 236 Germans. The majority of the respondents (approximately 90%) completed the questionnaire, which consisted of 42 multiple-choice questions and lasted for 15–20 minutes. Six cases were omitted from the final sample because they completed the survey in less than 10 minutes or in more than 30 minutes. Moreover, to ensure the representativeness of the German market, the inclusion criterion was to be a resident in Germany, resulting in the omittance of three cases. The online questionnaire was developed using an online platform, allowing participants to access it via different devices and operating systems. The questionnaire was distributed via social media, web forums, and contact lists in order to reach a wide and diverse range of respondents. Survey participants were randomly recruited. Moreover, to ensure the accuracy of the questions, and in order to avoid possible ambiguity regarding the items, a pretest at the beginning of November 2018 with 15 participants was carried out for one week (Meixner & Mörl von Pfalzen, 2018). Their feedback was considered, and the questionnaire was adjusted accordingly.

A final sample number of 393 participants consisting of 51% females and 49% males remained. In 2018, the German population consisted of about 50.7% females and 49.3% males—therefore, the dataset was considered to be balanced (Statistisches Bundesamt, 2018a). Participants' ages ranged from 13–82, with a mean age of 36 years. The sample showed a significant overrepresentation of the age group 26–35 (32.9%) compared to the German population (13%) (Statistisches Bundesamt, 2018b). Moreover, regarding the highest level of education, the sample was biased toward highly educated people compared to the German average (Statistisches Bundesamt, 2018c). This can be attributed to the use of online recruitment and a web-based questionnaire. The respondents who followed a vegetarian or vegan diet comprised 10.2% of the sample; only 2.5% were allergic to seafood. Comparisons of average values did not identify significant differences between questionnaires that were returned early and those that were returned later. Therefore, in accordance with Armstrong and Overton (1977), significant non-response bias was ruled out. While the sample was not perfectly balanced with the German population statistics, the results provided valuable evidence and indicators for the acceptance of entomophagy in Germany, especially for the young generation that represents future consumers.

The online questionnaire was divided into four parts. The first part contained questions measuring general attitude toward novel food and other factors regarding general food choices, which was later applied in the regression model. The questions addressed food neophobia, awareness of the environmental impact of food choices, and attitude toward food health characteristics. The second part identified the specific factors regarding insect consumption, measuring the familiarity, experience, disgust, risk assessment of whole and processed insects, and acceptance of insects as food; it made a distinction between the consideration of insects as a whole and processed product. To avoid confusion, and to ensure that participants understood what was meant by whole insect and processed insect products, a short explanatory text was included for specification. The third part of the questionnaire focused on general awareness and acceptance of several insect food products available in Germany to gain a better understanding of the current market situation from a consumer's perspective. Pictures of five different insect-based products and their ingredients were presented to make it easier to evaluate the products. Therefore, the products were chosen as follows: one product containing whole insects by Snack Insects (see Figure 1) and four processed insect products, namely, a protein bar by Swarm Protein (Figure 2), pasta by Plumento Foods (Figure 3), granola by Snack Insects (Figure 4), and an insect burger by Bug Foundation (Figure 5). Participants were asked the same three questions regarding their willingness to try and their familiarity and perception of all five products. The fourth and last part of the questionnaire collected the participants' sociodemographic data, including gender, age, level of education completed, nationality, and current place of residence. In addition, participants were asked whether they were allergic to seafood and whether they were vegan or vegetarian.

[Insert Figures 1, 2, 3, 4, and 5 around here]

3.2. Variable description

A theoretical model combining the most important factors in consumers' acceptance of insects was deduced from the prior literature review. The study differentiated between the acceptance of whole insects and the acceptance of processed insect products, identifying them as the two dependent variables, to better display their impact on the acceptance of insect-based food.

Table 1 summarizes the items, scales, and question types used in the survey, including the acronyms applied in the analysis. Where a 5-point Likert scale was employed, low values always indicated a low level of agreement with the given statement; high values indicated a high level of agreement, except for reverse-coded items, marked with an (R) in Table 1 and treated accordingly in the analysis.

[Insert Table 1 around here]

The variables derived from the theoretical analysis included the following: gender (Gender), age (Age), diet (Veg), highest level of education (Edu), food neophobia (FNS), environmental awareness (FEnv), health consciousness (Health), disgust (Disgust), risk (RiskWhole and RiskProcess), familiarity (Fam), and experience (Exp). The first four variables were used as control variables, whereas the others were explanatory parameters. Food neophobia, environmental awareness, and health consciousness are personality traits, disgust and risk perception of whole and processed insect products belong to psychological factors, and familiarity and experience belong to overall exposure.

To begin with the more straightforward parameters of the control group, the variable "Gender" was a dichotomous variable and was treated as such (0 = male, 1 = female). The variable "Age" was indicated on a metric scale and was included accordingly in the model. The highest level of education achieved had to be divided into groups that were assigned to four ordinally scaled categories. "Edu1" summed up all participants who were still in education, "Edu2" included all people with any kind of school education, "Edu3" combined all individuals with a professional training qualification, and "Edu4" consisted of all former students with any kind of university degree (bachelor's, master's, Ph.D., etc.).

Because they did not have a metric scale, the level of familiarity with entomophagy (Dummy_fam), experience (Dummy_Exp), and being on a vegan or vegetarian diet (Veg) had to be recoded and were included in the model as dummy variables. In order to create dichotomous variables for the item familiarity, the answer "No, I have never heard of the eating of insects" was coded as 0, whereas the answers, "Yes, I have heard of the eating of insects but actually don't know what it implies" and "Yes, I have heard of the eating of insects and I know what it implies" were coded as 1. With regard to experience, the question, "I have never tried edible insects in any form" was coded as 0; "I have tried edible insects on a single occasion," "I have tried edible insects on a few occasions," and "I eat edible insects regularly" were coded as 1. Furthermore, vegetarians and vegans were coded as 1; people who ate meat were coded as 0.

Due to the difficulty of measuring hypothetical constructs such as food neophobia, environmental awareness, disgust, health consciousness, and risk perception, these variables were tested using several questions that were operationalized by computing the mean value of the corresponding items. Utilizing the computed metric index value, new parameters were created by merging the items FNS (6 items, alpha = 0.707), FEnv (5 items, alpha = 0.907), Health (3 items, alpha = 0.747), Disgust (3 items, 0.835), RiskWhole (4 items, alpha = 0.897), and RiskProcess (4 items, alpha = 0.949). Table 2 describes the variables used, including their abbreviations, average values, standard deviations, and minimum and maximum values.

[Insert Table 2 around here]

3.3. Statistical modeling

Two different dependent variables were tested. The first, "AccWhole," explained the acceptance of whole insects as part of a regular diet. The second, "AccProcess," evaluated the acceptance of processed insects. Due to both of these variables being based on ordered categorical data (Likert scale), the use of an ordinal regression model was required (Göb et al., 2007). An ordered logit or cumulative link model was chosen because it is considered to be the most accurate (Christensen & Brockhoff, 2013). Following the example of Agresti (2002), such a model with a logit link was defined as

$$Logit(y_{i,j}) = logit(P(Y_i \leq j) = a_j + \beta x_i \qquad j = 1,2, \ldots, J\text{-}1, \qquad (3.1),$$

where $P(y_z \leq i)$ was the cumulative probabilities—the probability that the *i*-th individual was in the *j*-th or higher category at time t+1. The vector x_i indicated the *i*-th observation at time *t*. The corresponding set of regression parameters β denoted how an increase of one unit in the independent variable changed the log odds of being higher than category *j*. Moreover, a_j was the parameter providing the specific intercept for each cumulative logit (for each *j*). It varied between categories and satisfied the constraints $a_1 \leq a_2 \leq \ldots \leq a_{j-1} j$. In the sample, individuals were categorized independently (Stranieri et al., 2019). Following the theoretical regression model, the according cumulative link model specification was denoted as

$$Logit(AccWhole_{i,j}) = a_j + \beta controls_{z,i} + \beta traits_{z,i} + \beta psych_{z,i} + \beta exp_{z,i} \quad j = 1, \ldots, 4 \quad i = 1, \ldots, 393, \tag{3.2}$$

$$Logit(AccProcess_{i,j}) = a_j + \beta controls_{z,i} + \beta traits_{z,i} + \beta psych_{z,i} + \beta exp_{z,i} \quad j = 1, \ldots, 4 \quad i = 1, \ldots, 393, \tag{3.3}$$

where $\text{AccWhole}_{i,j}$ was the vector of the first dependent variable, and $\text{AccProcess}_{i,j}$ was the vector of the second dependent variable. $\text{Controls}_{z,i}$ denoted the influence of the *z*-th control variables; $\beta\text{traits}_{z,i}$, $\beta\text{psych}_{z,I}$, and $\beta\text{exp}_{z,I}$ represented the vectors of explanatory variables, personality traits, psychological factors, and exposure, respectively. All groups of explanatory variables were observed discretely while including the control variables. Finally, a whole model was provided to collectively examine the effects.

The CLM command from the ordinal package of the R 3.5.2 software was used to compute the cumulative link model (R Core Team, 2018). For a better understanding and comparability of coefficients in the full model, the antilog was used to estimate coefficients into odds ratios (OR) instead of scaled logs (Stranieri et al., 2017). Furthermore, the Akaike information criterion (AIC) and log-likelihood were assessed to evaluate goodness of fit. The best-fitting model generally has the lowest AIC and the highest log-likelihood. For a reliable interpretation of this kind of regression, a measure comparing the different models is important. Therefore, a base model including only the control variables was performed and compared to all the other models by applying a likelihood ratio (LR) test measuring the evidence in the data that supported the extra complexity of intricated models. In other words, the LR test indicated whether the more complex model containing more variables was better suited than the base model (Stranieri et al., 2017; Stranieri et al., 2019).

To ensure the robustness of the chosen regression model, its outcome was tested against an alternative model specification by choosing a multinomial logit model. Performing an LR test of the two regression sets showed that there was no significant statistical difference in the results; it therefore provided evidence that the conducted ordinal regression was fit to display the effects of the considered data (Stranieri et al., 2019).

4. Results

The majority of the sample (290 individuals, 74%) had never tried insects in any form before. A total of 85 contestants (22%) had tried insects on one occasion. Only 5% (18 people) had eaten insects more than once, and only one individual reported consuming insects regularly. Of those who had experience with entomophagy, 73 individuals (18.5%) had eaten whole insects, whereas only 48 (12.2%) had tried food that contained processed insect ingredients. Most people had eaten insects while on vacation (56 individuals), followed by events (n = 42) and in restaurants (n = 22). Sixteen contestants had prepared insects themselves or had eaten them when visiting friends. The majority of the participants declared that they were rather familiar with the concept of eating insects. Only fifteen people had never heard of insects as food.

A tendency toward aversion of entomophagy was observed. More than half (53%) of the participants could not imagine eating whole insects compared to only 38% who could not imagine eating processed insect products. Nearly 40% would eat products containing invisible insect ingredients, and only 22% were prepared to eat whole insects. A Wilcoxon signed-rank test supported this tendency, as 167 participants showed higher values for the acceptance of processed insect products than for eating whole insects; this was compared to a total of 38 individuals stating the reverse. However, nearly half the sample (n = 189) demonstrated no difference in their willingness to try whole or processed insect products.

A very prominent outcome of the survey was that 228 participants, equal to 56.7% of the sample, were not aware that insect food products were available in Germany. Accordingly, less than 12% (n = 47) could name familiar insect products and brands, and overall familiarity with the five products presented in this study was extremely low (over 90% did not know of any of the products). A non-parametric Friedman test was computed to investigate willingness to try (WTT) the presented products. No difference of the WTT for the insect burger, pasta, and granola was observed ($p > 0.1$). The protein bar was the most popular. Not surprisingly, the WTT to try whole insects was lower compared to the other presented products. The sample indicated a rather low level of curiosity to try any of the products. Nevertheless, few participants expected the products to be unsafe, and fewer feelings of disgust were associated with the products containing invisible insect ingredients compared to the product containing whole insects.

Table 2 displays the descriptive statistics of the chosen variables. Table 3 illustrates the correlation matrix for the two chosen dependent variables: acceptance of whole insects (AccWhole) and acceptance of processed insect products (AccProcess). Most of the explanatory variables were significantly negatively correlated to the dependent variables. Reviewing all the correlation coefficients in Table 3, the values among the variables were rather low, except for Dummy_fam with Dummy_exp. This was not surprising, as people who have eaten insects before automatically have some basic knowledge about the practice. The variance inflation factors (VIF) were computed to avoid collinearity bias, indicating a rather high value for the two parameters (above seven). To ensure the completeness of the model, however, both variables were kept in the proceeding analysis, since research assumes values from 5–10 to indicate a high correlation; this has to be treated with special vigilance, but there was no severe collinearity problem (O'Brien, 2007). All the other independent variables did not exhibit signs of multicollinearity.

[Insert Table 3 around here]

Table 4 summarizes the proportional odds logistic coefficient estimates of the first regression set (Set I) with the dependent variable AccWhole, while Table 5 contains the results for the second regression set (Set II) with the dependent variable AccProcess. The same strategy was followed in both regression aggregations, computing six models. The first model (Model I) reports the effects of the control variables on the respective dependent variables and represents the base model. The following models investigate each set of explanatory variables individually, while Model VI depicts the whole model, including all the identified variables. Model

II individually investigates the effect of FNS on acceptance, since a great emphasis on this factor was observed in the literature.

In both regression sets, the full model (Model VI) best explained the acceptance of whole insects (AccWhole) and the acceptance of processed insect products (AccProcess), respectively. All applied models (Model II, III, IV, V, VI) significantly added explanatory power to the dependent variables, indicated by the LR tests ($p < 0.001$). The fit of the full model increased compared to the base model for both sets as the AIC values decreased and the log-likelihood increased.

Regarding Set I, the coefficient estimates of the variables pertaining to Gender ($p < 0.001$), Age ($p < 0.001$), and Veg ($p < 0.01$) were statistically significant in all models. Their increases lead to an overall decrease of AccWhole. Thus, young non-vegetarian males were more likely to accept insects as food. Level of education showed no statistical significance, which coincides with the findings of previous studies (Hartmann et al., 2015; Meixner & Mörl von Pfalzen, 2018; Schösler et al., 2012; Verbeke, 2015). However, due to the education level of the sample being higher than average for the country, other effects could apply.

In Model II, the control variable estimates remained mostly stable toward the base model (the values differed slightly, but the overall indication remained). FNS has a highly significant negative influence on the acceptance of whole insects ($p < 0.001$).

Analyzing all the identified personality traits together, Model III showed the influence of FEnv and FNS to be is statistically significant ($p < 0.1$). FEnv had a positive effect on the acceptance of whole insects, implying that people with higher environmental awareness would be more likely to try insects as an alternative food source. The goodness of fit (measured by AIC and log-likelihood) only increased marginally compared to Model II. Hence, the personality trait category was dominated by the negative effect of FNS, supporting the associated strong effect of food neophobia found in the literature.

The psychological variables analyzed in Model IV held a very important amount of explanatory power for the dependent variable, as the log-likelihood (-494.36) for the model was only marginally lower and the AIC (1012.7) was only slightly higher than in the full model (log-likelihood = -489.15; AIC = 1012.3). Both psychological factors had a negative effect on the acceptance of insects, which was consistent with the general expectation of the variable definition. However, only the estimate for Disgust was statistically significant ($p < 0.001$), leading to the assumption that this explanatory variable combined with the control variables explained almost as much of the acceptance of whole insects as the full model.

The last class of variables (level of exposure) did not achieve statistical significance, although the p-value for Dummy_exp was very close to the threshold of acceptance. Testing for multicollinearity bias, the exclusion of either parameter did not change the coefficients or goodness of fit values.

The full model confirmed the findings for both the control and explanatory variables in the preceding partial data sets. The only exception was that the FEnv variable lost its significance in the full model. This can be explained by the proximity of the p-value to the significance threshold of 0.1 in Model III and the strong impact of FNS. Regarding the OR, a one-unit increase in FNS caused a decrease of the odds of being accepting by 26.7%; a one-unit increase of Disgust decreased the odds of being accepting by 63.2%.

Looking at Set II (Table 5), the only significant estimates ($p < 0.01$) in the base model (Model I) were the negatively influencing variables diet preferences (Veg) and Age. In comparison to Set I, gender lost its significance. All three variables in the third model achieved statistical significance. While FNS maintained a highly significant negative influence on the acceptance of processed insects in Models II and III ($p < 0.001$), both environmental awareness and individual health awareness had a significant positive influence ($p < 0.1$). Model IV discerned both psychological traits (disgust and risk) as having a distinctly negative and statistically significant ($p < 0.001$) effect on the acceptance of insect-based food, whereas only Disgust was significant for AccWhole. The psychological traits again seemed to have the largest explanatory power for the dependent variable in this set of regressions. However, other effects seemed to gain importance, as the difference in the goodness of fit (e.g., AIC for Model III = 1114.7; AIC for Model VI = 1012.3) was higher than for AccWhole.

In contrast to Set I, the positive coefficient for prior experience became statistically significant in Model V, Set II. When testing for a shift in coefficients and parameters for the goodness of fit of the models because of the possibility of multicollinearity by excluding either variable (Dummy_fam and Dummy_exp), both became statistically significant ($p < 0.001$). The other measures did not change; therefore, both variables were kept. When examined individually, however, it became apparent that prior experience helped to soften psychological blockades against eating processed insects, whereas a higher level of familiarity surprisingly had a negative impact. This indicated that just because people knew about entomophagy did not mean they automatically considered eating insects themselves.

To sum up, the acceptance of processed insects in food generally appeared to be explained by more positively contributing factors compared to AccWhole when comparing the full models for both sets. While only FNS and Disgust showed statistical significance in the AccWhole model, both FHealth and Risk could be added for the AccProcess model. As for AccWhole, FEnv became insignificant in the full model of Set II. The assumed reason for this was the proximity to the significance threshold in the first set. When excluding Dummy_fam from the model because of multicollinearity concerns, Dummy_exp remained a significantly positively influencing parameter (coefficient = 0.358; SD = 0.196; OR = 1.43, $p < 0.1$). Since all the other measures were not affected by this adoption, both variables were included in the model for completeness. Looking at the OR, a unit change of Health and Dummy_exp increased the odds of accepting processed insects by over 40%.

[Insert Tables 4 and 5 around here]

5. Discussion

Despite the media's and researchers' ongoing efforts to promote insects as a sustainable novel food, this study discovered a prevalence of skepticism toward entomophagy in Germany, coinciding with previous studies carried out in European countries (Caparros Megido et al., 2016; Hartmann & Siegrist, 2016; Lensvelt & Steenbekkers, 2014; Myers & Pettigrew, 2018; Piha et al., 2018; Tan et al., 2015; Verbeke, 2015, 2015; Verneau et al., 2016). Participants' low familiarity with the presented products and overall low experience with the consumption of insects indicates that insects are not yet a regular food in Germany. Nevertheless, a slight upward trend in the readiness to try insects could be observed compared to earlier studies by Schösler et al. (2012) and Verbeke (2015), whereas several indicators show that processed insect products are preferred to whole insects based on the invisibility of the insect ingredient (Gmuer et al., 2016; Tan et al., 2016b).

Observing sociodemographic factors, this study supports the assumption made by previous research: younger people have more positive attitudes toward entomophagy (Schösler et al., 2012; Verbeke, 2015). In this regard, Tranter (2013) suggested that children should be the main target of an increased number of education- and research-based projects to leverage the diffusion of insect-based food because they are not only the next generation of consumers, but they can also highly influence their peers' attitudes. Thus, by experimenting with visual aspects, quality, and taste of insect food, incorporating insects into European diets must continue to be marketed as both a healthy and sustainable source of protein. On the contrary, seniors reflect a total lack of desire to eat insect-based food. Myers and Pettigrew (2018) found that in this group, there was a very low level of awareness of the environmental and nutritional advantages of this practice. Moreover, most of the interviewed older people viewed entomophagy as a disgusting practice that was far from their cultural values.

Even though there are only a few vegetarians and vegans among the participants, their repulsion toward trying any insect product is significant. Despite entomophagy's many promises in improving sustainability, health, and ethics, this group of conscientious consumers remains averse, insisting that insects are sentient creatures and can suffer, even if this claim is scientifically unproven.

A prominent finding of this study is the different effect of gender in both regression sets. While women are assumed to have higher aversions to insects and men to find whole insects less disgusting, this discrepancy seems to disappear as soon as invisible insect ingredients are concerned, which should be kept in mind when creating target groups.

Surprisingly, even if positive, the level of education is not significant for the acceptance of insect-based food, as demonstrated by other studies. Indeed, Fischer and Steenbekkers (2018) observed that 45% of the interviewed Dutch students of Wageningen University had already eaten insects and would be willing to try them again.

This study observed that not all the explanatory variables derived from previous studies significantly affected consumer acceptance of this sample. Nevertheless, food neophobia and disgust have the most substantial negative influence on acceptance of whole and processed insect products, which corresponds to the findings of recent studies in Europe (Hartmann & Siegrist, 2016; La Barbera et al., 2018; Meixner & Mörl von Pfalzen, 2018; Ruby et al., 2015; Verbeke, 2015; Wilkinson et al., 2018; Myers & Pettigrew, 2018). In this regard, Mancini et al. (2019) reported that associating insects with familiar dishes within current diets might have a moderating role on food neophobia and disgust factors and improve willingness to try insect-based food.

Germans with a high environmental consciousness or who focus on a healthy diet do not demonstrate a significantly increased likelihood to consume whole insects. This coincides with a cross-cultural study between Germany and China, stating that German consumers cannot yet be motivated by health benefits or the favorable sustainability attributes of insect food (Hartmann et al., 2015). On the contrary, Kostecka et al. (2017) and Menozzi et al. (2017) examined the opinions of Polish and Italian consumers regarding their acceptance of insect-based food. They confirmed that one of the most important outcomes of eating products containing insects was the positive effect on the environment. As for whole insects, the environmental benefits of processed insect products still seem to be irrelevant, supporting the assumption that the majority of consumers are not yet convinced or aware of the possible sustainability advantages. Another interpretation of the non-significant coefficient in the regression models (both on whole and processed insects) could be the consequence of the wide-spread high German sensitivity (see the very high average value in Table 2) on environment-related topics which leads to a non-significance of the regression parameters because it is not possible to distinguish a clear trend between this explanatory variable and the dependent ones.

However, health-conscious consumers are keener to accept insect-based products, suggesting the argument of using healthiness to moderate the disgust factor toward processed insects. Furthermore, this target group is considered to be open to new, functional food alternatives and therefore might be more aware of the benefits of insect protein.

Previous research has confirmed the importance of familiarity as a driver for positive attitudes toward edible insects (Caparros Megido et al., 2016; Hartmann & Siegrist, 2016; Lensvelt & Steenbekkers, 2014; Piha et al., 2018; Tan et al., 2015; Verbeke, 2015; Verneau et al., 2016). In the present study, however, consumers' knowledge is not significant regarding the willingness to try whole insect food. Overall familiarity with entomophagy seems to be rather superficial, suggesting that the overall understanding of the beneficial health and environmental attributes is low. Abstract ideas about entomophagy do not have a direct influence on acceptance (Hartmann et al., 2015).

Except for the work by Meixner and Mörl von Pfalzen (2018), most studies associate product-related experience with growing acceptance, stating that people who have eaten insects before are definitely more likely to consume insects again (Caparros Megido et al., 2016; Gmuer et al., 2016; Hartmann et al., 2015; Hartmann & Siegrist, 2016; Lensvelt & Steenbekkers, 2014; Piha et al., 2018; Tan, 2017; Tan et al., 2017b, 2016b, 2016a; Verneau et al., 2016). The lacking significance of this factor in the present results can be explained by the composition of the sample—those who had experience with the consumption of insects only tried them once, mainly on vacation. It can be assumed that insects as food have thus far been perceived as an exciting, one-time culinary experience or a test of courage, suggesting that repeated taste experiences are necessary for a conclusive impact on acceptance of whole insects.

In contrast, the significant positive effect of the experience of eating processed insect food can be explained by the logical assumption that someone who is brave enough to eat whole insects once has much lower barriers to try processed insect products, whereas people who only have eaten invisible, processed insect products probably do not automatically consider whole insects to be unproblematic.

Overall, the analysis of the acceptance of whole insects primarily detected reasons why consumers did not consume whole insects; it was, therefore, somewhat less conclusive. Early adopters of whole insects can be profiled as young, non-vegetarian men who do not think of insects as disgusting and show a low level of food neophobia (Hartmann et al., 2015; Meixner & Mörl von Pfalzen, 2018; Ruby et al., 2015; Schösler et al., 2012; Verbeke, 2015; Verneau et al., 2016). By contrast, more significant explanatory variables can be observed concerning processed insect products, as health consciousness and previous experience increase readiness to try invisible insect ingredients. Possible early adopters of processed insect food are younger, health conscious people who are not vegetarian or vegan, have low food neophobia, do not associate processed insects with feelings of disgust or general health risks, and who have eaten insects before.

Unrecognizable insects in processed products are clearly preferable to whole insects and evoke fewer negative associations (Tan et al., 2016b). Thus, focusing on processed insect products is shown to be the most promising strategy to implement entomophagy into the German market, as an essential barrier to consumption is the visibility of the insects being implemented.

To conclude, consumers' acceptance is still the greatest hurdle to the successful introduction of insects into the German food market, which is mainly hindered by culturally induced aversions (Hartmann & Siegrist, 2017). To overcome the strong barriers of disgust and food neophobia, the benefits of insect consumption need to be emphasized in order for consumers to become more familiar with the practice.

The observed low awareness of insect products that are available in Germany suggests that the demand for insect products has to be created. Coupled with low consumption experience, it can be concluded that insects are not yet fully perceived as an appealing, healthy, and sustainable food source. As skepticism toward entomophagy prevails, insect food is expected to succeed only in niche markets in the near future. In order to achieve acceptance among Western consumers, it is as much a demand-side (change in consumers' perceptions) as a supply-side (tasty, appropriate, distinctive products) issue (Costa-Neto & Dunkel, 2016; Tan & House, 2018). For many authors, wide exposure in everyday life (e.g., availability in supermarkets, restaurants, etc.), the right choice of product category, and effective communication and marketing strategies are crucial to increasing consumers' likelihood to adopt insects into their local diets (Hartmann et al., 2015; Meixner & Mörl von Pfalzen, 2018; Ruby et al., 2015; Schösler et al., 2012; Sogari et al., 2019). However, solely promoting the global benefits of entomophagy does not provide sufficient motivation to change dietary behavior (Wilkinson et al., 2018).

Marketing activities should concentrate on the positive associations and convince consumers of the social acceptability of eating insects in order to interfere with the barriers of disgust and food neophobia (Van Huis, 2013; Shockley et al., 2017). Therefore, offering tastings would be an effective marketing tool to convince consumers and cause them to reconsider their negative expectations by creating positive taste experiences (e.g., overcome the fear of a bad taste) (Wilkinson et al., 2018). As entomophagy is still a delicate and emotional topic for many consumers, negative sensorial experiences with insect products have to be prevented and high-quality products should be focused on—otherwise, their willingness to try products again may be ruined (Tan et al., 2017a).

6. Conclusion

The primary objective of this work was to shed light on the potential of novel insect food by investigating the most important drivers influencing the acceptance of whole and processed edible insects in the German market. It found that they constitute a healthy and sustainable solution for today's food challenges, specifically facing the growing demand for animal protein. However, successfully implementing entomophagy in the German market still poses a big challenge.

The study discovered a prevalence of skepticism toward entomophagy in Germany, especially related to whole insect food, supporting the findings of previous studies carried out in other European countries. Its main findings are that food neophobia and disgust have the most significant negative impact on the acceptance of whole and processed insect products. Specifically, food neophobia is highly significant with respect to the acceptance of whole insect food, whereas disgust has a higher negative impact on willingness to try processed insect products.

Health-conscious consumers are keener to accept processed insect-based products, suggesting that the argument for healthiness might play a moderating role in the disgust factor regarding processed insects. Furthermore, this target group is considered to be open to new, functional food alternatives and therefore might be more aware of the benefits of insect protein. Surprisingly, respondents with high environmental consciousness, familiarity with entomophagy, and experience in eating insects do not demonstrate a significantly increased likelihood to consume insects. Finally, in terms of sociodemographic factors, the most interesting result is that women have higher aversions to eating whole insects than men; this is in line with this study's expectations, but this discrepancy seems to disappear in relation to processed insect foods.

Such results have implications for different policy interventions aimed at increasing consumers' acceptance of insect-based products. The present study highlights a low level of consumer awareness of the environmental and health-related benefits of insect-based products. The adoption of focused information campaigns on the sustainability of such products could increase consumers' propensity to introduce insects into their diets. Specifically, the importance of consumers' health consciousness for the acceptance of whole insects suggests that information highlighting the healthy aspects of such products could help to increase positive attitudes and intentions to eat them. Moreover, the higher propensity of young people to eat insects reveals that an educational policy targeted toward the younger generations could help to decrease consumers' disgust and neophobic tendencies toward insects.

This study has several limitations. First, an online questionnaire was carried out, which by definition cannot claim to be representative because participants decide for themselves whether or not to take part in the study. Second, the questionnaire only measured self-reported willingness to try insects and did not observe actual intention to eat insects. Third, qualitative studies always raise questions about the quality of the interviewed participants. Even if the data are collected and processed by experts with the utmost attention, questionnaires are strongly affected by which attributes are selected; thus, important dimensions might be left out. Finally, this study ran a cross-sectional analysis to examine the drivers for the acceptance of eating insects at a certain point in time. Future analyses using longitudinal or panel data could improve our understanding of the dynamics of willingness to consume insects as food in European markets.

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Insect Pasta by Plumento Foods

Ingredients Tagliatelle: durum wheat semolina, whole egg (20%), buffalo worms (10%) (Alphitobius diaperinus larvae, ground)
Energy: 368 kcal per 100g

Figure 1: Insect Pasta by Plumento Foods

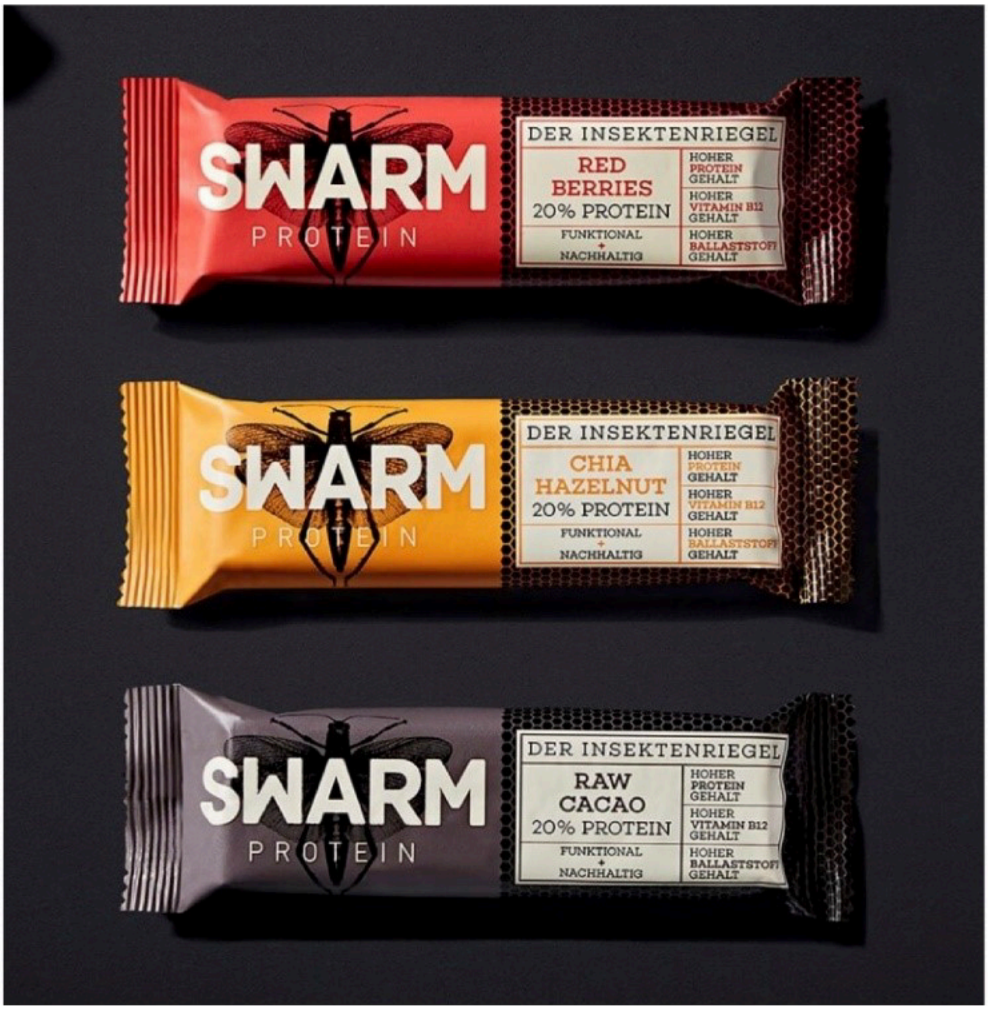

Figure 2: Protein Bar by Swarm Protein

Figure 3: Insect granola by Snack Insects

Figure 4: Whole insects by Snack insects (freeze dried)

Insect Burger by Bug Foundation

Ingredients: 45% rehydrated buffalo worm soy protein (60% buffalo worm Alphitobius diaperinus, 40% soy protein concentrate), Water, rapeseed oil, onions, egg white * (dried), tomato paste (tomatoes, salt), Soy sauce (water, soybeans, wheat, salt), mustard (water, mustard seed, vinegar, Salt, sugar, spices), potato starch, spices, salt, lemon juice, parsley
Energy: 282 kcal per 100g

Figure 5: Insect Burger by Bug Foundation

Table 1: Questionnaire structure and sources

Factor	Acronyms	Reference	Measurement Items	Scale
		Dependent Variables		
Acceptance whole insect	AccWhole	Caparros Megido et al., (2014), Meixner and Mörl von Pfalzen (2018), Piha et al. (2018)	• I am willing to eat insects as a whole in the future	5-point Likert scale
Acceptance processed insects	AccProcessed	* Adjusted from Piha et al. (2018)	• I am willing to eat processed insects products in the future (insect is not visible, e.g., insect flour)*	5-point Likert scale
		Control Variables		
Gender	Gender		What is your gender?	Male/female/other
Age	Age		How old are you?	Open question
Highest level of education	Edu		What is the highest level of education you have completed?	Single choice
Vegan/ Vegetarian	Veg		Are you vegan or vegetarian?	Vegan/ vegetarian/no
		Explanatory Variables		
		1. Personality traits		
Food neophobia score	FNS	Food neophobia scale by Pliner and Hobden (1992), Ritchey et al. (2003)	• I don't trust new foods • If I don't know what is in a food, I won't try it • I am afraid of eating things I have never had before • At dinner parties, I would try a new food (R) • I am constantly sampling new and different foods (R) • I will eat almost anything (R)	5-point Likert scale
Environmental awareness	FEnv	Verbeke (2015), Lindeman and Väänänen (2000), Meixner and Mörl von Pfalzen (2018), Steptoe et al. (1995)	• When I buy food, I try to consider how my use of it will affect the environment • It is important to me that the food was produced in an environmentally friendly way • It is important to me that the food has been packaged in an environmentally friendly way • If given a choice, I choose the more environmentally friendly product, even at higher costs • I try to reduce my impact on the environment through the choice of food	5-point Likert scale
Food health interest score	FHealth	General health interest scale by Roinen et al. (1999), Meixner and Mörl von Pfalzen (2018)	• I am very particular about the healthiness of food • I eat what I like, and I do not worry much about the healthiness of food (R) • A healthy and balanced diet plays an important role in my life	5-point Likert scale
		2. Psychological Traits		
Disgust	Disgust	Rozin and Fallon (1987), Meixner and Mörl von Pfalzen (2018)	• The idea of insects makes me ill • I am disgusted, if an insect crawls over my leg • Eating insects is disgusting	5-point Likert scale
Risk whole insect	RiskWhole	Meixner and Mörl von Pfalzen (2018), Vetter (2017)	• Insects are unhygienic and transmit diseases • Eating insects is risky • Eating insects poses a risk to human health • Insects are not suitable for human consumption	5-point Likert scale
Risk processed insects	RiskProcess	* Adjusted from Meixner and Mörl von Pfalzen (2018), Vetter (2017)	• Processed insect products are unhygienic and transmit diseases* • Eating processed insect products is risky* • Eating processed insect products poses a risk to human health* • Processed insect products are not suitable for human consumption*	5-point Likert scale
		3. Level of Exposure		
Familiarity	Dummy_Fam	Verbeke (2015)	• No, I have never heard of the eating of insects • Yes, I have heard of the eating of insects but actually don't know what it implies • Yes, I have heard of the eating of insects and I know what it implies	Single choice question
Experience	Dummy_Exp	Telles Sposito Gonçalves Neves (2015)	• I have never tried edible insects in any form • I have tried edible insects on a single occasion • I have tried edible insects on a few occasions • I eat edible insects regularly	Single choice question

Table 2: Variable description and descriptive statistics

	Description	Mean	Median	SD	Min	Max
Dependent Variables						
AccWhole	Level of Acceptance of whole insects (1=low level of acceptance, 5=high level of acceptance)	2.41	2	1.27	1	5
AccProcess	Level of Acceptance of processed insect products (1=low level of acceptance, 5=high level of acceptance)	2.96	3	1.36	1	5
Control Variables						
Gender	Dummy variable (1= female, 0= male)	0.51	1	0.50	0	1
Age	Individual age	35.73	32	12.37	13	82
Edu	Highest level of education achieved (Edu1=still in education, Edu2= school education, Edu3=professional training, 4= university degree), ordinal	3.04	3	0.91	1	4
Veg	Dummy variable (1= Vegan or vegetarian, 0= no particular diet)	0.12	0	0.33	0	1
Explanatory Variables						
1. Personality traits						
FNS	Degree of food neophobia (1=low food neophobia, 5=high food neophobia)	2.66	2.67	0.72	1	5
FEnv	Degree of environmental awareness (1=low environmental awareness, 5=high environmental awareness)	3.38	3.4	0.97	1	5
FHealth	Degree of health consciousness (1=low health consciousness, 5=high health consciousness)	3.49	3.67	0.83	1	5
2. Psychological factors						
FNS	Degree of food neophobia (1=low food neophobia, 5=high food neophobia)	2.66	2.67	0.72	1	5
FEnv	Degree of environmental awareness (1=low environmental awareness, 5=high environmental awareness)	3.38	3.4	0.97	1	5
FHealth	Degree of health consciousness (1=low health consciousness, 5=high health consciousness)	3.49	3.67	0.83	1	5
3. Level of Exposure						
Dummy_exp	Experience of consuming insects (1= experience, 0= no experience)	0.42	0	0.49	0	1
Dummy_fam	Familiarity with entomophagy (1=familiar, 0=unfamiliar)	0.54	1	0.50	0	1

Table 3: Correlation matrix

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**AccWhole**	1													
2	**AccProcess**	.653**	1												
3	**Age**	-.154**	-.095	1											
4	**Gender**	-.202**	-.055	-.038	1										
5	**Edu**	.045	.091	-.055	.096	1									
6	**Veg**	-.159**	-.166**	-.037	.137**	.077	1								
7	**Dummy_exp**	.204**	.238**	.029	-.001	.026	-.056	1							
8	**Dummy_fam**	-.201**	-.219**	-.030	.018	-.011	.023	-.926**	1						
9	**FNS**	-.352**	-.425**	.178**	.079	-.043	.189**	-.175**	.171**	1					
10	**FEnv**	.050	.105*	.070	.140**	.153**	.179**	.116*	-.105*	-.002	1				
11	**FHealth**	-.005	.084	.035	.200**	.170**	.161**	.047	-.030	.051	.401**	1			
12	**Disgust**	-.538**	-.516**	-.069	.226**	.067	.098	-.206**	.189**	.373**	-.032	.073	1		
13	**Risk_whole**	-.309**	-.368**	.084	-.055	-.041	.003	-.216**	.161**	.203**	-.163**	-.012	.504**	1	
14	**Risk_process**	-.264**	-.417**	.076	-.072	-.079	-.019	-.224**	.161**	.219**	-.116*	-.026	.455**	.852**	1

*Significance codes: *p < 0.05 ; **p < 0.01;*

Table 4: Regression results for the dependent variable AccWhole (Set 1)

Acceptance of whole insects	*Ordinal logistics regression models*						
	Model I	*Model II*	*Model III*	*Model IV*	*Model V*	*Model VI*	
Intercepts	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*O.R.*
AccWhole 1|2	-1.826	-3.664	-3.254	-4.839	-1.794	-4.918	
	(-0.882)*	(0.956)***	(1.005)***	(0.964)***	(1.014)*	(1.181)***	
AccWhole 2|3	-0.937	-2.729	-2.309	-3.663	0.889	-3.735	
	(-0.878)	(0.949)**	(0.999)*	(0.950)***	(-1.010)	(1.169)***	
AccWhole 3|4	0.289	-1.432	-1.002	-2.108	0.972	-2.155	
	(-0.879)	(-0.943)	(-0.996)	(0.940)*	(-1.013)	(1.164)*	
AccWhole 4|5	1.782	0.137	0.569	-0.381	1.905	-0.377	
	(-0.895)*	(-0.953)	(-1.007)	(-0.949)	(1.029)*	(1.172)	
Control variables							
Gender	-0.750	-0.711	-0.779	-0.493	-0.771	-0.570	0.566
	(0.190)***	(0.192)***	(0.197)***	(0.204)**	(0.192)***	(0.209)**	
Edu2	0.341	0.592	0.219	1.357	0.344	1.094	2.985
	(0.891)	(0.907)	(0.930)	(0.923)	(0.907)	(0.949)	
Edu3	-0.230	-0.011	-0.402	1.087	-0.222	0.762	2.143
	(0.907)	(0.923)	(0.948)	(0.944)	(0.922)	(0.972)	
Edu4	0.580	0.693	0.247	1.673*	0.558	1.281	3.602
	(0.886)	(0.901)	(0.931)	(0.919)	(0.900)	(0.952)	
Veg	-0.867	-0.511	-0.649	-0.707	-0.840	-0.709	0.492
	(0.290)**	(0.302)*	(0.310)*	(0.323)**	(0.295)**	(0.340)*	
Age	-0.026	-0.019	-0.021	-0.038	-0.027	-0.036	0.964
	(0.008)***	(0.008)*	(0.008)**	(0.008)***	(0.008)***	(0.009)***	
Personality traits							
FNS		-0.854	-0.837			-0.310	0.733
		(0.149)***	(0.149)***			(0.158)*	
FEnv			0.201			0.096	1.101
			(0.111)*			(0.114)	
FHealth			0.056			0.140	1.151
			(0.130)			(0.135)	
Psychological factors							
Disgust				-1.073		-1.001	0.368
				(0.119)***		(0.124)***	
RiskWhole				-0.163		-0.124	0.884
				(0.121)		(0.126)	
Level of exposure							
Dummy_exp					0.551	0.116	1.123
					(0.472)	(0.534)	
Dummy_fam					-0.196	-0.214	0.807
					(0.465)	(0.522)	
No. of observations	393	393	393	393	393	393	
AIC	1148.1	1115.2	1114.7	1012.7	1136.9	1012.3	
Log likelihood	-564.05	-546.62	-544.35	-494.36	-556.44	-489.15	
LR test		34.85***	39.39***	139.38***	15.22***	149.80***	

Standard errors are in parentheses; link = logit; Likelihood ratio (LR) test: Models II,III,IV,V and VI versus Model I
*Significance codes: *p < 0.1 ; **p < 0.01; ***p < 0.001.*

Table 5: Regression results for the dependent variable AccProcess (Set II)

Acceptance of processed insects	*Ordinal logistics regression models*						
	Model I	***Model II***	***Model III***	***Model IV***	***Model V***	***Model VI***	
Intercepts	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*O.R.*
AccProcess 1|2	-2.118	-4.665	-3.778	-5.442	-1.941	-6.271	
	(0.900)*	(0.954)***	(0.992)***	(0.989)***	(1.046)*	(1.212)***	
AccProcess 2|3	-1.189	-3.651	-2.744	-4.238	-0.991	-5.034	
	(0.895)	(0.945)***	(0.985)**	(0.975)***	(1.042)	(1.198)***	
AccProcess 3|4	-0.165	-2.506	-1.578	-2.892	0.085	-3.609	
	(0.894)	(0.937)**	(0.980)	(0.965)**	(1.042)	(1.187)**	
AccProcess 4|5	1.022	-1.174	-0.219	-1.385	1.324	-1.991	
	(0.897)	(0.932)	(0.978)	(0.959)	(1.046)	(1.179)*	
Control variables							
Gender	-0.202	-0.115	-0.245	0.027	-0.189	-0.064	0.938
	(0.182)	(0.185)	(0.189)	(0.197)	(0.183)	(0.201)	
Edu2	-0.075	0.218	-0.336	0.751	-0.112	0.373	1.452
	(0.908)	(0.897)	(0.916)	(0.947)	(0.944)	(0.955)	
Edu3	-0.009	0.293	-0.273	1.307	-0.009	0.886	2.426
	(0.916)	(0.907)	(0.927)	(0.961)	(0.952)	(0.971)	
Edu4	0.320	0.506	-0.183	1.241	0.266	0.684	1.983
	(0.900)	(0.889)	(0.917)	(0.942)	(0.937)	(0.958)	
Veg	-1.044	-0.600	-0.823	-0.882	-1.005	-0.895	0.409
	(0.294)***	(0.304)*	(0.312)**	(0.330)**	(0.300)***	(0.346)**	
Age	-0.016	-0.007	-0.008	-0.021	-0.015	-0.017	0.983
	(0.008)**	(0.008)	(0.007)	(0.008)**	(0.008)*	(0.008)*	
Personality traits							
FNS		-1.147	-1.158			-0.680	0.506
		(0.147)***	(0.148)***			(0.158)***	
FEnv			0.208			0.051	1.052
			(0.113)*			(0.114)	
FHealth			0.279			0.340	1.405
			(0.130)*			(0.130)**	
Psychological factors							
Disgust				-0.905		-0.774	0.461
				(0.108)***		(0.112)***	
RiskProcess				-0.501		-0.469	0.625
				(0.112)***		(0.115)***	
Level of exposure							
Dummy_exp					0.761	-0.205	0.814
					(0.458)*	(0.546)	
Dummy_fam					-0.101	-0.592	0.553
					(0.451)	(0.535)	
No. of observations	393	393	393	393	393	393	
AIC	1255.6	1192.5	1184.6	1105.4	1238.4	1082.2	
Log likelihood	-617.81	-585.23	-579.28	-540.70	-607.22	-524.08	
LR test		65.16***	77.06***	154.22***	21.17***	187.47***	

Standard errors are in parentheses; link = logit; Likelihood ratio (LR) test: Models II,III,IV,V and VI versus Model I
*Significance codes: *p < 0.1 ; **p < 0.01; ***p < 0.001.*