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Promoting the consumption of insect-based foods: The role of information, protein-based nutrition claims, and dietary styles

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Abstract

Although insects have been approved as novel foods since 2021, European consumers' willingness to purchase insect-based (IB) foods remains low. The aim of this study was to evaluate the effectiveness of (i) information treatments highlighting either the safety or environmental benefits of IB ingredients, and (ii) protein-based nutrition claims in promoting the consumption of IB foods. Additionally, we investigated how vegans, vegetarians, flexitarians, and omnivores differ in their entomophagy attitudes and choice behavior. We collected data from 844 German consumers via an online questionnaire that included a choice experiment featuring bread made with insect flour. Our findings highlight differences in entomophagy attitudes by diet, with vegetarians, and vegans showing a stronger aversion to insect consumption compared with omnivores and flexitarians. Results from random parameters logit models indicate that the information treatments had no effect and that the majority of consumers, regardless of their diet, would require a discount to buy bread made with insect flour. Protein-based nutrition claims only promoted the purchase of IB bread by vegetarians.

Keywords: Entomophagy, Novel food, Alternative proteins, Choice behavior, Willingness to pay
JEL codes: D12, Q13, Q18

1. Introduction

Using insects as a food ingredient has gained increasing interest due to their nutritional value and lower environmental impact compared with livestock production, and thus their potential contribution to achieve a more sustainable food system (e.g. Huis et al. 2013; Halloran et al. 2018). While insects are valued as delicacies in many cultures and countries (Deroy et al. 2015), the practice of eating insects has never gained popularity in most

European countries (Tan et al. 2015, 2016). Nevertheless, with the approval of mealworms and locusts as the first insect species as food in 2021 under the Novel Food Regulation (EU) 2015/2283, insect-based foods have started to appear in European food markets (Schiel et al. 2020).

As a result, several studies have investigated European consumers' attitudes toward entomophagy, which refers to the acceptance of insects as food or food ingredients. Evidence to date suggests that acceptance among European consumers is generally low but higher when insects are offered in a processed, i.e. invisible form (Hartmann et al. 2015; Tan et al. 2015, 2016; Orsi et al. 2019; Schäufele et al. 2019). In terms of consumer characteristics, existing evidence shows that factors such as disgust and food neophobia are major barriers to the acceptance and potential adoption of insect-based foods (Orsi et al. 2019; Russell and Knott 2021; Michel and Begho 2023), whereas prior knowledge, positive taste expectations, and positive sensory experiences increase the willingness to consume insects-based foods (e.g. Hartmann et al. 2015; Berger et al. 2018a; Sogari et al. 2018; La Barbera et al. 2020). Furthermore, marketing and communication strategies that highlight the health and environmental benefits of insect consumption have been shown to play a role in increasing consumer acceptance (e.g. Verneau et al. 2016; Ardoin and Prinyawiwatkul 2020). Beyond the initial motivations for consuming insect-based foods, the price, taste, and availability of these products are important factors in their repeated consumption (House 2016).

Most studies have focused on insects as a substitute for conventional animal proteins, such as in burger patties (Berger et al. 2018b; Gómez-Luciano et al. 2019; Kornher et al. 2019; Naranjo-Guevara et al. 2021) and sausages (Michel and Begho 2023). However, as a sustainable protein alternative, it could also have applications beyond meat substitution. Therefore, some studies have also investigated insects as a flour ingredient in snack and bakery products such as chips (Gmuer et al. 2016), cookies (Hartmann et al. 2015; Giotis and Drichoutis, 2021; Russell and Knott 2021), and pancakes (Naranjo-Guevara et al. 2021). Collectively, these studies have shown that a high degree of processing, combined with a familiar dish or carrier product can increase acceptance. Acceptance also appears to be highly dependent on the perceived appropriateness of the ingredient-carrier combination and the degree of fit with one's dietary habits (Tan et al. 2015, 2016; House 2016; Ardoin and Prinyawiwatkul 2020).

Previous studies have primarily focused on omnivorous participants, as meat substitution has been studied. However, previous authors have suggested that insects and insect-based foods may actually be accepted by vegetarians and possibly even vegans for environmental reasons and animal welfare reasons, as insects are often perceived as lacking sentience or the capacity to suffer (House 2016; Tan et al. 2016). For example, Elorinne et al. (2019) showed for a Finnish sample that most vegetarians had positive attitudes toward eating insects, and even among vegans, one in three could be classified as a potential consumer.

Building on these studies, our research aimed to investigate consumer attitudes toward entomophagy and to extend existing knowledge by providing new empirical evidence on the acceptance of bread containing insect flour as a protein-rich ingredient in a German context. We specifically chose bread as a carrier product for our analysis due to its status as a German staple food (Teuber et al. 2016; Meyerding et al. 2018), and its suitability for different dietary styles. Bread is widely consumed in Germany, and represents a carrier product to introduce many individuals to insect consumption. Therefore, the research question of our study is: Would consumers in Germany be willing to buy bread containing protein-rich insect flour? In addition, we investigate the role of different information treatments and nutrition claims on consumer preferences. To this end, we conducted an online discrete choice experiment (DCE) with German consumers in the summer of 2022 to assess their purchase intention and willingness to pay (WTP) for bread made with insect flour.

Consequently, our study makes several contributions. First, we investigate German consumers' familiarity with insects as food and their acceptance of a (traditional) carrier—(novel) ingredient combination. This investigation will generate new insights by examining the differences in entomophagy attitudes among different dietary groups, namely omnivores, flexitarians, vegetarians, and vegans, using the Entomophagy Attitude Questionnaire (EAQ) developed by La Barbera et al. (2020). Second, we analyze the role of different information treatments that address safety concerns and environmental concerns on the adoption of insects-based ingredients. Third, we study whether indicating a higher nutritional value in terms of protein content, i.e. nutrition claims, promotes the choice of bread enriched with insect flour. This aspect has received limited attention in the existing literature on insect-based foods. However, nutrition claims highlighting the high protein content of insect flour may prove to be an effective strategy to increase acceptance. Therefore, our study has practical implications for the food industry by providing information on potential customers, and their attitudes and intentions toward insect flour in bread, and how they are influenced by different information strategies and nutrition claims.

2. Methods

2.1 Data collection, survey instrument, and measures

We conducted a self-administered online consumer survey in Germany from June to August 2022, and recruited respondents through convenience sampling using university mailing lists of students and employees, social media, and personal contacts. The survey was presented as an assessment of attitudes toward alternative protein consumption and insects as food. As an incentive, respondents could enter a prize draw for one of five €20 gift vouchers. All respondents had to give informed consent to participate in the study and to the privacy statement. Of the 1,308 individuals who followed the survey link, 937 completed the survey after passing screening questions related to bread and roll purchasing behavior and age (16 years or older[1]). After a quality check to identify respondents who may have rushed through the survey or provided inconsistent information, 844 interviews remained for further analysis.

The questionnaire consisted of several sections. The first section inquired about the respondents' diets, their purchasing behavior of bread and rolls, and their food- and environment-related lifestyles. The second section explored participants' previous experiences with insects as food and asked those respondents open to entomophagy to rank different product types from highest (1) to lowest (5) preference. This was followed by the introduction of the information treatments and instructions for the choice experiment. We used a between-sample design and when starting the survey, participants were randomly assigned by the survey software to one of the two information treatments or to the control group. Those in the control group received only the experimental instructions. In the information treatments, respondents also received information about either the safety (*safety treatment*) or the potential environmental benefits (*eco treatment*) of consuming insects. Next, we repeatedly asked the respondents to choose from a set of breads the one that they would be most willing to buy. Section 3.2 presents details on the design and framing of the choice experiment. The survey continued with the EAQ by La Barbera et al. (2020), which we used to measure respondents feelings of disgust and interest in eating insects on a 7-point scale (endpoints: 1 = strongly disagree, 7 = strongly agree). It has recently been shown that the specific EAQ instrument outperforms the Food Neophobia instrument by Pliner and Hobden (1992) in predicting the willingness to consume insect-based foods (Sogari et al. 2023). Finally, socio-demographic data (age, gender, income, and level of education) were collected.

2.2 Choice experiment: attributes, design, and framing

DCEs are stated preference methods commonly used in marketing and consumer behavior settings for new and novel foods (e.g.Giampietri et al. 2016; Meyerding et al. 2018;

Table 1. Attributes and levels.

Attributes	Levels
Price in €/500 g	0.79, 1.49, 2.19, 2.89, 3.59, 4.29
Type of bread	mixed wheat bread, mixed rye bread, spelt bread
Supplemented	no, with oilseeds (sunflower seeds, flax seeds and sesame seeds), with insect flour (powdered mealworms)
Nutrition (protein) claim	no, source of protein, high protein
Certified organic	no, yes
Sourdough	no, yes
No added sugar	no, yes
Shelf life	1–3 days, 4–6 days, 7–9 days

Note: underlined levels reflect the base level used in the estimations.

Weinrich and Elshiewy 2019; Koemle and Yu 2020; Lizin et al. 2022; Gassler et al. 2023). They are well grounded in economic theory and are used to infer the preference parameters of a utility function from observed choices of product alternatives (McFadden 1986; Louviere et al. 2000; Train 2009).

In the present DCE, the breads were described by eight attributes with either two, three or six levels (Table 1). First, the *price* attribute indicates the price of 500 g of bread, which is a common package size in Germany. The price range is based on actual retail prices collected during a store check in May 2022. The lowest price (€0.79 for a mixed rye bread) mimics the store brand of a major supermarket chain. Popular private label brands sold mixed wheat breads for about €1.49, organic rye breads for about €2.19, and organic spelt breads for about €2.89. We added two additional price points (€3.59 and €4.29) using the prevailing 70-cent price intervals from the store check to account for the currently still high prices of insect flour in Europe (Niyonsaba et al. 2021, 2023), which would require higher prices for insect bread than for regular bread to be economically feasible. Second, we used the three most common bread types: mixed wheat bread, mixed rye bread, and spelt bread. Third, these breads could be supplemented with protein-rich ingredients (either powdered mealworms and thus insect flour or common oilseeds) or not. Fourth, we presented the *nutrition information* using the permitted nutrition claims for protein as listed in *Regulation (EC) No 1924/2006*, amended by *Regulation (EU) No 1047/2012*. To claim that a food is a source of protein, at least 12 per cent of the energy value of the food must be provided by protein; to claim that a food is high in protein, at least 20per cent is required (we used 12 per cent and 24 per cent, respectively). Further, we used two levels (yes or no) to describe whether breads carry an *organic* label, are made with *sourdough* or contain *added sugar*. Finally, we used three levels to convey differences in the shelf life of the breads.

We generated the experimental design in two steps using the software R (R Core Team 2018) and the packages ‘AlgDesign’ (Wheeler 2019) and ‘DoE.wrapper’ (Groemping and Russ 2019). The full factorial design (i.e. all 3,888 possible attribute combinations) served as the candidate design for a D-optimal design in 36 runs. We specified a main effects design, and since we were interested in whether the presence of a nutrition claim changes consumer preferences for the insect content, we also allowed for two-way interactions between the attribute levels *insect flour* and *source of protein*, and *insect flour* and *high protein*. We excluded the possibility of having a protein claim on a bread but no protein-enhancing ingredient (oilseeds or insect flour) in the design. To prevent fatigue and reduce the burden placed on individual respondents, we divided the design into nine blocks (AlgDesign allows for optimal design blocking to minimize information loss) and randomly assigned respondents to one of these blocks.

All participants received the experimental instructions stating that (i) we will ask them four times to select their preferred choice from two breads that differ in their attribute

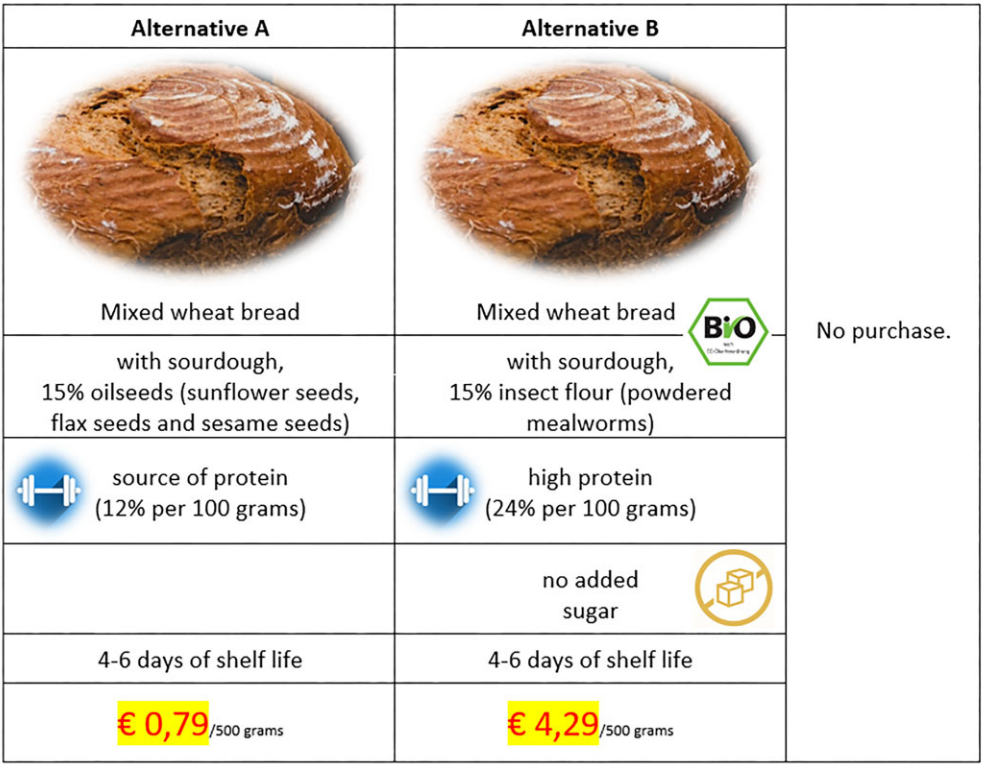

Figure 1. Sample choice set.

combinations; (ii) they should make their choice as if they were standing in their local supermarket and had to pay for the chosen product; and (iii) they could also decide against a purchase by choosing the opt-out alternative. We also included a cheap-talk script for participants to read before answering the DCE questions to address the lack of incentive compatibility in hypothetical choices where respondents may overestimate the price they are willing to pay (List and Gallet 2001; Lizin et al. 2022). Figure 1 shows a sample choice set (Supplementary Material 1 provides the framing and cheap-talk scripts).

Respondents assigned to the information treatments additionally received one of the following information:

> ***Safety treatment:*** *Since 2021, mealworms and locusts have been the first insect species to be approved as food in the EU. They may be marketed as whole insects, grounded as powders or as an ingredient in pasta, meat alternatives or other products. Prior to approval, the insect products were thoroughly tested by the European Food Safety Authority (EFSA) and found to be safe. This means they pose no risk to human health.*

> ***Eco treatment:*** *An insect-based diet has ecological and economic benefits. Conventional livestock production is responsible for a large part of man-made greenhouse gas emissions such as carbon dioxide, methane and nitrous oxide. Insect production, by comparison, requires less feed, land area, energy and water and thus results in fewer greenhouse gas emissions. In addition, the edible part of insects (about 80 per cent) is higher in percentage terms than that of farm animals (about 40 per cent), which is*

why insects are considered more sustainable. In addition, they have a fast growth rate and a more efficient feed conversion ratio.

2.3 Data analysis: random parameters logit models and factor analysis

The choice data were analyzed using the software R (R Core Team 2018) and the 'mlogit' package (Croissant 2020). We use a random parameters logit (RPL) model, which allows the preference parameters to vary across individuals, thereby allowing to study continuous preference heterogeneity (McFadden 1986, Train 2009). Alternative methods for accounting for preference heterogeneity exist. For instance, the latent class (LC) choice model is widely used and appropriate when respondents are to be segmented (with a certain probability) into groups with homogeneous preferences (Boxall and Adamowicz 2002). The LC model is conceptually similar to the RPL model, but assumes a discrete distribution of preferences across latent groups. In contrast, the RPL model captures preferences along a continuum, enabling a more comprehensive study of the preference distribution within the population. As we are not interested in segmentation per se, we consider the RPL model to be more suitable. It allows us to calculate the proportions of our sample with negative valuations of insect-based ingredients.

The RPL model requires the analyst to choose a distribution for each preference parameter. While there is no textbook rule, most papers choose the normal distribution when it can be safely assumed that the true distribution of the preference is symmetric and can take both positive and negative (Koemle and Yu 2020; Bronnmann et al. 2022). Therefore, we assume that all individual preferences (the coefficients ß$_i$ and γ_i in Equation 1) follow a normal distribution, whose parameters (i.e. mean and standard deviation) are estimated. While the price parameter is often either fixed or forced to take only negative values by choosing a lognormal distribution, we consider the price parameter to be normally distributed. In doing so, we take into account recent studies on choice behavior that report positive and negative price parameters for different consumer groups. Positive price coefficients in DCEs can be the result of some consumers having the tendency to assume that a higher priced product is of higher quality (e.g. Adamsen et al. 2013; Zhou et al. 2017; Gassler and Rehermann 2022). We also take the panel data nature of our data into account (i.e. repeated choices of the same individual) and fix the random parameters of individuals to be the same across their choice situations (Croissant 2020). We specify the observed utility V_{ij} for an individual i of choosing alternative j as

$$V_{ij} = \alpha_i + \beta_i price_{ij} + \gamma'_i x'_{ij,} \tag{1}$$

where α_i is an alternative specific constant (ASC), which takes a value of 1 if individual i chooses to buy a bread, and 0 if the opt-out alternative is preferred. ß$_i$ and γ'_i are the part-worth utilities to be estimated for the price (ß$_i$) and other product characteristics (γ'_i), respectively. Price enters the utility specification as a continuous variable; all other variables are dummy coded and take a value of 1 if the characteristic is present in the alternative and 0 otherwise.

First, we use the between-subject design of our study to estimate the effect of both information treatments (*eco* and *safety*) on consumer's utility for *insect flour*. Similar to previous studies (e.g. Gilmour et al. 2019; Paudel et al. 2022), we pooled the data from both treatments and the control group and estimated RPL models with and without interaction terms between the variable *insect flour* and the two treatment dummy variables (*dEco* and *dSafety* that took the value of one if the data were from the respective treatment group, and zero otherwise). The estimated coefficients for the interaction terms thus show differences in consumer utility for *insect flour* relative to the control group that acts as the reference level.

Second, we assess the effects of entomophagy attitudes on consumer utility for *insect flour* by including interaction effects between this attribute variable and the predicted factor scores for the *interest* and *disgust subscales* of the EAQ (La Barbera et al. 2020). We ran confirmatory factor analyses on these established scales using functions from the 'lavaan' package (Rosseel et al. 2020) to confirm these measures for our sample (see Supplementary Materials 2 for details). Third, to assess the interdependence of insect flour supplements and nutrition claims and thus differences in consumer utility for insect flour given the absence or presence of protein claims, we run models with second-order effects (δ'_i). Therefore, we add interaction terms (z'_i) that take a value of 1 if a protein-related nutrition claim (*source of protein* or *high protein*) is on an insect-enriched product and 0 otherwise:

$$V_{ij} = \alpha_i + \beta_i price_{ij} + \gamma'_i x'_{ij} + \delta'_i z'_{ij}. \quad (2)$$

Finally, we extend this model to assess differences in consumer utility for insect flour and the susceptibility to protein-based nutrition claims by diet. Therefore, we estimate an RPL model with interaction effects between the attribute level *insect flour*, the two nutrition claim levels (*source of protein* and *high protein*), all two-way interactions (e.g. *insect flour*high protein*), and three mutually exclusive diet dummy variables (*dVegetarian, dVegan,* and *dFlexitarian*) that took the value of 1 if the respondent followed the respective diet and 0 otherwise.

In addition, we follow Croissant (2020) and use the mean and standard deviation of the distribution of the random parameters to calculate the share of respondents with negative evaluations of insect flour (i.e. those with coefficients below 0) for selected models. We also estimate the WTP for bread attributes given different utility specifications (with and without two-way and dummy variable interaction terms): with respect to changes in the price and the relevant product characteristic k, the marginal WTP for a change in product attributes x_k and z_k is (Hensher et al. 2015):

$$WTP_k = -\frac{1}{ß}(\gamma_k + \delta_k), \quad (3)$$

where β is the fixed cost parameter, γ_k the parameter for the main effect of the product characteristic, and δ_k the parameter for the relevant interaction effect. We use the delta method as implemented in the 'car' package (Fox and Weisberg 2019) to calculate the 95 per cent confidence intervals. As indicated in Paudel et al. (2022), these confidence intervals can be used to assess statistically significant differences in WTP between multiple levels of a bread attribute (i.e. estimates differ significantly if the confidence intervals do not overlap).

3. Results

3.1 Sample descriptive statistics

Descriptive statistics of key socio-demographics and dietary characteristics of the three experimental groups are shown in Table 2. We find no statistically significant differences in age, gender, education level, diet, and frequency of bread consumption, but fewer respondents than expected fall into the lowest income bracket in the safety treatment ($p > 0.01$; see Supplementary Material 3). Overall, however, randomization was successful. In terms of diet, most respondents were either omnivores (37 per cent) or flexitarians (35 per cent); 22 per cent were vegetarians, and 6 per cent identified as vegans. The majority consumed bread and rolls once or more than once a week.

It is important to note that our sample ($N = 844$) tends to be more female, younger, and more educated than the general German population. In addition, vegetarian and vegan diets are more popular in our sample than in the general German population, where approximately 5 per cent follow a vegetarian diet and 1 per cent follow a vegan diet. However, meat-free and meat-reduced diets are becoming increasingly popular among German adolescents and young adults. The proportion of flexitarians in this group is about 25 per cent;

Table 2. Socio-demographic and dietary comparisons across experimental groups ($N = 844$).

	Description	Control Group[a] ($N = 275$)	Eco Treatment ($N = 273$)	Safety treatment ($N = 296$)	P-value
Age, in years	Mean (SD)	31.4 (12.3)	31.0 (11.5)	31.5 (12.3)	0.987[b]
Gender (%)	Female	68.7	66.7	70.3	0.532[c]
Net household income (%)	<1,300€	43.6	40.7	30.7	0.040[c]
	1,300€–2,599€	16.7	17.6	23.3	
	2,600€–3,599€	12.7	13.2	12.5	
	>3,599€	20.0	19.4	20.6	
	NA	6.9	9.2	12.8[d]	
Education (%)	A-levels, higher education entrance qualification	92.4	94.9	94.9	0.342[c]
Eating behavior (%)	Omnivore	37.1	38.1	36.1	0.894[c]
	Vegetarian	23.3	20.5	21.3	
	Vegan	5.5	6.2	7.1	
	Flexitarian	34.2	35.2	35.5[d]	
Bread and rolls consumption (%)	Once a month or less	7.3	6.6	8.4	0.620[c]
	Several times a month	8.7	5.1	8.4	
	Once a week	42.5	45.1	40.5	
	Several times a week	41.5	43.2	42.6[d]	

[a]Respondents were randomly assigned to either the control or one of the two treatment groups.
[b]Kruskal–Wallis rank sum test between experimental groups.
[c]Pearson's χ^2 test between experimental groups.
[d]Category percentages may not add up to 100 per cent due to rounding.

about 10 per cent eat a vegetarian diet, and about 2 per cent eat a vegan diet (Spiller et al. 2021). Regarding the consumption of bread and rolls, the frequency seems lower (mostly once or more than once a week) than reported, for example, by Teuber et al. (2016) (mostly daily to several times a week). For our relatively younger sample, however, this reflects the fact that the older people are, the more often bread and rolls are consumed (Zentgraf and Schulze 2008).

The results are therefore not representative of the general German population. Nevertheless, the sample provides valuable insights for marketing novel insect-based foods to a relevant consumer group. It has been shown that young and well-educated consumers are usually most open to novel foods (e.g. Garcez de Oliveira Padilha et al. 2021 for cultured meat), and in Germany younger people in particular are in favor of insects as food (Bundesinstitut für Risikobewertung (BfR) 2016). House (2016)—drawing on work on the establishment of other novel foods—suggests that consumer acceptance research for insect-based foods should focus more strongly on early adopters than on the general population. He argues that catering to the preferences of a small but committed group of early adopters makes a stronger business case in the long run, as their advocacy for insect-based foods will gradually lead to wider acceptance.

3.2 Respondents' familiarity with insects as food and their entomophagy attitudes

About a quarter of the participants had already consumed insects or insect-based foods.[2] These experiences were mainly in Germany and Asia. While the majority of participants (69 per cent) had not consumed insects or insect-based foods before, almost half of them expressed openness to do so in the future. We find no statistically significant differences for past ($p = 0.488$) and future insect consumption ($p = 0.487$) across experimental groups using Pearson's χ^2 tests. Whole insects were the least popular product type in our sample, while a high willingness to buy was observed for meat substitutes and pasta and bakery products (see Supplementary Material 4).

Regarding the attitudes of our sample toward entomophagy, Table 3 reports the means for each EAQ item for the full sample as well as for the four dietary groups, and contrasts the predicted factor scores for the EAQ subscales by diet (see Supplementary Material 2 for factor loadings). On average, the sample reports moderate levels of disgust and interest, and has a rather favorable attitude toward the use of insects as animal feed. When we assess the differences between the diet groups, several interesting results stand out. First, the means on the *disgust subscale* indicate that vegetarians and vegans are more repulsed by eating insects than omnivores and flexitarians. For example, they are more likely to avoid eating a dish that contains insects. Second, of all the diet groups, flexitarians show the strongest interest in trying insect-based foods, followed by omnivores. Vegetarians and especially vegans are less interested in eating foods and dishes containing insects. Third, across the EAQ subscales and on average, we find the strongest agreement for the items that make up the feeding animals subscale. In particular, omnivores and flexitarians shared strong positive attitudes in favor of feeding insects to fish and livestock raised for human consumption. Vegetarians and vegans differed significantly in their attitudes, with vegans showing the lowest level of agreement with feeding insects to animals, while vegetarians fell in the middle ground.

3.3 Choice experiment results

3.3.1 Preferences for bread baked with insect flour—with and without treatments

We start by assessing the effect of the information treatments on respondents' preferences for insect flour as a bread ingredient. Table 4 reports the RPL results for bread baked with insect flour in the control and treatment conditions. Looking only at the coefficient for the insects attribute level, we see a strong negative effect of insect flour on the choice probability in the control group. Neither the eco nor the safety treatment had a statistically significant effect on respondents' evaluation, as indicated by the insignificant treatment interaction coefficients given in model (1). Since no differences between the three groups emerged, we use the pooled sample and describe the results for preferences for bread attributes in model (2), which excludes the treatment interactions. The results for all product attributes are robust across these models (i.e. similar in sign, significance, and magnitude). As a robustness check, we also estimated separate models for each treatment group and assessed the equality of parameters for insect flour. Supplementary Material 5 shows that the relevant coefficients are similar across these treatments groups.

For model (2) in Table 4, the coefficient for added insect flour is negative (−1.523) and statistically significant at the 0.1 per cent level. It follows that participants preferred breads without this supplement and that insect flour strongly decreased their probability of choosing a bread. In contrast, they preferred breads with added oilseeds to those without supplements, as indicated by the positive coefficient (0.459), which is significant at the 1 per cent level. With regard to other bread attributes, the results indicate that respondents preferred cheaper breads. Thus, according to economic theory, the higher the price of a bread, the lower the probability of purchase (ceteris paribus). Regarding the preferred type of bread, the results suggest that mixed rye breads and spelt breads are more likely to be purchased than mixed wheat breads. Assessing the effect of nutrition claims on choice, the results suggest that respondents were indifferent between a bread with no claim and a bread marketed with the 'moderate' protein claim indicating that it is a source of protein. However, the 'stronger' protein claim, indicating that a bread is high in protein, significantly increased the probability of a purchase compared with a bread with no nutrition claim. Respondents were also more likely to choose breads that were labeled organic, had no added sugar, and were made with sourdough. Moreover, longer shelf live was preferred to a short shelf life of up to 3 days.

Table 3. Entomophagy attitudes and factor scores by EAQ subscale and diet ($N = 844$).

Subscale and items	Full sample	Omnivore[(1)] (37%)	Flexitarian[(2)] (35%)	Vegetarian[(3)] (22%)	Vegan[(4)] (6%)	*P*-value[c]
EAQ-D: Disgust subscale[a]		**−0.01**[3] (1.90)	**−0.25**[3,4] (1.72)	**0.31**[1,2] (1.79)	**0.40**[2] (1.98)	0.005
I would be disgusted to eat any dish with insects.[b]	3.95 (2.01)	3.95 (2.06)	3.73[3] (1.95)	4.23[2] (1.93)	4.26 (2.28)	0.037
Thinking about the flavor that a bug might have sickens me.	3.57 (1.89)	3.67 (2.04)	3.30[3] (1.76)	3.81[2] (1.79)	3.64 (1.95)	0.026
If I ate a dish and then came to know that there were insects among the ingredients, I would be disgusted.	3.51 (2.03)	3.48[3] (2.11)	3.25[3] (1.85)	3.88[1,2] (2.01)	3.87 (2.35)	0.010
I would avoid eating a dish with insects among the ingredients, even if it was cooked by a famous chef.	3.49 (2.27)	3.38[3,4] (2.28)	3.16[3,4] (2.09)	3.91[1,2] (2.29)	4.53[1,2] (2.60)	$6.7e^{-05}$
EAQ-I: Interest subscale		**0.05**[2,3,4] (1.95)	**0.39**[1,3,4] (1.73)	**−0.42**[1,2] (2.07)	**−1.00**[1,2] (2.33)	9.9e-06
I'd be curious to taste a dish with insects, if cooked well.	4.81 (2.11)	4.88[3,4] (2.12)	5.21[3,4] (1.87)	4.36[1,2] (2.16)	3.77[1,2] (2.44)	$3.2e^{-06}$
In special circumstances, I might try to eat a dish of insects.	4.99 (1.91)	5.03[3,4] (1.88)	5.32[3,4] (1.68)	4.61[1,2] (2.01)	4.25[1,2] (2.42)	<0.001
At a dinner with friends, I would try new foods prepared with insect flour.	4.64 (2.12)	4.65[2,4] (2.12)	5.05[1,3,4] (1.90)	4.30[2,4] (2.24)	3.49[1,2,3] (2.36)	$1.3e^{-05}$
EAQ-F: Feeding animals subscale		**0.13**[3,4] (0.89)	**0.17**[3,4] (0.83)	**−0.19**[1,2,4] (0.98)	**−1.03**[1,2,3] (1.41)	$1.4e^{-11}$
Using insects as feed is a good way of producing meat.	5.48 (1.59)	5.51[4] (1.57)	5.70[3,4] (1.37)	5.30[2] (1.63)	4.62[1,2] (2.22)	0.005
I think it is fine to give insect-based feed to fish that are farmed for human consumption.	5.77 (1.48)	6.05[3,4] (1.25)	6.02[3,4] (1.26)	5.44[1,2,4] (1.48)	3.91[1,2,3] (2.16)	$6.6e^{-16}$

[a]Values are means (SD in brackets) of predicted factor scores.
[b]Values are means (SD in brackets) of 7-point scales: *1* = disagree strongly, *7* = agree strongly.
[c]Kruskal–Wallis rank sum test between diet groups.
[1,2,3,4]Indicate significant differences ($P < 0.1$) between diet groups, e.g.[1] indicates significant differences from omnivores in this variable. Post-hoc test: Pairwise comparisons between diet groups using Wilcoxon rank sum test with continuity correction and BH adjustment.

Table 4. Random parameters logit estimates with and without treatment interactions.

Variable	Model (1) with treatment interactions		Model (2) without treatment interactions	
ASC (*1* = buy)	1.647***	(0.255)	1.637***	(0.254)
Price	−0.877***	(0.061)	−0.875***	(0.060)
Mixed rye bread	0.874***	(0.115)	0.873***	(0.114)
Spelt bread	0.709***	(0.130)	0.708***	(0.129)
Protein source	0.167	(0.112)	0.169	(0.111)
High protein	0.562***	(0.121)	0.562***	(0.121)
Oilseeds	0.458**	(0.158)	0.459**	(0.158)
Insects	−1.388***	(0.224)	−1.523***	(0.184)
insects*dEco	−0.107	(0.222)		
insects*dSafety	−0.301	(0.211)		
Certified organic	1.218***	(0.123)	1.216***	(0.122)
Sourdough	0.240*	(0.111)	0.241*	(0.111)
No added sugar	0.403***	(0.087)	0.402***	(0.086)
4–6 days shelf life	0.702***	(0.109)	0.702***	(0.109)
7–9 days shelf life	0.718***	(0.117)	0.717***	(0.117)
Std. dev. of random parameters				
sd.ASC	1.488***	(0.166)	1.480***	(0.165)
sd.price	0.061	(0.132)	0.074	(0.128)
sd.rye	0.645*	(0.257)	0.638*	(0.258)
sd.spelt	1.075***	(0.230)	1.071***	(0.230)
sd.oilseeds	0.223	(0.356)	0.228	(0.355)
sd.insects	2.384***	(0.203)	2.384***	(0.202)
sd.protein source	0.966***	(0.239)	0.945***	(0.240)
sd.high protein	0.016	(0.359)	0.012	(0.360)
sd.certified organic	0.742**	(0.246)	0.733**	(0.246)
sd.sourdough	0.400	(0.269)	0.405	(0.268)
sd.no added sugar	0.297	(0.289)	0.290	(0.292)
sd.4-–6 days shelf life	1.025***	(0.235)	1.021***	(0.235)
sd.7–9 days shelf life	0.601*	(0.243)	0.594*	(0.243)
Observations	10,128		10,128	
Log-likelihood	−2,861		−2,862	

Notes: Coefficients for dummy coded attribute levels are compared with their respective base levels as indicated in Table 1.
***, **, *, indicate statistical significance at 0.1 per cent, 1 per cent, 5 per cent, and 10 per cent, respectively. Numbers in parentheses represent standard errors.

We report the standard deviations of the distribution of the random parameters in the bottom half of Table 4. These coefficients, when statistically significant, describe the heterogeneity of the samples' preferences. The coefficient for added insect flour is normally distributed with a mean of −1.523 and a standard deviation of 2.384. The cumulative standard normal distribution with these parameters evaluated at 0 gives the share of respondents with negative preferences for added insect flour (i.e. 64 per cent). We also find that about 74 per cent of the sample is estimated to dislike bread baked with insect flour (Fig. 2).

3.3.2 How diets and nutrition claims shape preferences for bread baked with insect flour

To better understand how attitudes toward entomophagy shape the effect of insect flour on choice that emerged from our initial models, we include interaction effects between the *insects* attribute variable and the predicted factor scores for the *interest* and *disgust subscales* of the EAQ. The results are presented by model (3) in Table 5. Our results show that both interaction terms are significant at the 0.1 per cent level, indicating that the evaluation of insect-based ingredients in choice settings is related to consumers' attitudes toward

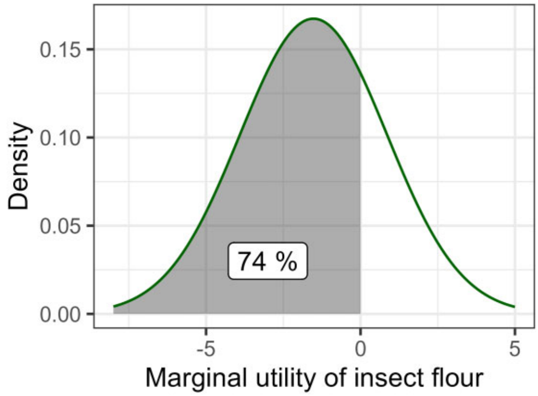

Figure 2. Distribution of the preference for added insect flour—model (2). Shaded area shows percentage of respondents with negative valuation.

entomophagy. Model (3) shows how the choice probability of a respondent with (sample) average factor scores for interest and disgust is affected (strongly negative as indicated by the coefficient: -1.589^{***}), and how this is attenuated or amplified by the two dimensions of entomophagy attitudes that are directly consumption oriented. Thus, above-average feelings of disgust result in even lower choice probabilities (and vice versa), while respondents with above-average interest in trying and tasting insects are relatively more likely to buy bread enriched with insect flour (and vice versa).

Next, we study whether indicating a higher nutritional value in terms of protein content promotes the choice of bread enriched with insect flour. Therefore, we include interaction effects between the attribute level *insect flour* and the two nutrition claim levels (*source of protein* and *high protein*). Looking at model (4), we find that the presence of the 'moderate' protein claim has no significant effect on the probability of choosing bread with insect flour. However, when a bread containing insects carried the 'stronger' protein claim, it was more likely to be purchased than an otherwise identical unlabeled bread, as indicated by the positive interaction coefficient (0.632), which is significant at the 5 per cent level. The results were robust (i.e. similar in sign, significance, and magnitude) for all product attributes except for the high protein claim, which was no longer significant. This suggests that respondents did not choose a bread because of its protein content, but there is evidence that the nutrition claim made insect flour more palatable—although an overall strong negative effect of added insect products on choice remained. Figure 3 shows the percentage of respondents with a negative evaluation of insect flour in the presence (67 per cent) or absence (76 per cent) of the high protein claim.

Finally, we contrast the choice behavior of respondents who follow *omnivorous, vegetarian, vegan*, and *flexitarian* diets and assess differences in their susceptibility to protein-based nutrition claims (model 5). Therefore, we extend model (4) by adding interaction effects between the attribute level *insect flour*, the two nutrition claim levels (*source of protein* and *high protein*), all two-way interactions (e.g. *insect flour*high protein*), and three diet dummy variables (*dVegetarian*, *dVegan*, and *dFlexitarian*). This leaves omnivores as the base group for comparison. With regard to *insect flour*, the results indicate that it decreases the probability of purchasing bread across all dietary styles. Compared with omnivores, insect flour has a relatively less negative effect on the purchase probability of flexitarians, but a comparatively stronger negative effect on the purchase probability of vegetarians and vegans. For nutrition claims, the insignificant coefficients for *protein source* (0.126) and *high protein* (0.167) indicate that omnivores are indifferent between breads with and without protein claims. In addition, the insignificant interaction coefficients for the diet dummies suggest

Table 5. Random parameters logit estimates with attitude, attribute, and diet interactions.

Variable	Model (3) with attitude interaction	Model (4) with two-way interactions	Model (5) with two-way*diet interactions
ASC (*1* = buy)	1.710*** (0.249)	1.577*** (0.275)	1.579*** (0.277)
Price	−0.874*** (0.060)	−0.859*** (0.060)	−0.863*** (0.062)
Mixed rye bread	0.859*** (0.110)	0.837*** (0.118)	0.895*** (0.123)
Spelt bread	0.674*** (0.125)	0.694*** (0.127)	0.712*** (0.129)
Oilseeds	0.428** (0.152)	0.570*** (0.166)	0.580*** (0.170)
Insects	−1.589*** (0.180)	−1.700*** (0.219)	−1.607*** (0.270)
insects*disgust.fa	−0.449*** (0.085)		
insects*interest.fa	0.799*** (0.091)		
insects*dVeggy			−1.562*** (0.410)
insects*dVegan			−2.160** (0.750)
insects*dFlexi			0.816** (0.303)
Protein source	0.162 (0.108)	0.085 (0.149)	0.126 (0.202)
protein source*dVeggy			−0.138 (0.281)
protein source*dVegan			0.554 (0.502)
protein source*dFlexi			−0.135 (0.241)
High protein	0.539*** (0.118)	0.293 (0.186)	0.167 (0.232)
high protein*dVeggy			−0.008 (0.284)
high protein*dVegan			0.881. (0.464)
high protein*dFlexi			0.157 (0.242)
insects*prot.source		0.322 (0.251)	0.107 (0.352)
insects*prot.source*dVeggy			1.394* (0.542)
insects*prot.source*dVegan			0.092 (1.045)
insects*prot.source*dFlexi			−0.061 (0.443)
insects*high protein		0.632* (0.308)	0.575 (0.399)
insects*h.protein*dVeggy			1.377* (0.596)
insects*h.protein*dVegan			0.934 (1.103)
insects*h.protein*dFlexi			−0.458 (0.448)
Certified organic	1.160*** (0.118)	1.194*** (0.121)	1.211*** (0.121)

Table 5. Continued

Variable	Model (3) with attitude interaction	Model (4) with two-way interactions	Model (5) with two-way*diet interactions
Sourdough	0.200. (0.107)	0.201. (0.112)	0.184. (0.112)
No added sugar	0.431*** (0.084)	0.397*** (0.092)	0.418*** (0.095)
4–6 days shelf life	0.725*** (0.105)	0.832*** (0.130)	0.880*** (0.136)
7–9 days shelf life	0.689*** (0.115)	0.873*** (0.158)	0.869*** (0.161)
Std. dev. of random parameters			
sd.ASC	1.471*** (0.163)	1.451*** (0.166)	1.531*** (0.170)
sd.price	0.206* (0.080)	0.152 (0.096)	0.122 (0.107)
sd.rye	0.431 (0.330)	0.201 (0.404)	0.765** (0.237)
sd.spelt	0.969*** (0.237)	1.075*** (0.237)	1.008*** (0.251)
sd.oilseeds	0.389 (0.291)	0.276 (0.306)	0.066 (0.358)
sd.insects	0.928*** (0.217)	2.364*** (0.203)	2.351*** (0.208)
sd.protein source	0.901*** (0.219)	0.879*** (0.244)	0.811** (0.251)
sd.high protein	0.148 (0.376)	0.401 (0.305)	0.173 (0.329)
sd.certified organic	0.620* (0.255)	0.601* (0.263)	0.542. (0.281)
sd.sourdough	0.571* (0.252)	0.707** (0.238)	0.414 (0.267)
sd.no added sugar	0.440. (0.260)	0.023 (0.294)	0.369 (0.259)
sd.4–6 days shelf life	0.698** (0.246)	1.011*** (0.225)	1.171*** (0.223)
sd.7–9 days shelf life	0.903*** (0.200)	0.637** (0.226)	0.584* (0.228)
Observations	10,128	10,128	10,128
Log-likelihood	−2,623	−2,861	−2,838

Notes: Coefficients for dummy coded attribute levels are compared with their respective base levels as indicated in Table 1.
***, **, *, indicate statistical significance at 0.1 per cent, 1 per cent, 5 per cent, and 10 per cent, respectively. Numbers in parentheses represent standard errors.

similar preferences for protein claims across diet groups, with the exception of the high protein claim, which seems to encourage vegans to purchase (their coefficient is positive and statistically significant at the 10 per cent level). Turning to the two-way interactions, we find insignificant coefficients for both *protein source* and *high protein* parameters for omnivores, and no significant differences in their preferences compared with those of vegans and flexitarians, suggesting that protein labeling does not promote the purchase of bread baked with insect flour among these consumers. Only for vegetarians do we find that both protein claims increase the probability of choosing insect products, as indicated by the

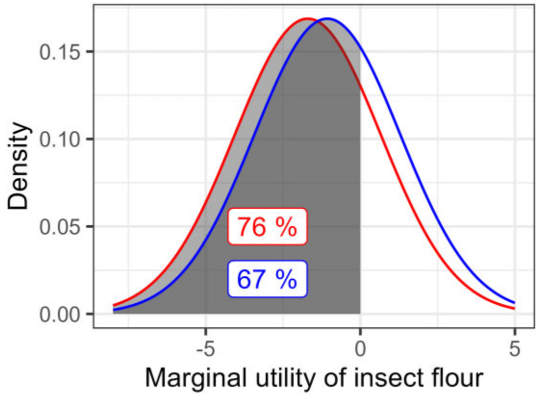

Figure 3. Distribution of the preference for added insect flour—model (4). Shaded areas show the percentages of respondents with a negative evaluation of insect flour in the presence (67 per cent) or absence (76 per cent) of the high protein claim.

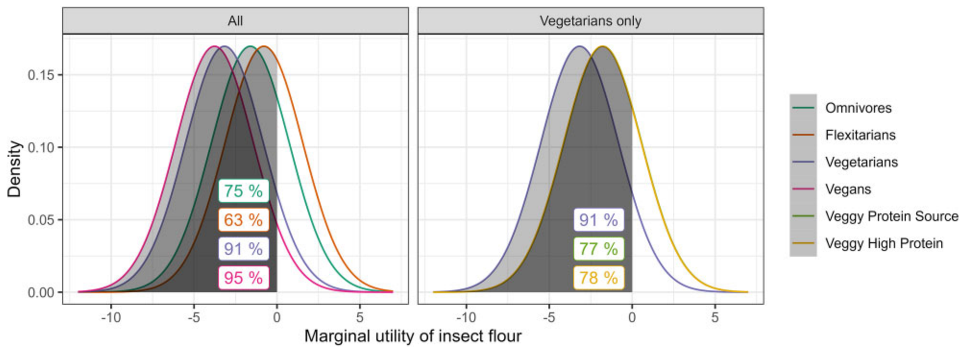

Figure 4. Distribution of the preference for added insects by diet model (5). The left panel shows the percentages of respondents with a negative valuation without a nutrition claim by diet; and the right panel shows how the percentage of vegetarians with a negative valuation of insect flour changes when a nutrition claim is present.

positive interaction coefficients for *protein source* (1.394) and *high protein* (1.377), which are significant at the 5 per cent level. Finally, we estimate the percentage of respondents with a negative evaluation of insect flour by diet. We find that about 75 per cent of omnivores, 91 per cent of vegetarians, 95 per cent of vegans, and 63 per cent of flexitarians dislike bread baked with insect flour (Fig. 4). When a protein claim is made, the percentage drops to 78 per cent for vegetarians.

3.3.3 Willingness to pay for insect-based food ingredients

We report WTP estimates for bread attributes for two models (see Supplementary Material 6): the general results from the pooled sample (model 2) and the detailed results by dietary styles and the two-way interactions (model 5). Starting with the general findings, the results for the use of protein-rich bread ingredients suggest that consumers are willing to pay, on average, €1.74 less for bread baked with insect flour, and €0.52 more for bread supplemented with oilseeds. Consumers were not willing to pay more for bread labeled as a source of protein, but were willing to pay, on average, €0.64 more for bread marketed as high in protein. Findings indicate that consumers are willing to pay, on average, €1.00 more for mixed rye bread, and €0.81 more for spelt bread than for mixed wheat breads. Examining the confidence intervals in Supplementary Material 6 shows that the WTP estimates for mixed rye and spelt breads are not significantly different. Similarly, respondents showed, on average, a willingness to pay price premiums for breads certified as organic (€1.39), with no added sugar (€0.46), and made with sourdough (€0.28). They were also willing to pay, on average, about €0.80 more for bread with a shelf life exceeding 3 days.

Turning to the WTP estimates for insect products and nutrition claims derived from model (5), several significant differences in WTP by diet become apparent. First, the results for the use of insect flour suggest that omnivores are willing to pay €1.86 less, on average, for bread baked with this ingredient. Vegetarians and vegans are willing to pay even less—on average, €3.67 and €4.36 less, respectively—while flexitarians ask for the lowest discount (€0.91) to be indifferent between a conventional bread and one baked with insect flour. All dietary groups were not willing to pay more for bread labeled as a source of protein, which is consistent with the WTP estimates in model (2). However, the estimates for the high protein claim by diet suggest that the WTP reported in model (2) is largely driven by vegans, who are willing to pay €1.02 more, on average, for high-protein breads. The two-way interactions indicate that bread containing insect flour receive smaller price discounts from vegetarians when these products carry protein claims: on average, vegetarians were willing to pay €2.05 or €2.07 less for a protein-labeled bread baked with insect flour compared with €3.67 less for an unlabeled one. Findings for the other bread attributes, except for sourdough, which is no longer significant, indicate similar WTP compared with model (2) estimates.

4. Discussion and conclusions

Entomophagy remains controversial among European consumers, where the consumption of insect-based products continues to evoke strong feelings of disgust (e.g. Lammers et al. 2019; Dagevos 2021; Russell and Knott 2021). Against this background, our objective was to assess the effectiveness of different information treatments and protein-based nutrition claims in promoting the consumption of insect-containing foods. We also contribute to the body of knowledge by exploring diet-related differences in attitudes and preferences toward eating insects. Therefore, we collected psychographic characteristics and stated preferences of German consumers in an online survey featuring a choice experiment for bread with insect flour.

Our results support the notion that edible insects and direct entomophagy are currently not a successful business case, as the majority of the sampled German consumers (74 per cent) would not buy a bakery product enriched with insect flour. This percentage is in line with a 2021 survey according to which only a quarter of Germans can imagine eating insects as an ingredient in food (YouGov 2021). The vast majority of our sample is unwilling to pay a premium for such products, even though respondents on average reported a general openness to try insect-based foods and indicated a high willingness to buy bakery products containing powdered insects in an initial ranking exercise. Bakery products have previously been found to be acceptable carriers before (e.g. Lombardi et al. 2019; Naranjo-Guevara et al. 2021), and it is well established that the degree of insect visibility influences consumer willingness-to-try, with processed insects being more acceptable to European consumers than whole insects or insect parts (Hartmann et al. 2015; Lammers et al. 2019; Orsi et al. 2019; Schäufele et al. 2019; Russell and Knott 2021). However, it has also been established that most European consumers would require a price discount for insect-based foods, as reported in recent studies in Greece (Giotis and Drichoutis 2021), Italy (Lombardi et al. 2019), the UK (Michel and Begho 2023), and Germany (Kornher et al. 2019), covering diverse carrier products (i.e. snack bars, cookies, pasta, sausages, and burger patties). Following Tan et al. (2016), we thus find it questionable whether adding powdered insects to traditional and familiar foods is a viable carrier-ingredient combination—at least for

German consumers. We find a more open attitude toward indirect entomophagy (i.e. insects as animal feed) compared with direct entomophagy, which is in line with previous research (La Barbera et al. 2018; Giotis and Drichoutis 2021; Naranjo-Guevara et al. 2021; Verneau et al. 2021). Thus, indirect entomophagy and industrial applications (e.g. insect-derived products as an alternative to vegetable oils, as a base for biodegradable plastics, etc.), as highlighted by van Huis (2022), may offer greater market potential. Future research on consumer acceptance should take these alternative uses into account.

While we find no statistically significant effect of our safety and environmental information treatments on consumer preferences for insect-based ingredients, the literature remains ambiguous. This may be due to the different acceptance measures used, the various products and regions studied, and the different aspects emphasized in information treatments. Lombardi et al. (2019), for example, found that disclosing information about individual health benefits and collective environmental benefits of insect consumption increased Italian consumers' WTP for insect-based pasta, cookies, and chocolate. Similarly effective in reducing price penalties assigned for insect-based sausages among UK consumers was an information briefing on the environmental advantages of insect-based foods relative to conventional animal proteins (Michel and Begho 2023). For German consumers, however, Kornher et al. (2019) showed that neither stressing the negative consequence of meat consumption nor stressing the safety and widespread adoption of insect foods globally had any effect on their stated willingness to consume insect-based foods in the future. Interesting are the findings of Berger et al. (2018a), who report that promoting immediate, hedonic benefits (e.g. taste) is effective in motivating German consumers to consume an insect-containing chocolate product, while highlighting distant utilitarian benefits (e.g. for the environment or one's health) is not. Since positive taste expectations and curiosity about novel foods are significant predictors of consumers' willingness to eat insects (Hartmann et al. 2015; La Barbera et al. 2020), taste-related interventions seem to be an interesting avenue for future research.

Turning to the effect of protein-based nutrition claims on the choice of bread enriched with insect flour, we find that only the 'stronger' protein claim (*high in protein*) increases the purchase probability of our sample. The percentage of respondents with a negative evaluation of insect flour decreased slightly to 67 per cent in the presence of the claim. Thus, the nutrition claim makes insect flour more palatable, but there remains an overall strong negative effect of insect flour on choice. Few studies have looked into the effect of nutrition or health claims on the uptake of insect-based foods. The exceptions are Michel and Begho (2023), who found no significant effect of the claim 'great source of protein and vitamin B12', and Kornher et al. (2019), who found that the positive claim 'contains omega-3 fatty acids' was associated with a higher probability of choice in a group of consumers interested in healthy and novel foods and with low meat consumption. Reducing one's meat consumption is popular, especially among German adolescents and young adults (Spiller et al. 2021). The large number of flexitarians (35 per cent), vegetarians (22 per cent), and vegans (6 per cent) in our sample also allowed us to contrast their preferences for insect-enriched bread and susceptibility to protein-based nutrition claims.

When we assessed these differences between diet groups, it became evident that vegetarians and vegans were more repulsed by eating insects than omnivores and flexitarians. Across all diets, the majority disliked bread baked with insect flour (75 per cent of omnivores, 63 per cent of flexitarians, 91 per cent of vegetarians, and 95 per cent of vegans), and respondents required significant price discounts—on average, flexitarians asked for the lowest discount (€0.91), followed by omnivores (€1.86), vegetarians (€3.67), and vegans (€4.36). This is in line with Elorinne et al. (2019), who found that vegans had more negative attitudes toward entomophagy than vegetarians and omnivores. With respect to the effectiveness of protein-based nutrition claims in promoting the consumption of insect-based foods, our findings suggest that protein labeling does not promote the purchase of insect-containing bread among omnivores, flexitarians, and vegans. Only for vegetarians did protein claims increase the probability of choosing such breads—which is consistent with the differences in susceptibility to a nutrition claim based on the level of meat consumption in Kornher et al. (2019). For omnivores and flexitarians, who do not exclude meat and dairy from their diets, a possible explanation is that they do not perceive themselves to be at risk of potential protein deficiencies and thus not in need for protein-enriched foods. For vegans, whose diets are lower in protein (Bakaloudi et al. 2021), this supports the notion that moral concerns for insects act as a strong barrier (parallel to animal welfare and animal rights issues) that is not mitigated by personal utilitarian (health) benefits (Elorinne et al. 2019; Russell and Knott, 2021; Delvendahl et al. 2022).

We acknowledge that our study is not without limitations. For example, our conclusions are based on the stated preferences of younger and more educated consumers, without offering tastings of the insect-enriched bread. Furthermore, we chose only one carrier product and one insect species. It would be interesting to replicate our study with general population samples from different countries, diverse carrier-ingredient combinations (including industrial applications), and taste-related interventions. Nevertheless, our results highlight diet-related differences in attitudes toward eating insects and underscore the strong dislike of insect-based ingredients in a traditional food product across dietary groups. While our safety and environmental information treatments were ineffective, we do find that vegetarians seem susceptible to protein-based nutrition claims, encouraging a significant proportion to consume insect-containing bread. However, the role of moral concerns in insect consumption across dietary groups remains largely unexplored, and we hope that our findings will stimulate future research on beliefs about how insects are farmed (e.g. housed, fed, transported, and killed) and consumers' willingness to substitute insect proteins for animal proteins. This may help policy makers and the food industry decide which alternative protein sources to promote or to abstain from for human consumption.

Acknowledgment

The study was conducted in accordance with the ethical principles for research involving human subjects and in accordance with local statutory requirements. Informed consent was obtained from all individual participants involved in the study.

Supplementary material

Supplementary data are available at *Q Open* online.

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Conflict of interest

The authors declare no conflict of interest.

Data availability

The data are available from the corresponding author upon request.

End Notes

1 In Germany, the consent of a legal guardian is required for minors up to and including the age of 15 for internet-based surveys in Germany (ADM et al. 2021). Sixteen-year-olds have 'limited contractual capacity'. They can enter into age-appropriate contracts themselves (without parental consent), such as buying a cell phone or a computer game. From the age of 16, young people can also take on jobs and earn extra pocket money. They begin to be consumers with their own wallets, and bakery products are a product category that they readily engage with.

2 In a representative sample of the German population from 2016, the proportion of people who had consumed insects was 14 per cent (Bundesinstitut für Risikobewertung (BfR) 2016).

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