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Willingness to consume insect-based food in France: Determinants and consumer perspectives

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ABSTRACT

Despite having an appealing nutritional profile and lower environmental impacts compared to traditional meat products, edible insects face challenges in gaining consumer acceptance, especially in western societies. No consumer study on edible insects has been conducted in France. Hence, this study aims to evaluate French consumers' willingness to adopt insect-based food (IBF) and identify factors influencing entomophagy (the consumption of insects as food). A 46-question online questionnaire was administered to 617 subjects to assess how various explanatory variables impact IBF acceptance through difference tests, correlation analysis, and multiple correspondence analysis. The results revealed that 69% of respondents were introduced to entomophagy, and 53% had consumed IBF before the survey. Environmental sustainability and nutritional value were identified as major motivators for entomophagy, which could inform promotional strategies for IBF in France. Unfamiliarity and disgust emerged as primary barriers to entomophagy. However, the study suggested that these challenges could be overcome by repeated exposure to entomophagy, which reduced food neophobia and food disgust sensitivity, increased familiarity with entomophagy, and improved insect-eating experiences and willingness to consume IBF. Overall, the study highlights the potential for entomophagy in France and emphasizes the need to address consumer perceptions to foster broader acceptance of IBF.

1. Introduction

The world's population is on a rapid upward trajectory and is projected to approach 10 billion by 2050, creating significant hurdles in achieving food security and sustainability (Searchinger et al., 2019). Persistent problems like hunger, malnutrition, and excessive greenhouse gas (GHG) emissions compound these challenges (FAO IFAD UNICEF WFP & WHO, 2023). Additionally, the combination of population growth and rising incomes have led to a substantial increase in global meat consumption (Parlasca & Qaim, 2022), resulting in significant environmental and climate consequences, as well as negative impacts on public health (Willett et al., 2019). To address the issues posed by conventional meat production, there is a growing need for sustainable and nutritious alternative protein sources. Edible insects have emerged as a viable option due to their low environmental footprints, high feed conversion efficiency, and excellent nutritional value (van Huis et al., 2021; van Huis & Oonincx, 2017).

Entomophagy, the practice of consuming insects as food, has been a part of human history worldwide (Govorushko, 2019), and is embraced by several hundred million people today (van Huis et al., 2022). While common in Asian, African, and South American countries, entomophagy is relatively unfamiliar to western societies, including Europe and North America (Govorushko, 2019). Studies have identified food disgust and food neophobia as the main factors influencing consumer acceptance of edible insects in western cultures (Caparros Megido et al., 2016; House, 2016). To increase familiarity with insect-based foods (IBF) and alleviate food neophobia, it may be beneficial to introduce more IBF into the market and encourage open discussions about these products (La Barbera et al., 2018). Additionally, investing in enhancing sensory and gastronomic aspects, alongside strategic advertising messages, can help reduce disgust reactions and foster a positive consumer attitude towards entomophagy (La Barbera et al., 2018). Moreover, positive experience

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with insect-based foods can influence implicit attitude through social learning (La Barbera et al., 2018), while repeated exposure plays a crucial role in developing consumer acceptance (Woolf et al., 2021).

Despite the potential of insects as a sustainable protein source, limited knowledge and acceptance from consumers continues to overshadow their benefits (Woolf et al., 2019). Consumer acceptance of IBF varies between countries and is influenced by culture, region, and level of exposure (Sun-Waterhouse et al., 2016; Woolf et al., 2019). In Europe, studies have been conducted to evaluate consumer acceptance of IBF using various methodologies including surveys, taste tests, hedonic tests, interviews, and non-verbal evaluations (Mancini et al., 2019). In France, only two related studies have been conducted. Le Goff & Delarue (2016) assessed consumer's non-verbal reactions to IBF through a facial expression analysis. Another qualitative study by Gallen et al. (2019) aimed to identify the cognitive acceptance process of IBF by investigating the classification and encoding mechanisms of mental categorization. Given the absence of research on the acceptance of IBF among the French population, our study is crucial to understanding not only the overall perception of entomophagy in France, but also the cultural, societal, and economical factors influencing their willingness to consume IBF.

2. Materials and methods

2.1. Data collection

An online survey was designed to analyze the French population's willingness to consume IBF. Our aim is to establish a connection between willingness to consume and overall acceptance of IBF with different variables such as demographics, traveling or living abroad experiences, knowledge on entomophagy, and other cultural and socioeconomic factors that may motivate consumers or prevent them from practicing entomophagy. In particular, the levels of food neophobia and food disgust that respondents may present were analyzed.

The survey was developed in English based on previous studies (Verbeke, 2015; Orsi et al., 2019; Woolf et al., 2019) and then translated into French for its distribution. The Institutional Review Board of the San Diego State University (HS-2021-0088) approved the study on April 24th, 2021. The survey was distributed from April 27th, 2021, to June 22nd, 2021, using Qualtrics. The link for the survey was sent via email and social media outlets to residents of France over the age of 18. Participation in the survey was voluntary and no incentive was given. Amongst 624 respondents, 98.9% (n = 617) completed the survey. Respondents (n = 7) who did not consent or complete the survey were excluded from the study.

2.2. Survey design

The survey consisted of an introduction with a brief description of the study, contact information of the moderators, and a consent form, followed by 46 qualitative questions including multiple choices and open answers.

Standard demographic information such as gender, age, region of origin, occupation, income, education, current residency, and longest residency in France was collected. Frequency of traveling, as well as countries visited or lived in was also asked. Food neophobia was measured through a series of standardized 7-point scale multiple choice questions developed by Pliner and Hobden (1992). The French translation of the scale by Siegrist et al. (2013) was used in our study. Similarly, food disgust was measured through standardized 6-point scale questions taken from Hartmann and Siegrist (2018). The French translation by Egolf et al. (2019) was followed. Participants were then asked to rank the importance of environmental sustainability, nutritional value, and flavor of food using a 5-point scale.

Exposure to entomophagy was measured by asking the participants: (1) to what extent they know the concept of using insects as human food (5-point familiarity scale), (2) where had they learned about entomophagy (family/friends, school, restaurant, museum/zoo/insectarium, TV/news/books, internet/social media, traveling abroad, other, have never learned), (3) at what age had they discovered entomophagy (<10 years old, 11–20 years old, 21–30 years old, >30 years old), (4) their knowledge of the advantages of consuming IBF (nutritional value, health benefits, environmental sustainability, good flavor, affordability, other, not aware of any advantages), and (5) if they had previously eaten IBF (yes/no).

Only participants who had eaten IBF were asked about: (1) places where they had eaten IBF (travel abroad, local restaurant, home meal, exposition/museum, market, food store, other), (2) to which frequency they consumed IBF (tried one time, tried 2–5 times, tried more than 5 times, a few times a year, more than once per month), (3) which type of IBF they had eaten (food with visible insects/insect fragments, food with invisible insect ingredients, other), (4) evaluation of their experience eating IBF (5-point scale).

All respondents were then asked regarding their readiness to consume IBF: (1) willingness to eat IBF regularly (5-point scale), (2) types of insect-based ingredients they would eat (whole insects/visible, whole insects/invisible, insect flour, isolated insect protein, not willing to eat insects), (3) motivations to eat IBF (cultural context, family/friends, curiosity, nutritional value, environmental sustainability, good flavor, affordability, novelty, other, nothing motivates me), (4) what prevents them from eating more IBF (feeling of disgust, unfamiliarity, food safety concern, social/cultural pressure, vegetarianism/veganism, religion, low availability, high price, bad flavor, poor nutritional value, negative environmental impact, other, nothing prevents me).

Lastly, respondents were asked if COVID-19 influenced their willingness to consume IBF (COVID-19 makes me more willing to consume, COVID-19 makes me less willing to consume, COVID-19 does not affect my willingness to consume). The average time to complete the survey was 20 min. Refer to Appendices A and B for the English and French version of the survey, accordingly.

2.3. Statistical analysis

Statistical analysis was performed using R (version 4.1.3) in RStudio interface (version 2022.02.0 + 443). Wilcoxon test (ordinal data with two independent groups), Kruskal-Wallis test (ordinal data with more than two independent groups), and χ^2 test (categorical data) were used to detect statistical differences. When a significant difference was detected in a Kruskal-Wallis test, a pairwise Wilcoxon test was conducted as the post hoc test. Bivariate correlations were conducted using Pearson product-moment correlation, Spearman's rank-order correlation, and Cramér's V correlation for numerical, ordinal, and categorical variables, respectively. Multiple correspondence analysis (MCA) was used to visualize clusters of respondents based on their motivators and willingness to consume edible insects. Differences with $P < 0.05$ were considered statistically significant. The following packages were used for statistical analysis or data visualization: DescTools, dplyr, factoextra, FactoMineR, ggmap, ggplot2, ggpubr, ltm, and tidyr.

3. Results

3.1. Demographics

A total of 617 participants completed the survey, which comprised 427 females (69.2%), 183 males (29.7%), and 3 participants who identified as other (0.5%) (Table 1). About half of the respondents fell between the ages of 18–30 (50.1%). Respondents within this age group reported to be more willing to consume insects than subjects above 50 ($P < 0.001$). Regarding regions of origin, most respondents were from France (88.8%). Geographical distributions of the respondents based on their longest residing cities were shown in Fig. 1. The residences of our respondents covered 71% of French regions. The majority of the

Table 1
Demographics of the respondents and their willingness to consume insect-based food.

Variable	Percentage	Willingness Scores	
		Mean ± SD	Median (Q_1–Q_3)
Gender			
Female	69.2%	2.78 ± 1.38	3.00 (1.00–4.00)
Male	29.7%	2.95 ± 1.40	3.00 (2.00–4.00)
Other	0.5%	3.00 ± 2.00	3.00 (2.00–4.00)
Age			
18–30	50.1%	3.12 ± 1.38	3.00 (2.00–4.00)[a]
31–50	31.6%	2.63 ± 1.27	3.00 (1.00–4.00)[ab]
>50	18.3%	2.40 ± 1.42	2.00 (1.00–4.00)[b]
Origin			
France	88.8%	2.83 ± 1.38	3.00 (1.00–4.00)
Other countries of the EU	3.2%	2.80 ± 1.40	3.00 (1.00–4.00)
Africa	2.1%	2.46 ± 1.45	2.00 (1.00–4.00)
North America	1.8%	3.73 ± 1.19	4.00 (3.00–5.00)
European countries outside the EU	1.5%	1.89 ± 0.93	2.00 (1.00–3.00)
Asia	1%	3.00 ± 1.67	3.50 (1.50–4.00)
South America	1%	3.50 ± 1.64	4.00 (2.50–4.75)
Oceania	0.5%	3.33 ± 1.15	4.00 (3.00–4.00)
Russia	0.2%	4.00 (n = 1)	4.00 (n = 1)
Occupation			
Professional	49.6%	2.51 ± 1.32	2.00 (1.00–4.00)[b]
Student	37.6%	3.19 ± 1.37	4.00 (2.00–4.00)[a]
Worker	6.6%	3.12 ± 1.38	4.00 (2.00–4.00)[ab]
Entrepreneur	3.1%	2.95 ± 1.51	4.00 (1.00–4.00)[ab]
Unemployed	1.9%	3.17 ± 1.53	3.00 (2.50–4.25)[ab]
Retired	0.6%	2.25 ± 1.50	2.00 (1.00–3.25)[ab]
Farmer	0.1%	2.67 ± 1.53	3.00 (2.00–3.50)[ab]
Monthly Income			
<1500€	36.3%	3.26 ± 1.36	4.00 (2.00–4.00)[a]
1500€ - 1999€	16%	2.76 ± 1.36	3.00 (1.00–4.00)[b]
2000€ - 2499€	13.9%	2.77 ± 1.29	3.00 (2.00–4.00)[b]
3000€ - 3999€	11.5%	2.28 ± 1.35	2.00 (1.00–3.00)[b]
2500€ - 2999€	10.7%	2.42 ± 1.30	2.00 (1.00–4.00)[b]
>4000€	3.9%	2.50 ± 1.41	2.00 (1.00–4.00)[ab]
Education Level			
Master	42.3%	2.90 ± 1.39	3.00 (2.00–4.00)[ab]
Doctorate	26.4%	2.64 ± 1.37	3.00 (1.00–4.00)[b]
Other	16.5%	2.66 ± 1.39	3.00 (1.00–4.00)[ab]
Bachelor	13.1%	3.19 ± 1.33	4.00 (2.00–4.00)[a]

SD: Standard deviation, Q_1: first quartile, Q_3: third quartile. Values with different superscript letters differ significantly ($P < 0.05$).

respondents reported to be professionals (49.6%) and students (37.6%) with students being more willing to consume IBF ($P < 0.001$). The participants' monthly incomes ranged from under 1500€ to over 4000€. Participants who earn less than 1500€ per month were more willing to consume IBF than those with a higher income ($P < 0.033$). The education level of participants was mostly of master's level (42.3%) and Doctorate (26.4%). Participants with a Doctorate degree had lower willingness scores than those with a bachelor's degree ($P = 0.020$).

3.2. Food neophobia and food disgust scores

Cronbach's alpha was used to measure the internal consistency of both food neophobia and food disgust scales. In general, the values for good internal consistency fall between 0.8 and 0.9 and between 0.7 and 0.8 for acceptable internal consistency. For this study, Cronbach's alpha was 0.8 for the food neophobia scale and 0.7 for the food disgust scale. Similarly, for the food neophobia scale, Siegrist et al. (2013) reported an alpha = 0.82 for French-speaking subjects and alpha = 0.79 for German-speaking subjects in Switzerland, which is comparable to these results.

Traveling and living abroad experiences were found to influence the food neophobia scores. As shown in Table 2, the number of regions traveled to was negatively correlated with food neophobia ($\rho = -0.187$, $P < 0.001$). In addition, respondents who had never lived outside of France had higher food neophobia scores than subjects who had lived outside of France for 6–12 months ($P = 0.033$) or >12 months ($P = 0.012$). Similar to the food neophobia scores, the number of regions traveled to was negatively correlated ($\rho = -0.129$, $P = 0.001$) with food disgust score, and subjects who had never lived outside of France had higher food disgust scores than subjects who had lived outside of France for 1–6 months ($P = 0.034$) or >12 months ($P = 0.004$).

Overall, food neophobia was positively correlated with food disgust sensitivity ($\rho = 0.417$, $P < 0.001$), while both food neophobia ($\rho = -0.390$, $P < 0.001$) and food disgust sensitivity ($\rho = -0.253$, $P < 0.001$) were negatively correlated with willingness to eat insects (Table 2).

3.3. Food choice influencers

As shown in Table 2, importance of environmental sustainability as a food choice influencer negatively correlated with food neophobia ($\rho = -0.096$, $P = 0.017$) and food disgust sensitivity ($\rho = -0.115$, $P = 0.004$) and positively correlated with willingness to eat IBF ($\rho = 0.129$, $P = 0.001$). On the other hand, a significant ($\rho = -0.112$, $P = 0.005$) negative correlation was found between the importance of flavor in food choice and willingness to eat insects.

3.4. Familiarity and exposure to entomophagy

A positive correlation was found between the number of regions traveled to and familiarity with entomophagy ($\rho = 0.139$, $P < 0.001$). Respondents who had never traveled ($P = 0.006$) or lived outside of France ($P < 0.027$) were less familiar with entomophagy, had less exposure to IBF than those who had lived outside for 1–6 months or >12 months ($P \leq 0.009$) and thus, were less willing to eat insects compared to those who had traveled or lived outside of France ($P \leq 0.023$). Familiarity with entomophagy correlated negatively with food neophobia score ($\rho = -0.157$, $P < 0.001$) and food disgust sensitivity ($\rho = -0.106$, $P = 0.008$) and positively with willingness to consume IBF ($\rho = 0.201$, $P < 0.001$).

Sixty-nine percent of respondents had been introduced to entomophagy before the survey (Fig. 2). Family/friends (27.3%), internet/social media (22.4%), traveling abroad (21.6%), TV/news/books (17.7%), and school (17.3%) were the top sources of exposure to entomophagy. Subjects 18–30 years old reported more sources where they had learned about entomophagy than older subjects ($P < 0.001$). The number of sources of exposure negatively correlated with food

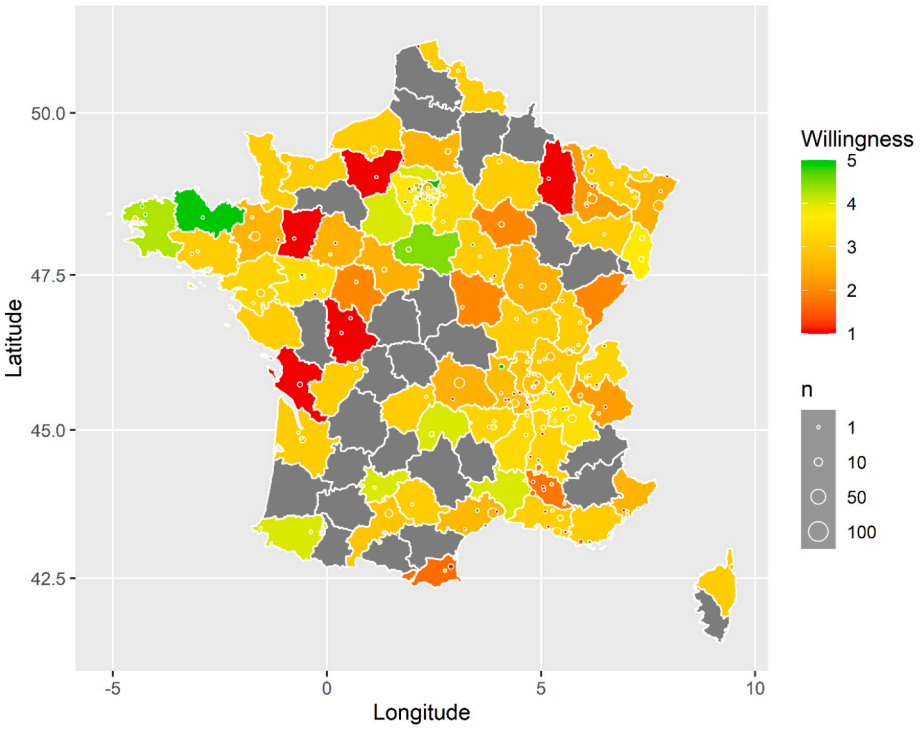

Fig. 1. Geographical distribution of the respondents and their willingness to consume insect-based food. Each circle represents a city, and its size represents the number of respondents in that city. Color of each circle or region represents the average willingness score of respondents in that city or region. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Bivariate correlations between variables.

	trv	neo	dis	sus	ntr	flv	fam	xpo	bnf	eat	exp	mot	bar	wil
trv	1													
neo	−0.19~	1												
dis	−0.13^	0.42~	1											
sus	0.04	−0.10*	−0.12^	1										
ntr	0.00	−0.01	0.04	0.37~	1									
flv	0.09*	−0.05	0.00	0.09*	0.14~	1								
fam	0.14~	−0.16~	−0.11^	0.16~	0.09*	0.00	1							
xpo	0.06	−0.23~	−0.12^	0.08*	0.05	−0.04	0.39~	1						
bnf	0.00	−0.16~	−0.17~	0.19~	0.10*	0.06	0.24~	0.21~	1					
eat	0.14~	−0.28~	−0.20~	0.06	−0.04	−0.09*	0.37~	0.42~	0.15~	1				
exp	−0.10	−0.17^	−0.01	0.02	0.03	0.02	0.09	0.25~	0.18^	0.15^	1			
mot	−0.04	−0.35~	−0.25~	0.11^	0.06	−0.05	0.20~	0.35~	0.37~	0.26~	0.50~	1		
bar	−0.03	0.04	−0.00	0.05	0.01	0.03	−0.01	0.05	0.06	−0.03	−0.05	0.13^	1	
wil	−0.07	−0.39~	−0.25~	0.13^	0.06	−0.11^	0.20~	0.33~	0.28~	0.37~	0.63~	0.68~	0.00	1

trv: number of regions traveled to; neo: food neophobia score; dis: food disgust sensitivity; sus: importance of environmental sustainability; ntr: importance of nutritional value; flv: importance of flavor; fam: familiarity with entomophagy; xpo: number of sources of exposure to entomophagy; bnf: number of known benefits of entomophagy; eat: number of insect-eating occasions; exp: rating of insect-eating experiences; mot: number of motivators for entomophagy; bar: number of barriers to entomophagy; wil: willingness to eat insects; *: $P < 0.05$; ^: $P < 0.01$; ~: $P < 0.001$.

neophobia ($\rho = -0.231$, $P < 0.001$) and food disgust sensitivity ($\rho = -0.121$, $P = 0.003$) while positively correlated with familiarity to entomophagy ($\rho = 0.390$, $P < 0.001$) and willingness to eat IBF ($\rho = 0.327$, $P < 0.001$).

3.5. Knowledge of benefits

Nutritional value (76.7%) and environmental sustainability (69.5%) were the most well-known benefits of entomophagy among respondents (Fig. 3). Predictably, from the exposure analysis, participants within the 18–30 age group were found to know more benefits of entomophagy than older respondents ($P \leq 0.037$). The number of benefits known was shown to be negatively correlated to food neophobia ($\rho = -0.156$, $P < 0.001$) and food disgust sensitivity ($\rho = -0.166$, $P < 0.001$). Moreover, food choice influencers such as the nutritional value ($\rho = 0.097$, $P = 0.016$) and environmental sustainability ($\rho = 0.188$, $P < 0.001$) were found to be positively correlated with the number of benefits known.

As expected, there was a significant ($\rho = 0.238$, $P < 0.001$) positive correlation between familiarity and number of benefits known. Similarly, the number of benefits known positively correlated with willingness to eat IBF ($\rho = 0.282$, $P < 0.001$). Specifically, respondents who believed insects are affordable ($P = 0.023$), tasty ($P < 0.001$), nutritious ($P < 0.001$), and beneficial to health ($P < 0.001$) and environment ($P < 0.001$) were more willing to eat insects, while those who knew no benefit of entomophagy were less willing to eat insects (Fig. 4).

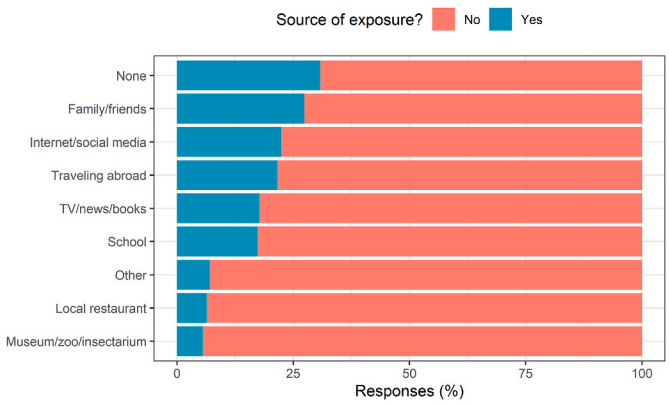

Fig. 2. Sources of exposure to entomophagy among the respondents.

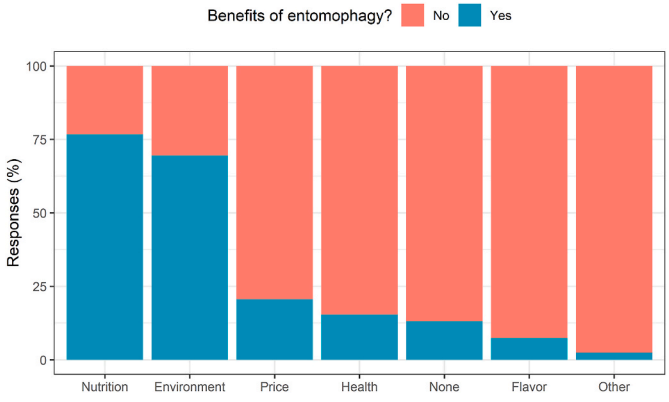

Fig. 3. Knowledge about benefits of entomophagy among respondents.

3.6. Occasions of insect consumption

Insect consumption was shown to be more common among respondents who had traveled or lived outside of France ($P = 0.008$), particularly those who had traveled to or lived in Asian ($P = 0.012$), Latin American ($P = 0.015$), and other European countries ($P = 0.042$). There was a significant correlation between the number of regions traveled to and occasions of insect consumption ($V = 0.191$, $P < 0.001$).

Food neophobia and disgust sensitivity scores were lower amongst subjects who had consumed insects ($P < 0.001$). Not surprisingly, respondents who had consumed insects were more familiar with entomophagy ($P < 0.001$). Subjects who had more exposure to entomophagy had more occasions of insect consumption ($P < 0.001$). Subjects who had consumed insects over five times reported lower food disgust sensitivities ($P = 0.006$) compared to those who had only consumed once. Familiarity with entomophagy was higher amongst respondents who had consumed insects more than once ($P < 0.05$) as well as those who had consumed more types of insects ($P = 0.003$).

The willingness scores were positively influenced by insect consumption, as higher scores were found amongst those who had consumed insects ($P < 0.001$). There was a significant positive correlation ($\rho = 0.367$, $P < 0.001$) between the number of eating exposures and the willingness score. Contrarily, subjects who had eaten insects only once had lower willingness scores than those who ate insects more frequently ($P < 0.011$).

3.7. Insect consumption experiences

Respondents falling within the age group of 18–30 reported having a better experience of entomophagy than older subjects ($P < 0.001$). Moreover, those who had been introduced to entomophagy before 20 years of age had better entomophagy experiences than those introduced after 30 years of age ($P < 0.006$). Entomophagy experiences were found to be negatively correlated to food neophobia ($\rho = -0.172$, $P = 0.002$) and positively correlated to the number of exposure sources ($\rho = 0.249$, $P < 0.001$), number of eating occasions ($\rho = 0.146$, $P = 0.008$), and number of benefits known ($\rho = 0.181$, $P = 0.001$). Interestingly, the best

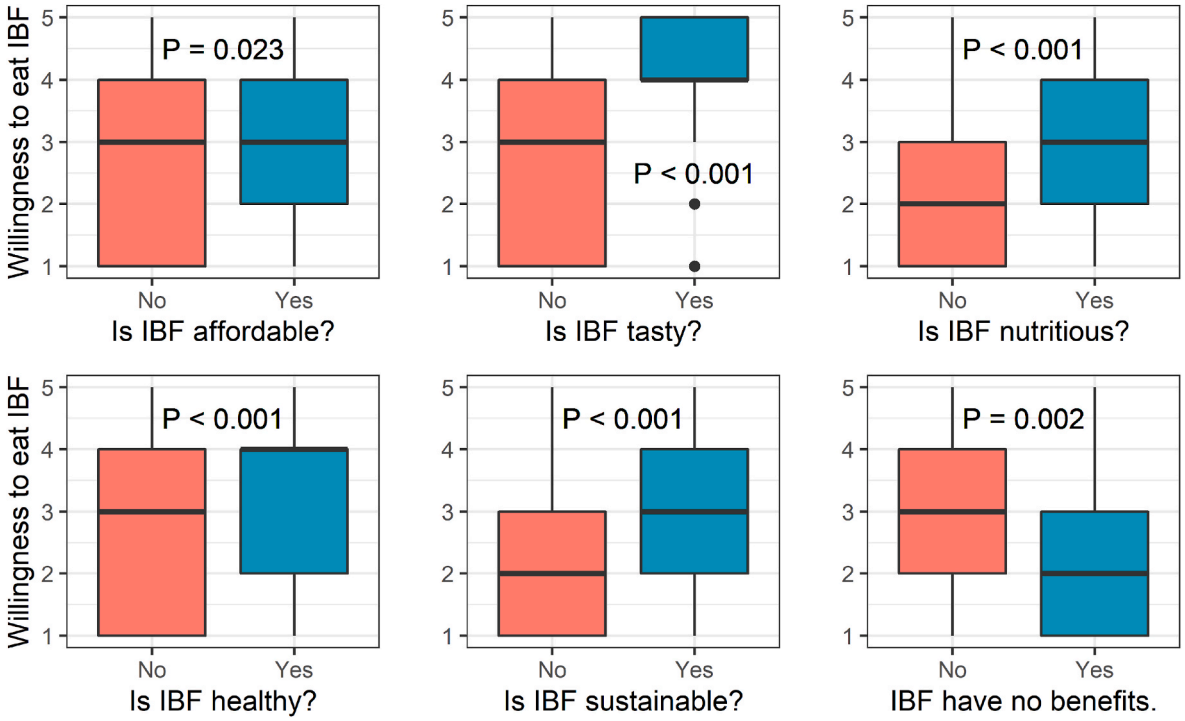

Fig. 4. Willingness to eat insect-based food (IBF) based on benefits known.

exposure source was found to be at restaurants, where respondents reported having better experiences than those exposed in other settings (P = 0.022). The frequency of insect consumption was also linked to the entomophagy experience of respondents. Those who had only consumed insects once had not as good experiences (P < 0.032) and lower willingness scores (P < 0.011) than those who had eaten more frequently. As expected, the experience of entomophagy had a strong positive correlation with willingness scores (ρ = 0.626, P < 0.001).

3.8. Entomophagy motivators and barriers

Environmental sustainability (52.6%), curiosity (50.2%), nutritional value (40.3%), and product novelty (29.9%) were the major motivators of entomophagy while unfamiliarity (39.2%), limited availability (32.7%), and the disgust factor (22.4%) were the major barriers to entomophagy among respondents (Fig. 5).

The number of entomophagy motivators of the participants showed negative correlations with food neophobia (ρ = −0.349, P < 0.001) and food disgust sensitivity (ρ = −0.246, P < 0.001) and positive correlations with the importance of environmental sustainability as a food choice influencer (ρ = 0.107, P = 0.008), familiarity with entomophagy (ρ = 0.202, P < 0.001), number of exposures to entomophagy (r = 0.346, P < 0.001), number of known benefits of entomophagy (r = 0.370, P < 0.001), number of eating occasions (r = 0.262, P < 0.001), rating of eating experiences (ρ = 0.498, P < 0.001), number of barriers to entomophagy (r = 0.129, P = 0.002), and willingness to eat IBF (ρ = 0.681, P < 0.001). In contrary, the number of entomophagy barriers of the participants was not associated with other variables except the number of entomophagy motivators (r = 0.129, P = 0.002). According to the MCA analysis, participants who reported a willingness score of 4 or 5 tended to possess at least one motivator of entomophagy and were mainly encouraged by their curiosity and the environmental sustainability of IBF to consume insects while those who were very unwilling to eat IBF (willingness score = 1) tended to lack motivators such as curiosity, seeking nutritional values of IBF, and valuing environmental benefits of IBF (Fig. 6). The majority of the respondents (94.5%) indicated that COVID-19 did not influence their willingness to eat IBF.

4. Discussion

To the best of our knowledge, this is the first study analyzing the

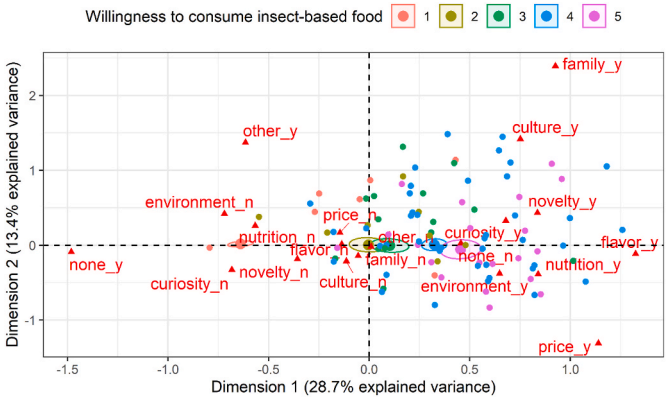

Fig. 6. Multiple correspondence analysis of entomophagy motivators among participants. The suffixes y and n indicate an answer of yes and no to the motivator question, respectively. The entomophagy motivators were shown as red triangles. Participants were shown as dots in different colors based on their willingness to consume insect-based food. Confidence ellipses around the mean points of different willingness scores were shown in the same color scheme. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

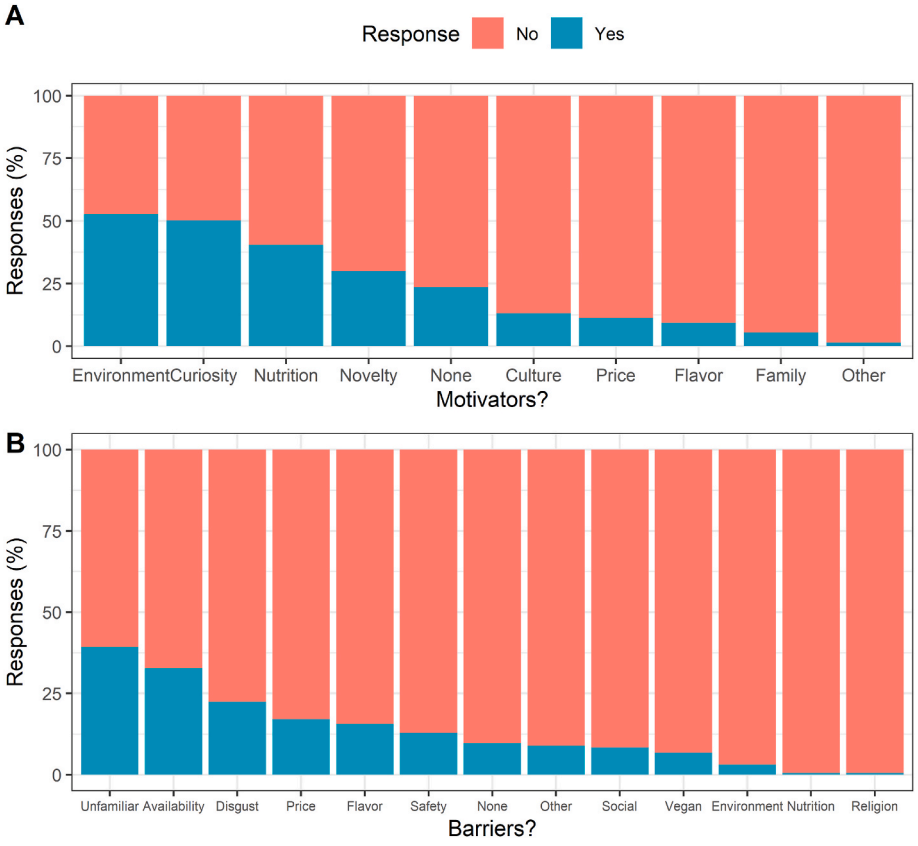

Fig. 5. Motivators (A) and barriers (B) of entomophagy among respondents.

factors that affect the French population's willingness to consume IBF. In France, other studies have applied different methods to explore the cognitive process of IBF acceptance and the reactions of consumers (Le Goff & Delarue, 2016; Gallen et al., 2019). In other European countries, similar studies have also been carried out, with different methodologies, to evaluate consumer acceptance of IBF and its market potential (Cicatello et al., 2016 Tan et al., 2016; Barsics et al., 2017; Hartmann et al., 2015; House, 2016; Kostecka et al., 2017; Laureati et al., 2016; Le Goff & Delarue, 2017; Verbecke, 2015; Mancini et al., 2019). While the latter are certainly beneficial to estimate the current level of entomophagy acceptance throughout western Europe, it was essential to fill the gap in research regarding the willingness of the French population to consume IBF.

Within the demographic analysis, it was found that age had a significant effect on entomophagy experiences and willingness to consume IBF. More specifically, people under 30 years old showed better entomophagy experiences and higher willingness than older subjects, which could be related to the usually lower levels of food neophobia and higher awareness of environmental issues amongst younger generations. These results are consistent with those of Laureati et al. (2016) and Verbeke (2015). They suggested that curiosity and openness are characteristics that differentiate younger consumers from older consumers who report higher levels of food neophobia (Laureati et al., 2016). At present, younger consumers have weaker attitudes towards meat, whether it be due to their curiosity or due to the concern for the environmental impact of their food choices, an acceptance and transition to alternative meal patterns has been observed amongst this age group (Verbeke, 2015). This, combined with their lower levels of food neophobia, increases the likelihood of adopting insects as a part of their diet and makes them a possible target for the trendsetting of entomophagy. However, other studies have varied results on the impact of age on willingness to consume IBF (Cicatiello et al., 2016; Tan et al., 2016).

Traveling is another factor that influences food neophobia. The present study found that people who traveled more were less afraid of trying new foods such as edible insects likely due to more exposure to such foods. These results fall in line with several studies that reported traveling as a main facilitator to gain familiarity with entomophagy (Cicatiello et al., 2016; Gere et al., 2017; Schlup & Brunner, 2018; Tan et al., 2016). The development of familiarity is a main criterion for consumer acceptance and appreciation of a new product (Gallen et al., 2019). Therefore, traveling not only increased familiarity with and exposure to entomophagy, but also willingness scores amongst respondents.

Besides traveling, family/friends, internet/social media, TV/news/books, and school were also major sources of exposure to entomophagy. Once again, it was the respondents within the 18–30 age group who reported more sources of exposure. Given that edible insects have only lately been approved as a novel food in Europe, it is expected that the younger generations have more exposure to and knowledge about entomophagy. Although effective, traveling is not a medium that can be applied for the general exposure of the population to entomophagy. Therefore, these other sources could represent focus points for the promotion of IBF. For instance, Woolf et al. (2019) suggested the inclusion of visuals of insects as a protein source in textbooks, nutrition recommendations, and websites as a simple but effective way to initiate the familiarization with insect products. Gallen et al. (2019) found that the presence of insect-based products from known brands that are price-accessible and widely available, as well as recommendations from institutions and professionals, would favor the categorization of insects as edible and therefore promote consumer acceptance.

Moreover, the negative correlations found between food disgust/neophobia and the number of exposure sources suggest that repetitive exposure to IBF is necessary to decrease food neophobia and disgust, as observed equally by Siegrist et al. (2013). Laureati et al. (2015) explained that food exposure reduces neophobic reactions by increasing familiarity with a stimulus through a learnt safe behavior mechanism. Yet, to avoid having to decrease food neophobia and disgust amongst consumers, it is essential to cease the disgust reaction that is normally acquired in the early years of life and passed on to next generations (La Barbera et al., 2018; van Huis, 2016; Woolf et al., 2019). To persuade future generations and change social norms regarding entomophagy, adults must be educated and eventually convinced that edible insects can be a normal part of their daily diet and, therefore, influence the eating habits of their children (Woolf et al., 2019).

Another factor that has shown to improve consumer acceptance of IBF is knowledge about entomophagy. Entomophagy practices can be promoted by providing information on the benefits of using insects as feed and food (Laureati et al., 2016; Verbeke, 2015). Barsics et al. (2017) showed that information sessions and tasting sessions could facilitate the consumption of IBF, as it improved willingness in consumers. However, the identification of food choice influencers is necessary for the development of promotion strategies, since various studies have reported differences in what consumers value or look for in products (Hartmann et al., 2015; Menozzi et al., 2017; Woolf et al., 2019). For instance, while Italian and American consumers are influenced by the environmental and nutritional benefits (Menozzi et al., 2017; Woolf et al., 2019), consumers in Germany and China seem to care more about the social acceptability of insects (Hartmann et al., 2015; Woolf et al., 2019). The present study found that nutritional value and environmental sustainability were the main influencers of entomophagy. Respondents who believe edible insects are nutritious, health beneficial, and sustainable to produce were more willing to eat IBF. This is to be expected, given that the most widely marketed benefits of entomophagy are environmental sustainability and nutritional value. People who value these two characteristics are more likely to pay attention to food that makes such claims. Our findings contradict Berger et al. (2018) who claimed that promotion strategies focused on nutritional values and environmental benefits were not effective but aligned well with many other studies (Hartmann et al., 2018; Kostecka et al., 2017; Menozzi et al., 2017; Sogari, 2015; Verbeke, 2015; Woolf et al., 2021).

The results regarding the occasion of insect consumption suggest that repetitive exposure is necessary to overcome food neophobia and disgust sensitivity, increase familiarity and ultimately increase the willingness to practice entomophagy, as also seen in Woolf et al. (2021). The positive correlation found between the number of exposures and willingness scores confirm that. While introduction to entomophagy is essential, a single exposure or consumption is not enough to encourage consumers to include entomophagy into their lifestyles. Therefore, a focus should be placed on the factors affecting repeat consumption (House, 2016) and how to make consumers incorporate insects into their daily diet (Cicatiello, 2016).

Prior entomophagy experiences strongly influenced participants' willingness to eat IBF. As seen in Woolf et al. (2021), positive tasting experiences are one way to not only educate, but also encourage consumers to incorporate insects into their culinary routines. The present study found that respondents had better experiences in restaurants compared to other settings. This could be due to the feeling of sanitation and safety people expect from restaurants, or the more attractive presentation and palatability of food compared to other settings, easing the consumption of insects. Therefore, it could represent a potential environment to continue the propagation of insect consumption in France. On this note, the frequency of insect consumption also showed an impact on the experience of consumers, as those who had eaten IBF more frequently reported better experiences and higher willingness scores than those who had eaten only once. This is to be expected since the repeated exposures reduced food neophobia and food disgust sensitivity, increased familiarity with entomophagy, and finally helped develop a taste for this novel food.

5. Conclusions

The findings of this study revealed that the French population was

slightly unwilling to consume IBF with an average willingness score of 2.83/5. Consumers between the ages of 18–30 showed lower levels of food neophobia and disgust, higher knowledge on entomophagy and its benefits, more exposure, and overall, a higher willingness to consume IBF. Education about benefits of edible insects and repeated exposure to entomophagy seem to be good strategies to promote entomophagy practices among young French consumers. It is essential that older consumers are also educated on the benefits of entomophagy to prevent the disgust reaction to be passed on to younger generations. Restaurants represent a potential and effective environment for the exposure to and propagation of entomophagy, as it is where consumers reported better experiences. The main influencers of entomophagy were environmental sustainability, nutritional value, and flavor, providing valuable information to consider for the promotion and marketing strategies of IBF products in France. The main barriers for French consumers were unfamiliarity, limited availability, and the disgust factor. Future research should place focus on the factors that will affect repeat consumption of IBF to achieve the incorporation of insects into the French diet, as it was shown that higher frequency of consumption positively impacted the experience of consumers and improved willingness scores. As more insect species are being approved in Europe it is expected that a greater variety of IBF will be available to consumers, and it will become more common, available, and affordable to practice entomophagy.

Some limitations of this study were small sample size and poor representation of the French population. For example, there were considerably more females than males who responded and the majority of the respondents live in Lyon. In addition, we opted not to include children and adolescents in our survey, despite their significance as a consumer group that holds influence over family purchasing decisions and has the potential to shape future market trends. Future studies at a larger scale and with subjects more representative of the general French population should be considered.

CRediT authorship contribution statement

María Fernanda Ordoñez López: Investigation, Writing – original draft. **Sami Ghnimi:** Conceptualization, Investigation, Resources, Writing – review & editing. **Changqi Liu:** Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – review & editing, Visualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lwt.2023.115179.

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