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RESEARCH ARTICLE

Cricket flour integration in biscuits: a study on formulation and consumer acceptance

S. Puleo[1], *A. Fiore*[2], *A. Sieghartsleitner*[2], *G.L. Russo*[1], *J. Grigor*[2]* *and R. Di Monaco*[1]

[1]Department of Agricultural Science, University of Naples Federico II, Portici, Italy; [2]Department of Engineering and Food Science, University of Abertay, Dundee, UK; *j.grigor@abertay.ac.uk

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Abstract

Crickets have recently been approved by the European Food Safety Authority as suitable for human consumption, providing an essential opportunity to exploit this sustainable food source commercially. In this study, the cricket powder was baked into a biscuit matrix to maximise its acceptability to Western consumers by incorporation into a familiar and affordable snack food. First, the formula was optimized through a simplex centroid design, followed by a sensory approach based on the Ideal Profile Method (IPM). Secondly, the optimized biscuit was evaluated by 164 consumers randomly allocated in different experimental conditions (blind-expected-informed). Moreover, consumers were also asked to fill in a questionnaire containing demographic information, the Food Neophobia Scale (FNS), and the attitudes towards insect-based food. In particular, the first condition was performed with a control biscuit containing no cricket flour. In the second condition, consumers tasted the biscuit containing cricket flour. In the third condition, the same cricket-fortified biscuit was evaluated, but an additional educational text was distributed among the consumers. A fortified biscuit with 10% cricket flour was successfully identified as the optimal formulation containing cricket flour. The biscuit received an overall hedonic liking of 6.55 (like slightly) on the 9-point hedonic scale. However, food neophobia significantly affected the overall insect-friendliness and hedonic liking of insect-fortified food. The educational message did not improve the overall sensory hedonic responses to the cricket-fortified biscuit.

Keywords

entomophagy – food neophobia – future food – insect flour – insect-friendliness

1 Introduction

Over a quarter of the world's population, i.e. 2 billion people, mainly residing in Asia, Africa and Latin America consume insects (Gu *et al.*, 2021). From a Western perspective, this figure may seem surprising – where insects are seen as the least popular of possible alternative meat protein sources such as soya, mycoprotein and in-vitro-grown meat (Kröger *et al.*, 2022). Emotional reactions of disgust and fear (La Barbera *et al.*, 2018; Sogari *et al.*, 2023) have been reported by Western consumers when confronted with insect protein. However, this theoretically would be expected, because during early childhood food choices are framed within a cultural setting which influences adult food choices and may cause these extreme emotional reactions (Ardoin and Prinyawiwatkul, 2021).

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This would likely be the end of the story if it were not for the fact that the world's population is growing at an alarming rate. Some estimates for 2050 have put the global population at a staggering 9.6 billion; this is a net increase of 1.9 billion from 2019 (UN Economic Council, 2018). In addition to this rise in population, food supply systems are likely to be put under strain by climate change, water shortages, and dwindling wild fish stocks. This has led some forecasters to predict that food production will need to almost double from current levels to meet population needs in 2050 (Malila *et al.*, 2024). Insects as a food source offer 2000 edible species (Jongema, 2017), with more sustainable rearing compared to livestock (Dermody and Chatterjee, 2016; Nikkhah *et al.*, 2021; Skrivervik, 2020) whilst also providing high-quality nutritional profiles (van Huis, 2020). It is not surprising that the Food and Agriculture Organization of the United Nations (FAO) in response to this growing food crisis has identified entomophagy as one of some possible technological solutions with cricket powder, the focus of this study, being one of the approved insects for human consumption (Turck *et al.*, 2021).

To promote entomophagy several psychological, socio-cultural and practical barriers need to be considered. In the arena of psychological factors, the concept of food neophobia plays a significant role. Concerning entomophagy, the prevalence of food neophobic personality traits is the most influential factor in the inhibition of the acceptability of insect-based foods (Erhard *et al.*, 2023; Hopkins *et al.*, 2023; Sogari *et al.*, 2023;Verbeke, 2015). The measurement of food neophobia using the food neophobia scale (FNS) by Pliner and Hobden (1992) can hence serve as a screening tool for separating neophobic from non-neophobic consumers and allows a better interpretation of true consumer's acceptability of insect-based foods as well as further psychometric measurements.

Alongside the necessary psychological research, actual sensory testing should be performed due to the important role of sensory perceptions in food choice (Puleo *et al.*, 2021). In many of the studies on insect food acceptability, actual product tasting has not been performed and relatively low degrees of consumer willingness to taste edible insects were found (Caparros Megido *et al.*, 2016) and hunger also not seen to affect consumer willingness to try (White *et al.*, 2023). Where studies have been performed to taste insects and insect-based products sensory attributes are not favourably evaluated (Ribiero *et al.*, 2024). Combining both is expected to identify elements that make insect-based foods more acceptable and appealing to Western consumers.

Edible insect exposure and experimental tasting could also diminish neophobia among developed populations and change their negative perception of insects (Caparros Megido *et al.*, 2016). In the Western world, consumer acceptability will relate to pricing, perceived environmental benefits, and the development of tasty insect-derived protein products (Ardoin and Prinyawiwatkul, 2021). A research on mealworms (Tan *et al.*, 2016a) showed that appropriate product design could strongly improve acceptability, which is why formula optimization is important for the design of insect-based foods.

Research of formula optimization regarding insect food, however, remains scarce. Formula optimization is commonly used to evaluate food products by simultaneously considering attributes such as flavour, texture, colour, and production costs. This is a way to consider different attributes at once and show the weight of each attribute to make an ideal product of its class. Both classical and innovative sensory methods can be performed to achieve formula optimization.

The decision to use cricket-fortified biscuits for the tasting sessions was based on previous research confirming that in regards to product preparation consumers prefer processed insect food where the insect ingredient cannot be recognised as a whole as well as the incorporation of the insect ingredients into familiar foods such as biscuits compared to exotic or unknown dishes (Ardoin and Prinyawiwatkul, 2021; Kroger *et al.*, 2022; Tan *et al.*, 2016a).

In this study, a new cricket-fortified biscuit was developed and its consumer acceptability evaluated. A sweet biscuit was chosen as the sweetness may help mask any potential unfavourable flavours, whilst a biscuit is a universally familiar food product. The experiment was conducted in two steps: first, developing optimizing the formulation using a design of experiment approach; secondly, the optimized formulation was evaluated by consumers, in a consumer test performed in different experimental conditions.

Through the consumer evaluation of the cricket-fortified biscuit in combination with essential psychological research about consumer acceptability of insect food, the main drivers for overcoming negative emotional connotations connected to insects were also investigated. The main aim was to draw valuable conclusions for the creation of successful communication strategies and persuasive marketing messages (Puteri *et al.*, 2023). This will ultimately support consumers

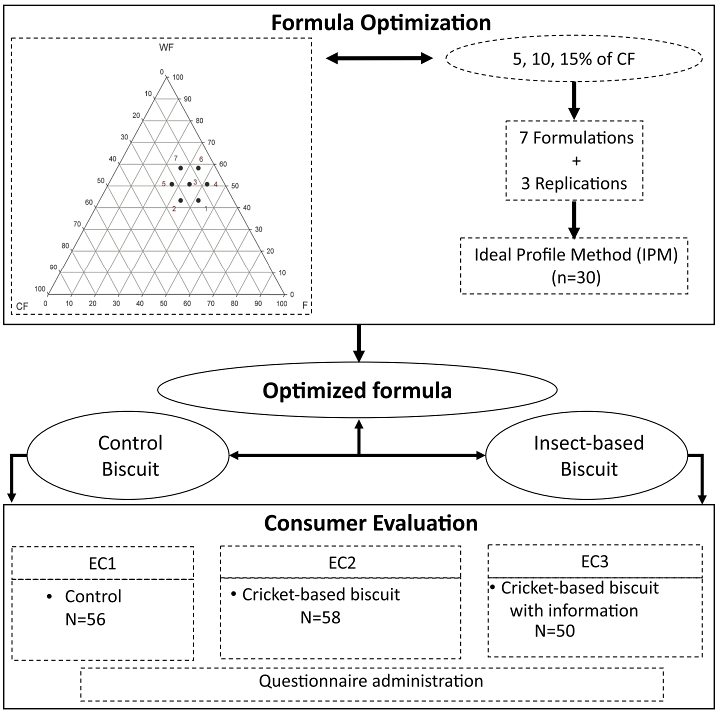

FIGURE 1 Experimental procedure scheme.

in embracing entomophagy as normal eating behaviour and making more sustainable food choices.

2 Materials and ethods

Research overview

In Figure 1 the schematic experimental procedure is illustrated. The formula optimization experiment was conducted at the Department of Agricultural Science, University of Naples Federico II. A total of 7 formulations were tested by varying the levels of wheat flour (WF), cricket flour (CF) and butter (F). Thirty consumers evaluated ten samples, the 7 formulations more 3 blind replicated ones, by using the Ideal Profile Method (IPM).

The optimized formula was generated by using the desirability function (Di Monaco *et al.*, 2010), it was added with an orange extract as a flavouring ingredient and then was evaluated in the next consumer test.

The consumer evaluation was performed at the Division of Engineering and Food, Abertay University.

The consumer data collection was performed in three different experimental conditions (EC1; EC2; EC3), explained in detail in the next paragraph. Consumers were asked to fill in a questionnaire containing demographics, food neophobia scale, insect acceptability items before tasting and insect acceptability items after tasting.

Formula optimization

Ingredients

Wheat flour (WF), purchased from a local Tesco store in Dundee, UK, cricket (*Acheta domesticus*) flour (CF), purchased from Crunchy critters (UK) and butter (F) purchased from a local Tesco store in Dundee, UK, were chosen to be the independent variables in the mixture experiment (Figure 1) with a total fixed proportion of 67%. Other ingredients (wheat flour, cricket flour, butter, sugar, eggs, leavening agent, salt, cocoa fibre, and orange extract), accounted for 33% of the total weight. Cocoa fibre was used to mask the colour of cricket flour and also to increase dietary fibre since the biscuit is rich in fat. The product can be claimed as a "source of fibre" under the European Commission for food regulation (Regulation (EC) No 1924/2006).

According to the reference recipes and based on preliminary experiments, the percentage range for wheat flour and butter was defined as: 5, 10, and 15% substitution of wheat flour with cricket flour being accounted for (Bas and El, 2022; Smolinski *et al.*, 2015). The constraints for each ingredient were then used by the Design-Expert software creating seven formulas using a simplex-centroid design with three ingredients being picked for repetition (formulas 8, 9, and 10) to check the consistency of the perception during sensory evaluation (Table 1). For more details on formulation and ingredients, see the supplementary data reported in Appendix A.

TABLE 1 Composition of the formulae obtained from mixture design for cricket-fortified biscuit optimization

Formula	Variable ingredients (%)			Fixed ingredients						
	Wheat flour	Cricket flour	Butter	Sugar	Egg yolk	Egg white	Leavening agent	Salt	Cocoa fiber	Orange extract
F1	29	10	28	20	4.6	4.6	0.4	0.1	3	0.3
F2	29	15	23	20	4.6	4.6	0.4	0.1	3	0.3
F3	34	10	23	20	4.6	4.6	0.4	0.1	3	0.3
F4	34	5	28	20	4.6	4.6	0.4	0.1	3	0.3
F5	34	15	18	20	4.6	4.6	0.4	0.1	3	0.3
F6	39	5	23	20	4.6	4.6	0.4	0.1	3	0.3
F7	39	10	18	20	4.6	4.6	0.4	0.1	3	0.3
F8*	29	15	23	20	4.6	4.6	0.4	0.1	3	0.3
F9*	34	5	28	20	4.6	4.6	0.4	0.1	3	0.3
F10*	39	10	18	20	4.6	4.6	0.4	0.1	3	0.3

*F8, F9, F10 are repeated from F2, F4, F7, respectively.

Sample preparation

The samples were prepared in a 400-g amount of dough for 25 units of biscuits. All ingredients were weighed (ACCULAB, Model 1200, capacity 1200 g, graduation 0.1 g) and allowed to reach room temperature before mixing. The dough was mixed using an electronic Mixer (Kenwood Cooking Chef Mixer KM080) with a K-beater. The dry ingredients including wheat flour, cricket flour, cocoa fibre, sugar, leavening agent and salt were blended. The butter was microwaved at 800 W for 30 s/100 g until it was melted. Thus, melted butter was poured into the mixer and mixed for 10 s, and then egg yolk and egg white were added. The mixture was batted for 30 seconds, therefore the dough was put in a plastic bag, shaped to 10 mm in height, and refrigerated at 5 °C overnight. The day before the session, the dough was taken out from the fridge, left at room temperature for 30 minutes, and rolled until 4 mm in height (Joseph Joseph 20085 Adjustable Rolling Pin 4 mm disc). Then it was cut with a biscuit cutter into 3.6 cm × 6 cm samples. The biscuits were cooked in a preheated convection oven (Smeg, ALFA43, Italy) at 160 °C for 12 min, and after cooling for 30 min, they were stored in an airtight container until the sensory evaluation.

Sensory evaluation

Three focus group interviews were performed in the meeting room of the sensory laboratory in the Department of Agricultural Sciences (University of Naples, Federico II). Each one was held with a total of 10 expert assessors (aged 22 to 30) perfectly aware of the meaning of sensory descriptive attributes to be used for a product like a biscuit. The participants were given 3 formulas of biscuits (F2, F4 and F7) and a sample of cricket flour. All the participants tasted the same formula simultaneously, and answers, intended as descriptive attributes, were collected before moving on to the next formula. The questions to ask the participants were decided in advance, "What do you perceive from this biscuit/cricket flour?" and they were formulated in such a way as to require an elicitation of descriptive attributes. Each interview lasted approximately 60 min and the answers were written down by the host. The collected sensory attributes were descriptive, not hedonic and not redundant.

The sensory attributes generated by the focus group interviews were evaluated by using the Ideal Profile Method (IPM). The 10 samples (Table 1) were given in random and balanced monadic order to the consumers and data were collected by Fizz Acquisition software (Biosystemes, Couternon, France). Thirty consumers were asked to score the intensity of each sensory attribute on a 10 cm linear scale (0 = low intensity; 10 = high intensity). At the end of the session, the consumers were asked also to rate the ideal intensity of each attribute for a biscuit. In the classical procedure of IPM, both perceived and ideal intensity are rated for each sample. A modified approach to this procedure was used, asking the consumers to rate the ideal only once at the end of the test to do not make too demanding the procedure for the consumers (Worch and Punter, 2015).

Data analysis

Concerning the generation of sensory attributes, only the terms elicited by at least 50% of participants in FG were considered for the following sensory evaluation. A descriptive comparison of terms used for biscuits and cricket flour was done. ANOVA was used to find significant differences in the sensory attributes among the different biscuit formulations ($p \leq 0.05$). Then, Principal Component Analysis (PCA) was performed to analyze data from IPM, taking formulas as observations and the sensory attributes as active variables, whereas wheat flour, cricket flour and butter were added as supplementary categorical variables. Both ANOVA and PCA were performed by using XLSTAT 2014.

The statistical tool Design Expert (software Stat-Ease 360, 2023) was used for formula optimization. The Design method was I-optimal design. The desirability function was used and the Ideal score for each attribute was set to be targeted to generate the optimal formula (Di Monaco *et al.*, 2010).

Consumer evaluation

Consumers

The tasting sessions for the cricket-fortified biscuit were advertised at Abertay University in Dundee, UK informing consumers about the requirement to taste a biscuit containing edible cricket flour as an ingredient. Even though EC1 was performed with a control biscuit, all consumers were willing to try insect-containing food (i.e. were informed that they were required to taste a cricket-fortified biscuit for participation in the consumer evaluation). Allergen information was provided, and consumers' consent was confirmed via the online provided questionnaire. A consumer sample of 164 consumers (76 males, 88 females; 35 ± 13.3 years; white/European 93.%, multiple ethnicity 3.0%, Asian 2.5%, African/Caribbean 1.2%) participated in the tasting session and completed the online questionnaire. Ethical approval was granted by the Abertay University ethics committee (ref. Number 856), and the study was conducted in agreement with the guidelines of the Declaration of Helsinki and the Italian ethical requirements on research activities and personal data protection (D.L. 30.6.03 n. 196). Informed consent was obtained from all respondents involved in the study.

Samples

Both the cricket-fortified biscuit and the control biscuit were evaluated. The optimized formula of the cricket-fortified biscuit was added with an orange extract as a flavouring ingredient. The amount of wheat flour and butter for the control biscuit were, respectively, amended according to the fat ratio of the cricket flour in the insect biscuit. The biscuits were prepared at the kitchen laboratory of Abertay University, by using the same procedure described above.

Consumer evaluation procedure

The tasting sessions were performed at the Consumer Sciences laboratory of Abertay University Dundee. Consumers received safety and allergen advice, information on anonymity and confidentiality of the data and their consent was taken. The laboratory was provided with 12 individual booths where the consumers received one single biscuit, and a cup of water at ambient temperature and they were also given the link to the online questionnaire which they completed by using their own devices (e.g. smartphone). The completion of the consumer test took about 15 min.

First, consumers were presented with a standard demographic item battery, secondly, the 10-item Food Neophobia Scale (Pliner and Hobden, 1992), attitudes towards cricket-based food (Lensvelt and Steenbekkers, 2014) as well as the 9-point hedonic scales for evaluating the overall liking and the liking for specific attributes of the biscuit sample (for detailed scales and items, the questionnaire is in Box C1 supplementary data).

The data collection was performed in three different experimental conditions to which consumers were randomly allocated. Experimental condition one (EC1) was performed with a control biscuit containing no cricket flour (CF). Consumers of EC1 who were receiving the control biscuit were not debriefed after the tasting. This means that the consumers continued to think that they had tasted an cricket-fortified biscuit although they had not. Experimental condition two (EC2) consisted of the same procedure as in EC1 but the biscuit containing cricket flour was received and tasted. In experimental condition three (EC3) the same cricket-fortified biscuit as in EC2 was evaluated, but an additional educational text, giving information on the nutritional and environmental benefits of eating insects as well as the normality of entomophagy in other countries was distributed among the consumers (Figure 2).

Items for measuring attitudes towards insect-based food were presented to the consumers. Items covered general attitudes towards insects as an alternative protein source (asked before tasting the product) as well as specific attitudes towards the cricket-fortified biscuit (asked after tasting the product). All ratings were made on a 7-point Likert scale from 'not at all' to 'extremely'. The items contained questions about familiarity, appro-

Before you answer the questions below, please read the following information related to the use of insects for human consumption.

Insects are rich in protein and some minerals. The breeding of insects emits fewer greenhouse gases, uses less land and water, and has a higher feed-protein conversion rate compared to other meat products such as chicken, pork and beef.
Bugs are widely consumed in Africa, Asia and Latin America. In Europe, products made from insects are called "novel foods". Food companies trying to commercialise new foods and/or ingredients must request permission from the European Union and present detailed scientific information and a safety report. Currently, several insect-based foods can be purchased both online and in-store in Belgium, the Netherlands, UK, USA, etc.

FIGURE 2 Information text EC3.

priateness for consumption, expected liking, willingness to try, willingness to buy and willingness to pay extra for it based on Lensvelt and Steenbekkers (2014).

Between the attitude measures before and after tasting, the overall acceptability and the acceptability for the appearance, odour, texture, taste, and aftertaste of the biscuit were evaluated by the consumers by using the 9-point hedonic scales. Furthermore, consumers had the chance to make comments about the biscuit in an open-text format.

Data analysis
Food Neophobia Scores (FNS) were computed as a sum score of the 10 neophobia items (Cronbach's $\alpha = 0.857$) based on Pliner and Hobden (1992). To be able to easily interpret the attitudes towards insect-based food of consumers, a single so-called 'Insect Friendliness Score' (IFS) was established by creating a mean score over five acceptability items taken before and after product tasting. Based on Cronbach's alpha ($\alpha = 0.863$) items on appropriateness (APP), expected liking (EXL), willingness to try (WLT), willingness to buy (WLB) and willingness to pay extra (WLP) were selected to form the IFS. Homogeneity between groups for the individual items (before tasting and after) was checked using one-way ANOVAs (assumptions of normality were checked) and found to be non-significant ($p \leq 0.05$).

Statistical analysis of the collected data was performed by calculating Pearson's correlation coefficients (assumptions of normality were checked) between IFS, FNS and sensory hedonic liking to interpret the relationship between the level of insect friendliness and actual liking of the product. Differences in the IFS before and after the tasting of the biscuit were analysed using a paired sample t-tests (assumptions of normality were checked). Furthermore, the interpretation of differences in sensory hedonic measures across the three experimental conditions was performed using Multivariate (using Pillais Trace) and univariate ANCOVA's (assumptions of normality were checked) with multiple comparison post hoc tests (LSD, $p \leq 0.05$) on estimated marginal means (adjusting for the covariate FNS) where appropriate.

3 Results

Formula optimization
The most cited attributes by the consumers during the 3 focus group interviews were categorized into appearance, texture, taste, and flavour; the attributes used to describe the pure cricket flour were also listed. The only common attribute was umami taste, thus all the other attributes of cricket flour are not retained in the biscuit, even when prepared with the highest concentration of cricket flour (Table 2). This is a good result considering that attributes such as mouth-puckering, fish and animal-feed flavours are potentially negative sensory attributes in a biscuit.

The biscuit attributes were then evaluated by thirty consumers, using IPM (Worch and Punter, 2015), and all of them discriminated among the samples (ANOVA results are in Appendix B of supplementary data). Thus, all the sensory attributes were used in the following analyses.

The biplot of the principal component analysis of the IPM data for the matrix formulations × sensory attributes and ingredients (as supplementary variables) is shown in Figure 3. The first and second principal components described 56% and 35% of the variance, respectively, thus, together the first two principal components represented 91% of the total variability, making them highly effective for describing IPM results.

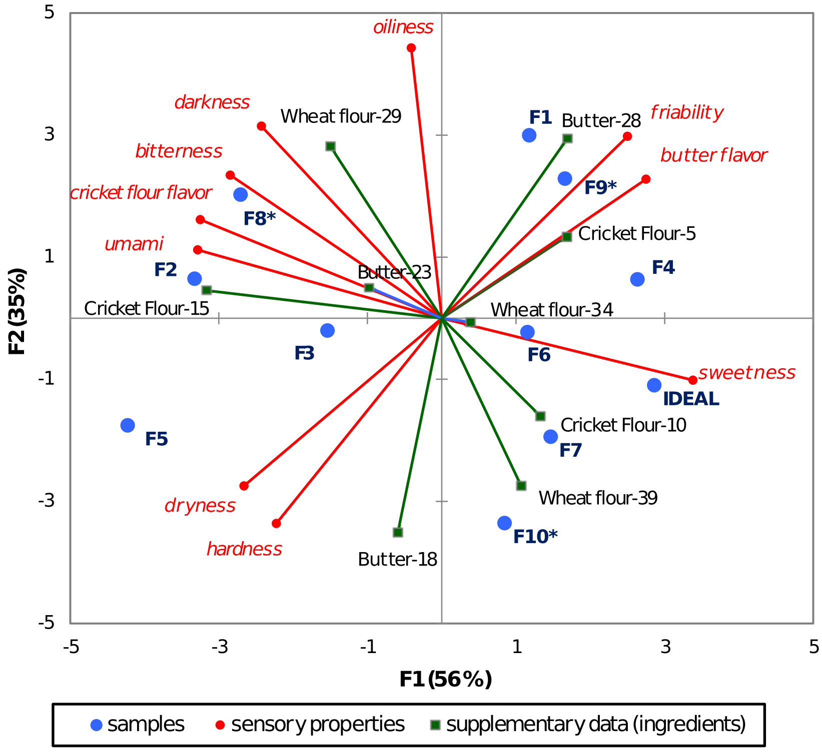

FIGURE 3 PCA loadings plot of IPM data.

TABLE 2 List of sensory attributes elicited during the focus group interviews

Category	Biscuit attribute	Cricket flour attribute
Appearance	Darkness	
Texture	Friability	Adhesiveness
	Dryness	Mouth-puckering
	Hardness	
	Oiliness	
Taste	Umami	Umami
	Bitterness	
	Sweetness	
Flavour	Cricket flour	Fish
	Butter	Animal feed

The highest amount of the ingredient cricket flour (15%) is positively related to attributes such as darkness, bitterness, cricket flour flavour, and umami; and negatively to sweetness. The highest amount of butter (28%) is positively related to oiliness, friability and butter flavour; and negatively to hardness and dryness. The highest amount of wheat flour (39%) is positively related to sweetness. Friability and oiliness are opposite to hardness and dryness; and sweetness, as expected, is opposite to bitterness and umami.

The biplot shows that the ideal formula fell near the vector representing the sweetness. Other attributes are positively related to the ideal, such as butter flavour and friability whereas bitterness, cricket flour flavour and umami taste are perceived as negative sensory attributes. Formulation 6, with the lower percentage of CF (5%) fell on the vector to the ideal product. The other formulations close to the ideal formula are F4 and F9 (5% of CF), and F7 and F10, containing 10% of CF. The position of the vector corresponding to the cricket flour-10 confirms that result.

It is also interesting to note that the replicated formulations (F2 and F8; F4 and F9; F7 and F10) are, respectively, located one to each other on the map, demonstrating that consumers were able to evaluate the samples accurately.

The next step was finding the optimal formulation by using the desirability function in the Design Expert software. The ideal intensities of IPM were set to be the target values for the optimization stage. Two solutions were found to achieve the highest desirability (Table 3), that is the best compensation of the ingredients to achieve ideal intensity from every single attribute. In solution 1, 37.7% wheat flour, 9.9 % cricket flour and 20.0% butter were proposed to achieve 0.783 desirability.

The solution with maximum desirability was selected to be evaluated by consumers in the second step of the experiment.

Table 4 lists the final recipe formulas for both the cricket-fortified biscuit and the control one. By considering that cricket flour contains almost 30% fat, the con-

TABLE 3 Solutions of ideal formula designs proposed by Design Expert to achieve the highest product desirability

Optimal formula	Wheat flour	Cricket flour	Butter	Darkness	Oiliness	Bitterness	Sweetness	Umami	Cricket flour flavour	Butter flavour	Friability	Hardness	Dryness	Desirability
1	37.7	9.9	20.0	5.72	3.54	3.77	5.34	3.17	5.01	3.07	5.38	5.06	5.00	0.783
2	37.8	8.0	21.2	5.80	3.72	3.66	5.34	2.96	5.05	2.89	5.38	5.22	5.00	0.779

TABLE 4 Final biscuit recipe formulas obtained after the desirability function

Ingredient	Cricket-fortified biscuit (%)	Control biscuit (%)
Wheat flour	37	43
Cricket flour	10	0
Butter	20	24
Soft brown sugar	20	20
Egg yolk	4.6	4.6
Egg white	4.6	4.6
Cocoa fibre	3	3
Leavening agent	0.4	0.4
Orange extract	0.3	0.3
Salt (NaCl)	0.1	0.1
Sum	100	100

trol biscuit was prepared by substituting 10% of cricket flour with 6% of wheat flour and 4% of butter.

Consumer evaluation

Insect friendliness measures before and after tasting

Attitude towards insect consumption consisted of six items on familiarity, appropriateness, expected liking, willingness to try, willingness to buy and willingness to pay extra for insect-based food measured before and after the consumers tested the presented biscuit. The highest acceptability scores were reached for the item of willingness to try (mean = 5.27, SD = 1.60 before; mean = 5.05, SD = 1.81 after), appropriateness (mean = 4.33, SD = 1.68 before; mean = 5.21, SD = 1.48 after), expected liking (mean = 3.77, SD = 1.32 before; mean = 4.62, SD = 1.47 after) and willingness to buy (mean = 4.16, SD = 1.67 before; mean = 4.30, SD = 1.80 after). These averages are conglomerated around the neutral measure of 4. The lowest average scores were reached for familiarity (mean = 2.55, SD = 1.68 before; mean = 3.02, SD = 1.72 after), and willingness to pay extra (mean = 2.87, SD = 1.45 before; mean = 2.93, SD = 1.47 after).

Overall IFS scores for the different experimental conditions were EC1 (mean = 4.06, SD = 1.40 before; mean = 4.59, SD = 1.51 after), EC2 (mean = 4.23, SD = 1.20 before; mean = 4.37, SD = 1.23 after), EC3 (mean = 3.92, SD = 1.13 before, mean = 4.30, SD = 1.35 after). For determining significant differences in the consumer attitudes towards insect-based food measured before and after tasting, a paired sample t-test (95 % CI) was performed on the insect friendliness scores (IFS) which showed that insect friendliness went up after tasting for the control condition EC1 (t_{55} = 3.183, p = 0.002) and for the biscuit fortified with cricket flour and educational message EC3 (t_{49}, p = 0.004) but not for condition EC2 (biscuit fortified with cricket flour but no educational message). However, it is worth noting that the average for all three conditions even after these increases in IFS never goes beyond 4.6 which is only slightly above the midpoint of the 7-point scale. In addition, further investigation of IFS showed that it was negatively correlated with FNS (ρ = −0.366, $p < 0.001$) and positively correlated with overall sensory hedonic liking (ρ = 0.443, $p < 0.001$).

Consumer sensory hedonic evaluation of the biscuits

The sensory evaluation measures, appearance, odour, flavour, texture, aftertaste and overall liking were rated. Across all consumers, hedonic ratings were mostly above the *like slightly* measure of 6 (except for aftertaste) on the 9-point hedonic scale. The highest ratings in descending order were reached for flavour (mean = 6.69), texture (mean = 6.64), overall liking (mean = 6.57), odour (mean = 6.50), appearance (mean = 6.47) and lastly aftertaste (mean = 5.31). This data includes the hedonic ratings of all three experimental condition groups including the control biscuit without cricket flour (Table 5).

A multivariate ANCOVA was run with all hedonic items as the dependent variables, the three groups (EC1, EC2 &EC3) as the fixed effect and the food neophobia scores (FNS) as a covariate. The consumers of the three groups evaluated the biscuits as significantly different from each other ($F_{12,312}$ = 2.234, p = 0.010). However, the self-evaluation of consumers in terms of their food neophobia scores was a greater determinant of the likely scores given to the various biscuit types ($F_{6,155}$ = 3.690, $p < 0.002$). Univariate ANCOVA for each hedonic item found only odour (p = 0.030) and aftertaste (p = 0.023)

TABLE 5 Results of consumer tests on biscuits performed in different experimental conditions

Experimental condition		Appearance	Odour	Flavour	Texture	Aftertaste	Overall
EC1 (control)	Average	6.38	6.89	6.89	6.61	5.73	6.77
	N	56	56	56	56	56	56
	SD	1.42	1.29	1.42	1.76	2.08	1.50
EC2 (insect fortification)	Average	6.45	6.69	6.64	6.79	5.69	6.55
	N	58	58	58	58	58	58
	SD	1.96	1.66	1.66	1.66	2.31	1.70
EC3 (insect fortification and educational message)	Average	6.60	5.84	6.52	6.50	4.40	6.36
	N	50	50	50	50	50	50
	SD	1.46	1.90	1.55	1.16	2.29	1.65
Total	Average	6.47	6.50	6.69	6.64	5.31	6.57
	N	164	164	164	164	164	164
	SD	1.63	1.67	1.55	1.56	2.29	1.62

as significant when FNS was included in the ANCOVA as a highly significant covariate ($p < 0.001$) for all hedonic items except for appearance ($p = 0.210$). Running pairwise comparisons on the estimated marginal means (adjusting for the covariate FNS standardised at 29.58 ($p \leq 0.05$)) revealed that this significance is primarily caused by EC3 (cricket-fortified biscuit + educational message) being rated lower than the other two experimental conditions. It is important to point out that in EC2 and EC3 the same cricket-fortified biscuit was evaluated by the consumers. The overall liking and the liking for appearance and texture were not evaluated significantly differently from each other in any of the groups

4 Discussion

The idea to use biscuits as a case study for the acceptability evaluation of cricket-based foods is based on evidence that using familiar preparations effectively increases the liking and willingness to eat novel foods (Ardoin and Prinyawiwatkul, 2021; Puteri *et al.*, 2023; Shelomi, 2015; Tan *et al.*, 2016a). However, Mishyna *et al.* (2020) report how the inclusion of CF (and other insects as well) in food preparations may alter different sensory properties, such as texture, aroma and taste (Mishyna *et al.*, 2020).

Therefore, the first aim of the present study was to identify an optimal formulation for cricket-fortified biscuits, by using a design of experiment approach. The IPM results (Figure 2) find many correspondences in the literature. Indeed, increasing CF concentration (i.e. 15%), enhances negative attributes, such as darkness, bitterness and umami resulting in characterising the biscuits. This result is largely reported in other studies which included CF in whole-wheat snack crackers (Ardoin *et al.*, 2021), bread and cookies (Bawa *et al.*, 2020), gluten-free bread (Wieczorek *et al.*, 2022). On the contrary, when the CF concentration is lower (i.e. 5%), the characterising attributes (such as friability, oiliness and butter flavour) are more led by the presence of butter.

The next step after the IPM data collection was finding the optimal formulation by using the desirability function. As reported in the results paragraph, two solutions were found to achieve the highest desirability. In particular, the solution including 37.7% wheat flour, 9.3 % cricket flour and 20.0% butter allows to achieve 0.783 desirability. This result can be also observed in Figure 3, where the ideal formulation falls close to that one containing 10% of CF. This percentage is perfectly in line with other studies reporting the concentrations of CF enrichment/substitution, always ranging between 5 and 15% (Mishyna *et al.*, 2020). This was confirmed in the second part of the project where consumer ratings were remarkably consistent between the three conditions (EC1, EC2 and EC3) with nearly all hedonic sensory scores from consumers averaging over 6 (like slightly) with a few notable significant exceptions (odour and aftertaste) as mentioned in the results section.

Another main finding of the consumer trial was that the food neophobia scale is a strong predictor of the sensory hedonic liking of insect-containing foods. This negative association between the food neophobia scale and the sensory hedonic measures provided a notable contrast to the limited effect (odour and aftertaste only) observed between the biscuit without cricket powder, the biscuit with cricket powder and the biscuit with the cricket powder plus an educational message. The high levels of sensory hedonic liking for the fortified biscuits are promising. In particular if one considers the fortification of biscuits with dietary fibre where a meta-analytical study showed that a 10 g per 100 g unit increase in fibre caused very large reductions in overall acceptability (Grigor *et al.*, 2016). The reasons for sensory hedonic changes in novel food systems are complex and multifactorial (Mehta, 2024), but in part can be considered due to technical issues optimising the novel product and in part psychological. Insect flour has been reported to have technical issues in terms of imparting off flavours and textural changes in bakery products (Yazici and Ozer, 2021) and house cricket has been reported as having an upper substitution limit of 10% wheat flour replacement in bread (Kowalski *et al.*, 2022). This substitution limit (before acceptability changes become too extreme) varies depending on the type of insect flour, the processing and rearing of the insects, and the final target food matrix. In addition, further processing to extract purely the protein fraction has also beneficial effects on the overall hedonic liking of the final substituted product (Borges *et al.*, 2022). Therefore more interdisciplinary research where entomologists, food technologists, engineers and consumer scientists tackle the rearing, processing and creation of food products for the target average western consumer (with little to no exposure to insect containing foods) is likely to create products with the highest average population hedonic sensory ratings.

However, this research highlights that the psychological aspects of including insect flour are as important, if not more, in predicting sales in Western populations. A crucial preliminary factor for food acceptability is the liking of a food. Not only the food's sensory properties but also many situational and psychological factors which are often subconscious influences of acceptability (Torrico *et al.*, 2023). Food choice is a very individual process and based on specific characteristics and can also be variable over different eating situations (Motoki *et al.*, 2020). The negative emotional states like disgust and fear (Erhard *et al.*, 2023; Sogari *et al.*, 2023), and familiarity and appropriateness (Tan *et al.*, 2016a,b) which are connected to insects, are expected to influence consumer's likeability ratings of tasted insect-based food products. In this study the general familiarity of subjects towards insect containing foods, although consistent between groups was low (2.55 on a 7 point scale with 1 indicating not at all familiar). It is therefore important to apply control measures to enable the comparison and interpretation of the true likeability of an insect-based food. In this study even with optimization of the sensory experience of the fortified food product, overall sensory hedonic liking and insect friendliness of consumers (for which acceptability items familiarity and appropriateness are part of the IFS construct) are likely determined by the food neophobia scale. This means that for these people regardless of the flavour qualities of the fortified food item or even unfortified food item will be rating the hedonic properties of the food product lower if associated with insect fortification. In a Belgian study, the increase of one unit in the food neophobia score was associated with an 84% decrease in the probability of accepting insect-based foods (Verbeke, 2015). Because of this, it is hypothesised that people with a high manifestation of the food neophobia trait are less likely to adopt insect-eating as normal behaviour and hence are not deemed innovators, early adopters, or an early majority of potential target consumer groups (Rogers *et al.*, 2019). Nevertheless, we know that neophobia and willingness to try new insect foods are correlated (van Huis and Rumpold, 2023). In this study we observed that attempts to mask the insect flour fortification may have little effect on the overall neophobia towards consuming insect-fortified foods. Consequently, neophobic people may not be viewed as potential consumers of insect-food products. This also means that the investigation of psychological and practical inhibitors for entomophagy as well as strategies that could help to overcome these inhibitors should focus on people who are not extreme neophobes.

This study also investigated if providing a simple factual educational message might positively impact the marketability of such a product. In the first experimental condition (EC1) consumers rated a control food with no insect ingredients, believing that it was insect-fortified. This deception was necessary to avoid influencing other present consumers in the room and can be considered uncritical since they did not consume any ingredients they hadn't agreed to consume. In the second experimental condition (EC2) a group of different consumers rated a true insect-fortified food. Furthermore, given the limited knowledge of Western society about the benefits of eating insects and unfamiliarity with the concept of entomophagy (Tan *et al.*, 2016a; Verbeke, 2015), it was also important to measure the influence of an educational appeal on the likeability of the insect-fortified food. Another group of consumers in a third experimental condition (EC3) was hence presented with a short text, explaining the benefits and normality of entomophagy in other countries just before they ate and rated the cricket-fortified food. This allows the comparison and interpretation of the effectiveness of informed versus uninformed sensory product ratings.

The educational message did not have a positive impact on the sensory hedonic liking of the cricket-fortified biscuit as measured by the sensory hedonic items. A similar study with cricket-fortified biscuits also found no hedonic improvements with the educational messaging (Gorman *et al.*, 2024). However, in this study, there was a significant increase in the insect friendliness score once the sensory hedonic testing of the product was completed, which might be in part attributable to the information presented. The literature reports that willingness to try insect-fortified foods can be promoted by positive educational messages (van Huis and Rumpold, 2023). In addition a recent systematic review reported that the effectiveness of messaging in general improves intentions to try insect-based foods but effectiveness may vary depending on the match of information being provided and the consumer profile being targeted .They also reported positive attitudes after sensory testing of the insect-based food products highlighting the importance of positive messaging combined with the need for tasting (Puteri *et al.*, 2023). However, it must be noted that for this project we did not run a sample where no cricket fortification was combined with a positive educational message. Therefore, the overall effect of the educational message could not be fully assessed. In addition, from a psychological research perspective, it is important to consider that general insect-food acceptability measures should be interpreted with caution. For example, the consumers in this trial were selected in part as they were willing to try an insect-based food product. Data from a one-time trial at a cricket food tasting session might not be a valid indicator for the general acceptability of edible cricket-based foods and the adoption of entomophagy as a normal behaviour (Tan *et al.*, 2016b).

5 Conclusion

This study used a combined sensory approach to optimize cricket-fortified biscuit formula and measure the consumers' liking by evaluating the effect of blind and informed tasting. The results of the present study revealed several insights. First, the design of the experimental approach was useful to guarantee the maximum acceptable level of substitution, which in this study was equal to 10% of cricket flour. Secondly, biscuits with 10 % cricket flour received an overall liking score of 6.55 (like slightly) on a 9-point scale during the consumer test. This value did not change (neither positively nor negatively) after providing an educational message about the importance of insects. Therefore, the authors suggest that food familiarity plays a more significant role than communication messages. However, overcoming psychological barriers such as neophobia is crucial for wider acceptance. Indeed, higher food neophobia scores are likely to be a good predictor of reduced overall insect friendliness and hedonic liking of insect-containing products.

Some limitations in this study should be acknowledged. First, the effect of repeated consumption that can potentially improve the acceptability was not explored, secondly, other foods such as savoury snacks or complete meals were not studied in this work.

Therefore, further research should focus on long-term consumer exposure, different communication strategies to reduce neophobia, and exploring other familiar food formats to enhance the acceptability of insect-based foods in Western diets, since they are not only sustainable products but also have a high nutritional quality

Supplementary materials

Data is available on https://doi.org/10.1163/23524588-bja10218 under Supplementary Materials.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

Data availability

The authors declare that the data supporting the findings of this study are available within the paper and its Supplementary Information files. Should any raw data files be needed in another format they are available from the corresponding author upon reasonable request.

Ethical approval

Ethical approval was granted by the Abertay University ethics committee (ref. Number 856). The study was conducted in agreement with the guidelines of the Declaration of Helsinki, the rules of "Personal Data Protection Code", Reg. EU 2016/679 of the European Parliament and the Italian ethical requirements on research activities and personal data protection (D.L. 30.6.03

n. 196). Informed consent was obtained from all consumers involved in the study, ensuring the respect of privacy, participants' rights and any information related to allergy or intolerances of participants to the ingredients of our formulations.

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References

Ardoin, R., Marx, B.D., Boeneke, C. and Prinyawiwatkul, W., 2021. Effects of cricket powder on selected physical properties and US consumer perceptions of whole-wheat snack crackers. International Journal of Food Science and Technology 56: 4070-4080. https://doi.org/10.1111/ijfs.15032

Ardoin, R. and Prinyawiwatkul, W., 2021. Consumer perceptions of insect consumption: a review of western research since 2015. International Journal of Food Science and Technology 56: 4942-4958. https://doi.org/10.1111/ijfs.15167

Bas, A. and El, S.N., 2022. Nutritional evaluation of biscuits enriched with cricket flour (*Acheta domesticus*). International Journal of Gastronomy and Food Science 29: 100583. https://doi.org/10.1016/j.ijgfs.2022.100583

Bawa, M., Songsermpong, S., Kaewtapee, C. and Chanput, W., 2020. Nutritional, sensory, and texture quality of bread and cookie enriched with house cricket (*Acheta domesticus*) powder. Journal of Food Processing and Preservation: 44. https://doi.org/10.1111/jfpp.14601

Borges, M.M., da Costa, D.V., Trombete, F.M. and Câmara, A.K.F.I., 2022. Edible insects as a sustainable alternative to food products: an insight into quality aspects of reformulated bakery and meat products. Current Opinion in Food Science 46: 100864. https://doi.org/10.1016/j.cofs.2022.100864

Caparros Megido, R., Gierts, C., Blecker, C., Brostaux, Y., Haubruge, É., Alabi, T. and Francis, F., 2016. Consumer acceptance of insect-based alternative meat products in Western countries. Food Quality and Preference 52: 237-243. https://doi.org/10.1016/j.foodqual.2016.05.004

Dermody, J. and Chatterjee, I., 2016. Food glorious food, fried bugs and mustard! exploring the radical idea of entomophagy in advancing sustainable consumption to protect the planet. Academy of Marketing Annual Conference, Newcastle-upon-Tyne.

EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA), Turck, D., Bohn, T., Castenmiller, J., De Henauw, S., Hirsch-Ernst, K.I., Maciuk, A., Mangelsdorf, I., McArdle, H.J., Naska, A., Pelaez, C., Pentieva, K., Siani, A., Thies, F., Tsabouri, S., Vinceti, M., Cubadda, F., Frenzel, T., Heinonen, M., Marchelli, R., Neuhäuser-Berthold, M., Poulsen, M., Prieto Maradona, M., Schlatter, J.R., van Loveren, H., Goumperis, T. and Knutsen, H.K., 2021. Safety of frozen and dried formulations from whole house crickets (*Acheta domesticus*) as a novel food pursuant to Regulation (EU) 2015/2283. EFSA Journal 19: e06779. https://doi.org/10.2903/j.efsa.2021.6779

Erhard, A.L., Silva, M.Á., Damsbo-Svendsen, M., Sørensen, H. and Frøst, M.B., 2023. Acceptance of insect foods among Danish children: Effects of information provision, food neophobia, disgust sensitivity, and species on willingness to try. Food Quality and Preference 104: 104713. https://doi.org/10.1016/j.foodqual.2022.104713

Gorman, M., Moss, R. and McSweeney, M.B., 2024. Knowledge of traditional insect consumption impacts sensory perception and emotional responses to cookies containing crickets. Food Quality and Preference 117: 105180. https://doi.org/10.1016/j.foodqual.2024.105180

Grigor, J.M., Brennan, C.S., Hutchings, S.C. and Rowlands, D.S., 2016. The sensory acceptance of fibre-enriched cereal foods: A meta-analysis. International Journal of Food Science and Technology 51: 3-13. https://doi.org/10.1111/ijfs.13005

Gu, D., Andreev, K. and Dupre, M.E., 2021. Major Trends in Population Growth Around the World. China CDC Weekly 3: 604-613. https://doi.org/10.46234/ccdcw2021.160

Hopkins, I., Farahnaky, A., Gill, H., Danaher, J. and Newman, L.P., 2023. Food neophobia and its association with dietary choices and willingness to eat insects. Frontiers in Nutrition 10: 1150789. https://doi.org/10.3389/fnut.2023.1150789

Jongema, Y., 2017. List of edible insect species of the world. Laboratory of Entomology, Wageningen University, Wageningen.

Kowalski, S., Mikulec, A., Mickowska, B., Skotnicka, M. and Mazurek, A., 2022. Wheat bread supplementation with various edible insect flours. Influence of chemical composition on nutritional and technological aspects. LWT 159: 113220. https://doi.org/10.1016/j.lwt.2022.113220

Kröger, T., Dupont, J., Büsing, L. and Fiebelkorn, F., 2022. Acceptance of Insect-Based Food Products in Western Societies: A Systematic Review. Frontiers in Nutrition 8: 759885. https://doi.org/10.3389/fnut.2021.759885

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

Lensvelt, E.J.S. and Steenbekkers, L.P.A., 2014. Exploring consumer acceptance of entomophagy: a survey and experiment in Australia and The Netherlands. Ecology of Food and Nutrition 53: 543-561. https://doi.org/10.1080/03670244.2013.879865

Malila, Y., Owolabi, I.O., Chotanaphuti, T., Sakdibhornssup, N., Elliott, C.T., Visessanguan, W., Karoonuthaisiri, N. and Petchkongkaew, A., 2024. Current challenges of alternative proteins as future foods. npj Science of Food 8: 53. https://doi.org/10.1038/s41538-024-00291-w

Mehta, A., Serventi, L., Kumar, L., Morton, J.D. and Torrico, D.D., 2024. Packaging, perception, and acceptability: a comprehensive exploration of extrinsic attributes and consumer behaviours in novel food product systems. International Journal of Food Science and Technology 59: 6725-6745. https://doi.org/10.1111/ijfs.17463

Mishyna, M., Chen, J. and Benjamin, O., 2020. Sensory attributes of edible insects and insect-based foods – Future outlooks for enhancing consumer appeal. Trends in Food Science and Technology 95: 141-148. https://doi.org/10.1016/j.tifs.2019.11.016

Motoki, K., Ishikawa, S.I., Spence, C. and Velasco, C., 2020. Contextual acceptance of insect-based foods. Food Quality and Preference 85: 103982. https://doi.org/10.1016/j.foodqual.2020.103982

Nikkhah, A., Van Haute, S., Jovanovic, V., Jung, H., Dewulf, J., Cirkovic Velickovic, T. and Ghnimi, S., 2021. Life cycle assessment of edible insects (Protaetia brevitarsis seulensis larvae) as a future protein and fat source. Scientific Reports 11: 14030. https://doi.org/10.1038/s41598-021-93284-8

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

Puleo, S., Masi, P., Cavella, S. and Di Monaco, R., 2021. Oral sensitivity to flowability and food neophobia drive food preferences and choice. Foods 10: 1024. https://doi.org/10.3390/foods10051024

Puteri, B., Jahnke, B. and Zander, K., 2023. Booming the bugs: How can marketing help increase consumer acceptance of insect-based food in Western countries?. Appetite 187: 106594. https://doi.org/10.1016/j.appet.2023.106594

Ribeiro, J.C., Pintado, M.E. and Cunha, L.M., 2024. Consumption of edible insects and insect-based foods: A systematic review of sensory properties and evoked emotional response. Comprehensive Reviews in Food Science and Food Safety 23: e13247. https://doi.org/10.1111/1541-4337.13247

Rogers, E.M., Singhal, A. and Quinlan, M.M., 2019. Diffusion of innovations 1. In: Stacks, D.W., Salwen, M.B. and Eichhorn, K.C. (eds.) An integrated approach to communication theory and research. Routledge, Abingdon, pp. 415-434.

Shelomi, M., 2015. Why we still don't eat insects: Assessing entomophagy promotion through a diffusion of innovations framework. Trends in Food Science and Technology 45: 311-318.

Shepherd, R. and Raats, M., 2006. The psychology of food choice. CABI, Wallingford. https://doi.org/10.1079/9780851990323.0000.

Skrivervik, E., 2020. Insects' contribution to the bioeconomy and the reduction of food waste. Heliyon 6: e03934. https://doi.org/10.1016/j.heliyon.2020.e03934

Smolinski, H., Telebrico, M., Tao, J., Mai Ali Hasan, L., Jones, S. and Hernandez, G., 2015. Rizquet: A solution for food insecurity in developing countries through entomophagy. Acailable online at https://scholarworks.calstate.edu/downloads/pk02cc77x

Sogari, G., Riccioli, F., Moruzzo, R., Menozzi, D., Sosa, D.A.T., Li, J., Liu, A. and Mancini, S., 2023. Engaging in entomophagy: The role of food neophobia and disgust between insect and non-insect eaters. Food Quality and Preference 104: 104764. https://doi.org/10.1016/j.foodqual.2022.1047

Squeo, G., De Angelis, D., Leardi, R., Summo, C. and Caponio, F., 2021. Background, applications and issues of the experimental designs for mixture in the food sector. Foods 10: 1128. https://doi.org/10.3390/foods10051128

Tan, H.S.G., Fischer, A.R.H., van Trijp, H.C.M. and Stieger, M., 2016a. Tasty but nasty? Exploring the role of sensory-liking and food appropriateness in the willingness to eat unusual novel foods like insects. Food Quality and Preference 48: 293-302. https://doi.org/10.1016/j.foodqual.2015.11.001

Tan, H.S.G., van den Berg, E. and Stieger, M., 2016b. The influence of product preparation, familiarity and individual traits on the consumer acceptance of insects as food. Food Quality and Preference 52: 222-231. https://doi.org/10.1016/j.foodqual.2016.05.003

Torrico, D.D., Mehta, A. and Borssato, A.B., 2023. New methods to assess sensory responses: A brief review of innovative techniques in sensory evaluation. Current opinion in food science 49: 100978. https://doi.org/10.1016/j.cofs.2022.100978.

UN Economic Council, 2018. World demographic trends: report of the Secretary General. Commission on Population and Development 51st Session.

van Huis, A., 2020. Edible insects. In: Meiselman, H.L. (ed.) Handbook of eating and drinking: interdisciplinary perspectives. Springer, Cham, pp. 965-980.

van Huis, A. and Rumpold, B., 2023. Strategies to convince consumers to eat insects? A review. Food Quality and Preference 110: 104927. https://doi.org/10.1016/j.foodqual.2023.104927

Verbeke, W., 2015. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. Food Quality and Preference 39: 147-155. https://doi.org/10.1016/j.foodqual.2014.07.008

White, K.P., Al-Shawaf, L., Lewis, D.M. and Wehbe, Y.S., 2023. Food neophobia and disgust, but not hunger, predict willingness to eat insect protein. Personality and Individual Differences 202: 111944. https://doi.org/10.1016/j.paid.2022.111944

Wieczorek, M., Kowalczewski, P., Drabińska, N., Różańska, M. and Jeleń, H., 2022. Effect of Cricket Powder Incorporation on the Profile of Volatile Organic Compounds, Free Amino Acids and Sensory Properties of Gluten-Free Bread. Polish Journal of Food and Nutrition Sciences 72: 431-442. https://doi.org/10.31883/pjfns/156404

Worch, T. and Punter, P.H., 2015. Ideal profiling as a sensory profiling technique. In: Delarue, J., Lawlor, J.B. and Rogeaux, M. (eds.) Rapid sensory profiling techniques. Elsevier, Amsterdam, pp. 307-332.

Yazici, G.N. and Ozer, M.S., 2021. Using edible insects in the production of cookies, biscuits, and crackers: a review. Biology and Life Sciences Forum 6: 80. https://doi.org/10.3390/Foods2021-10974