PLOS ONE

RESEARCH ARTICLE

Attitudes and purchase intentions of polish university students towards food made from insects—A modelling approach

Anna T. Mikulec[1], Anna M. Platta[2], Monika Radzymińska[3], Millena Ruszkowska[2], Karolina Mikulec[4], Grzegorz Suwała[5], Stanisław Kowalski[6], Przemysław Łukasz Kowalczewski[7]*, Marcin Nowicki[8]*

1 Faculty of Engineering Sciences, University of Applied Science in Nowy Sącz, Nowy Sącz, Poland, **2** Faculty of Management and Quality Science, Gdynia Maritime University, Gdynia, Poland, **3** Faculty of Economic Sciences, Institute of Management Science and Quality, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland, **4** Graduate of the Warsaw School of Economics, Warszawa, Poland, **5** Department of Food Product Quality, Krakow University of Economics, Kraków, Poland, **6** Faculty of Food Technology, Department of Carbohydrate Technology and Cereal Processing, University of Agriculture in Krakow Poland, Krakow, Poland, **7** Department of Food Technology of Plant Origin, Poznań University of Life Sciences, Poznań, Poland, **8** Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN, United States of America

* mnowicki@utk.edu (MN); przemyslaw.kowalczewski@up.poznan.pl (PŁK)

Citation: Mikulec AT, Platta AM, Radzymińska M, Ruszkowska M, Mikulec K, Suwała G, et al. (2024) Attitudes and purchase intentions of polish university students towards food made from insects—A modelling approach. PLoS ONE 19(3): e0300871. https://doi.org/10.1371/journal.pone.0300871

Editor: Hidenori Komatsu, Central Research Institute of Electric Power Industry, JAPAN

Received: January 2, 2024

Accepted: March 6, 2024

Published: March 29, 2024

Data Availability Statement: All anonymized data are available at https://github.com/ArticlesData/Attitudes-and-purchase-intentions-of-polish-university-students-towards-food-made-from-insects.

Funding: The Authors received no specific funding for this work. The publication costs are covered by the University of Tennessee Open Publishing Fund, awarded to MN. The funders had no role in study

Abstract

The marketing of insect-derived protein has led to the development of respective legal regulations on such insects-based foods in the European Union. Despite the interest in the area of insect-based food, European researchers have paid relatively little attention to consumer attitudes and behaviors towards such products or the factors that may affect them. Attempts undertaken so far in this respect are insufficient; therefore, there is a need to continue and expand research in this field. The present study attempts to verify the following research hypotheses: H1. Attitudes towards food containing insects are related to the attributes/characteristics of these products, care for health and the natural environment, and attitudes towards novelty (neophilic/neophobic); H2. Intentions to purchase food containing insects can be predicted based on attitudes towards food from insects, product attributes, and attitudes towards environmental health and novelties. An empirical study was conducted among university students (N = 1063) by an indirect interview method using a specially designed questionnaire, via an online platform (Computer-Assisted Web Interview, CAWI) in November 2023. The questionnaire was validated by assessing the construction validity and estimating the reliability of the scales used. The study results demonstrated that the attributes of insect-based food products can influence the positive attitudes towards them and behavioral intentions to consume them, and that the strength of the impact of health quality traits is far greater than that of the organoleptic or functional traits. A negative, statistically significant value of the correlation coefficient between neophobic attitude and intention to purchase this type of food was observed. Thus, respondents without food neophobia were characterized by a positive attitude towards the purchase of foods containing edible insects in their composition.

design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

1. Introduction

Foods and dishes made from insects are particularly valued by certain consumers in Asian countries, especially in parts of China, Thailand, and India, and also in parts of Latin America and Africa [1–13], where their consumption is not only based on traditions and dietary preferences but is also trendy. In turn, over the last few years, the European Union (EU) countries have expressed a growing interest in pursuit of alternative high-protein foods. This pursuit has led to the emergence of a new niche on the agri-food market and an increased interest in insect-derived protein. Production of insect protein can offer an attractive alternative to the costly production of animal protein, which is important due to the demographic explosion and the need to feed a growing human population. In addition, insects represent a source of excellent-quality feed for livestock [14] and a source of protein-, vitamin-, and mineral-rich human food [15,16]. The marketing of insect-derived protein has led to the development of respective legal regulations on the use of insects in the EU. Pursuant to Implementing Regulations (EU Commission) 2022/188 (of 10 February 2022) and 2023/5 (of 3 January 2023) [17,18], the EU Commission together with the European Food Safety Authority (EFSA) has approved the introduction of the frozen, dried, and powdered forms and partially skimmed powder made from house crickets (*Acheta domesticus*) into the consumer food market, towards the enrichment of confectionery, baked goods, beverages, and other food products, including corn meal-based snack products and snacks other than potato chips. The EU list of novel foods currently includes three types of insects: mealworm (*Tenebrio molitor*)—dried larvae; migratory locust (*Locusta migratoria*)—frozen, dried, and powdered forms; and the previously mentioned house cricket (*A*. *domesticus*)—frozen, dried, and powdered forms.

The available scientific literature highlights many benefits, including health, environmental, and economic ones, that stem from the production and consumption of insect-based food and dishes [19–23]. In addition, the insect food is indicated as the so-called sustainable food category, as it is an excellent source of protein, lipids, minerals and vitamins [24–26]. At the same time, it contains large amounts of fiber-like chitin polysaccharides, which can cause a feeling of satiety for a sufficiently long time and ensure prolonged time until the next meal [22,27–29]. Insects also contain antioxidative compounds [30], essential amino acids [31], and polyunsaturated fatty acids [32]. The ingredients of edible insects can improve gut health, exert anti-inflammatory and antioxidative effects, and reduce the risk of development of cardiovascular diseases. Vitamins and minerals found in insects contribute to proper mental development and bone health [33]. From the standpoint of sustainable development and environmental protection, breeding and processing insects is also associated with many environmental benefits as it, i.a., requires less area and smaller water consumption than conventional production, generates lower greenhouse gas emissions than mass production, and may use waste from the agri-food industry as inputs to produce food and feedstuffs, which further corresponds to the current trends of "zero waste" and "circular economy" [5,9,34–38]. Beside the environmental aspect, insect production ensures a higher feed conversion ratio compared to the conventional animal production [23,39–41]. The production of food containing insects is also economically viable. A literature overview has shown that the sales prices of insects are very diverse and depend on many factors, including: insect species, product type (larva, pupae, adult), forms of sales (fresh, processed–processing requires additional costs), type of market (sales prices of food products intended for human consumption are higher than for feed or pet food, which is due to higher quality requirements set for food products), and large differences in operating costs (e.g., water, electricity, labor, etc., and feed for insects) particularly between western and non-western countries where insect sales prices are relatively low [42,43]. The possibility of composing lower-cost diets due to the lower prices of insect protein than of the protein from

conventional meat production is another economic benefit of insect food production [21,22]. However, it should be emphasized that this type of production requires establishing the precise cost estimates, including veterinary care, as well as generates concerns for food safety control and consumer acceptance assessment.

A review of the literature on insect food [44–56] has shown that the number of scientific publications in this field has increased dynamically over the last dozen or so years. In Europe, the subject matter has been undertaken by scientific and research centers in Belgium [44], Denmark [48,54], Germany [47,49], Portugal and Norway [53], and Italy [50]. The following areas of research interest can be distinguished within the works published in English-language literature that addresses food and dishes made from insects:

- the nutritional and feeding value of insect protein [57–59],
- the process of enriching food products with insect-derived protein [60–67],
- the motives of consumers when deciding to purchase food and dishes made from insects and assessing the degree of acceptance of products with added insects, e.g., bread [60], beef burgers and green lentils [44], jellies [7], protein energy bars [68], pasta [69,70], and oat cakes [71],
- the nutritional and environmental benefits and safety of insect consumption as a novel food source [72–76].

Despite the interest in the area of insect-based food, researchers have paid relatively little attention to consumer attitudes and behaviors towards these products and the factors that may affect them. Attempts undertaken so far in this respect should be deemed insufficient; therefore, there is a need to continue and expand research in this field. Many innovative projects and concepts related to the development of insect-based food products, including muffins, pâtés, corn extrudates, pancakes, sponge cake, and bars [23,69,77–81], have been elaborated, and their results are being implemented across Poland. Nevertheless, there is a cognitive gap in the Polish and central and eastern European scientific literature in this field. Undertaking research in this area is therefore justified, both from the standpoint of cognitive values and future implementation of the results.

This study is distinguished by the fact that it attempts to determine whether the attitudes of university students (young consumers) towards food containing insect protein and their declared intentions to purchase it will be related to the following variables (psycho-social determinants):

- concern for health,
- concern for the natural environment,
- attitude towards novelty (neophilic/neophobic)
- attributes/characteristics relevant to the purchase of novel, innovative food from insects.

The above variables were selected based on an overview of literature data of the subject. Authors of previous works have claimed that the health-promoting value [82,83] and ethical motives, including the environmental factors, play an increasingly important role in the decision-making process among consumers from developed countries. Persons who are concerned about the environmental degradation are more likely to accept novel types of food if they are convinced of the beneficial effects to the natural environment [73,84–87]. Factors influencing the consumer acceptance of insect-containing food, presented in the literature [51,88], included three categories: product attributes (e.g., price, quality, health benefits/risk,

naturalness, and convenience of use); trust and social norms; and psychological factors (attitudes and culture). In addition, studies have demonstrated that food neophobia significantly and negatively affected consumers' willingness to eat insect-based foods [89–91].

The present study attempts to verify the following research hypotheses:

H1. Attitudes towards food containing insects are related to the attributes/characteristics of these products, care for health and the natural environment, and attitudes towards novelty (neophilic/neophobic).

H2. Intentions to purchase food containing insects can be predicted based on attitudes towards food from insects, product attributes, and attitudes towards environmental health and novelties.

2. Research methodology

2.1. Subjects

The research results presented in this article derive from a questionnaire survey accomplished under an inter-university project conducted in five Polish entities offering higher education. An empirical study was conducted among university students, by indirect interview method using a custom-designed questionnaire, via an online platform (Computer-Assisted Web Interview, CAWI) in November 2023. Our study and the survey protocol received positive written consent from the University Ethics Committee for Research–Krakow University of Economics (KEBN/71/0044/D26/2023; 2023-10-27). Respondents gave written informed and voluntary consent to participate in the study and acknowledged the risk factors associated with participation in the CAWI study. The survey was conducted using the technique of non-probabilistic sample selection–purposeful sampling. Persons who were vegetarians, vegans, and on a flexitarian diet were excluded from the study. The study participants were persons who declared that they consumed all foods and did not limit their consumption of meat or animal products. During the research procedure, 1087 survey questionnaires were collected, and 24 incomplete and incorrectly completed ones were eliminated: 7 persons did not agree to participate in the study (they did not complete the survey further), 15 persons refused to answer question about gender, and 2 persons entered very large, unrealistic values in the age field. All respondents gave their free, informed consent to participate in the survey and were assured of its anonymity. The structure of the surveyed sample (N = 1063 respondents) is presented in Table 1.

Women accounted for ca. 61% of the surveyed population. The survey was conducted mainly among students of the following university profiles: engineering-technical sciences (ca. 40% of all respondents), social sciences (ca. 36%), medical and health sciences (ca. 11%), exact and natural sciences (ca. 7%); and being inhabitants of the following Provinces: Pomeranian (ca. 31% of all respondents), Lesser Poland (ca. 23%), Warmian-Mazurian (ca. 17%), and Mazovian (ca. 6%).

2.2. Questionnaire and data analysis

The research tool was constructed in such a way that the variables analyzed were a source of data allowing to achieve the assumed research goal and enabling verification of the research hypotheses under consideration. A set of statements adapted from studies/works by other authors was used while preparing the survey questionnaire (Table 2), which ultimately contained items related to:

- health attitudes—**HA** (5 items),

Table 1. Characteristics of the study sample (N = 1063).

Variable	N	% of Total
Gender		
women	649	61.05
men	414	38.95
Study profile		
engineering-technical sciences	424	39.89
social sciences	382	35.94
medical and health sciences	121	11.38
exact and natural sciences	71	6.68
agricultural sciences	30	2.82
humanities	30	2.82
theological sciences	4	0.38
the arts	1	0.09
Origin (Province)		
Pomeranian	331	31.14
Lesser Poland	247	23.24
Warmian-Mazurian	182	17.12
Mazovian	63	5.93
Greater Poland	48	4.52
Subcarpathian	31	2.92
Kuyavian-Pomeranian	30	2.82
Podlaskie	27	2.54
Silesian	21	1.98
West Pomeranian	19	1.79
Lubuskie	18	1.69
Świętokrzyskie	12	1.13
Lublin	10	0.94
Lower Silesia	10	0.94
Łódź	9	0.85
Opole	5	0.47

https://doi.org/10.1371/journal.pone.0300871.t001

- environmental attitudes—**EA** (3 items),
- attitude towards novel food—**NF** (7 items),
- attributes of novel food: organoleptic traits **CA1** (3 items), health quality—**CA2** (3 items), functional traits—**CA3** (4 items),
- attitudes towards food made from insects—**ATT** (4 items),
- intention to purchase food made from insects—**PI** (5 items).

During the survey, the respondents expressed the level of approval or disapproval of all the items listed, using a 5-point Likert scale, where the values 1,2 meant: definitely no, no; value 3 denoted an answer: I do not know, I have no opinion; and values 4,5, corresponded to answers: yes, definitely yes.

The questionnaire was validated by assessing the construction validity and estimating the reliability of the scales used. The collected empirical material obtained from the research underwent statistical analysis using the following methods:

Table 2. Variables and their measuring items.

Variables and their measuring items		Source
HA	1.1. The natural character of food products is an important quality attribute to me.	Kornher et al. (2019) [92]
	1.2. I try to buy organic food products.	
	1.3. I try to avoid food products containing food additives.	
	1.4. The quality certificate of purchased food is important to me.	
	1.5. The natural character of a production method is important to me.	
EA	2.1. When buying food, I try to pay attention to the fact how its production affects the natural environment.	Verbeke (2015) and Roberts (1996); Modlinska (2021) [84,91,93]
	2.2. I try to avoid food products, whose production has adverse effects on the natural environment.	
	2.3. I am interested in the impact of food production on the natural environment.	
NF	3.1. I am constantly trying new and different foods.	Pliner and Hobden (1992) [94]
	3.2 I do not trust new, unknown foods.	
	3.3 I do not try unknown foods.	
	3.4. I like foods from various national cuisines (ethnic food).	
	3.5. During parties/when I am out, I enjoy trying new foods.	
	3.6 I eat almost everything.	
	3.7. I like trying foods that are new to me.	
	3.8. The so-called "healthy food" looks too weird for me to eat.	
	3.9. I am afraid to eat something I have not eaten before.	
	3.10. I am very picky about the food I eat.	
CA1	4.1. Attractive taste.	Kornher et al. (2019) [92]
	4.2. Attractive aroma.	
	4.3. Attractive appearance.	
CA2	4.4. High nutritional value. 4.5. Health claims.	
	4.6. Nutritional claims.	
CA3	4.7. Various assortment and availability in retail. 4.8. Package size and attractiveness.	
	4.9. Convenience of use.	
	4.10. Availability of recipes on blogs and websites.	
ATT	5.1. I find buying novel food containing insects a good idea.	Wang et al. (2013) [95]
	5.2. I find buying novel food containing insects a wise choice.	
	5.3. I like the idea of buying novel, innovative food containing insects.	
	5.4. Buying novel, innovative food containing insects would be nice.	
PI	6.1. I would try dishes made from insects or with insect ingredients if I had the opportunity.	Kornher et al. (2019); Lee et al. (2010) [92,96]
	6.2. I am interested in eating dishes or food/food products made from insects in the near future.	
	6.3. If a "novel innovative food" appears on the market containing edible insects (fresh, frozen, dried, powdered, e.g., flour), which has such attributes as: reduction of CO_2 emissions, nutritional claims, health claims, attractive taste, and high nutritional value I would be willing to buy it.	
	6.4. I am willing to buy new food containing edible insects.	
	6.5. I will make an effort to buy foods containing insect protein in the near future.	

Explanatory notes

HA—health attitudes; EA- environmental attitudes; NF—- attitude towards novel food; CA1—attributes of novel food—organoleptic traits; CA2—attributes of novel food—health quality; CA3—attributes of novel food—functional traits; ATT—attitudes towards food made from insects; PI- intention to purchase food made from insects.

https://doi.org/10.1371/journal.pone.0300871.t002

- **Exploratory factor analysis and scale reliability analysis based on Cronbach's α coefficients.** These methods were used at the initial stage of data analysis to assess the validity and reliability of the scales used in the research tool.
- **Spearman correlation analysis**. This analysis was used to establish the strength and significance of correlations between dependent variables (ATT and PI) and independent variables (HA, EA, NF, CA1, CA2, and CA3).
- **Multiple Regression Analysis (MRA)** The MRA made it possible to build a model adjusted to empirical data, on the basis of which the potential of the examined independent variables (X) to explain consumer attitudes towards food made from insects and purchase intentions (Y), was estimated. The results were analyzed statistically using Statistica ver. 13.3.
- **Path analysis.** It was used to verify a hypothetical structural model depicting the immediate and intermediate effect(s) of the variables on the intention to purchase food made from insects. The latent variables of the model included, on the one hand, predictors of attitude (i.e., statistically significant variables selected on the basis of multidimensional linear regression analysis) and the attitude, and, on the other hand, the purchase intention. In-depth model verification was performed using R (ver. 4.1.2) and packages: lavaan (ver. 0.6.16) and tidySEM (ver. 0.2.4) (Bell Laboratories, New Jersey, USA). The criteria for assessing the quality of structural models are explicit. The quality of model fit was assessed using the RMSEA coefficient (*Root Mean Square Error of Approximation*), the Bentler CFI index (*Comparative Fit Index*), and the TLI index (*Tucker-Lewis Index*) [97,98].

3. Results

The validity and reliability of the measurement were estimated based on factor analysis and assessment of the internal consistency of individual scales using Cronbach's α coefficients (Table 3). The reliability assessment method deployed is one of the most commonly used scale homogeneity measurement techniques [99,100]. The reliability analysis was based on the correlation coefficients of all items of a given scale with the overall score of the scale. The values of the Cronbach's α coefficient range from 0 to 1. The minimal value of Cronbach's α coefficient greater than 0.7 was adopted according to the Nunnally's criterion [101,102]. Outliers, uncorrelated items and those that lowered the value of the reliability coefficient of a given scale were removed from the research tool. These included items 3.8, 3.9, and 3.10 of the NF scale. All scales used for further analyses were characterized by high internal consistency, above the threshold of satisfactory compliance ($\alpha > 0.7$). Values of Cronbach's α coefficients (Table 3) ranged from 0.82 to 0.94. The factor loadings of all items of the scale were above 0.6 (in the range from 0.65 to 0.97), meeting the criterion posited by Chin et al. [103].

The degree of association between dependent variables and independent variables was determined in the next stage of the study (Table 4). Statistically significant correlations were found both between the variable "attitude towards food made from insects" (ATT) and the variables assumed in the model as well as between the variable "intention to purchase food from insects" (PI) and the examined variables, whereas the strength of these correlations was observed to vary. In both cases, the values of correlation coefficients indicated moderate and weak but statistically significant correlations ($p < 0.05$). The analysis of the ATT demonstrated it was the most strongly correlated with the variables related to the following attributes of novel food products: CA1 ($r = 0.76$), CA2 ($r = 0.80$), and CA3 ($r = 0.77$). In contrast, the variables "environmental attitude" EA ($r = 0.22$) and "health-promoting attitude" HA ($r = 0.08$) were weakly corrected with ATT. Nevertheless, these correlations were statistically significant

Table 3. Measurement model: Reliability and validity.

Construct	Measurement item	Factor loadings	Cronbach α
HA	1.1.	-0.73	0.82
	1.2.	-0.78	
	1.3.	-0.74	
	1.4.	-0.75	
	1.5.	-0.82	
EA	2.1.	-0.92	0.86
	2.2.	-0.91	
	2.3.	-0.89	
NF	3.1.	-0.66	0.83
	3.2.	-0.65	
	3.3.	-0.66	
	3.4.	-0.65	
	3.5.	-0.77	
	3.6.	-0.71	
	3.7.	-0.82	
CA1	4.1.	-0.97	0.96
	4.2.	-0.97	
	4.3.	-0.96	
CA2	4.4.	-0.91	0.94
	4.5.	-0.96	
	4.6.	-0.97	
CA3	4.7.	-0.92	0.93
	4.8.	-0.88	
	4.9.	-0.93	
	4.10.	-0.88	
ATT	5.1.	-0.92	0.90
	5.2.	-0.95	
	5.3.	-0.91	
	5.4.	-0.76	
PI	6.1.	0.89	0.94
	6.2.	-0.93	
	6.3.	-0.95	
	6.4.	-0.86	
	6.5.	-0.83	

Abbreviations are defined in Table 2.

https://doi.org/10.1371/journal.pone.0300871.t003

($p < 0.05$). In addition, a significant negative correlation (r = - 0.32) was observed between the variables "attitude towards novelty" NF and "attitude towards food made from insects" ATT. When considering the correlations between the PI and the other variables, the strongest

Table 4. Correlations between the attitude and the intention and the analyzed variables.

	HA	EA	NF	CA1	CA2	CA3	ATT
ATT	0.08*	0.22*	-0.32*	0.76*	0.80*	0.77*	
PI	0.12*	0.23*	-0.30*	0.59*	0.75*	0.65*	0.80*

Abbreviations are defined in Table 2; *statistically significant correlations (at $p < 0.05$).

https://doi.org/10.1371/journal.pone.0300871.t004

statistically significant correlation (r = 0.80) was shown in the case of the variable ATT. There were also moderate statistically significant correlations between PI and CA1 ($r = 0.59$), CA2 ($r = 0.75$), and CA3 ($r = 0.65$). In turn, the variables HA, EA, and NF were weakly correlated with PI, with negative linear correlations found between NF and PI.

In order to verify hypotheses H1 and H2, an attempt was made to examine the combined effect of independent variables on the dependent variables ATT and PI using multiple regression analysis (MRA). All statistically significant variables ($p < 0.05$) that correlated with the attitude (ATT) (Eq 1) and with the purchase intention (PI) (Eq 2) were included in the regression equation. The analyzed regression equations were as follows:

$$\mathrm{ATT} = f(\mathrm{HA},\ \mathrm{EA},\ \mathrm{NF},\ \mathrm{CA1},\ \mathrm{CA2},\ \mathrm{CA3}) \tag{1}$$

$$\mathrm{PI} = f(\mathrm{HA},\ \mathrm{EA},\ \mathrm{NF},\ \mathrm{CA1},\ \mathrm{CA2},\ \mathrm{CA3},\ \mathrm{ATT}) \tag{2}$$

In the next stage of the analysis, models were built and verified in accordance with generally accepted procedures. The results of the estimation of the model parameters enabled selecting independent variables which had a significant impact on ATT and PI. Tables 5 and 6 present the values of parameters related to the models indicating the variables important for the attitudes and the intentions of purchasing novel food from insects. The values of the coefficient of determination R^2 of the proposed models were 0.69 and 0.70, which means that 69% and 70% of the total variability of the dependent variables ATT and PI, respectively, were explained by the adopted linear regression models. Thus, these models are characterized by a good fit to experimental data. According to the results obtained, the variable ATT (Table 5) was the most strongly influenced by the attributes of new products related to health quality CA2 ($\beta = 0.41$, $p = 0.00$) and organoleptic attributes CA1 ($\beta = 0.33$, $p = 0.00$), whereas the "functional trait" variable CA3 exerted a slightly weaker effect ($\beta = 0.11$, $p = 0.01$). In turn, the variables HA, EA and NF had the weakest influence on the variable ATT ($p < 0.05$). From the presented model showing variables important for the intention to purchase new food (Table 6), it appears that the strongest predictors of the variable PI were: attitudes toward food made from insects ATT ($\beta = 0.64$, $p = 0.00$) and health quality characteristics of the novel products CA2 ($\beta = 0.59$, $p = 0.00$). In turn, the variables CA1 and CA3 had a negative impact on PI, which was interpreted as reluctance of the persons paying much attention to organoleptic and functional

Table 5. Values of parameters related to the model indicating variables important for attitudes towards insects.

Variables	Non-standardized Coefficients β	Standard error	Standardized coefficients β	Values t	p
Intercept term	0.62	0.11		5.42	0.00
HA	-0.06	0.03	-0.05	-2.29	0.02
EA	0.08	0.02	0.07	3.47	0.00
NF	-0.09	0.03	-0.06	-3.49	0.00
CA1	0.28	0.03	0.33	10.89	0.00
CA2	0.37	0.04	0.41	9.66	0.00
CA3	0.09	0.04	0.11	2.47	0.01
$R^2 = 0.69$ $F(6.10) = 391.55$		standard error of the estimate = 0.72			
$p < 0.00$					

Abbreviations are defined in Table 2.

https://doi.org/10.1371/journal.pone.0300871.t005

Table 6. Values of parameters related to the model indicating variables important for the intention to purchase food made from insects.

Variables	Non-standardized coefficients *β*	Standard error	Standardized coefficients *β*	Values *t*	*p*
Intercept term	0.13	0.11		1.18	0.24
HA	0.02	0.02	0.02	0.78	0.44
EA	0.01	0.02	0.01	0.51	0.61
NF	-0.03	0.03	-0.02	-1.04	0.30
CA1	-0.16	0.03	-0.19	-5.99	0.00
CA2	0.51	0.04	0.59	13.50	0.00
CA3	-0.20	0.04	-0.23	-5.41	0.00
ATT	0.63	0.03	0.64	21.09	0.00
R^2 = 0.70 F(7.10) = 352.04		standard error of the estimate = 0.69			
$p < 0.00$					

Abbreviations are defined in Table 2.

https://doi.org/10.1371/journal.pone.0300871.t006

attributes of food to purchase this food. But, the variables HA, EA and NF had no statistically significant ($p < 0.05$) effect on the model.

In the next stage of the study, an attempt was made to identify the variables which enabled predicting the intentions of purchasing food from insects. A path analysis was used to this end. The results of a multidimensional regression analysis showed that not all variables affected the intentions of purchasing food from insects. Only those variables that were statistically significant ($p < 0.05$) were included in the model. Fig 1 and Table 7 presents the parameters of the structural model accepted due to the matching measures of the structural model showing the intermediate and immediate impact of the variables on the intention to purchase food from insects. Good model fit was evidenced by the following indicators: RMSEA value not exceeding 0.06; the CFI = 1, which means that the model explains 100% of covariance; and TLI value level 1.

Our study suggested that the variable most strongly influencing the intentions of purchasing food from insects was related to the health quality of products CA2. That variable affected intentions both directly ($\beta = 0.53$, $p = 0.00$) and indirectly through attitudes ATT ($\beta = 0.63$, $p = 0.00$). Furthermore, it was found that the variables organoleptic attributes CA1 ($\beta = -0.16$, $p = 0.00$) and functional characteristics of the products CA3 ($\beta = -0.20$, $p = 0.00$) had an immediate negative effect on the intentions to purchase food from insects. In turn, these variables were found to affect indirectly, through attitudes ATT, the purchasing intentions PI at the levels: CA1 $\beta = 0.28$, $p = 0.00$ and CA3 $\beta = 0.09$, $p < 0.05$, respectively. The least dominant variables with the indirect (through ATT) influence on the variable PI were also HA, EA, and NF. These variables explained ca. 70% of the total variance ($R^2 = 0.69$) for both ATT and PI (Fig 1). In addition, the study demonstrated strong correlations between ATT and PI ($\beta = 0.63$, $p = 0.00$). The proposed structural model offers a highly probable prediction of the intentions to purchase food from insects PI based on the variable "attitude toward food made from insects" ATT.

4. Discussion

Analysis of the results of empirical research presented in this manuscript enabled accomplishing the study goal and verifying the research hypotheses. The results of quantitative research allowed us to propose models indicating variables important for the attitudes and behaviors of

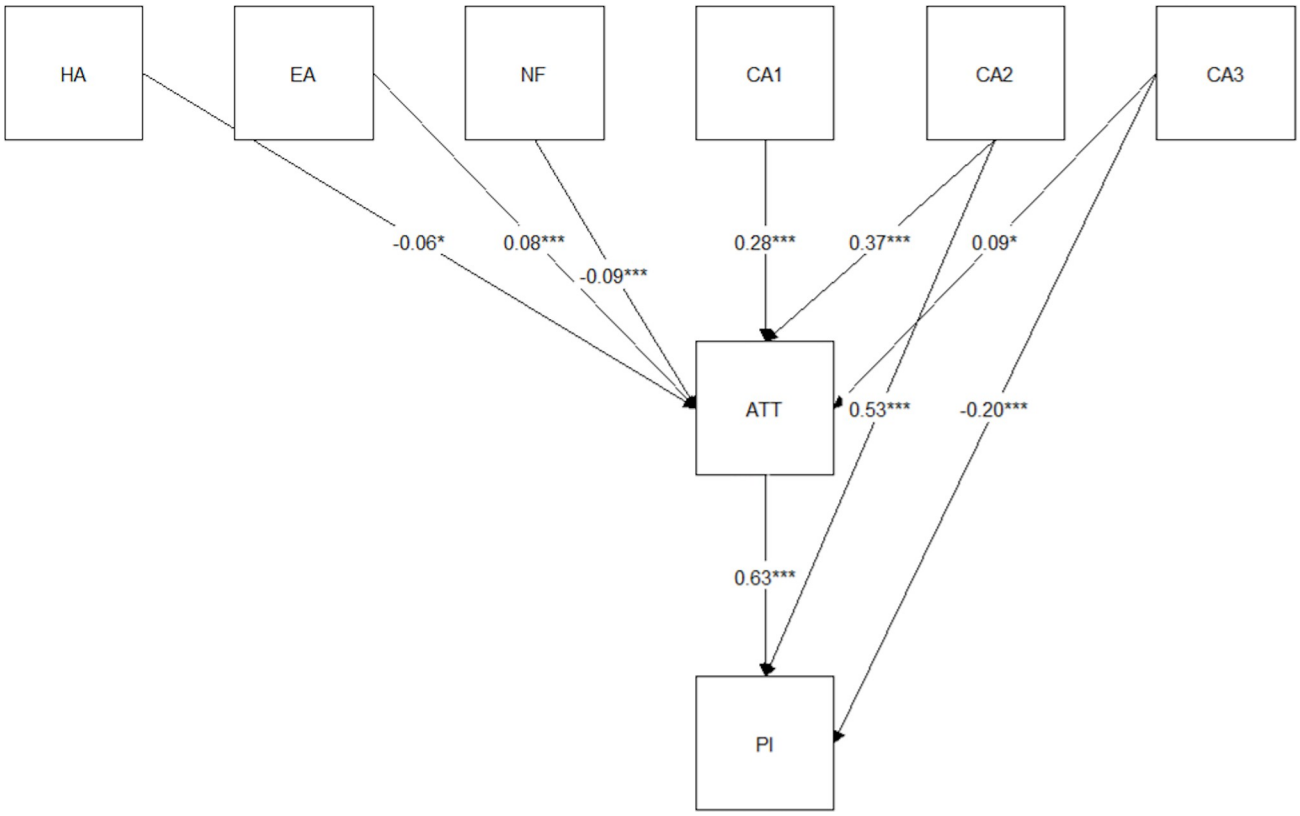

Fig 1. A structural model showing the intermediate and immediate impact of the predictors on the intention to purchase food from insects.
Explanatory notes: Abbreviations are defined in Table 2; *values statistically significant at p<0.05; ***values statistically significant at p<0.001.

https://doi.org/10.1371/journal.pone.0300871.g001

young consumers towards food made from insects The models based on multidimensional linear regression analysis (Tables 5 and 6) and the path analysis (Fig 1), developed using empirical data, demonstrated that attitudes towards novel products as well as health and environmental

Table 7. Values of parameters related to the structural model.

Variables	Standardized β values	Standard error	Values	*p*
ATT ~				
HA	-0.06	0.02	-2.29	0.02
EA	0.08	0.02	3.48	0.00
NF	-0.09	0.02	-3.50	0.00
CA1	0.28	0.03	10.92	0.00
CA2	0.37	0.04	9.69	0.00
CA3	0.09	0.04	2.47	0.01
PI ~				
ATT	0.63	0.03	21.53	0.00
CA1	-0.16	0.03	-6.05	0.00
CA2	0.53	0.04	14.12	0.00
CA3	-0.20	0.04	-5.63	0.00

Abbreviations are defined in Table 2.

RMSEA = 0.00, Comparative Fit Index (CFI) = 1.00, Tucker-Lewis Index (TLI) = 1.00, p = 0.00, R2(ATT) = 0.69, R2(PI) = 0.69.

https://doi.org/10.1371/journal.pone.0300871.t007

attitudes do not play a significant role in explaining positive attitudes and intentions to purchase food from insects. The survey results proved that food quality characteristics (nutritional value, health claims, nutritional claims) were predictors of attitudes and behaviors of young consumers towards food made from insects. The study also showed that the intention to purchase such food can be predicted based on the assessment of the importance of sensory attributes and functional characteristics of these novel products. Thus, the research hypotheses (H1 and H2) advanced in the study were in part verified positively.

The paucity of data on attitudes and behaviors of young consumers towards insect food impairs in-depth comparison of the results obtained with other authors' findings. In the light of the results obtained, it is also expected that those consumers who value the quality of products certified by the manufacturer will show a more positive attitude towards food from insects and the willingness to purchase it in the future. Other studies have confirmed that perception of beneficial features of a product, such as its health and nutritional value, may to some extent increase consumers' willingness to try insect-based foods [49,51,88,104–110]. Some authors [111] have emphasized that sensory attributes of insect-based foods may be the dominant factors or barriers, depending on the degree of similarity to known foods. Processing insects into well-known food products promotes their acceptance. A growing interest has recently been noted in the subject of food neophobia in the acceptance of entomophages, especially in European countries where the concept of eating insects is relatively new [112–114]. One of the studies addressing this issue [115] demonstrated that persons with lower overall neophobia and a greater tendency to seek diversity tried food from insects earlier than those from the other studied groups. Negative effects of food neophobia on the acceptance of insects as food have also been observed [88] in both developed and developing countries, for example Italy [7,74,104,114–118], Germany [47,49,119–121], Poland [122], Switzerland [123], Australia [7], Hungary [46], Taiwan [124], China [106], and Uganda [125]. On the other hand, although the present study results demonstrated negative correlations between the level of neophobia and the attitudes and purchase intentions towards food from insects (Table 4), they failed to confirm that the neophobic attitudes among young consumers were important in explaining their positive attitudes and intentions to purchase food from insects. In view of the results obtained, it seems appropriate to further explore consumer attitudes toward novel foods. The proposed models, fitted to empirical data, are the starting point for further research. In the future, it would be necessary to verify the fit of the developed models with empirical data obtained from a broader range of subjects. In addition, the obtained study results confirm findings from earlier works proving that the attitudes make important prognostic factors of purchase intentions. The literature works emphasize the high prognostic usefulness of models illustrating the influence of attitudes on purchasing intentions of buyers [126–131].

Our findings could inform policymakers about potential strategies to promote the adoption of insect-based foods, such as incentivizing manufacturers to highlight health and environmental benefits on product labels or providing subsidies for research and development in this area. Furthermore, insights from the study can guide future marketing efforts to effectively communicate the nutritional and environmental benefits of insect-based foods, to target specific consumer segments identified as more receptive to such messaging. As such, understanding consumer preferences can inform product development efforts, guiding manufacturers in optimizing the sensory attributes and functional characteristics of insect-based food products to better align with consumer expectations. Indeed, educating consumers about the nutritional value, sustainability, and safety of insect-based foods through targeted educational campaigns could help overcome barriers to acceptance and foster more positive attitudes towards these products.

However, there are some limitations related to the presented study. The research was conducted in a narrow subjective approach and only among university students representing but a

segment of young buyers. The proposed models, fitted to empirical data, generated the starting points for further research. In the future, they should be revised in a broader range of subjects. An additional follow-up longitudinal study could provide deeper insights into how attitudes and behaviors towards insect-based foods evolve over time. This would help understand the sustainability of acceptance and consumption patterns, allowing for more robust predictions and interventions and helping to predict market trends and to inform strategic planning.

5. Conclusions

We identified moderate to weak, but statistically significant, relationships between both attitude and the variables assumed in the model and intention and the variables studied. The study results demonstrated that the attributes of insect-based food products can influence the positive attitudes towards them and behavioral intentions to consume them, and that the strength of the impact of health quality traits is far greater than that of the organoleptic or functional traits. Intention to purchase food containing insects correlated most strongly with the purchasers' attitudes towards insect food. Thus, respondents who did not exhibit food neophobia were characterized by positive attitudes towards purchasing foods containing edible insects in their composition. The variable that has the strongest effect on the purchase intentions for insect food is the characteristics related to the health quality of the products. This variable affects intentions both directly and indirectly through attitudes. From the proposed structural model, it is clear that purchase intentions for insect food can be predicted with high probability from the variable "attitudes towards insect food". As part of further research on consumer attitudes towards food made from insects in Poland, it is planned to: (a) characterize potential consumers of food from insects, and (b) identify factors that determine and diminish the demand for this category of food. Further research in this area seems useful and justified in order to support sustainable development in the environmental dimensions.

Author Contributions

Conceptualization: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska.

Data curation: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Karolina Mikulec, Marcin Nowicki.

Formal analysis: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Millena Ruszkowska, Karolina Mikulec, Grzegorz Suwała, Marcin Nowicki.

Funding acquisition: Marcin Nowicki.

Investigation: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Millena Ruszkowska, Grzegorz Suwała.

Methodology: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Karolina Mikulec, Grzegorz Suwała.

Project administration: Anna T. Mikulec, Anna M. Platta.

Resources: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Przemysław Łukasz Kowalczewski.

Supervision: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Stanisław Kowalski, Przemysław Łukasz Kowalczewski, Marcin Nowicki.

Validation: Anna T. Mikulec, Monika Radzymińska, Karolina Mikulec, Grzegorz Suwała, Stanisław Kowalski, Przemysław Łukasz Kowalczewski.

Visualization: Anna T. Mikulec, Marcin Nowicki.

Writing – original draft: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Millena Ruszkowska, Stanisław Kowalski.

Writing – review & editing: Anna T. Mikulec, Anna M. Platta, Monika Radzymińska, Przemysław Łukasz Kowalczewski, Marcin Nowicki.

References

1. Cerda H, Martinez R, Briceno N, Pizzoferrato L, Manzi P, Ponzetta MT, et al. Palm Worm: (*Rhynchophorus palmarum*) Traditional Food in Amazonas, Venezuela-Nutritional Composition, Small Scale Production and Tourist Palatability. Ecol Food Nutr. 2001; 40:13–32. https://doi.org/10.1080/03670244.2001.9991635.
2. Yi C, He Q, Wang L, Kuang R. The Utilization of Insect-Resources in Chinese Rural Area. J Agric Sci. 2010; 2:146. https://doi.org/10.5539/jas.v2n3p146.
3. Belluco S, Losasso C, Maggioletti M, Alonzi CC, Paoletti MG, Ricci A. Edible insects in a food safety and nutritional perspective: A critical review. Compr. Rev. Food Sci Food Saf. 2013; 12: 296–313. https://doi.org/10.1111/1541-4337.12014.
4. Kinyuru J N, Konyole SO, Roos N, Onyango CA, Owino VO, Owuor BO, et al. Nutrient composition of four species of winged termites consumed in western Kenya. J Food Compos Anal. 2013; 30:120–124. https://doi.org/10.1016/j.jfca.2013.02.008.
5. van Huis A, Rumpold BA, van der Fels-Klerx HJ, Tomberlin J.K. Advancing edible insects as food and feed in a circular economy. J Insects Food Feed. 2021; 7:935–948. https://doi.org/10.3920/JIFF2021.x005.
6. Raheem D, Carrascosa C, Oluwole OB, Nieuwland M, Saraiva A, Millán R, et al. Traditional consumption of and rearing edible insects in Africa, Asia and Europe. Crit Rev Food Sci Nutr. 2019; 59: 2169–2188. https://doi.org/10.1080/10408398.2018.1440191 PMID: 29446643
7. Sogari G, Bogueva D, Marinova D. Australian consumers'response to insects as food. Agric. 2019; 9:1–15. https://doi.org/10.3390/agriculture9050108.
8. Gómez-Luciano CA, de Aguiar LK, Vriesekoop F, Urbano B. Consumers' Willingness to Purchase Three Alternatives to Meat Proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. Food Qual Prefer. 2019; 78:103732. https://doi.org/10.1016/j.foodqual.2019.103732.
9. Baiano A. Edible insects: An overview on nutritional characteristics, safety, farming, production technologies, regulatory framework, and socio-economic and ethical implications. Trends Food Sci Technol. 2020; 100:35–50. https://doi.org/10.1016/j.tifs.2020.03.040.
10. Gahukar RT. Edible insects collected from forests for family livelihood and wellness of rural communities: A review. Glob. Food Secur. 2020; 25:100348. https://doi.org/10.1016/j.gfs.2020.100348.
11. Egonyu JP, Kinyuru J, Fombong F, Ng'ang'a J, Ahmed YA, Niassy S. Advances in Insects for Food and Feed. Springer: Berlin/Heidelberg, Germany. 2021; 41:1903–1911. https://doi.org/10.1007/s42690-021-00610-8.
12. Liceaga AM. Edible insects, a valuable protein source from ancient to modern times. Adv Food Nutr Res. 2022; 101:129–152. https://doi.org/10.1016/bs.afnr.2022.04.002 PMID: 35940702
13. Matandirotya NR, Filho WL, Mahed G, Maseko B, Murandu CV. Edible Insects Consumption in Africa towards Environmental Health and Sustainable Food Systems: A Bibliometric Study. Int. J Environ Res Public Health. 2022; 19:14823. https://doi.org/10.3390/ijerph192214823 PMID: 36429542
14. Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein. https://data.europa.eu/eli/reg/2017/893/oj.
15. Kim TK, Yong HI, Kim YB, Kim HW, Choi YS. Edible Insects as a Protein Source: A Review of Public Perception, Processing Technology, and Research Trends. Food Sci Anim Resour. 2019; 39(4):521–540. https://doi.org/10.5851/kosfa.2019.e53 PMID: 31508584
16. Gałęcki R, Zielonka Ł, Zasępa M, Gołębiowska J, Bakuła T. Potential Utilization of Edible Insects as an Alternative Source of Protein in Animal Diets in Poland. Front Sustain Food S. 2021; 5:675796. https://doi.org/10.3389/fsufs.2021.675796.
17. Commission Implementing Regulation (EU) 2022/188 of 10 February 2022 authorising the placing on the market of frozen, dried and powder forms of Acheta domesticus as a novel food under Regulation

(EU) 2015/2283 of the European Parliament and of the Council, and amending Commission Implementing Regulation (EU) 2017/2470. https://data.europa.eu/eli/reg_impl/2022/188/oj.

18. Commission Implementing Regulation (EU) 2023/5 of 3 January 2023 authorising the placing on the market of Acheta domesticus (house cricket) partially defatted powder as a novel food and amending Implementing Regulation (EU) 2017/2470. https://data.europa.eu/eli/reg_impl/2023/5/oj.
19. van Huis A, Oonincx DGAB. The environmental sustainability of insects as food and feed. A review Agron Sustain Dev. 2017; 37:1–14. https://doi.org/10.1007/s13593-017-0452-8.
20. Berggren Å, Jansson A, Low M. Approaching Ecological Sustainability in the Emerging Insects-as-Food Industry. Trends Ecol Evol. 2019; 34:132–138. https://doi.org/10.1016/j.tree.2018.11.005 PMID: 30655013
21. Skotnicka M, Karwowska K, Kłobukowski F, Borkowska A, Pieszko M. Possibilities of the Development of Edible Insect. Based Foods in Europe. Foods. 2021; 10:766. https://doi.org/10.3390/foods10040766.
22. Skotnicka M, Mazurek A, Karwowska K, Folwarski M. Satiety of Edible Insect-Based Food Products as a Component of Body Weight Control. Nutrients. 2022; 14:2147. https://doi.org/10.3390/nu14102147 PMID: 35631288
23. Ruszkowska M, Tańska M, Kowalczewski PŁ. Extruded Corn Snacks with Cricket Powder: Impact on Physical Parameters and Consumer Acceptance. Sustainability. 2022; 14:16578. https://doi.org/10.3390/su142416578.
24. Shantibala T, Lokeshwari RK, Debaraj H. Nutritional and Antinutritional Composition of the Five Species of Aquatic Edible Insects Consumed in Manipur, India. J Insect Sci. 2014; 14:14. https://doi.org/10.1093/jis/14.1.14 PMID: 25373161
25. Zielińska E, Baraniak B, Karaś M, Rybczyńska K, Jakubczyk A. Selected Species of Edible Insects as a Source of Nutrient Composition. Food Res Int. 2015; 77:460–466. https://doi.org/10.1016/j.foodres.2015.09.008.
26. Kim SK, Weaver CM, Choi MK. Proximate Composition and Mineral Content of Five Edible Insects Consumed in Korea. CYTA J Food. 2016; 15:143–146. https://doi.org/10.1080/19476337.2016.1223172.
27. Hong J, Han T, Kim YY. Mealworm (Tenebrio molitor Larvae) as an Alternative Protein Source for Monogastric Animal: A Review. Animals. 2020; 10:2068. https://doi.org/10.3390/ani10112068 PMID: 33171639
28. Shah AA, Wanapat M. Gryllus testaceus walker (crickets) farming management, chemical composition, nutritive profile, and their effect on animal digestibility. Èntomol Res. 2021; 51:639–649. https://doi.org/10.1111/1748-5967.12557.
29. Shah AA, Totakul P, Matra M, Cherdthong A, Harnboonsong Y, Wanapat M. Nutritional composition of various insects and potential uses as alternative protein sources in animal diets. Anim Biosci. 2022; 35:317–331. https://doi.org/10.5713/ab.21.0447 PMID: 34991214
30. Ghosh S, Sohn HY, Pyo SJ, Jensen AB, Meyer-Rochow VB, Jung C. Nutritional Composition of Apis mellifera Drones from Korea and Denmark as a Potential Sustainable Alternative Food Source: Comparison between Developmental Stages. Foods. 2020; 9:389. https://doi.org/10.3390/foods9040389 PMID: 32230865
31. Köhler R, Kariuki L, Lambert C, Biesalski HK. Protein, Amino Acid and Mineral Composition of Some Edible Insects from Thailand. J Asia Pac Entomol. 2019; 22:372–378. https://doi.org/10.1016/j.aspen.2019.02.002.
32. Ghosh S, Lee SM, Jung C, Meyer-Rochow VB. Nutritional Composition of Five Commercial Edible Insects in South Korea. J Asia Pac Entomol. 2017; 20:686–694. https://doi.org/10.1016/j.aspen.2017.04.003.
33. Nowakowski AC, Miller AC, Miller ME, Xiao H, Wu X. Potential health benefits of edible insects. Crit Rev Food Sci Nutr. 2022; 62(13):3499–3508. https://doi.org/10.1080/10408398.2020.1867053 PMID: 33397123
34. FAO. Edible Insects—Future Prospects for Food and Feed Security. 2013. Available online: https://www.fao.org/docrep/018/i3 253e/i3253e00.htm (accessed on 06 November 2023).
35. Rumpold BA, Schluter OK. Potential and challenges of insects as an innovative source for food and feed production. Innov. Food Sci Emerg. Technol. 2013; 17:1–11. https://doi.org/10.1016/j.ifset.2012.11.005.
36. Borrello M, Caracciolo F, Lombardi A, Pascucci S, Cembalo L. Consumers' perspective on circular economy strategy for reducing food waste. Sustainability. 2017; 9(1). https://doi.org/10.3390/su9010141.

37. Ojha S, Bußler S, Schlüter OK. Food waste valorisation and circular economy concepts in insect production and processing. Waste Manag. 2020; 118:600–609. https://doi.org/10.1016/j.wasman.2020.09.010 PMID: 33010691

38. Imathiu S. Benefits and food safety concerns associated with consumption of edible insects. NFS Journal. 2020; 18:1–11. https://doi. org/10.1016/j.nfs.2019.11.002.

39. Müller A, Evans J, Payne C, Roberts R. Entomophagy and Power. J Insects Food Feed. 2016; 2:121–136. https://doi.org/10.3920/JIFF2016.0010.

40. FAO. Looking at Edible Insects from a Food Safety Perspective. Challenges and Opportunities for the Sector; FAO: Rome, Italy, 2021. https://doi.org/10.4060/cb4094en.

41. Zugravu C, Tarcea M, Nedelescu M, Nu¸t ˘a D, Guiné RPF. Constantin, C. Knowledge: A Factor for Acceptance of Insects as Food. Sustainability. 2023; 15:4820. https://doi.org/10.3390/su15064820.

42. Niyonsaba HH, Höhler J, Kooistra J, Van der Fels-Klerx HJ, Meuwissen MPM. Profitability of insect farms. J Insects as Food Feed. 2021; 7: 923–934. https://doi.org/10.3920/JIFF2020.0087.

43. Orkusz A. Edible insects–future food. Engineering Sciences and Technologies. 2021; 37:151–160. https://doi.org/10.15611/nit.2021.37.08.

44. Megido RC, Gierts C, Blecker C, Brostaux Y, Haubruge E, Alabi T, et al. Consumer acceptance of insect-based alternative meat products in Western countries. Food Qual Prefer. 2016; 52:237–243. https://doi.org/10.1016/j.foodqual.2016.05.004.

45. House J. Consumer acceptance of insect-based foods in the Netherlands: Academic and commercial implications. Appetite. 2016; 107:47–58. https://doi.org/10.1016/j.appet.2016.07.023 PMID: 27444958

46. Gere A, Székely G, Kovács S, Kókai Z, Sipo L. Readiness to adopt insects in Hungary: A case study. Food Qua. Prefer. 2017; 59:81–86. https://doi.org/10.1016/j.foodqual.2017.02.005.

47. Lammers P, Ullmann LM, Fiebelkorn F. Acceptance of insects as food in Germany: Is it about sensation seeking, sustainability consciousness, or food disgust? Food Qual Prefer. 2019; 77:78–88. https://doi.org/10.1016/j.foodqual.2019.05.010.

48. Onwezen MC, van den Puttelaar J, Verain MCD, Veldkamp T. Consumer acceptance of insects as food and feed: The relevance of affective factors. Food Qual Prefer. 2019; 77:51–63. https://doi.org/10.1016/j.foodqual.2019.04.011.

49. Dupont J, Fiebelkorn F. Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany. Food Qual Prefer. 2020; 85:103983. https://doi.org/10.1016/j.foodqual.2020.103983.

50. La Barbera F, Verneau F, Amato M, Grunert KG, Schnettler B. Acceptance of insect-based food in Chile: Evidence from a survey using the entomophagy attitude questionnaire (EAQ). Food Qual Prefer. 2021; 93:104269. https://doi.org/10.1016/j.foodqual.2021.104269.

51. Motoki K, Park J, Spence C, Velasco C. Contextual acceptance of novel and unfamiliar foods: Insects, cultured meat, plant-based meat alternatives, and 3D printed foods. Food Qual Prefer. 2021; 96:104368. https://doi.org/10.1016/j.foodqual.2021.104368.

52. Hopkins I, Farahnaky A, Gill H, Newman LP, Danaher J. Australians' experience, barriers and willingness towards consuming edible insects as an emerging protein source. Appetite. 2022; 169:105832. https://doi.org/10.1016/j.appet.2021.105832 PMID: 34896167

53. Ribeiro JC, Gonçalves ATS, Moura AP, Varela P, Cunha LM. Insects as food and feed in Portugal and Norway-Crosscultural comparison of determinants of acceptance. Food Qual Prefer. 2022; 102:104650. https://doi.org/10.1016/j.foodqual.2022.104650.

54. Erhard AL, Silva M, Damsbo-Svendsen M, Karpantschof BEM, Sørensen H, Frøst MB. Acceptance of insect foods among Danish children: Effects of information provision, food neophobia, disgust sensitivity, and species on willingness to try. Food Qual Prefer. 2023; 104:104713. https://doi.org/10.1016/j.foodqual.2022.104713.

55. Palmieri N, Nervo C, Torri L. Consumers' attitudes towards sustainable alternative protein sources: Comparing seaweed, insects and jellyfish in Italy. Food Qual Prefer. 2023; 104:104735. https://doi.org/10.1016/j.foodqual.2022.104735.

56. White KP, Al-Shawaf L, Lewis DM, Wehbe YS. Food neophobia and disgust, but not hunger, predict willingness to eat insect protein. Pers Individ Differ. 2023; 202:111944. https://doi.org/10.1016/j.paid.2022.111944.

57. Stull VJ, Finer E, Bergmans RS, Febvre HP, Longhurst C, Manter DK, et al. Impact of edible cricket consumption on gut microbiota in healthy adults, a double-blind, randomized crossover trial. Sci Rep. 2018; 8:10762. https://doi.org/10.1038/s41598-018-29032-2 PMID: 30018370

58. Montowska M, Kowalczewski PŁ, Rybicka I, Fornal E. Nutritional value, protein and peptide composition of edible cricket powders. Food Chem. 2019; 289:130–138. https://doi.org/10.1016/j.foodchem.2019.03.062 PMID: 30955594

59. Stone A, Tanaka T, Nickerson M. Protein quality and physicochemical properties of commercial cricket and mealworm powders. J Food Sci Technol. 2019; 56:3355–3363. https://doi.org/10.1007/s13197-019-03818-2 PMID: 31274903

60. Osimani A, Milanovi´c V, Cardinali F, Roncolini A, Garofalo C, Clementi F, et al. Bread enriched with cricket powder (Acheta domesticus): A technological, microbiological and nutritional evaluation. Innov Food Sci Emerg Technol. 2018; 48:150–163. https://doi.org/10.1016/j.ifset.2018.06.007.

61. da Rosa Machado C, Thys RCS. Cricket powder (Gryllus assimilis) as a new alternative protein source for gluten-free breads. Innov. Food Sci Emerg Technol. 2019; 56:102180. https://doi.org/10.1016/j.ifset.2019.102180.

62. Smarzyński K, Sarbak P, Musiał S, Jeżowski P, Piątek M, Kowalczewski PŁ. Nutritional Analysis and Evaluation of the Consumer Acceptance of Pork Pâté Enriched with Cricket Powder-Preliminary Study. Open Agric. 2019; 4:159–163. https://doi.org/10.1515/opag-2019-0015.

63. Walkowiak K, Kowalczewski PŁ, Kubiak P, Baranowska HM. Effect of cricket powder addition on 1H NMR mobility and texture of pork pate. J Microbiol Biotechnol Food Sci. 2019; 9:191–194. https://doi.org/10.15414/jmbfs.2019.9.2.191–194.

64. Bawa M, Songsermpong S, Kaewtapee C, Chanput W. Nutritional, sensory, and texture quality of bread and cookie enriched with house cricket (Acheta domesticus) powder. J Food Process Preserv. 2020; 44,e14601. https://doi.org/10.1111/jfpp.14601.

65. Kowalczewski PŁ, Gumienna M, Rybicka I, Górna B, Sarbak P, Dziedzic K, et al. Nutritional Value and Biological Activity of Gluten-Free Bread Enriched with Cricket Powder. Molecules. 2021; 26:1184. https://doi.org/10.3390/molecules26041184 PMID: 33672127

66. Kowalczewski PŁ, Walkowiak K, Masewicz Ł, Smarzyński K, Thanh-Blicharz JL, Kac˘ániová M, et al. LF NMR spectroscopy analysis of water dynamics and texture of gluten-free bread with cricket powder during storage. Food Sci Technol Int. 2021; 27:776–785. https://doi.org/10.1177/1082013220987914 PMID: 33444100

67. Zielińska E, Pankiewicz U, Sujka M. Nutritional, physiochemical, and biological value of muffins enriched with edible insects flour. Antioxidants. 2021; 10:1122. https://doi.org/10.3390/antiox10071122 PMID: 34356355

68. Adámek M, Adámková A, Ml˘cek J, Borkovcov M, Bedná˘rová M. Acceptability and sensory evaluation of energy bars and protein bars enriched with edible insect. Potravin. Slovak J Food Sci. 2018; 12:431–437. https://doi.org/10.5219/925

69. Biró B, Fodor R, Szedljak I, Pásztor-Huszár K, Gere A. Buckwheat-pasta enriched with silkworm powder: Technological analysis and sensory evaluation. LWT. 2019; 116:108542. https://doi.org/10.1016/j.lwt.2019.108542.

70. Duda A, Adamczak J, Chełmińska P, Juszkiewicz J, Kowalczewski P. Quality and Nutritional/Textural Properties of Durum Wheat Pasta Enriched with Cricket Powder. Foods. 2019; 8:46. https://doi.org/10.3390/foods8020046 PMID: 30717098

71. Biró B, Sipos MA, Kovács A, Badak-Kerti K, Pásztor-Huszár K, Gere A. Cricket-Enriched Oat Biscuit: Technological Analysis and Sensory Evaluation. Foods, 2020; 9:1561. https://doi.org/10.3390/foods9111561 PMID: 33126518

72. Lensvelt E, Steenbekkers L.P.A. Exploring Consumer Acceptance of Entomophagy: A Survey and Experiment in Australia and the Netherlands. Ecol. Food Nutr. 2014, 53,543–561. https://doi.org/10.1080/03670244.2013.879865 PMID: 25105864

73. Verneau F, la Barbera F, Kolle S, Amato M, del Giudice T, Grunert K. The effect of communication and implicit associations on consuming insects: An experiment in Denmark and Italy. Appetite. 2016; 106:30–36. https://doi.org/10.1016/j.appet.2016.02.006 PMID: 26855371

74. Mancini S, Sogari G, Menozzi D, Nuvoloni R, Torracca B, Moruzzo R, et al. Factors Predicting the Intention of Eating an Insect-Based Product. Foods. 2019; 8:270. https://doi.org/10.3390/foods8070270 PMID: 31331106

75. Dagevos HA. Literature review of consumer research on edible insects: recent evidence and new vistas from 2019 studies. J Insects Food Feed. 2021; 7:249–259. https://doi.org/10.3920/JIFF2020.0052.

76. Tzompa-Sosa DA, Moruzzo R, Mancini S, Schouteten JJ, Liu A, Li J. Consumers' acceptance toward whole and processed mealworms: A cross-country study in Belgium, China, Italy, Mexico, and the US. PLoS ONE. 2023; 18(1):e0279530. https://doi.org/10.1371/journal.pone.0279530 PMID: 36630382

77. Pauter P, Różańska M, Wiza P, Dworczak S, Grobelna N, Sarbak P, et al. Effects of the Replacement of Wheat Flour with Cricket Powder on the Characteristics of Muffins. Acta Sci Pol Technol Aliment. 2018; 17:227–233. https://doi.org/10.17306/J.AFS.0570 PMID: 30269462

78. Kowalski S., Mikulec A, Skotnicka M, Mickowska B, Makarewicz M, Sabat R, et al. Effect of the Addition of Edible Insect Flour from Yellow Mealworm (Tenebrio molitor) on the Sensory Acceptance, and the Physicochemical and Textural Properties of Sponge Cake. Pol J Food Nutr Sci. 2022; 72:393–405. https://doi.org/10.31883/pjfns/155405.

79. Mazurek A, Palka A, Skotnicka M, Kowalski S. Consumer Attitudes and Acceptability of Wheat Pancakes with the Addition of Edible Insects: Mealworm (*Tenebrio molitor*), Buffalo Worm (*Alphitobius diaperinus*), and Cricket (Acheta domesticus). Foods. 2023; 12:1. https://doi.org/10.3390/foods12010001.

80. Gumul D, Oracz J, Kowalski S, Mikulec A, Skotnicka M, Karwowska K, et al. Bioactive Compounds and Antioxidant Composition of Nut Bars with Addition of Various Edible Insect Flours. Molecules. 2023; 28:3556. https://doi.org/10.3390/molecules28083556 PMID: 37110790

81. Kowalski S, Gumul D. Oracz J, Rosicka-Kaczmarek J, Mikulec A, Mickowska B, et al. Chemical Composition, Antioxidant Properties and Sensory Aspects of Sponge Cakes Supplemented with Edible Insect Flours. Antioxidants. 2023; 12:1912. https://doi.org/10.3390/antiox12111912 PMID: 38001765

82. Ruby MB, Rozin P, Chan C. Determinants of willingness to eat insects in the USA and India. J. Insects Food Feed. 2015; 1:215–225. https://doi.org/10.3920/JIFF2015.0029

83. Testa M; Stillo M, Maffei G, Andriolo V, Gardois P, Zotti C.M. Ugly but tasty: A systematic review of possible human and animal health risks related to entomophagy. Crit Rev Food Sci Nutr. 2017; 57:3747–3759. https://doi.org/10.1080/10408398.2016.1162766 PMID: 27008043

84. Modlińska K, Adamczyk D, Maison D, Goncikowska K, Pisula W. Relationship between Acceptance of Insects as an Alternative to Meat and Willingness to Consume Insect-Based Food—A Study on a Representative Sample of the Polish Population. Foods. 2021; 10:2420. https://doi.org/10.3390/foods10102420 PMID: 34681469

85. Verbeke W. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. Food Qual Prefer. 2015; 39:147–155. https://doi.org/10.1016/j.foodqual.2014.07.008.

86. Kostecka J, Konieczna K, Cunha LM. Evaluation of insect-based food acceptance by representatives of polish consumers in the context of natural resources processing retardation. J Ecol Eng. 2017; 18:166–174. https://doi.org/10.12911/22998993/68301.

87. Gumussoy M, Macmilla C, Bryant S, Hunt DF, Rogers PJ. Desire to eat and intake of 'insect' containing food is increased by a written passage: The potential role of familiarity in the amelioration of novel food disgust. Appetite. 2021; 161:105088. https://doi.org/10.1016/j.appet.2020.105088 PMID: 33385476

88. Alhujaili A, Nocella G, Macready A. Insects as Food: Consumers' Acceptance and Marketing. Foods. 2023; 12:886. https://doi.org/10.3390/foods12040886 PMID: 36832961

89. Hartmann C, Siegrist M. Becoming an insectivore: results of an experiment. Food Qual Prefer. 2016; 51:118–122. https://doi.org/10.1016/j.foodqual.2016.03.003.

90. La Barbera F., Verneau F., Amato M. and Grunert K. Understanding westerners' disgust for the eating of insects: the role of food neophobia and implicit associations. Food Qual Prefer.2018; 64:120–125. https://doi.org/10.1016/j.foodqual.2017.10.002.

91. Verbeke W. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. Food Qual Prefer. 2015; 39:147–155. https://doi.org/10.1016/j.foodqual.2014.07.008.

92. Kornher L, Schellhorn M, Vetter S. Disgusting or Innovative-Consumer Willingness to Pay for Insect Based Burger Patties in Germany. Sustainability. 2019; 11:1878. https://doi.org/10.3390/su11071878.

93. Roberts JA. Green consumers in the 1990s: Profile and implications for advertising. Journal of Business Research. 1996; 36:217–231. https://doi.org/10.1016/0148-2963(95)00150-6.

94. Pliner P, Hobden K. Development of a scale to measure the trait of food neophobia in humans. Appetite. 1992; 19:105–120. https://doi.org/10.1016/0195-6663(92)90014-w PMID: 1489209

95. Wang Y, Wiegerinck V, Krikke H, Zhang H. Understanding the purchase intention towards remanufactured product in closed-loop supply chains: An empirical study in China. Int J Phys Distrib. 2013; 43 (10):866–888. https://doi.org/10.1108/IJPDLM-01-2013-0011.

96. Lee JS, Hsu LT, Han H, Kim Y. Understanding how consumers view green hotels: how a hotel's green image can influence behavioral intentions. J Sustain Tourism. 2010; 18(7):901–914. https://doi.org/10.1080/09669581003777747.

97. Browne MW, Cudeck R. Alternative ways of assessing model fit. Sociol Methods Res. 1992; 21 (2):230–258. https://doi.org/10.1177/0049124192021002005.

98. Garson GD. 2012. Structural Equation Modeling. Blue Book Series. NC Statistical Associates Publishing, Asheboro.

99. Michaelidou N, Hassan LM. The role of health consciousness, food safety concern and ethical identity on attitudes and intentions towards organic food. Int J Consum Stud. 2008; 32(2):163–170. https://doi.org/10.1111/j.1470-6431.2007.00619.x.

100. Pieniak Z, Verbeke W, Vanhonacker F, Guerrero L, Hersleth M. Association between traditional food consumption and motives for food choice in six European countries. Appetite. 2009; 53(1):101–108. https://doi.org/10.1016/j.appet.2009.05.019 PMID: 19500626

101. Panayides P. Coefficient Alpha. Interpret with caution. Eur J Psychol.2013; 9(4):687–696. https://doi.org/10.5964/ejop.v9i4.653.

102. Nunnally JC. 1978. Psychometric theory. 2nd ed. McGraw-Hill Book Company, New York.

103. Chin WW, Gopal A, Salisbury WD. Advancing the theory of adaptive structuration: the development of a scale to measure faithfulness of appropriation. Inform Syst Res. 1997; 8(4):342–367. https://doi.org/10.1287/isre.8.4.342.

104. Palmieri N, Perito MA, Macrì MC, Lupi C. Exploring consumers' willingness to eat insects in Italy. Br Food J. 2019; 121:2937–2950. https://doi.org/10.1108/BFJ-03-2019-0170.

105. Schlup Y, Brunner T. Prospects for insects as food in Switzerland: A tobit regression. Food Qual Prefer. 2018; 64:37–46. https://doi.org/10.1016/j.foodqual.2017.10.010.

106. Liu AJ, Li J, Gómez MI. Factors Influencing Consumption of Edible Insects for Chinese Consumers. Insects. 2020; 11:10. https://doi.org/10.3390/insects11010010.

107. Menozzi D, Sogari G, Veneziani M, Simoni E, Mora C. Eating novel foods: An application of the Theory of Planned Behaviour to predict the consumption of an insect-based product. Food Qual Prefer. 2017; 59:27–34. https://doi.org/10.1016/j.foodqual.2017.02.001

108. Clarkson C, Mirosa M, Birch J. Consumer acceptance of insects and ideal product attributes. Br Food J. 2018; 120:2898–2911. https://doi.org/10.1108/BFJ-11-2017-0645

109. Van Thielen L, Vermuyten S, Storms B, Rumpold B, Van Campenhout L. Consumer acceptance of foods containing edible insects in Belgium two years after their introduction to the market. J Insects Food Feed. 2019; 5:35–44. https://doi.org/10.3920/JIFF2017.0075.

110. Petersen M, Olson O, Rao S. University Student Perspectives of Entomophagy: Positive Attitudes Lead to Observability and Education Opportunities. J Insect Sci. 2020; 20:30. https://doi.org/10.1093/jisesa/ieaa120 PMID: 33098432

111. Pantin-Sohier G, Hémar-Nicolas V, Gallen C. 2022. „Do you eat insects?" Acceptance of insects as food by children. J Consum Mark. 2022; 39(5):505–522. https://doi.org/10.1108/JCM-12-2020-4289.

112. Caparros Megido R, Sablon L, Geuens M, Brostaux Y, Alabi T, Blecker C, et al. Edible insects acceptance by Belgian consumers: promising attitude for entomophagy development. J Sens Stud. 2014; 29:14–20. https://doi.org/10.1111/joss.12077.

113. Piha S, Pohjanheimo T, Lähteenmäki-Uutela A, Křečková Z, Otterbring T. The effects of consumer knowledge on the willingness to buy insect food: an exploratory cross-regional study in northern and Central Europe. Food Qual Prefer. 2018; 70:1–10. https://doi.org/10.1016/j.foodqual.2016.12.006.

114. Tuccillo F, Marino MG, Torri L. Italian consumers' attitudes towards entomophagy: influence of human factors and properties of insects and insect-based food. Food Res Int. 2020; 137:109619. https://doi.org/10.1016/j.foodres.2020.109619 PMID: 33233207

115. Modlińska K, Adamczyk D, Goncikowska K, Maison D, Pisula W. The Effect of Labelling and Visual Properties on the Acceptance of Foods Containing Insects. Nutrients. 2020; 12:2498. https://doi.org/10.3390/nu12092498 PMID: 32824991

116. Laureati M, Proserpio C, Jucker C, Savoldelli S. New sustainable protein sources: Consumers' willingness to adopt insects as feed and food. Ital J Food Sci. 2016; 28:652–668. https://doi.org/10.14674/1120-1770/ijfs.v476.

117. La Barbera F.; Verneau F.; Amato M.; Grunert K. Understanding Westerners' disgust for the eating of insects: The role of food neophobia and implicit associations. Food Qual. Prefer. 2018, 64,120–125. https://doi.org/10.1016/j.foodqual.2017.10.002.

118. Lombardi A, Vecchio R, Borrello M, Caracciolo F, Cembalo L. Willingness to pay for insect-based food: The role of information and carrier. Food Qual Prefer. 2019, 72:177–187. https://doi.org/10.1016/j.foodqual.2018.10.001.

119. Schäufele I, Albores EB, Hamm U. The role of species for the acceptance of edible insects: Evidence from a consumer survey. Br Food J. 2019; 121:2190–2204. https://doi.org/1010.1108/BFJ-01-2019-0017.

120. Orsi L, Voege LL, Stranieri S. Eating edible insects as sustainable food? Exploring the determinants of consumer acceptance in Germany. Food Re. Int. 2019, 125:108573. https://doi.org/10.1016/j.foodres.2019.108573.

121. Ruby MB, Rozin P. Disgust, sushi consumption, and other predictors of acceptance of insects as food by Americans and Indians. Food Qual Prefer. 2019; 74:155–162. https://doi.org/10.1016/j.foodqual.2019.01.013.

122. Orkusz A, Wolańska W, Harasym J, Piwowar A, Kapelko M. Consumers' Attitudes Facing Entomophagy: Polish Case Perspectives. Int J Environ Res Public Health. 2020; 17:2427. https://doi.org/10.3390/ijerph17072427 PMID: 32252454

123. Schlup Y, Brunner T. Prospects for insects as food in Switzerland: A tobit regression. Food Qual Prefer. 2018; 64:37–46. https://doi.org/10.1016/j.foodqual.2017.10.010.

124. Chang HP, Ma CC, Chen HS. Climate Change and Consumer's Attitude toward Insect Food. Int J Environ Res Public Health. 2019; 16:1606. https://doi.org/10.3390/ijerph16091606 PMID: 31071928

125. Olum S, Wesana J, Mawadri J, Nakiranda JK, Odongo W. Insects as food: Illuminating the food neophobia and socio-cultural dynamics of insect consumption in Uganda. Int J Trop Insect Sci. 2020; 41:1–10. https://doi.org/10.1007/s42690-020-00309-2.

126. Skallerud K, Wien AH. Preference for local food as a matter of helping behaviour: Insights from Norway. J Rural Stud. 2019; 67:79–88. https://doi.org/10.1016/j.jrurstud.2019.02.020.

127. Yang Z, Sun S, Lalwani AK, Janakiraman N. How does consumers' local or global identity influence price-perceived quality associations? The role of perceived quality variance. J Mark. 2019; 83(3):145–162. https://doi.org/10.1177/002224291882526.

128. Zhang T, Grunert KG, Zhou Y. A values-beliefs–attitude model of local food consumption: An empirical study in China and Denmark. Food Qual Prefer. 2020; 83,103916. https://doi.org/10.1016/j.foodqual.2020.103916.

129. Kumar S, Murphy M, Talwar S, Kaur P, Dhir A. What drives Brand love and purchase intentions toward the local food distribution system? A study of social media-based REKO (fair consumption) groups. J Retail Consum Serv. 2021; 60,102444. https://doi.org/10.1016/j.jretconser.2021.102444.

130. Majeed MU, Aslam S, Murtaza SA, Attila S, Molnár E. Green Marketing Approaches and Their Impact on Green Purchase Intentions: Mediating Role of Green Brand Image and Consumer Beliefs towards the Environment. Sustainability. 2022; 14,11703. https://doi.org/10.3390/su141811703.

131. Maas M, Abebe GK, Hartt CM, Yiridoe EK. Consumer Perceptions about the Value of Short Food Supply Chains during COVID-19: Atlantic Canada Perspective. Sustainability. 2022; 14(13),8216. https://doi.org/10.3390/su14138216.