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Investigation of the Level of Knowledge in Different Countries about Edible Insects: Cluster Segmentation

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Citation: Guiné, R.P.F.; Florença, S.G.; Costa, C.A.; Correia, P.M.R.; Ferreira, M.; Cardoso, A.P.; Campos, S.; Anjos, O.; Chuck-Hernández, C.; Sarić, M.M.; et al. Investigation of the Level of Knowledge in Different Countries about Edible Insects: Cluster Segmentation. *Sustainability* **2023**, *15*, 450. https://doi.org/10.3390/su15010450

Academic Editor: Michael A. Long

Received: 11 October 2022
Revised: 6 December 2022
Accepted: 21 December 2022
Published: 27 December 2022

Abstract: This study aimed to investigate the level of knowledge about edible insects (EIs) in a sample of people from thirteen countries (Croatia, Greece, Latvia, Lebanon, Lithuania, Mexico, Poland, Portugal, Romania, Serbia, Slovenia, Spain, and Turkey). Data collection was based on a questionnaire survey applied through online tools between July and November 2021. For data analysis, techniques such as factor analysis, cluster analysis, and chi-square tests were used, with a significance level of 5%. A total of 27 items were used to measure knowledge on a five-point Likert scale. Applying factor analysis with principal components and Varimax rotation, a solution that explains about 55% of variance was obtained. This accounts for four factors that retained 22 of the 27 initial items: F1 = Sustainability (8 items), F2 = Nutrition (8 items), F3 = Production Factors (2 items), and F4 = Health Concerns (4 items). Internal consistency was evaluated through Cronbach's alpha. The cluster analysis consisted of the application of hierarchical methods followed by k-means and produced three clusters (1—'fearful', 2—'farming,' and 3—'ecological' individuals). The characterisation of the clusters revealed that age did not influence cluster membership, while sex, education, country, living environment, professional area, and income all influenced the composition of the clusters. While participants from Mexico and Spain were fewer in the 'fearful' cluster, in those from Greece, Latvia, Lebanon, and Turkey, the situation was opposed. Participants from rural areas were mostly in cluster 2, which also included a higher percentage of participants with lower income. Participants from professional areas linked with biology, food, and nutrition were mostly in cluster 3. In this way, we concluded that the level of knowledge about EIs is highly variable according to the individual characteristics, namely that the social and cultural influences of the different countries lead to distinct levels of knowledge and interpretation of information, thus producing divergent approaches to the consumption of insects—some more reluctant and measuring possible risks. In contrast, others consider EIs a good and sustainable protein-food alternative.

Keywords: knowledge; edible insects; factor analysis; cluster analysis; sustainable food; nutritional value

1. Introduction

The practice of eating insects (entomophagy) has been attracting attention on a global scale for a number of reasons, among which the following stand out: environmental sustainability, nutrition properties, health benefits, and social/economic advantages [1]. Being able to achieve food security is presently one of the most challenging aspects of dealing with the world population, and being able to do so with the lowest possible environmental impact is pivotal in today's context of climate changes and societies' pressure on the ecosystems [1,2].

A wide variety of edible insect (EI) species with high nutritional value is available for human consumption. Insect consumption has been a traditional practice throughout the history of the human race [3–5]. However, their consumption is variable according to the region of the globe, with some areas where eating insects is recognised as an old practice, and EIs are a much-appreciated type of food. In contrast, for other regions, entomophagy is not seen as natural. The number of people estimated to consume insects regularly in their diets, as a traditional practice, has been estimated at over two billion worldwide [6]. Presently, a wide range of insects is consumed in Africa, Asia, Latin America, and Australia. On the other hand, in Western societies, including Europe and the United States, eating insects is not common, and there is still a high resistance to adopting such exotic dietary practices [7,8]. Neophobia is present in the minds of Western consumers still today, even despite their recognition that EIs have environmental advantages over other types of animal protein [9,10]. A recent review [11] discussing consumer perceptions of EIs, revealed that it is widely accepted that EIs are not part of the diets in Western countries, and therefore it is difficult to include them as regular foods. A way to improve consumer acceptance is by renowned chefs using them in their culinary practices or by using insects as food ingredients rather than consuming whole insects [12–14].

The nutritional quality of EIs is not inferior to that of other meats (beef, pork, chicken, turkey, and others), and sometimes the macro and micro components' balance is even more advantageous from a nutritional point of view. Insects are rich in protein and fat and are a very energy-dense food. Therefore, they could assume a leading role in a solution to mitigate hunger worldwide. Not only are EIs rich in protein, but those proteins are also high-quality proteins with a good balance of amino acids, especially essential amino acids. Additionally, most EIs contain a low saturated/total fatty acids ratio (less than 40% of the total fatty acids are saturated). On the other hand, EIs are rich in micronutrients, such as minerals (particularly zinc and iron) and vitamins (among which are vitamin E and vitamin B12) [1,15–17]. However, there are also some possible hazards and problems related to consuming insects. Some EIs can be a source of anti-nutrients, such as oxalates, hydrogen cyanides, phytic acid, and tannins, which, even though occurring naturally in foods, can compromise the digestion, absorption, and utilisation of certain nutrients [18–20]. Additionally, there is still a gap in guaranteeing food safety and antinutritional factors associated with edible insects, as discussed by Murefu et al. [21]. In the case of tannins, although tannins can act as agents limiting the absorption of some nutrients in some EIs [22,23], they can also act as antioxidants in some food matrices like wine [24,25] or cheese [26,27], and they can even be added into chitosan and cellulose-based films to provide antioxidant and antimicrobial properties [28]. Thus, tannins may have both a positive and a negative contribution to the impact of their consumption.

The consumption of edible insects is a culturally accepted practice in some parts of the world while not so readily accepted in others. Studies undertaken in some Western countries report some reluctance to adopt EIs into their diets while also stating that people tend to feel motivated to consumption by sustainable aspects. A study conducted in Australia [9] showed barriers to consumption, but people there are more ready to accept foods containing insects or those in which the insects are "disguised," like insect-based flour or chocolate-covered ants. A study conducted among German adults [12] showed that they were generally willing to try insects and concluded that an attractive packaging design did not increase the willingness to try them. Another study conducted in Germany [29] showed that there were some important barriers to consumption that must be taken into consideration when implementing the adoption of EIs.

The consumption of EIs could be strongly influenced by both cultural influences and knowledge about their effects and their impact. However, a search in the scientific literature proved that this topic is highly understudied and requires attention from the scientific community, unlike the motivations for the consumption of EIs, which have been intensively studied [9,30–32]. Hence, the aim of this study, as part of the international project EISuFood, was to characterise the level of knowledge about EIs in a sample of people from thirteen countries and to understand how this knowledge could lead to the formation of groups of people based on their knowledge regarding various aspects related to EIs, going from nutrition and health effects to sustainability issues. Additionally, it also sought to understand how sociodemographic, geographic, or professional characteristics influenced the composition of the clusters.

2. Materials and Methods

2.1. Instrument

This research was based on a questionnaire survey using an instrument that was pre-validated for a sample of Portuguese participants [33]. The items of the questionnaire were grouped into two sets, one with the items aimed at measuring knowledge and the other with items measuring perceptions. For this study, 27 items were used to measure knowledge, as indicated in Table 1. The participants had to express their agreement on a five-point Likert scale as follows: 1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, and 5 = strongly agree [34].

Table 1. Items used for measuring knowledge about edible insects.

N°	Item Description
1	Entomophagy is a dietary practice that consists in the consumption of insects by humans.
2	There are thousands of species of insects that are consumed by humans in the world.
3	Insects are a more sustainable alternative when compared with other sources of animal protein.
4	Insect production for human consumption emits much less greenhouse gases than beef production.
5	Insects efficiently convert organic matter into protein.
6	The production of insect protein uses considerably less feed than beef protein.
7	Insects are a possibility for responding to the growing world demand for protein.
8	The production of chicken protein requires much less water than insect protein. *
9	The ecological footprint (impact) of insects is smaller when compared with other animal proteins.
10	The production of insect protein requires much more area than pork protein. *
11	Insects are collected as a means of pest control for some cultivated crops.
12	The loss of biodiversity is lower with insect production compared with other animal food production.
13	The energy input needed for production of insect protein is lower than for the production of other proteins from animal origin.
14	Insects have poor nutritional value. *
15	Insects are a good source of energy.
16	Insects have high protein content.
17	Insect proteins are of poorer quality compared with other animal species. *
18	Insects provide essential amino acids necessary for humans.
19	Insects contain group B vitamins.
20	Insects contain dietary fibre.
21	Insects contain minerals of nutritional interest, such as calcium, iron, and magnesium.
22	Insects contain fat, including unsaturated fatty acids.
23	Insects contain anti-nutrients, such as oxalates and phytic acid.
24	There are appropriate regulations to guarantee the food safety of edible insects.
25	Insects contain bioactive compounds beneficial to human health.
26	Insects are potential sources of allergens.
27	Aflatoxins, which are carcinogens, can be present in insects.

* False statement.

2.2. Data Collection

This descriptive cross-sectional study was carried out on a non-probabilistic sample of 6899 participants from the following 13 countries: Croatia, Greece, Latvia, Lebanon, Lithuania, Mexico, Poland, Portugal, Romania, Serbia, Slovenia, Spain, and Turkey. The questionnaire was first prepared and validated in Portugal [33] and then translated into English to send to all the partners in the project. In all participating countries, the questionnaire was translated into the corresponding native language following a standard back-translation procedure. In each country, the data were collected based on the translated questionnaire, using the native languages of all participants.

All ethical principles were strictly followed when designing the questionnaire and collecting data, especially those of the Declaration of Helsinki. The Ethics Committee of the Polytechnic Institute of Viseu approved this questionnaire survey on 25 May 2020 with reference number 45/SUB/2021.

Due to the restrictions caused by the COVID-19 pandemic, data were collected between July and November 2021 using the electronic platform Google Forms. Recruitment was done using email and social media and followed a snowball methodology in each of the participating countries. This methodology has proven more effective than multisite data collection [35]. Only adult citizens (18 years old or over) who expressed their informed consent were allowed to participate in the survey.

2.3. Sample Characterization

The sample of 6899 participants was distributed among the participating countries, as indicated in Table 2. The participants were recruited according to variable sociodemographic characteristics in an attempt to have individuals of different groups, such as gender, age, level of education, or living environment. Although the survey had the limitation of not having equal representation across all sociodemographic classes, representation was nevertheless ensured by including a high number of participants.

Table 2. Distribution of the participants by country.

Country	N	%
Croatia	686	9.9
Greece	636	9.2
Latvia	300	4.3
Lebanon	357	5.2
Lithuania	510	7.4
Mexico	1139	16.5
Poland	520	7.5
Portugal	527	7.6
Romania	492	7.1
Serbia	344	5.0
Slovenia	517	7.5
Spain	575	8.3
Turkey	296	4.3
Total	**6899**	**100**

The participants' ages varied from 18 to 88 years, with an average age of 35 $\pm$ 14 years. Most of the participants were female (63.0%). Regarding the living environment, 68.6% of the participants lived in urban areas, and a smaller percentage lived in suburban (15.9%) or rural areas (15.5%). With respect to the highest education level attained, 36.5% had completed secondary or elementary school, 32.4% had completed a university degree, and 31.1% had completed postgraduate studies (master's or doctoral degree).

2.4. Statistical Analyses

The software used for the statistical analysis was SPSS Version 28 from IBM, Inc. (Armonk, NY, USA). Basic descriptive statistics were used, and more complex analyses were also performed, namely Factor Analysis (FA) and Cluster Analysis (CA). As the first step, exploratory factor analysis was applied using the method of Principal Component Analysis (PCA), aimed at determining if there was a grouping structure between the items. After this, the factors identified in the first step were submitted to cluster analysis.

Initially, the data were analysed to verify if they were appropriate for the techniques of FA using PCA. The correlation matrix between the variables was analysed to identify possible correlations. The Kaiser-Meyer-Olkin (KMO) measure of the adequacy of the sample was calculated, and Bartlett's test was performed to evaluate correlations between variables [36]. The reference values of the KMO are as follows: excellent for $0.9 \leq$ KMO ≤ 1.0, Good for $0.8 \leq$ KMO < 0.9, Acceptable for $0.7 \leq$ KMO < 0.8, Tolerable for $0.6 \leq$ KMO < 0.7, Bad for $0.5 \leq$ KMO < 0.6, and unacceptable for KMO < 0.5 [37].

To apply FA, the false items (9, 11, 15, and 18) were reversed for compatibility with the other items measuring knowledge. In this way, higher values of the score always correspond to higher knowledge.

Upon verification of the adequacy of the data, FA was applied with extraction using PCA and Varimax rotation with Kaiser Normalization. The number of components was determined based on the Eigenvalues greater than 1. The communalities were calculated to indicate the percentage of variance explained by the factors extracted [36]. Factor loadings with an absolute value lower than 0.4 were excluded [38,39]. The internal consistency of each factor was evaluated using Cronbach's alpha (α) [36,40]. Regarding the reference values for alpha, although dependent on the authors, in general, values over 0.7 are desirable, with values over 0.8 considered very good. Nevertheless, some authors also state that values over 0.5 could be acceptable [41–43].

The CA started with the application of hierarchical methods based on the factors obtained by FA (4 variables) to establish the most adequate number of clusters. The seven methods tested were: Within Groups Linkage (WGL), Between Groups Linkage (BGL), Nearest Neighbour (NN), Furthest Neighbour (FN), Centroid (CE), Median Clustering (MC), and Ward (WA), all considering the Squared Euclidean distance for interval measurement. The coefficients obtained in the agglomeration schedule for the different methods indicated that the optimal number of groups that should be formed was three. Then, the seven methods were run again with the fixed number of clusters, and the obtained solutions were compared by means of contingency tables (crosstabs) in order to evaluate stability (Table 3). Some of the solutions showed a possible similarity of over 98% (BGL, NN, CE, MC), which is very high and indicative of potential stability. Therefore, these four clustering solutions were used as initial solutions to proceed with the analysis using the partitive method of k-means, which is particularly recommended and frequently used in CA [44].

Table 3. Similarity between the solutions obtained through hierarchical clustering methods.

Methods [1]	WGL	BGL	NN	FN	CE	MC	WA
WGL	100%						
BGL	43%	100%					
NN	43%	99%	100%				
FN	41%	52%	51%	100%			
CE	43%	98%	99%	50%	100%		
MC	44%	99%	99%	52%	98%	100%	
WA	69%	45%	37%	41%	45%	45%	100%

[1] WGL = Within Groups Linkage, BGL = Between Groups Linkage, NN = Nearest Neighbour, FN = Furthest Neighbour, CE = Centroid, MC = Median Clustering, WA = Ward.

The chi-square test was used to assess differences between clusters according to the sociodemographic factors. A level of significance of 5% was used, and the Cramer's V coefficients were also calculated as a measure of the association between the categorical variables tested. The Cramer's V coefficient varies from 0 to 1; for $V \approx 0.1$, the association was considered weak; for V ≈ 0.3, the association was moderate; and for V ≈ 0.5 or over, the association was strong [45].

3. Results

3.1. Factor Analysis

The correlation matrix showed that there were some correlations between the variables, with 30 values higher than 0.5. The highest value in the correlation matrix was found to be 0.647, corresponding to the correlation between items 4 and 6. Based on this evidence, some relevant correlations between the variables were indicative that we could apply FA. Additionally, Bartlett's test was significant ($p < 0.0005$), confirming the rejection of the null hypothesis "H0: The correlation matrix is equal to the identity matrix". The value of KMO (0.944) can be classified as excellent, based on the classification of Kaiser and Rice [37], confirming once more the suitability for the application of PCA and FA techniques. The anti-image matrix showed that there was no value of MSA (Measure of Sampling Adequacy) below 0.5, meaning that all the variables were properly included in the analysis (the values of MSA ranged between a minimum of 0.660 for item 8 to a maximum of 0.973 for item 25).

The solution obtained by FA with PCA and Varimax rotation retained five components (eigenvalues. 8.551, 2.618, 1.750, 1.301, and 1.009). The percentages of total variance explained (VE) by the factors were: F1—19.45%, F2—13.70%, F3—9.25%, F4—6.67%, and F5—6.32%, resulting in a total variance explained of 55.39% (Table 4). Items with higher communalities were 10 (0.684, 68.4% VE), 21 (0.682, 68.2% VE), and 6 (0.674, 67.4% VE). The item with the lowest variance explained by the solution was 24 (22.1% VE). Item 24 was not included in any of the factors due to loading values lower than 0.4.

Table 4. Solution obtained through factor analysis.

Factor	%VE [1]	Items	Loadings	Factor Name	Cronbach's Alpha (α)
F1	19.45	3. Insects more sustainable than other animal proteins	0.650	Sustainability (SUS)	0.899
		4. Insects emit fewer greenhouse gases than cows	0.748		0.905 [2]
		5. Insects efficiently convert organic matter into protein	0.685		
		6. Insects use considerably less feed than cows	0.781		
		7. Insects can meet the growing demand for protein	0.718		
		9. The footprint of insects is smaller than other animals	0.755		
		11. Insect collection is a pest control mechanism	0.528		
		12. Insects originate lower loss of biodiversity	0.670		
		13. Insects require less energy than other animals	0.750		
F2	13.70	18. Insects provide essential amino acids	0.639	Nutrition (NUT)	0.832
		19. Insects contain group B vitamins	0.740		0.844 [3]
		20. Insects contain dietary fibre	0.694		
		21. Insects contain minerals of nutritional interest	0.740		
		22. Insects contain fat, including unsaturated fatty acids	0.711		
		23. Insects contain anti-nutrients	0.499		
		25. Insects contain bioactive compounds	0.444		
F3	9.25	1. Entomophagy consists in the consumption of insects	0.545	Insects as Protein Food (IPF)	0.712
		2. There are thousands of species of edible insects	0.580		
		14. Insects have poor nutritional value (reversed)	0.558		
		15. Insects are a good source of energy	0.516		
		16. Insects have high protein content	0.518		
		17. Insect proteins are of poorer quality (reversed)	0.450		
F4	6.67	26. Insects can contain allergens	0.790	Health Risks (HR)	0.577
		27. Insects can contain aflatoxins	0.740		
F5	6.32	8. Chickens require less water than insects (reversed)	0.794	Production Factors (PF)	0.617
		10. Insects require more area than pigs (reversed)	0.823		

[1] VE = Variance explained. [2] Alpha if item 11 is removed. [3] Alpha if item 23 is removed.

The FA solution converged in six iterations. Table 4 shows that the first group of items seems related to sustainability aspects of EIs and was named Sustainability (SUS). Items in factor F2 are associated with the nutritional aspects of edible insects and were named Nutrition (NUT). The items in factor F3 are related to the consumption of insects as a source of protein, so it was named Insects as Protein Food (IPF). Factor F4 contained only two items and was named Health Risks (HR) because the items relate to the presence of compounds harmful to human health. Finally, the last factor, F5, also contained two items, both related to insect production specifications and was, for that reason, named Production Factors (PF).

In general, the item loadings for all factors were high (for F1, varying from 0.528 to 0.781; for F2, varying from 0.444 to 0.740; for F4, varying from 0.740 to 0.790; for F5, varying from 0.794 to 0.823), with factor F3 being just a little lower (varying from 0.450 to 0.580). High loadings are indicative of the high contribution of the items to the definition of the factors. Items with the highest loadings are item 10 (loading of 0.823 into factor F5) and item 26 (loading of 0.790 into factor F4), meaning that these items are most strongly associated with the respective factors.

To validate the solution, Cronbach's alpha (α) values were determined to measure the internal consistency within each factor [36]. The value of Cronbach's alpha for factor F1 (SUS) was 0.899 and 0.832 for factor F2 (NUT), both of which are considered very good [41–43]. However, factors F1 and F2 could have a higher internal consistency if one item were removed from each of those factors (items 11 and 23, respectively), as shown in Table 4.

The value of alpha for F3 was 0.712, which is good, being over the threshold of 0.7. The values of alpha for F4 and F5 were 0.577 and 0.617, respectively, and although lower than for the other factors, they can still be considered acceptable [41–43]. For factor F3, the value of alpha would not increase with the removal of any item, and factors F4 and F5, are also fixed for having only two items.

Considering these results, we conclude that the scale would be stronger if three items were removed [38]—11, 23, and 24, as discussed earlier—and for that reason, the final factor solution was run considering only 24 items instead of the 27 originally tested. For this group of items, the KMO was 0.942, and the significance of Bartlett's test was significant ($p < 0.0005$). This final solution (Table 5) explains 55.07% of the variance and comprises four factors. Items 1 and 2 ("Entomophagy consists in the consumption of insects" and "There are thousands of species of edible insects", respectively) were not included in any of the factors due to loading values lower than 0.4.

The first factor, named Sustainability (SUS), has the exact same eight items as in the previous solution ($\alpha = 0.905$) and accounts for items related to the sustainability of EIs as alternative protein foods. Factor F2 included the six items from the previous solution but added two new items, 15 and 16, both also related to nutritional aspects of edible insects, the first relating to energetic value and the second to protein content. So, this factor name was kept as Nutrition (NUT) because it accounted for a total of eight items related to dietary components of EIs, and its internal consistency increased as compared with the previous solution ($\alpha = 0.872$).

Factor F3 remained equal to F5 from the previous solution, Production Factors (PF) ($\alpha = 0.617$) and consists of two items that compare production factors of EIs with other sources of animal protein, specifically chickens and pigs.

The last factor, F4, added two items to the previous factor, F4. This factor accounted for items related to allergens or aflatoxins and was named Health Concerns (HC). The internal reliability of this factor is lower than 0.5, which can be explained by the negative values of the loading for items 14 and 17.

In all factors, the values of alpha would not improve with the removal of any item, so this is considered the final solution, including four factors and 22 items.

Table 5. Final solution obtained through factor analysis, considering 22 items.

Factor	%VE [1]	Items (Loadings)	Factor Name	Cronbach's Alpha (α)
F1	22.51	Item 3 (0.696), item 4 (0.778), item 5 (0.715), item 6 (0.793), item 7 (0.758), item 9 (0.750), item 12 (0.641), item 13 (0.732)	Sustainability (SUS)	0.905
F2	18.27	Item 15 (0.594), item 16 (0.560), item 18 (0.714), item 19 (0.746), item 20 (0.711), item 21 (0.788), item 22 (0.653), item 25 (0.579)	Nutrition (NUT)	0.872
F3	7.15	Item 8 (0.802), item 10 (0.801)	Production Factors (PF)	0.617
F4	7.14	Item 14 (−0.401), item 17 (−0.492), item 26 (0.761), item 27 (0.780)	Health Concerns (HC)	<0.5

[1] VE = Variance explained.

3.2. Cluster Analysis

Table 6 shows the results obtained for the application of k-means clustering to the four initial solutions obtained with hierarchical methods, which offered a higher probability of stability (BGL, CE, MC, and NN). From the tested initial solutions, two of them converged to the same final solution (CE and NN), as can be seen, both from the number of cases classified in each cluster and also the coordinates of the cluster centres. Additionally, because the values of ANOVA p-value are significant ($p < 0.0005$) and the values of the test statistic (F) are high, they indicate similarity between the cases within the groups and differentiation between groups. Furthermore, while factors F1 (SUS) and F3 (PF) contributed more to the definition of the clusters (with values of F in the same magnitude), factors F2 (NUT) and F4 (HC) contributed less (also with values of F in the same magnitude). In this way, the final solution is accepted as that originating from the initial CE and NN solutions, and the clustering analysis was more deeply influenced by the sustainability issues and lower production requirements of EIs as compared with other animal species than the nutritive aspects or health issues associated with the consumption of EIs.

Table 6. Results for the k-means clustering.

Initial Solution [1]	Factors	ANOVA		Cluster 1		Cluster 2		Cluster 3	
		F	p-Value	PC [2]	FCC [3]	PC [2]	FCC [3]	PC [2]	FCC [3]
BLG	F1 (SUS)	1467	$p < 0.0005$	50%	−0.433	25%	−0.057	25%	0.901
	F2 (NUT)	2961	$p < 0.0005$		−0.526		1.129		−1.068
	F3 (PF)	1712	$p < 0.0005$		−0.334		−0.338		0.990
	F4 (HC)	34	$p < 0.0005$		0.092		−0.147		−0.031
CE	F1 (SUS)	3287	$p < 0.0005$	61%	−0.061	10%	−1.815	29%	0.741
	F2 (NUT)	169	$p < 0.0005$		−0.080		−0.402		0.304
	F3 (PF)	3776	$p < 0.0005$		−0.576		0.687		0.969
	F4 (HC)	158	$p < 0.0005$		0.157		−0.446		−0.177
MC	F1 (SUS)	2098	$p < 0.0005$	53%	0.126	35%	0.378	12%	−1.613
	F2 (NUT)	152	$p < 0.0005$		−0.186		0.260		0.056
	F3 (PF)	841	$p < 0.0005$		0.274		−0.595		0.519
	F4 (HC)	1340	$p < 0.0005$		0.502		−0.565		−0.538
NN	F1 (SUS)	3286	$p < 0.0005$	61%	−0.063	10%	−1.845	29%	0.737
	F2 (NUT)	171	$p < 0.0005$		−0.090		−0.382		0.312
	F3 (PF)	3747	$p < 0.0005$		−0.573		0.701		0.966
	F4 (HC)	163	$p < 0.0005$		0.159		−0.459		−0.181

[1] BLG = Between Groups Linkage, NN = Nearest Neighbour, CE = Centroid, MC = Median Clustering. [2] PC = percentage of cases in the cluster. [3] FCC = final cluster centres.

Concerning the final clusters, cluster 1 includes 61% of the individuals, and those have a positive input for factor F4 (HC), meaning that they are informed about health concerns related to the consumption of EIs. Factors F1 (SUS) and F2 (NUT) have a marginally negative input for cluster 1, so these individuals are not informed about the sustainability issues or the nutritive aspects of EIs. On the other hand, they reveal a very low level of knowledge about the production characteristics of EIs (F3—PC). Individuals in cluster 2 represent a minority of only 10% and possess high knowledge about the production factors associated with EIs (positive centre for F3—PF) but low knowledge about all other aspects associated with factors F1 (SUS), F2 (NUT), and F4 (HC). Finally, individuals in cluster 3 represent nearly one-third of the participants, and these are well-informed about all aspects except for the health issues, as evidenced by the positive centres for factors F1 (SUS), F2 (NUT), and F3 (PF). Based on these results, the clusters can be defined accordingly:

- Cluster 1 ('fearful' individuals)—individuals with low knowledge about EIs, but who are aware of the possible harmful effects resulting from their consumption;
- Cluster 2 ('farming' individuals)—individuals with very low knowledge about EIs, but who are informed about their production;
- Cluster 3 ('ecological' individuals)—individuals with very high knowledge about EIs, particularly concerning sustainability aspects and the production of EIs, but who are not informed about their possible health effects.

3.3. Characterisation of the Clusters

After defining the clusters, it is important to characterise the individuals in each of the groups. For this, the sociodemographic, geographic, and professional variables were used as segmentation characteristics.

Table 7 presents the clusters' membership according to sociodemographic variables like sex, age, and education level. The results indicate that, with respect to sex, cluster 2 (the 'farming' individuals) had proportionally more male participants, while cluster 1 (the 'fearful') had comparatively more female participants than the other two clusters (these differences being significant, $p < 0.0005$). Concerning age, no significant differences were found ($p > 0.05$) among clusters, with a similar distribution among the three age classes: most individuals in the young adults' class, followed by the adults' class and a smaller number of individuals in the senior adults' class, following the trend of the age distribution of the study sample. As for education level, significant differences were found ($p < 0.0005$), so members of cluster 2 (the 'farming') tended to have lower levels of education than those in cluster 1 (the 'fearful') and cluster 3 (the 'ecological'). This last cluster had the highest education level, which indicates that more educated people are better informed about sustainability issues related to EI.

Table 8 shows the clusters in terms of the geographical variables, country and living environment. The results highlight a significant difference among the clusters according to country ($p < 0.0005$), with a moderate association according to the value of Cramer's coefficient (V = 0.221). In some countries, like Greece, Latvia, Lebanon, or Turkey, a clearly higher percentage of individuals fall into cluster 1 (the 'fearful'). There are other countries, such as Croatia or Serbia, for which more individuals are categorised in cluster 2 (the 'farming'). Finally, cluster 3 (the 'ecological') is predominant in countries like Lithuania, Mexico, Poland, Slovenia, and Spain. With respect to the living environment, people in rural areas are classified more in cluster 2 (the 'farming'), while people in urban areas are more in cluster 3 (the 'ecological'). People in suburban areas are divided equally among the three clusters.

Table 7. Association between cluster membership and sociodemographic variables.

Variables		**Cluster 1 Fearful**	**Cluster 2 Farming**	**Cluster 3 Ecological**	**Total**
Sex ($p < 0.0005$; V = 0.054)	Female	65.9%	57.5%	58.9%	63.0%
	Male	33.5%	42.0%	40.2%	36.3%
	Other	0.6%	0.5%	0.9%	0.7%
Age group ($p = 0.327$; V = 0.018)	Young adults (18–30 y)	48.4%	46.1%	48.8%	48.3%
	Adults (31–50 y)	35.8%	36.3%	36.7%	36.1%
	Senior adults (51 y or over)	15.8%	17.6%	14.5%	15.6%
Education level ($p < 0.0005$; V = 0.066)	Postgraduate education (master's or PhD)	30.3%	21.8%	35.5%	31.0%
	University degree	32.6%	32.0%	32.3%	32.5%
	No University degree	37.1%	46.2%	32.2%	36.5%

Table 8. Association between cluster membership and geographical variables.

Variables		**Cluster 1 Fearful**	**Cluster 2 Farming**	**Cluster 3 Ecological**	**Total**
Country ($p < 0.0005$; V = 0.221)	Croatia	10.9%	16.8%	5.3%	9.8%
	Greece	10.9%	9.5%	5.6%	9.2%
	Latvia	5.7%	2.3%	2.3%	4.4%
	Lebanon	6.3%	2.6%	3.7%	5.2%
	Lithuania	7.5%	3.0%	8.6%	7.4%
	Mexico	12.8%	20.2%	23.1%	16.5%
	Poland	6.5%	2.7%	11.4%	7.6%
	Portugal	7.5%	7.7%	7.7%	7.6%
	Romania	8.2%	8.2%	4.5%	7.1%
	Serbia	5.8%	9.5%	1.9%	5.0%
	Slovenia	6.7%	6.0%	9.7%	7.5%
	Spain	5.4%	8.3%	14.4%	8.3%
	Turkey	5.7%	3.2%	1.7%	4.3%
Living environment ($p = 0.005$; V = 0.033)	Rural	16.0%	18.3%	13.2%	15.4%
	Urban	67.6%	66.2%	71.3%	68.6%
	Suburban	16.4%	15.5%	15.5%	16.0%

In Table 9, the cluster membership is reported according to professional variables (area of work and income). The results show that individuals with professional areas of food/nutrition and biology are more prone to be in cluster 3 (the 'ecological'), but for the other professions, the distribution among the different clusters is more even. The results further indicate that participants in the agricultural sector are slightly more likely to be in clusters 2 and 3 ('farming' and 'ecological'). The participants with professional activity linked to the environment are mostly in the 'ecological' cluster, although some are also present in cluster 1 ('fearful'). People engaged in professions related to tourism tend to fit into cluster 2 ('farming'), and this is also the case for individuals with professions related to the health sector. Nevertheless, for these two types of professionals, cluster 1 ('fearful') is also representative.

Table 9. Association between cluster membership and professional variables.

Variables		Cluster 1 Fearful	Cluster 2 Farming	Cluster 3 Ecological	Total
Professional area ($p < 0.0005$; V = 0.107)	Food/Nutrition	30.0%	24.0%	38.2%	31.9%
	Agriculture	7.8%	8.5%	8.6%	8.1%
	Environment	5.2%	3.2%	5.4%	5.1%
	Biology	4.9%	2.2%	7.8%	5.5%
	Health	12.4%	16.1%	11.4%	12.5%
	Tourism	3.1%	3.8%	2.1%	2.9%
	Others	36.6%	42.2%	26.5%	34.0%
Family income ($p < 0.0005$; V = 0.057)	Much below average	6.0%	8.7%	5.5%	6.1%
	Below average	16.6%	19.3%	15.5%	16.5%
	Average	40.4%	40.0%	38.1%	39.7%
	Above average	32.5%	26.0%	33.4%	32.2%
	Much above average	4.5%	6.0%	7.5%	5.5%

When it comes to income (Table 9), people with an average income are more or less equally distributed among the three clusters. However, differences become clearer for low or very low incomes, for which the individuals tend to be more in cluster 2 (the 'farming') and on the other hand, those with high or very high incomes tend to be more in cluster 3 (the 'ecological').

4. Discussion

4.1. Analysis of the Scale

The validation of the scale showed that some items included in the questionnaire were not strong enough to be part of the scale.

Item 24, "There are appropriate regulations to guarantee the food safety of edible insects", relates to a very complex issue because regulations can be highly variable according to the geographic regions, countries, and even different political environments. In many countries, the rearing of insects for human food has been restrained by regulatory measures. For example, in Europe, regulations are very strict, and the topic of edible insects is still novel, as evidenced in the EU Novel Foods Regulation (EC) No 258/97 [46], which applies to foods and food ingredients that have not been used for human consumption to a significant degree within the European Community before 15 May 1997. EIs are considered novel foods under Regulation (EU) 2015/2283 [47] and can only be commercialised after a safety assessment and authorisation. The most recent advancement in this field in Europe was the recognition of dried yellow mealworm (*Tenebrio molitor* larva) as a safe novel food by EFSA [48]. Schiel et al. [49] discuss the possible application of analytical methods to analyse the composition of EIs for the purpose of food control in Germany. In Finland, despite the need to comply with the official existing EU regulations, EI production has been a reality since 2014 [50]. In the English-speaking markets (United States, United Kingdom, Canada, Australia, and New Zealand), EIs have been approved by their food safety agencies [15,51]. In areas where insects are considered traditional foods and have been consumed over generations (Africa, Southeast Asia, and Latin America), there is still a lack of regulatory measures regarding the production and consumption of EIs [15].

Item 11, "Insects are collected as a means of pest control for some cultivated crops", refers to wild insects that populate some agricultural crops, and this practice is specific to farmers and crop producers [52]. Therefore, it is highly probable that it might be difficult for the general public to be informed about such crop protection measures. Forest biodiversity is important not only in connection with the conservation of trees but also for the continued presence of insect populations [52]. However, in areas where edible forest insects grow into vast populations that can compromise cultivated crops, they are collected as a means of pest control and are included in a planned and nutritionally more valuable diet throughout the year [53,54].

Item 23, "Insects contain anti-nutrients, such as oxalates and phytic acid", refers to particular components that can be present in EIs, and which can be considered anti-nutrients [20]. Oxalate and phytic acid are biologically active compounds which can directly chelate nutrients such as minerals and proteins, thus making them unavailable for absorption. This immobilises the nutrients in undigested food complexes or, even if digestion and absorption occur, the anti-nutrients can represent barriers to the efficient utilisation of the nutrients [55]. In this way, they will prevent the human body from obtaining the necessary amounts of these nutrients. In some cases, anti-nutrients bind to proteins, especially digestive enzymes [56]. These properties of such substances are known by some people, like doctors or nutritionists, but most likely are unknown to the majority of the general public.

Items 1 and 2 ("Entomophagy consists in the consumption of insects" and "There are thousands of species of edible insects", respectively) were also problematic and therefore were excluded. Both items refer to true statements [4,57], and they deal with the knowledge that is most likely to be present for participants originating from countries where traditional insects consumption is a common practice. However, most countries included in this research do not fall into this category and this may explain the lower relevance of these items for the final factorial solution.

The factorial structure obtained included four factors. The first factor, named Sustainability (SUS), accounts for items related to the sustainability of EIs as alternative protein foods. EIs have been pointed out as considerably more sustainable compared to other sources of animal protein. In this way, the partial replacement of meat by EIs can alleviate pressure on the environment, while contributing to the feeding of a growing world population [57]. Ordoñez-Araque and Egas-Montenegro [58] present a literature review that demonstrates the viability of EIs as an alternative that can relieve nutritional deficiencies while contributing to slowing down the rate of deterioration of the environment.

Factor F2 was named Nutrition (NUT) and included items related to dietary components of EIs. Insects are categorised as one of the pillars of future human nutrition [59]. One of the reasons that contribute to this claim is that in many places where the availability of nutritious foods is scarce, EIs are usually present abundantly, and their nutritional value must be considered [15]. Proteins constitute the highest fraction of the composition of EIs, ranging from 50 to 70% on a dry basis. Lipids represent the second largest fraction of the nutritional composition of EIs, right after proteins [60]. Additionally, EIs contain dietary fibre, minerals, vitamins, and also some bioactive compounds with beneficial health properties [60–64].

Factor F3 (Production Factors—PF) consisted of two items that compared production factors of EIs with other sources of animal protein, specifically chickens and pigs. The production of insects has a lower environmental impact when compared to other sources of animal protein, namely, beef, pork, or chicken meats. Some of the advantages include lower emissions of greenhouse gases, the need for considerably less area/land for their rearing, a more efficient use of energy, and much lower needs for feed and water [57,65].

The last factor, F4 (Health Concerns—HC), accounts for items related to allergens or aflatoxins, which can be harmful to human health, and allied to items associated with a poor nutritional value or poor protein content, which can result in deficient nutrition. This factor includes items that have been reversed because they refer to statements that were false. However, the responses of the participants are against this reversion, which implies that, in general, the perceptions of the participants are towards agreement with the false statements, thus revealing a lack of knowledge when it comes to the quality of EIs as a nutritious food and containing high-quality proteins. It has been demonstrated that EIs present high-quality proteins in interesting amounts and these proteins contain all the essential amino acids in the recommended ratios [61,66,67].

4.2. Characterisation of the Participants' Clusters and Discussion of Sociocultural Influences

The cluster membership showed that more male participants were categorised into cluster 2 (the 'farming' individuals) than females. Farmers and people with knowledge about agriculture and husbandry are more frequently men. This is, in fact, a sector where there is still a high gender inequality [68,69], although some countries have started to empower women in this domain, such as Europe [68,70] or Africa [71–73]. Additionally, members of cluster 2 (the 'farming') tended to have lower levels of education than those in cluster 1 (the 'fearful') and cluster 3 (the 'ecological'). This last cluster had the highest education level, which indicates that more-educated people are better informed about sustainability issues related to EIs. The work by Guiné et al. [74] studied the level of information about the sustainability of EIs in Portugal and found that the most relevant discriminating sociodemographic variable was education, with people having a university degree being considerably more informed than those with lower education levels. Additionally, the study by Palmieri et al. [67] reinforces this aspect.

The professional area of the participants was also found to be related to cluster membership. In the work by Florença et al. [75], it was found that people in the areas of nutrition, agriculture, and environment tended to have more correct perceptions about EIs than those with professions linked to food, biology, or the health sector. In our work, the participants in the agricultural sector were more prone to be included in clusters 2 and 3 ('farming' and 'ecological'), which can be explained by their close relationship with agricultural practices, the land, and natural systems from which they derive their livelihood. Participants with work related to the environment tended to be categorised into the 'ecological' cluster, which is expected given their higher consciousness about the ecological and sustainability aspects.

People with professions linked to tourism or health tended to fit into cluster 2 ('farming') and cluster 1 ('fearful'). Possible explanations can be linked to the fear of consuming novel foods and the possible adverse effects that these can have, namely the safety issues associated with the consumption of EIs. Murefu et al. [21], reviewing the safety of EIs, alerted readers to the limitations of the actual food systems around the world in controlling hazards derived from the production and processing of insects, although highlighting that Europe was at the forefront when it came to the safety of EIs.

The results further showed that the level of income also affected the distribution of the participants by clusters. Differences were major for low or very low incomes, corresponding to participants categorised as 'farmers', while participants with high or very high incomes were categorised more into the 'ecological'. People with higher incomes usually also have a higher level of education, and those are associated with a higher ecological conscience [76,77]. On the other hand, people from rural environments, such as farmers, can have a lower level of income.

With regards to the cluster distribution by country, differences were found, resulting from the different sociocultural influences. Social and cultural influences greatly shape people's attitudes and level of knowledge. In the case of EIs, aspects related to ecological or health concerns were greatly present in Western societies, even in those countries where entomophagy was not a traditional practice. Cultural and social influences were drivers that influenced consumers towards the willingness to have EIs. Bisconsin-Júnior et al. [4] discussed the social aspects related to edible insects in regions where entomophagy was not familiar. Among the factors pointed out associated with positive and negative associations with EI, the authors referred to risk perception, level of acceptance or disgust, sustainability, culture, and organoleptic characteristics. Hartmann et al. [78] addressed the psychological factors underlying the consumption of EIs in countries with very diverse cultural influences towards insects, namely an Asian country (China) and a European country (Germany). Not surprisingly, they reported that the Chinese revealed a higher willingness to consume insects compared to the Germans. Ribeiro et al. [79] referred to differences in acceptance of insects as food and feed between consumers in a Southern Europe country (Portugal) and a Northern Europe country (Norway). In a work by Florença et al. [75] studying the motivations for consuming insects in a sample of the Portuguese population, it was shown that the preservation of the environment and natural resources constituted the strongest motivations to consume EIs for people who were not usual consumers of this type of food.

Schardong et al. [80] investigated consumers' perceptions of EIs in Brazil, a Latin American country, with some regions where the consumption of insects is possibly traditional. Their survey included participants from different regions of Brazil: North, Northeast, Midwest, Southeast, and South. Their results showed that men were more willing to consume insects than women. Flour was the preferred form of consumption, but the whole insect was preferred for those participants with familiarity with the insects. Gasca-Álvares et al. [81] conducted a review of EIs as food among indigenous communities of Colombia and reported that 69 edible insects were ingested by 13 ethnic groups originally from the Amazon and Caribbean regions. With regards to African countries, the study by Ebenebe et al. [82] highlighted that the tradition of entomophagy is somehow compromised by Western dietary patterns, which have been imposed over traditional insect eating. Still, they were able to do an inventory of 17 insect species consumed in Nigeria. In Ivory Coast, a study by Ehounou et al. [83] revealed that more than half the people in Abidjan consumed insects (60%), and they identified eight insect species consumed by the participants in the survey. Additionally, the trade of insects represented an important source of income for families. In Ghana, the survey conducted by Anankware et al. [84] aimed at identifying edible insects that were still underutilised and that should be more intensively used as human food and animal feed. They identified nine edible insects that were consumed differently depending on the region of the country. In South Africa, a questionnaire survey by Hlongwane et al. [85] investigated the level of indigenous knowledge about edible insects, namely what insects were consumed and how they were collected and prepared for food among the rural people. This work revealed that, like in other African countries, the influence of Western diets is leading to a decline in entomophagy. A review by Matandirotya et al. [86] made an overview of the consumption of edible insects in African countries. Some of the most relevant conclusions of this study point out the existence of a high number of edible insect species on the continent. These were easily accessible to the communities, and the populations had an incentive to use traditional knowledge to take advantage of this sustainable food source. However, they alert us to the need to establish food safety guidelines as a way to safely consume insects and their derived food products.

A work by Ruby et al. [87] investigated the willingness to consume EIs in two different countries with different cultural backgrounds, the United States of America and India. Their results showed that in both countries, the majority of participants were willing to consider eating at least some form of insect food (72% for Uthe SA and 74% for India). In China, Liu et al. [31] studied the factors that conditioned consumption of EIs and found that buying intentions were mostly dictated by phobia and disgust, but also knowledge level, age, household size and income, as well as the geographical region had a remarked influence.

In Hungary, the willingness to consume insect-based food was found to be low; however, it was higher for men and for those with higher school levels (university degrees) [88]. According to Detilleux et al. [89], Belgian youngsters showed a willingness to consume edible insects as processed foods, and their negative perception of entomophagy was changed towards a more positive one after actually tasting food products made with insects (falafel). The work by House [90] revealed that in the Netherlands, the development of a Dutch edible insect network was ongoing, focused on the production, supply, and consumption of a variety of insect-based foods. The paper also discussed the question of frequent consumption as opposed to just trying EI-based foods sporadically. In Switzerland, a study by Penedo et al. [91] showed that the acceptability of consumers towards EIs was related to various sociodemographic and behavioural factors. Although the participants were potentially willing to consume EIs, there were some practical barriers that impeded their adoption, such as disgust. In the Czech Republic, Kulma et al. [92] reported that peoples' preferences were towards consuming EIs as ingredients in foods, and they were generally favourable to the use of EIs to feed cattle to serve as human food. Orkusz et al. [93] showed that the willingness to adopt edible insects as a meat substitute was still low among the Poles, and the main constraints were related to psychological barriers, such as neophobia and disgust. However, the authors also reported that the consumption of insect-based foods was considerably higher than that of unprocessed whole insects. Among the positive drivers to incentive consumption of EIs stood the environmental benefits. In another study in Poland, Zielinska et al. [94] revealed that people over 40 years old were more ready to possibly accept edible insects in the future. When it comes to foods containing EIs, a great majority of respondents said they would consider accepting products that were made from insect protein. A study by Gałęcki et al. [95] showed that in Poland, insect farming could become a novel branch of agriculture, and it could create new opportunities for Polish farmers.

5. Conclusions

The present research allowed the statistical analysis of the results obtained for a set of items aimed at measuring knowledge about EIs, producing a solution with four factors, which included 22 of the 27 initial items. The solution explains 55% of the variance, and the four factors were identified as relating to sustainability (8 items), nutrition (8 items), production factors (2 items), and health concerns (4 items). For the first two factors, the internal consistency was very high, as given by the values of Cronbach's alpha, but for the health concerns factor, the internal consistency was low. Posterior cluster analysis revealed three clusters (fearful, farming, and ecological individuals). The cluster characterisation indicated that age did not influence cluster membership, while sex, education, country, living environment, professional area, and income all influenced the composition of the clusters.

In conclusion, this work confirmed the statistical validation of the present scale used to measure knowledge about EIs. Furthermore, its application to a wide set of countries, different in nature, allows its future usage on a global scale, making it a valuable instrument for application for a wide set of circumstances in the future, with participants in different countries with different cultural backgrounds and different population segments. The measurement of knowledge about EIs is a valuable way to define strategies for the implementation of policies designed to possibly improve EIs' attractiveness to people as a way to better contribute to more sustainable food systems while also benefiting from adequate nutrition and health improvement. This is of particular relevance since EIs are considered an instrument to contribute to food security while ensuring food safety.

Although providing a great deal of new information and wide coverage in terms of the geographical distribution of the study, the present research has some limitations that are worth highlighting. One of them is related to unequal group distribution, particularly by country (more participants from Mexico), sex (more men), and living environment (more people residing in urban areas). Another limitation is related to the countries included in the study, which, by being selected based on an invitation from the project manager and past collaboration, resulted in a higher representation of European countries as compared with other regions of the globe. Finally, it is worth mentioning that the design of the instrument itself has some limitations, which resulted from the fact that the same instrument should be suitable for participants with such a diverse cultural background regarding EIs, namely some in countries where eating insects is part of the local culture since time immemorial and others where it is still seen as a strange and somehow daring practice.

Author Contributions: Conceptualisation, R.P.F.G., C.A.C., P.M.R.C., M.F., A.P.C., S.C. and O.A.; methodology, R.P.F.G.; software, R.P.F.G.; validation, R.P.F.G.; formal analysis, R.P.F.G.; investigation, R.P.F.G., C.A.C., P.M.R.C., S.G.F., M.F., A.P.C., S.C., O.A., C.C.-H., M.M.S., M.P., J.M.F.B., M.K., M.Č.-B., E.B., M.T., N.M.B., I.D., D.K. and E.D.; resources, R.P.F.G., C.A.C., P.M.R.C., M.F., A.P.C., S.C. and O.A.; data curation, R.P.F.G.; writing—original draft preparation, R.P.F.G. and S.G.F.; writing—review and editing, R.P.F.G., C.A.C., P.M.R.C., S.G.F., M.F., A.P.C., S.C. and O.A.; 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.

Funding: This work was funded by the CERNAS Research Centre (Polytechnic Institute of Viseu, Portugal) in the ambit of the project EISuFood (Ref. CERNAS-IPV/2020/003). We also received funding from the FCT—Foundation for Science and Technology (Portugal) through projects Ref. UIDB/00681/2020, UIDB/05507/2020 and UIDB/007421/2020. The APC was funded by FCT through project Ref. UIDB/00681/2020, project Ref. UIDB/05507/2020, project Ref. UIDB/007421/2020.

Institutional Review Board Statement: This research was implemented, taking care to ensure all ethical standards and following the guidelines of the Declaration of Helsinki. The development of the study by questionnaire survey was approved on 25 May 2020 by the ethics committee of the Polytechnic Institute of Viseu (Reference No. 45/SUB/2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available from the corresponding author upon request.

Acknowledgments: This work was supported by the FCT—Foundation for Science and Technology, I.P. Furthermore, we would like to thank the CERNAS, CIDEI and UCISA:E Research Centres, and the Polytechnic Institute of Viseu for their support. This research was developed in the ambit of the project "EISuFood—edible Insects as Sustainable Food", with reference CERNAS-IPV/2020/003.

Conflicts of Interest: The authors declare no conflict of interest.

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