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Research article

Information about nutritional aspects of edible insects: Perspectives across different European geographies

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Abstract: Edible insects (EIs) have recently gained attention as an alternative and more sustainable food, emerging as an alternative to other protein foods with higher environmental impacts, like bovine meat. EIs contain a valuable composition of macro and micronutrients, important for human nutrition. Nevertheless, their consumption is not yet widespread in Western countries, such as in Europe. This work aimed to study how consumers in three different European locations perceive the role of EIs in human nutrition. Data collection was carried out by a questionnaire survey in three countries (Croatia, Lithuania, and Portugal), and 1723 participants were included in the study. For the treatment of the data, SPSS software was used, and chi-square tests and tree classification analysis were performed. The results showed that for all the statements presented to the participants, significant differences were found in information about EIs according to country. The results further highlighted that the participants were better informed about the high protein content of EIs, while not being well informed about their possible anti-nutritive effects. Tree classification revealed that the most important discriminating variable was country, with Lithuanian participants being better informed than those from Portugal or Croatia.

Keywords: consumer study; questionnaire survey; eating insects; nutritive value

1. Introduction

A great diversity of insects have been consumed since ancient times by people from many cultures around the world, most especially in developing countries where edible insects (EIs) constitute a part of the gastronomic culture, being even considered a delicacy [1]. The practice of eating insects is termed entomophagy and, in the present day, has been gaining attention in both developed and developing countries [2]. Entomophagy played a vital role in the evolution of hominids, being present in different parts of the world. The association of man with insects is of great significance, not only as a food source. Entomophagy provides insights into the sustainability of local livelihoods, vulnerabilities, food culture, and ecology. Entomophagy is more present in the East, and it is suggested that the loss of eating insects as part of dietary patterns in the West might be related to seasonality and possible religious issues. In Asian, African, and Latin American countries, eating insects has been part of traditional customs. Their significance is not only cultural but also nutritional, economic, and social, providing accessible means of livelihood [3–6]. In fact, the perception that eating insects was characteristic of "poor undeveloped people" has led to a low acceptability among people in developed countries. Nevertheless, this negative image has been quickly changing in recent years, and EIs are becoming trendy sustainable food [7,8]. The consumption of EIs has become a new food trend, particularly since 2013 when the Food and Agriculture Organization of the United Nations (FAO) published a report about the role of EIs in mitigating food insecurity and highlighting their nutritional value [9].

EIs can be consumed whole or processed, for example, into flour, which is then incorporated into other food items, with good nutritional value. However, processing technologies impact both the nutritional value and possible safety risks [10].

EIs constitute a potential food source since they contain macro and micronutrients while also having environmental and economic advantages. Insect-based food can have equal or even higher nutritional value when compared to those from birds, mammals, or fish [11,12]. EIs contain appreciable amounts of protein, lipids, carbohydrates, and certain minerals and vitamins [12]. Additionally, according to Hui et al. [13], the nutritional value of insects can be manipulated to meet specific requirements. Although there are some food safety risks associated with EIs, these are low and mostly relate to allergenicity. Additionally, the presence of bioactive compounds in EIs may contribute to a reduction in health risks [13]. EIs contain antioxidant peptides and exhibit antimicrobial activity, fat reduction capacity, and protection against hypertension [13,14].

Given that the consumption of insects is not yet very common in Europe despite them being recommended by FAO as sustainable sources of protein from animal origin, incentivizing their consumption might be achieved through a better understanding of their nutritional richness. Hence, this study focused on the knowledge among participants from three European countries: Portugal (situated in the Iberian Peninsula, on the Atlantic coast), Croatia (situated in Southern Europe on the Adriatic coast of the Mediterranean Sea), and Lithuania (Situated in Northern Europe, in the Baltic

Sea coast). The aim was to compare the level of information between participants from these countries, which, although being all European, are geographically apart.

2. Materials and methods

2.1. Instrument

This work was conducted using a questionnaire survey within the scope of the EISuFood international project. The instrument was validated in previous work [15], and ethics approval was obtained from the Ethics Committee of the Polytechnic University of Viseu (Ref. Nº 45/SUB/2021).

This research describes a transversal descriptive study that targeted adult individuals from three European countries: Portugal, Croatia, and Lithuania. The questionnaire contained ten questions to investigate whether the participants were or were not informed about the nutritional value of EIs. The participants had to answer the following questions using a 5-point central Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree [16]:

1. Insects have poor nutritional value.
2. Insects are a good source of energy.
3. Insects have a high protein content.
4. Insect proteins are of poorer quality compared to other animal species.
5. Insects provide essential amino acids necessary for humans.
6. Insects contain group B vitamins.
7. Insects contain dietary fiber.
8. Insects contain minerals of nutritional interest, such as calcium, iron, and magnesium.
9. Insects contain fat, including unsaturated fatty acids.
10. Insects contain anti-nutrients, such as oxalates and phytic acid.

2.2. Participants and data collection

This was a transversal descriptive study applied to adult individuals aged 18 years or older. The questionnaire was translated into the native languages (Portuguese, Lithuanian, and Croatian) before being distributed to the participants in the three countries selected for the study. The survey was conducted through online tools, specifically Google Forms®. The invitation to participate in the study was distributed on social networks, and the link was posted by email from July to November 2021.

Only adults who voluntarily agreed to participate were able to access the questionnaire to respond, and there was no monetary reward involved.

All ethical considerations were scrupulously considered when constructing the questionnaire and collecting the data, namely those from the American Psychological Association (APA) Ethical Guidelines for Research Involving Human Subjects and the Declaration of Helsinki.

2.3. Data analysis

Data were analyzed using basic descriptive statistics, complemented with other statistical tools as contingency tables and chi-square tests. To assess the strength of the associations between categorical variables the Cramer's V coefficient was calculated, which varies from 0 to 1; for $V \approx 0.1$, the association is considered weak; for V ≈ 0.3, the association is moderate; and for V ≈ 0.5 or over, the association is strong [17].

The relative influence of the sociodemographic variables on the level of information was assessed by means of tree classification analysis. For this, a classification and regression trees (CRT) algorithm was used with cross-validation [18]. The minimum change in improvement was equal to 0.001, and the minimum number of cases for parent and child nodes was established as 20 and 10, respectively.

The software used for data analysis was SPSS (Version 28) from IBM Inc. (Armonk, NY, USA), and the level of significance considered was 5% ($p < 0.05$).

3. Results

3.1. Sociodemographic characterization of the sample

Figure 1 shows the spatial distribution across Europe of the three countries selected for the study: Portugal, close to the Atlantic Ocean, Croatia in the Southern European Mediterranean coast, and Lithuania, in the North of Europe, facing the Baltic Sea. The total number of participants in the study was 1723, distributed as follows: 38.8% Croatian, 30.6% Portuguese, and 29.6% Lithuanian.

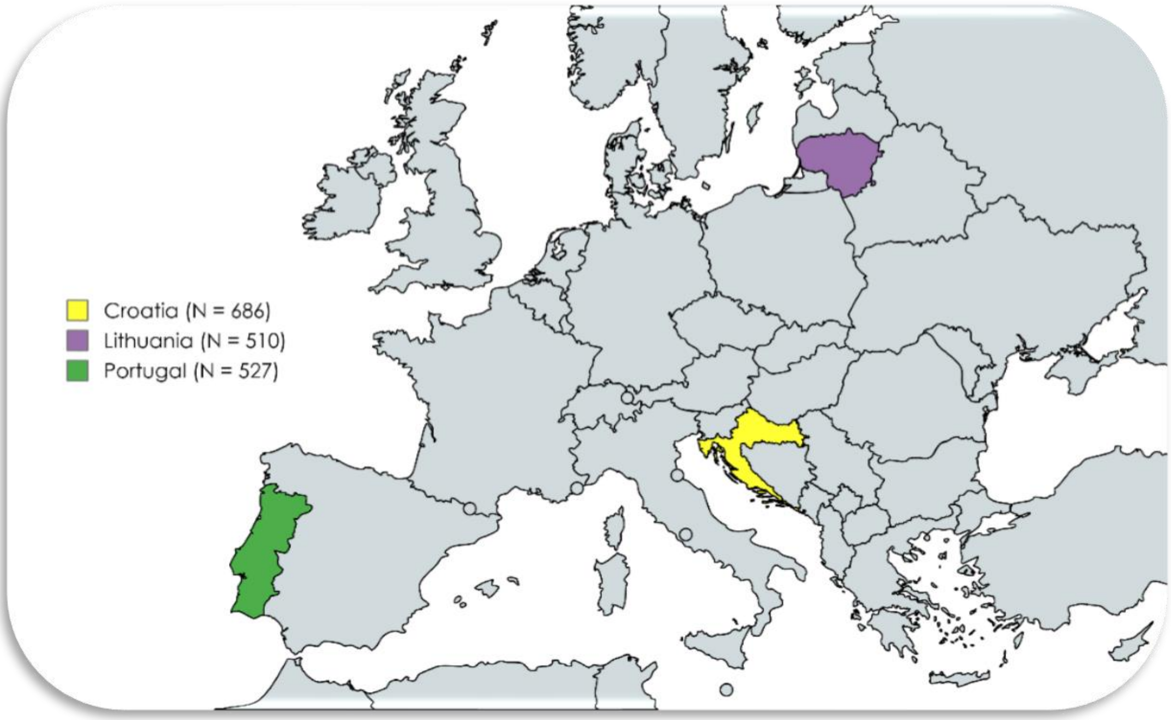

Figure 1. Geographical distribution of the countries considered for the study (total number of participants, N = 1723).

Figure 2 presents the distributions of the participants according to the groups defined for the sociodemographic variables considered: gender, age, and education. For the definition of the age classes, the following intervals were considered: 18–31 years old—young adults; 31–50 years old—adults; and 51 or more years old—senior adults. Most of the participants were female (60.3%), young adults (aged between 18 and 30 years) (48.3%), and those who had an under-university level of education (49.6%).

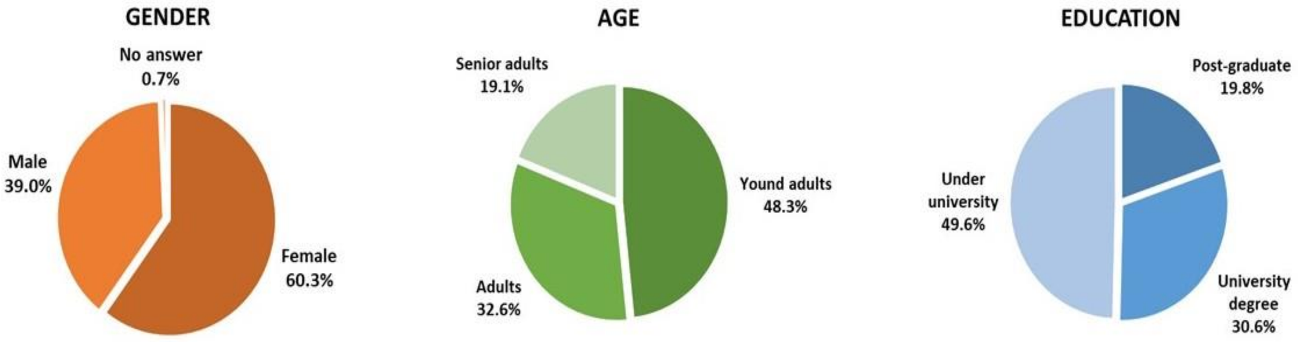

Figure 2. Sociodemographic characterization of the participants (N = 1723).

3.2. Country differences in agreement about nutritional facts of EIs

The results in Table 1 refer to the cross-tabulation between the variable country and the responses given by the participants to the ten questions regarding nutritional facts related to EIs. It can be observed that for all questions, significant differences were encountered between participants according to country. Nevertheless, the strength of the associations was variable, with most questions having a low association between responses and country but with some questions presenting a value of Cramer's coefficient that can be considered moderate (Q7: V = 0.265; and Q6: V = 0.223). These two questions refer to the presence of dietary fiber and vitamins of the B group in EIs, respectively. The highest agreement was found for the true questions Q3 (EIs being rich in protein) and Q2 (EIs being a source of energy). The two questions that were given as false statements showed a high percentage of responses of disagreement or strong disagreement, revealing that the participants were able to detect that the question was false: Q1 (EIs having poor nutritional value) and Q4 (EIs having poor quality proteins).

Table 1. Crosstabs and chi-square tests for country differences for the responses to the questions about the nutritional value of EIs.

Country	Level of agreement[1] (% of answers)					Chi-square test[2]	
	1	2	3	4	5	p-value	V
*Q1. Insects have poor nutritional value.**							
Portugal	23.5	30.0	39.3	4.7	2.5	<0.001	0.157
Croatia	19.8	22.6	34.0	16.5	7.1		
Lithuania	21.0	36.5	28.8	10.6	3.1		
Q2. Insects are a good source of energy.							
Portugal	4.4	6.5	42.7	32.3	14.1	<0.001	0.167
Croatia	10.9	14.1	34.0	29.2	11.8		
Lithuania	5.3	15.1	23.1	34.1	22.4		

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Country	Level of agreement[1] (% of answers)					Chi-square test[2]	
	1	2	3	4	5	p-value	V
Q3. Insects have high protein content.							
Portugal	3.4	2.8	37.6	35.1	21.1	<0.001	0.181
Croatia	8.0	9.9	29.7	35.3	17.1		
Lithuania	2.5	3.3	20.8	41.4	32.0		
*Q4. Insect proteins are of poorer quality compared to other animal species.**							
Portugal	12.0	25.0	51.8	7.4	3.8	<0.001	0.158
Croatia	8.5	21.0	46.9	15.9	7.7		
Lithuania	19.8	28.4	32.4	12.4	7.0		
Q5. Insects provide essential amino acids necessary for humans.							
Portugal	2.8	3.6	60.3	23.7	9.5	<0.001	0.179
Croatia	8.3	14.9	51.2	18.4	7.3		
Lithuania	6.5	15.9	37.1	25.1	15.5		
Q6. Insects contain group B vitamins.							
Portugal	2.8	4.2	72.9	14.4	5.7	<0.001	0.223
Croatia	8.9	8.0	59.6	18.6	4.8		
Lithuania	5.1	17.8	38.0	27.8	11.2		
Q7. Insects contain dietary fiber.							
Portugal	3.4	7.0	62.3	20.5	6.8	<0.001	0.265
Croatia	10.5	8.9	58.9	17.3	4.4		
Lithuania	7.0	10.4	25.9	35.9	20.8		
Q8. Insects contain minerals of nutritional interest, such as calcium, iron, and magnesium.							
Portugal	3.0	4.6	63.0	22.6	6.8	<0.001	0.178
Croatia	7.7	10.1	52.7	23.7	5.8		
Lithuania	4.7	11.8	35.5	34.5	13.5		
Q9. Insects contain fat, including unsaturated fatty acids.							
Portugal	5.1	10.6	67.4	12.9	4.0	<0.001	0.211
Croatia	8.6	14.6	56.6	15.5	4.5		
Lithuania	6.5	19.8	32.9	28.4	12.4		
Q10. Insects contain anti-nutrients, such as oxalates and phytic acid.							
Portugal	5.3	6.1	77.1	8.5	3.0	<0.001	0.171
Croatia	6.9	11.4	62.2	14.4	5.1		
Lithuania	7.0	11.8	62.4	14.2	4.6		

[1]Five-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = indifferent, 4 = agree, 5 = strongly agree. [2]Significance of the chi-square test is 5% ($p < 0.05$); V = Cramer's coefficient, only if the p is significant. *Questions marked with an asterisk are false.

3.3. Association between information about the nutritive value of EIs and sociodemographic variables

The questions that were given as false statements (Q1 and Q4) were reversed in order to have all ten questions on the same scale—a five-point Likert scale—where the highest value corresponded to the highest level of information. After this, the ten questions were recoded into the following parameters: "Informed" participants (those who responded with scores 4 and 5) and "not informed" participants (those who scored 1, 2, or 3).

Figure 3 presents the percentage of informed participants for all ten questions, considering the global sample. The results clearly indicate the questions for which the level of information is highest: Q3 (59.7% of participants were informed), Q1 (30.3%), and Q2 (47.2%), as well as those for which the level of information was lowest: Q10 (only 18.9% of informed participants), Q9 (25.3%), and Q6 (27.0%).

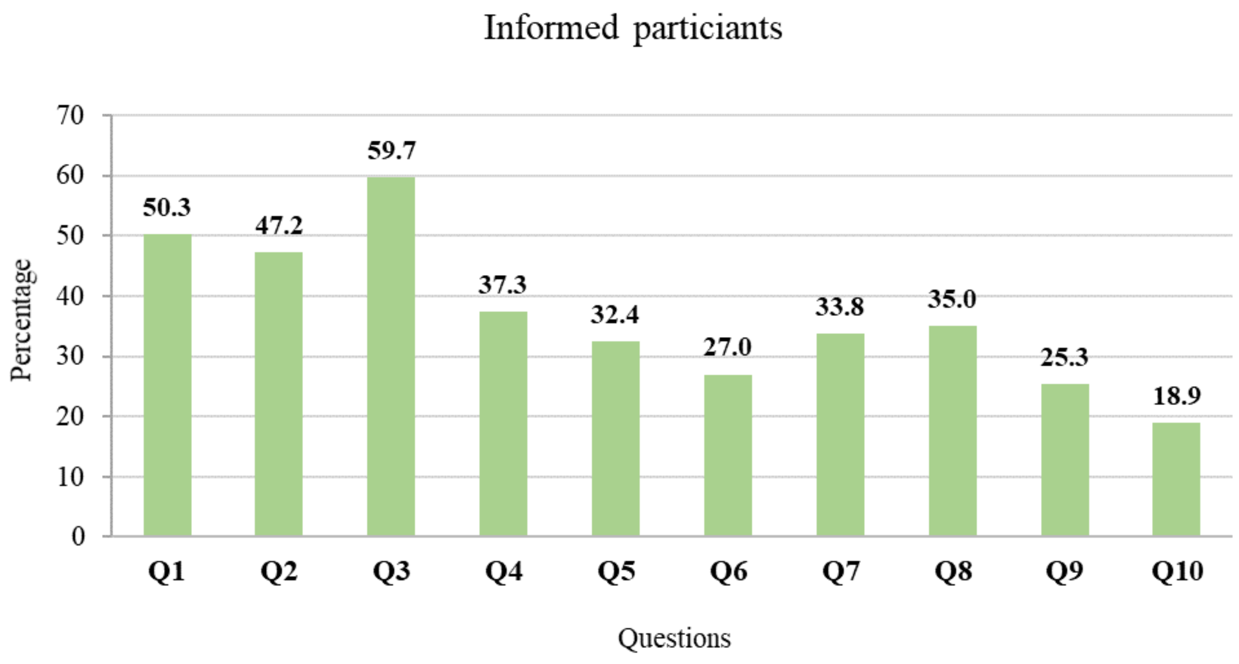

Figure 3. Percentage of informed participants considering the global sample (N = 1723).

Table 2. Crosstabs and chi-square tests for country differences regarding the level of information about the nutritional value of EIs.

Question	% of informed participants			Chi-square test[1]	
	Portugal (N = 527)	Croatia (N = 686)	Lithuania (N = 510)	p-value	V
Q1	53.5	42.4	57.5	<0.001	0.131
Q2	46.5	41.0	56.5	<0.001	0.128
Q3	56.2	52.3	73.3	<0.001	0.183
Q4	37.0	29.5	48.2	<0.001	0.160
Q5	33.2	25.7	40.6	<0.001	0.132
Q6	20.1	23.4	39.0	<0.001	0.178
Q7	27.3	21.7	56.7	<0.001	0.318
Q8	29.4	29.5	48.0	<0.001	0.178
Q9	16.9	20.3	40.8	<0.001	0.233
Q10	11.6	19.5	25.5	<0.001	0.139

[1]Significance of the chi-square test is 5% ($p < 0.05$); V = Cramer's coefficient, only if the p is significant.

Table 2 shows the results of cross-tabulation between the variable country and the level of information of the participants about the nutritive value of EIs. The results showed significant differences between countries for all questions, with low-to-moderate associations. The question with the highest association between information and country was Q7 (V = 0.318) about EIs containing edible fiber. It was further observed that for all ten questions, the participants from Lithuania were the most informed, with percentages always higher than those of Portuguese or Croatian samples.

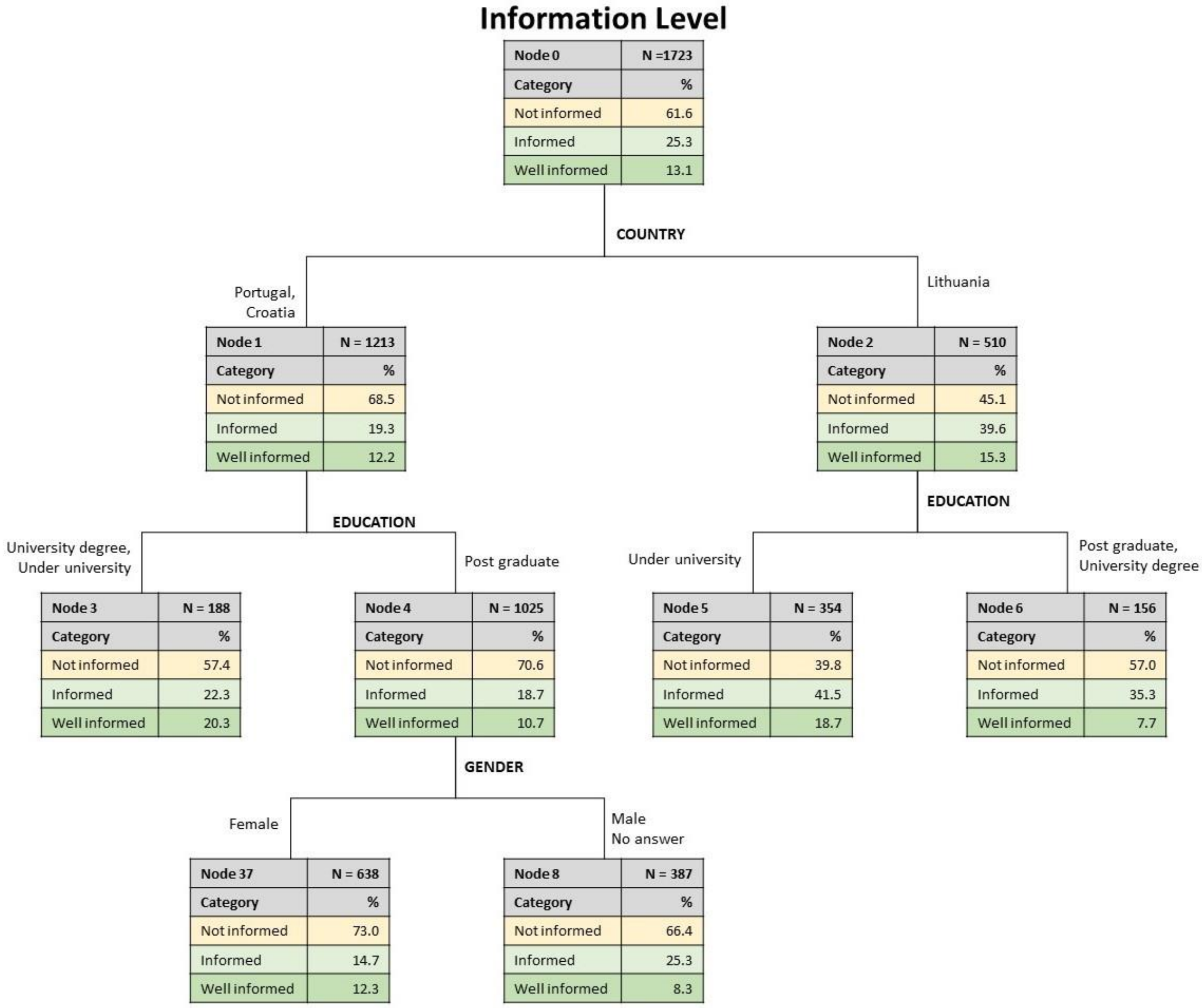

Figure 4. Tree classification for the level of information according to sociodemographic variables.

A global level of information was calculated for each participant as the sum of the scores in all ten questions. Hence, the final score scale for each participant is as follows: not informed (sum up to 4 points, corresponding to participants who answered correctly to less than half of the questions), informed (sum between 5 and 7 points, corresponding to 5–7 questions answered correctly), and well informed (sum between 8 and 10 points, for participants who answered correctly at least eight of the ten questions). These data were analyzed for the relative importance of sociodemographic variables (country, age, gender, education) on the level of knowledge by a tree classification analysis, whose results are shown in Figure 4. The obtained tree has three levels and nine nodes, of which five are terminal. From the four independent variables included in the analysis (country, age, gender, and education), only three were found to influence the level of knowledge, so the variable age class was excluded. The risk estimate was 0.381 with a standard error of 0.012 for re-substitution and 0.384 with a standard error of 0.012 for cross-validation. It was further observed that the obtained model has an associated probability of correctly predicting the cases according to the class of knowledge equal to 61.9%. The information of the initial node (node 0) indicated that globally, 61.6% of participants were not informed, 25.3% were informed, and only 13.1% were well informed, considering the whole set of ten questions. The first discriminating variable was found to be country, thus confirming the strong influence of this variable on the information of participants, separating the Lithuanian participants from those of the two other countries, as previously reported. Considering the whole set of questions, the Lithuanian participants revealed a lower percentage of not-informed participants (46.1%) than participants from other countries (68.5% of not-informed). In the next level, and regardless of country, the second discriminating variable was education, and in the final level, the next discriminating variable was gender.

4. Discussion

The work by Sheafer et al. [19] highlighted the positive association between nutrition knowledge and diet quality among US Army soldiers. Also, Elmskini et al. [20] reported that higher nutrition knowledge directly impacts body weight and health status. Similar works relate knowledge with a better quality diet and improved health status [21–24].

Although nutritional knowledge has a direct positive impact on food choices, leading to healthier food consumption and better health status, it is also reported that knowledge can shape peoples' food choices toward more sustainable diets. Many studies indicate that better knowledge is positively associated with dietary patterns that bear a lower environmental impact and footprint [25–27].

In the present study, participants were more informed about the following subjects, in decreasing order: Q3 (insects have high protein content), Q1 (insects have poor nutritional value—false), and Q2 (insects are a good source of energy). Hence, participants were aware of EIs richness in proteins, energy, and nutritional value, even though this last statement was given as a false statement, which the respondents identified as not true. Scientific evidence supports the nutritional facts about EIs, namely their high protein content and diversity and quality of amino acids [28,29]. Also, research has pointed out the technological functionality of proteins from EIs, as highlighted in the work by Queiroz et al. [29], as well as their biofunctionalities, as reported by Nolan et al. [30]. With respect to the nutritional value of EIs, many studies support their richness in several macro and micronutrients as well as bioactive compounds. Sánchez-Estrada et al. [31] reviewed the nutritional and bioactive compounds of EIs as well as their biological activities, especially protein, lipids, carbohydrates, minerals, vitamins, and bioactive molecules like phenolic compounds.

The questions where participants showed the least knowledge were Q10 (insects contain anti-nutrients, such as oxalates and phytic acid), Q9 (insects contain fat, including unsaturated fatty acids), and Q6 (insects contain group B vitamins). Sánchez-Estrada et al. [31] reported the possible presence of some components with antinutritional effects, like hydrocyanide, oxalates, soluble oxalate, and phytate, in EIs. However, these phytochemical components can negatively affect humans through allergenic reactions or reduced nutrient viability, but only when consumed in high amounts and/or for long periods of time [31]. As such, it is not expected that consumption of EIs as part of a varied diet will have a particular impact on the availability of nutrients. Still, higher care must be given to the potential allergenicity of some components present in EIs as these can have a higher effect on vulnerable people. Verhoeckx and Heijer [32] stated that EIs with potential allergenic effects include mealworms, mopane worms, bee larvae, and silkworms.

The results of the present work indicate that the major sociodemographic variables influencing the level of information were country, education, and gender. Although there are no specific studies about the information related to nutritional facts of EIs, many other studies published in the scientific literature relate differences in nutritional knowledge in general according to sociodemographic variables. Le Turc et al. [33] identified significant differences in the knowledge about the dietary relevance of fruits and vegetables according to country, gender, and education. Guiné et al. [34] examined consumers' knowledge about breakfast and identified the country as the second most important discriminating variable, followed by gender and education. On the other hand, a study focusing on knowledge about edible flowers revealed that the major sociodemographic variable influencing consumers' level of information was education, followed by country [18].

Research clearly indicates that knowledge is very closely associated with food choices and dietary patterns, shaping consumers' attitudes toward food, with a direct impact also on their well-being and health status [35–38].

5. Conclusions

The results revealed that, for all ten questions regarding the nutritive value and risks of Eis, significant differences were found between the participants from the three countries. Concerning the associations between country and the questions, higher associations were found (i.e., higher values of the Cramer's coefficient) for questions about EIs containing dietary fiber, vitamins of group B, and unsaturated fatty acids. It was also observed that, in general, participants were more informed about the high protein content of EIs while being less informed about their possible components with anti-nutrient effects, such as oxalates and phytic acid.

Regarding the association between the level of information and sociodemographic variables, significant differences were also found, with the highest association for questions about dietary fiber and unsaturated fatty acids. A tree classification showed that the first discriminating variable for the level of information was country, followed by education and then gender. Concerning the variable country, the participants who were more informed were those from Lithuania, while regarding gender, the more informed were female participants. In what concerns education, apparently, a higher level of education was not unequivocally associated with higher information about the nutritional facts of EIs.

In conclusion, this work showed that, despite the participants being all from European countries, a high level of differences was still observed according to country. This might be useful to plan national strategies in each country to help citizens be more informed about the nutritional value and implications of EIs consumption, which has been suggested as a more sustainable source of protein than other animal sources and could constitute a complement to the diet of European populations.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization, R.P.F.G., S.G.F., C.A.C., P.M.R.C., M.F., A.P.C., S.C., O.A., E.B., and M.M.S.; methodology, R.P.F.G., E.B., and M.M.S.; software, R.P.F.G.; validation, R.P.F.G.; formal analysis, R.P.F.G., and S.G.F.; investigation, R.P.F.G., S.G.F., C.A.C., P.M.R.C., M.F., A.P.C., S.C., O.A., E.B., and M.M.S.; resources, R.P.F.G., C.A.C., P.M.R.C., M.F., A.P.C., and S.C.; data curation, R.P.F.G..; writing—original draft preparation, R.P.F.G.; writing—review and editing, R.P.F.G.. S.G.F., C.A.C., P.M.R.C., M.F., A.P.C., S.C., O.A., E.B., and M.M.S.; visualization, R.P.F.G.; supervision, R.P.F.G.; project administration, R.P.F.G.; funding acquisition, R.P.F.G., C.A.C., P.M.R.C., M.F., A.P.C., and S.C. All authors have read and agreed to the published version of the manuscript.

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