BRILL
WAGENINGEN
ACADEMIC

JOURNAL OF INSECTS AS FOOD AND FEED 11 (2025) S105–S115

Journal of Insects as Food and Feed
brill.com/jiff

RESEARCH ARTICLE

Evaluation of innovative insect-based products by Portuguese consumers using a repeated exposure approach under a controlled setting

B. Barbosa[1,2], *C. Rocha*[1,2], *J.C. Ribeiro*[1], *R.C. Lima*[2], *A.I.A. Costa*[3], *M.J.P. Monteiro*[4], *C. Maya*[5], *N. Roos*[5] *and L.M. Cunha*[1]*

[1]GreenUPorto/Inov4Agro, DGAOT, Faculty of Sciences, University of Porto, 4169-007 Porto, Portugal; [2]Sense Test – Sociedade de Estudos de Análise Sensorial a Produtos Alimentares, 4400-345 Vila Nova de Gaia, Portugal; [3]CATÓLICA-LISBON School of Business & Economics, Universidade Católica Portuguesa, 1649-023 Lisboa, Portugal; [4]CBQF - Centro de Biotecnologia e Química Fina - Laboratório Associado, Escola Superior de Biotecnologia, Universidade Católica Portuguesa, 4169-005 Porto, Portugal; [5]Department of Nutrition, Exercise and Sports (NEXS), University of Copenhagen, 1958 Frederiksberg C, Denmark; *lmcunha@fc.up.pt

Received 10 April 2024 | Accepted 6 January 2025 | Published online 27 February 2025 | Published in issue 9 May 2025

Abstract

In an era of considerable environmental pressures, edible insects have demonstrated their ability to integrate innovative and sustainable food production methods. Nonetheless, there are clear obstacles to their acceptance, particularly in Western countries. With a view to a longitudinal analysis of the consumption moment, the study's main goal was to assess how the repeated exposure approach can impact consumer's liking and sensory perception of different insect-based products. At the same time, these products were compared with commercially available plant-based analogue products, as these types of products can be targeted to the same market. For each group of products, the impact of repeated exposure on participants exposed to the products in a household context was compared with a group of participants who had no intervention at home. This comparative assessment was carried out in a sensory laboratory environment. Five different insect and plant-based products were assessed on a 9-point hedonic scale with open comments to complement the analysis by two panels of 58 participants. Significant differences were found between products throughout the exposure, with most products decreasing the liking scores between exposures. However, no significant differences concerning exposure were identified between the intervention and non-intervention groups. Regarding the evaluation of the samples according to the different exposure groups, it was observed that there was no noticeable impact of exposure on the evaluation of the insect-based products evaluated by the intervention group and the plant-based products tasted by the non-intervention group. This study reinforces the impact of repeated exposure on the overall liking levels of the samples, with valuable findings on sensory perception that can be translated into insect-based product development.

Keywords

consumer liking – entomophagy – food choice – intervention study – repeated exposure

1 Introduction

The substantial improvement in the health conditions of individuals, coupled with the increase in hygiene conditions in modern societies, has made it possible for the world's population to grow significantly (Searchinger *et al.*, 2019). The correlation of this topic with increased environmental pressure on agriculture and livestock farming has required the search for innovative food production methodologies and techniques that consider the nutritional, environmental and socio-cultural dimensions of food sustainability.

Recent trends promoting the use of insects as a human food product aim to meet demands of this nature. Compared to the production of conventional animal-based protein sources, the production of insects as an alternative protein source is associated with a lower environmental impact through reductions in natural resources use (e.g. water, feed, agricultural land), production space as well as in greenhouse gases emissions (FAO *et al.*, 2023). Furthermore, although the nutritional content of insects is dependent on species, life stage and feed, insects present high protein content with high quality (e.g. amino acid profile, digestibility) and are also rich in bioactive compounds that are beneficial to human health (e.g. essential fatty acids, micronutrients) (van Huis *et al.*, 2021; van Huis and Oonincx, 2017). Despite these advantages, there are still several issues surrounding consumers' acceptance of insect-based foods, their incorporation into people's diets, and their success on the market (particularly in Western countries).

The rejection of edible insects is mainly motivated by emotional factors, with disgust towards insects being identified as the main predictor of entomophagy (intentional consumption of insects) (Sogari *et al.*, 2023; Ribeiro *et al.*, 2022). Alongside these emotional factors, food neophobia (a psychological construct describing a person's tendency to reject foods that are new or unfamiliar) (Pliner *et al.*, 1992) has also been described as a major factor leading to entomophagy rejection (Megido *et al.*, 2016; House, 2016). Despite these two factors being different constructs, they can be related to consumer's lack of familiarity with edible insects and association with disgusting cues, which leads to negative expectations towards sensory properties and can ultimately lead to consumers not considering insects as food (Kröger *et al.*, 2022).

As such, several mechanisms must be employed to encourage the consumption of insect-based foods, ranging from rational discoursed focused on increasing consumer's knowledge of entomophagy and its benefits (Woolf *et al.*, 2019) to strategies more geared to improve the sensory appeal of edible insects, such as gastronomic adaptation of the products, making it sensory appealing, which will give the meal greater familiarity and closeness (La Barbera *et al.*, 2018). To improve and optimise the applied strategies, three factors of particular interest must be considered: (1) the characteristics of the product itself, namely its flavour, convenience, and the availability of information that it shares. (La Barbera *et al.*, 2018), (2) the personal traits of individuals are also considered to be central to this choice, with it currently being revealed that men are more likely to adopt insects in their diet, and (3) the environment in which it is purchased and consumed also seems to have an impact on this experience.

Reflecting on consumers' unfamiliarity with the sensory properties of insect-based foods and the extent to which the stigma surrounding these products can impact tasting them, it becomes essential to assess consumers' perceptions of these products (Woolf *et al.*, 2021). In this context, it is particularly important to invest in methodologies that make it possible to faithfully assess consumer responses, portraying the moment of food consumption as closely as possible. It is important to reflect that the general taste of a product may change over time, i.e. the initial appreciation of a particular food may not correspond in the same way at the moment of consumption or even after tasting. So, the long-term enjoyment of a product may also be influenced by fluctuations in sensory perceptions arising from the repeated consumption of a product (Koster, 2003). In line with these thoughts, investing in strategies for evaluating the evolution of consumer perception over repeated exposure is important, as it will allow a true representation of product interpretation. Pineau *et al.* (2009) proposed a perspective for evaluating moments of multiple ingestion to minimise potential biases from a single-tasting sensory evaluation, which is not representative of the actual consumption of a food. In addition, it is recognized that hedonic evaluation through a single tasting session may not reflect the real perception of consumers (Lévy and Köster, 1999). Several studies have demonstrated this impact of exposure on consumer preference, both through a significant increase in food taste (Pliner *et al.*, 1982) and through the reverse effect of decreased preference (Sulmont-Rossé *et al.*, 2008). These effects have been shown to be correlated with the individual characteristics of consumers and/or the properties of the stimulus itself (Lévy and Köster, 1999), which is why

it is of particular interest to assess consumer dynamic behaviour in the face of repeated exposure. In this sense, studies with controlled time intervals and adjusted to the type of product seem to be advantageous for measuring changes in sensory perceptions over time of food consumption.

The main goal of the present study was to assess how repeated exposure approach can impact consumer's liking and sensory perception of different insect-based products. Furthermore, insect-based products were compared with commercially available plant-based analogue products, as these types of products can be targeted at the same market. Specifically, for each group of products, the impact of repeated exposure on 'intervention' participants was compared to the products at home, compared to a group of non-intervention participants in a sensory lab context.

2 Materials and methods

Participants

The participants included in this research were recruited using Sense Test's (sensory evaluation and consumer tests company in Portugal) database, which consists of a wide range of members, mainly residents of the Oporto metropolitan area. All those involved were recruited according to the following criteria: (1) selection of young Portuguese couples without children or only with children under the age of 3 to ensure that meals were only eaten by adults, (2) positive propensity to consume edible insects and plant-based products, according to the completion of a screening questionnaire, and (3) inexistence of any food allergies. These criteria were applied to selecting all the participants, who were then randomly assigned to one of the groups: insect or plant-based. The panels of tasters were informed *a priori* of the objectives and conditions of the tests. Likewise, all the individuals were informed of the guarantee of confidentiality of the information collected, as well as their right to consult, rectify and delete personal data throughout the study without any measurable harm being caused.

To minimise any neophobic effects, the selected participants were not given any information about the type of product that would be evaluated in each test session.

Approximately 200 participants completed the screening questionnaire, but only two panels of 58 participants fulfilled the criteria, which comprised 84 females (72%) and 32 males (28%). The entity involved in the intervention ensures the protection and confidentiality of the data collected through authorisation 2063/2009 from the National Data Protection Commission and appropriate professional conduct, complying with the requirements of the General Data Protection Regulation (EU) 2016/679. Nevertheless, data anonymisation strategies are guaranteed through the random coding of participants (i.e. ID number).

Samples

The samples used in the study included foods developed as outputs of the European project SUSINCHAIN and plant-based alternatives commercially available on national and international markets. The SUSINCHAIN project partners developed and supplied the insect-based products, as described in Table 1. The formulations and processing steps of each product had been previously optimised, following preliminary sensory tests with naive participants.

The developed products represent a wide variety of product typologies and consumption moments, and the goal of this project was to assess their potential incorporation into consumers' diets, considering consumers' perceptions. Introducing a similar menu of vegetable protein-based counterparts is intended to help identify specific barriers to introducing insect-based foods into the human diet.

The preparation mode of each product at the Sensory Lab was defined at the beginning of the study and remained constant throughout all the tasting sessions (see Table 1). The samples were coded with random 3-digit codes and served in white porcelain crockery. Natural mineral water and biscuits were available on the tasting tray so participants could cleanse their palates between products. Whenever possible, the products were tasted in a balanced order according to the assumptions of the Latin square methodology, thus avoiding possible order effects (MacFie *et al.*, 1989).

The microbiological safety of each food was guaranteed by the producers themselves, with data provided on the labels of each package. Regarding the insect-based products, each producer has carried out microbial quality assessment tests to ensure their safety for human consumption. Sense Test also further performed this validation, reproducing these analyses before the sensory tests at a laboratory accredited with ISO/IEC 17025 (Mérieux NutriSciences, Silliker Portugal and S.A., Vila Nova de Gaia, Portugal).

Experimental design

The present work is part of an intervention study that aimed to assess the potential of incorporating edible

TABLE 1 Products evaluated in the study, respective producer and country of origin, insect species, protein content and preparation/consumption method

Menu	Product	Producer / brand	Country	Insect species	Protein content (g/100 g)	Preparation / consumption method
Insect	Crispbread	Universitá Politecnia Delle Marche	Italy	*A. domesticus*	17.0	Ready-to-eat
	Falafel	New Generation Nutrition	Netherlands	*A. diaperinus*	11.0	Oven-finished
	Sausages	Leitat	Spain	*A. diaperinus* and *A. domesticus* blend	13.0	Warmed in water
	Spice Mix	Technical University of Denmark	Denmark	*A. domesticus*	38.0	Cooked with tomato sauce and spices, and served with Thai rice
	Umami Paste	Bugging	Denmark	*A. domesticus*	18.3	Heated in a frying pan with carrots and tomato pulp, and tasted with spaghetti and Parmesan cheese
Veggie	Crispbread	Amisa®	United Kingdom	Not applicable	10.8	Ready-to-eat
	Falafel	Iglo®	Portugal	Not applicable	6.7	Oven-finished
	Sausages	Izidoro®	Portugal	Not applicable	15.0	Warmed in water
	Spice Mix	Mother's Recipe®	India	Not applicable	7.0	Heated on microwave, and served with Thai rice
	Umami Paste	Conca®	Spain	Not applicable	6.1	Heated in a frying pan, and tasted with spaghetti and Parmesan cheese

insects into the daily diet of young Portuguese adults through an intervention taking place in participant's home, focused on the delivery of food baskets containing three family portions of insect-based products a week for six weeks (ISRCTN53814211) and to contrast these results with a repeated exposure approach on sensory laboratory (Sense Test, Portugal), the latter corresponding to the data and methodology that is described in this work.

The sensory lab tests included 116 participants, organised according to product typology to be evaluated (insect-based or plant-based). Figure 1 shows a schematic representation of the organisation and size of the panels used. The participants considered as "Intervention" were the ones who simultaneously took part in the intervention study at home, while the participants labelled as "Non-intervention" only tested the products in the lab.

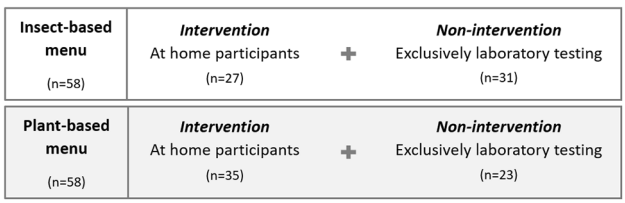

FIGURE 1 Representation of the groups of participants included in the sensory tests carried out in the laboratory, according to the type of product being tested.

Despite the type of exposure (i.e. at home [intervention group] or exclusive contact in the laboratory [non-intervention group]), all participants were exposed to the designated foods at different intervals: Exposure 1 (corresponding to the beginning of the study and

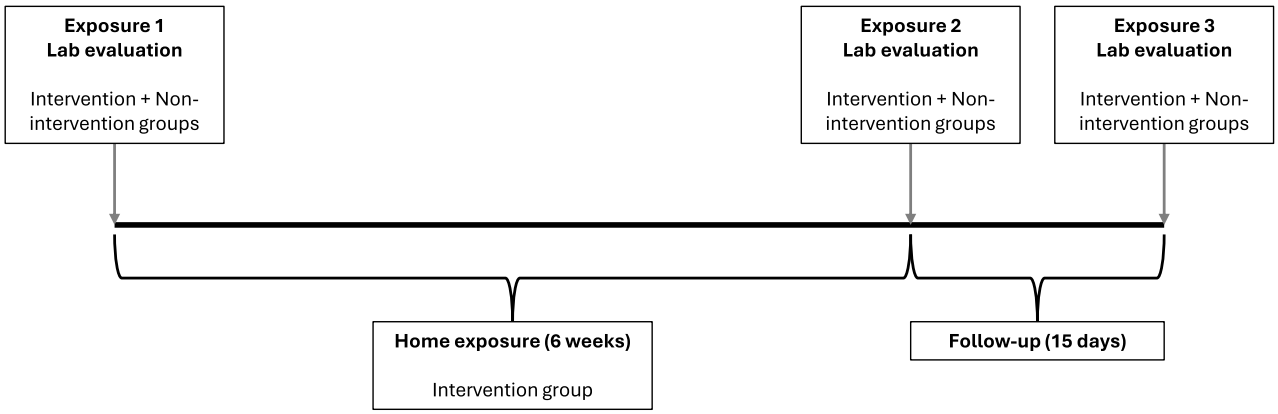

FIGURE 2 Presentation of the different evaluation moments for each of the groups (intervention and non-intervention).

the first contact with the products), Exposure 2 (corresponding to the sixth week of the study and the end of the home exposure), and Exposure 3 (corresponding to the period of 15 days after the end of the home exposure) (Figure 2).

Each participant was informed that all the products evaluated were based on alternative proteins, and that they would be randomly allocated to insect-based or plant-based products.

All the tests were prepared and conducted by a duly trained technical team in accordance with ISO 13300-1:2006 (Sensory analysis – General guidance for the staff of sensory evaluation laboratory – Part 1: Staff responsibilities) and ISO 13300-2:2006 (Sensory analysis – General guidance for the staff of sensory evaluation laboratory – Part 2: Recruitment and training of panel leaders).

The intervention protocol was approved by the Ethics Committee of the Faculty of Nutrition and Food Sciences of the University of Porto, under number 140/2023/CEFCNAUP.

Sensory evaluation

The tests carried out in a sensory laboratory environment were conducted under controlled and replicable conditions, both by tracking the room's temperature and by managing the lighting in the environment, which was kept at a light level close to natural light (6500K).

The study was applied to a global panel of 116 participants exposed to the insect and plant-based menus (58 for each menu), through which overall liking scores and open comments about the products were collected.

The data on the samples' overall liking was collected using a 9-point hedonic scale, ranging from: "1 – Dislike extremely" to "9 – Like extremely" (Peryam and Pilgrim, 1957).

To complement the quantitative information collected, consumers answered an open comments question on each evaluated sample, highlighting each product's main positive and negative aspects. In this way, a qualitative characterisation of the samples under study was possible.

Statistical analysis

The significance of the effect of the intervention on the product's liking (split by insect or plant-based) was assessed using a mixed repeated measures ANOVA. The assumptions of the method, namely the normal distribution of liking at the three exposure moments and the sphericity of the data matrix, were assessed using the Kolmogorov-Smirnov test and the Mauchly test, respectively. To identify which pairs of means differed from each other, for the interaction between the group type (intervention vs non-intervention) and for the moments of exposure, a multiple comparison of means with Bonferroni correction was carried out. As a first assessment, the Mauchly test indicates that the assumption of sphericity has been violated for the effects of exposure, $\chi 2(2) = 0.161 - 27.059$, $P < 0.05$ for almost all the groups, the reason why the conclusions regarding repeated measures will be made using the Greenhouse-Geisser correction.

All data was analysed using the software Statistical Package for Social Sciences (SPSS) – version 27 ®, with all statistical tests applied at a 95% confidence level.

3 Results and discussion

Overall liking

Overall liking scores for the insect-based and plant-based products (for both 'Intervention' and 'Non-intervention' groups) are shown in Table 2.

It is possible to observe that regardless of the group, all the tested products had positive scores (≥5.0) across

TABLE 2 Average and standard deviation values (average ± SD) for the different tests carried out

Menu	Product	Intervention			Non-intervention		
		Exposure 1	Exposure 2	Exposure 3	Exposure 1	Exposure 2	Exposure 3
Insect-based (n = 58)		n = 27			n = 31		
	Crackers	6.7 ± 1.5$^{(n.s)}$	6.5 ± 1.7$^{(n.s)}$	6.4 ± 2.1$^{(n.s)}$	6.2 ± 1.9$^{(n.s)}$	6.2 ± 1.7$^{(n.s)}$	6.4 ± 1.5$^{(n.s)}$
	Falafel	7.9 ± 1.2^{a}	7.5 ± 1.4$^{a, b}$	7.3 ± 1.5^{b}	7.2 ± 1.7$^{(n.s)}$	7.1 ± 1.8$^{(n.s)}$	7.1 ± 1.6$^{(n.s)}$
	Sausages	5.4 ± 1.7$^{(n.s)}$	5.3 ± 1.8$^{(n.s)}$	5.3 ± 1.9$^{(n.s)}$	5.3 ± 2.0^{b}	6.0 ± 1.9^{a}	6.0 ± 1.9^{a}
	Spice Mix	6.7 ± 2.1$^{(n.s)}$	6.0 ± 2.2$^{(n.s)}$	6.7 ± 1.9$^{(n.s)}$	6.5 ± 2.0$^{(n.s)}$	6.5 ± 1.9$^{(n.s)}$	6.6 ± 2.3$^{(n.s)}$
	Umami Paste	8.0 ± 1.2^{a}	7.0 ± 2.0^{b}	7.1 ± 1.7^{b}	7.4 ± 1.5$^{(n.s)}$	7.4 ± 1.4$^{(n.s)}$	7.1 ± 1.9$^{(n.s)}$
Plant-based (n = 58)		n = 35			n = 23		
	Crackers	7.2 ± 1.4$^{(n.s)}$	6.7 ± 1.7$^{(n.s)}$	6.9 ± 2.0$^{(n.s)}$	7.0 ± 1.5$^{(n.s)}$	7.2 ± 1.2$^{(n.s)}$	6.9 ± 1.7$^{(n.s)}$
	Falafel	7.9 ± 1.4$^{(n.s)}$	7.9 ± 1.3$^{(n.s)}$	7.4 ± 1.7$^{(n.s)}$	7.8 ± 0.9^{a}	7.8 ± 1.2$^{a, b}$	7.3 ± 1.3^{b}
	Sausages	7.8 ± 0.9$^{(n.s)}$	7.3 ± 1.5$^{(n.s)}$	7.3 ± 1.3$^{(n.s)}$	7.7 ± 0.9$^{(n.s)}$	7.5 ± 1.2$^{(n.s)}$	7.5 ± 1.2$^{(n.s)}$
	Spice Mix	6.8 ± 1.7$^{(n.s)}$	6.0 ± 2.6$^{(n.s)}$	6.5 ± 2.3$^{(n.s)}$	6.7 ± 2.4$^{(n.s)}$	6.3 ± 2.7$^{(n.s)}$	7.3 ± 1.6$^{(n.s)}$
	Umami Paste	5.5 ± 1.9$^{(n.s)}$	5.4 ± 2.3$^{(n.s)}$	5.7 ± 2.8$^{(n.s)}$	5.7 ± 2.3^{b}	5.9 ± 2.3^{b}	7.2 ± 1.9^{a}

$^{a, b}$ Homogenous groups for each product and intervention group across exposure sessions, according to mixed repeated measures ANOVA model, across the three exposures (95% confidence).

all exposure sessions. For the insect-based products, the samples with the highest scores (≥7.0 for both groups across all exposure sessions) were 'Falafel', and 'Umami paste'. The 'Falafel' is among the most liked plant-based products, but umami paste only had an average score ≥7.0 for Exposure 3 in the 'Non-Intervention' group. Instead, the 'Plant-based sausages' had average scores ≥7.0 for all the exposure sessions in both groups.

Starting with global interpolations within each product typology (i.e. plant or insect-based), it was decided to analyse both groups of products (insect and plant-based) separately. When examining the effect of exposure sessions for insect-based products, it is noticeable that the "Intervention" and "Non-intervention" groups displayed different behaviours in most samples. For the 'Falafel' and 'Sausage' samples, significant differences were found for the "Intervention" group (between exposures 1 and 3, where the liking decreased ($F(1.987;51.668) = 7.332$, $P = 0.002$)) and "Non-intervention" group (between exposure one and exposures 2 and 3, where the liking increased ($F(1.775;53.240) = 5.901$, $P = 0.034$)), respectively. For 'Umami paste', although average liking scores decreased for both groups, this decrease was more pronounced and significant in the "Intervention" group ($F(1.586; 41.241) = 7.635$, $P = 0.003$).

When the focus of the analysis is on plant-based products, the results were very similar to the ones observed for the group that evaluated insect-based samples. Once again, more positive results across exposure sessions were observed for the "Non-intervention" group ('crackers' – similar scores; 'sausages' – similar scores; 'umami paste' – increased scores) than for the "Intervention" group (crackers – decreased scores; sausages – decreased scores; umami paste – similar scores). In the specific case of the "Non-intervention" group, for 'falafel' ($F(1.598;35.155) = 3.650$, $P = 0.045$) and 'umami paste' ($F(1.506;33.135) = 8.410$, $P = 0.003$) significant differences were found between exposures decrease and increase, respectively). Notably, liking decreases were observed for the "Intervention" group in three samples ('crackers', 'falafel' and 'sausages'). Concerning comparisons in liking scores between both groups, it was possible to observe that the "Non-intervention" group gave higher liking scores for the 'spice mix' and 'umami paste' samples.

Comparing the results between both panels (Insect vs Plant-based), the plant-based products had higher average scores than the insect-based products ("Intervention" – crackers, sausages; "Non-intervention" – crackers, falafel, sausages). The only products with higher liking scores for the insect-based samples were the umami paste in "Intervention" groups. Furthermore, liking decreases were observed in a higher number of insect-based products than plant-based products.

These differences are not surprising since the plant-based products were commercially available and formulations that have already undergone a high level of sensory scrutiny. In contrast, the insect-based products were prototypes under development without much work on scale-up, marketing and branding. Also, it is relevant to note that the analysis of Table 1 shows that

the insect-based products used in this research have a higher protein content than their plant-based counterparts, except for sausages. Therefore, it is clear that the process of masking the development of off-flavours typically associated with the incorporation of high levels of insect-based proteins is still a difficult one and can only be achieved by using protein mixtures or highly palatable ingredients such as tomato-based sauces and spices, since the products with the highest incorporation of spices ('falafel') and tomato sauce ('umami paste'), were the insect-based products with the highest level of acceptance. These results are not surprising since it has been previously reported that in bakery-type products, at incorporation levels of 5-10%, 10-20% and >20%, more than 60% of evaluated samples presented lower hedonic scores than control samples (Ribeiro *et al.*, 2024). Furthermore, as observed in this study, the increased complexity of the dishes (Ssepuuya *et al.*, 2017) and association with familiar flavours (Megido *et al.*, 2014) can increase the liking scores of the developed products.

Directing the analysis towards assessing possible correlations between the intervention and non-intervention groups, pairwise comparisons were made, which showed no significant differences between the groups regarding exposure ($P > 0.05$). Regarding the insect products evaluated by the intervention group and plant-based products tasted by the non-intervention group, there was no noticeable effect of exposure ($P > 0.05$).

Following the topics discussed, the plant-based umami paste sample showed an increase in value throughout the tasting sessions. At the same time, the insect-based protein source counterpart tended to decrease its overall liking values throughout the different exhibitions.

Sensory profile perception

Analysing the free elicited sensory profile of the insect-based samples obtained through open comments in the 1st evaluation (Figure 3), the non-intervention group associated sausages with very harmful properties (bitter, unappealing, low-intensity flavour), but in the 3rd exposure, there is no such strong association. This is also related to a slight increase in this product's overall liking value between the exposures mentioned earlier. On the other hand, the opposite occurred with the intervention group, which associated sausage with intense, appealing, and spicy enough in the 1st session, and in the last session, it was associated with an unappealing appearance. These associations with a bitter taste and an unattractive appearance/dark colour have been reported in other studies with insects and may justify lower levels of acceptance (Cruz-Lopez *et al.*, 2022; Ribeiro *et al.*, 2022; Ribeiro *et al.*, 2019).

In the second exposure (Figure 3), the non-intervention group shows more significant discrimination between the samples. Between Exposures 2 and 3, the non-intervention group also had higher liking scores for Sausages and Spice mix, related to the less derogatory association in the third exposure (Sausage: intense (T) and appealing (A); spice mix: intense (O) and tempered (T)).

In the third and final stage of exposure to the products (Figure 3), the samples were discriminated between the intervention and non-intervention groups at a balanced level, which correlates with their identical overall acceptability values.

Regarding plant-based products, an initial analysis showed a decrease in the samples' ability to discriminate between the various sessions (Figure 4). Similarly to what was seen in the insect-based segment, plant-based products have a sensory perception that aligns with the liking values presented.

Regardless of the exposure group, the products with a decrease in liking over the three tasting sessions are sequentially associated with more negative attributes (crackers, falafel and sausages). On the other hand, the reverse effect is also observed, particularly in evaluating umami paste. In the first exposure, this product is associated with a more consistent texture, while in the last evaluation, it is characterised mainly as a creamy product. In terms of flavour, the product is considered intense, a characteristic that remains unchanged over time. It is also interesting to note that both participant groups perceived the products similarly on the first and second exposure, with slight differences on the third exposure, mainly because of the bitterness associated with 'sausages' on the third exposure by the 'Intervention group'.

4 Limitations

Besides all the constraints mentioned throughout the previous sections, some additional aspects should be reflected upon when discussing the results obtained. One of the first limitations of this study is the relatively small sample size. The research was conducted with a sample of 116 people, who were then split into smaller groups, which may not fully represent the diversity of the target population. Additionally, participants

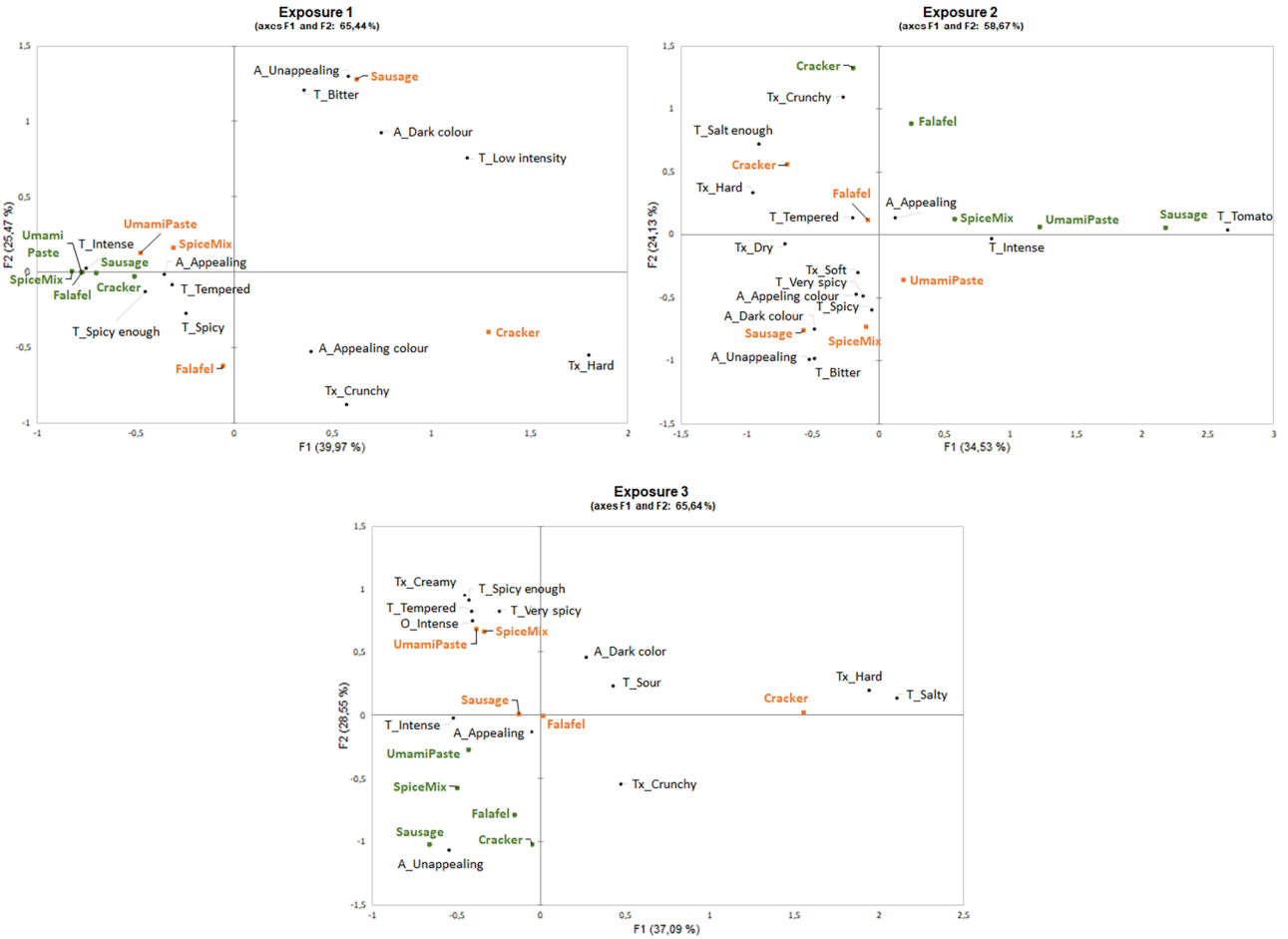

FIGURE 3 Correlation of the insect-based products evaluated by the intervention (shown in green) and non-intervention (shown in orange) groups in the first, second and third exposure session. The initials stand for: A – Appearance, O – Odour, Tx – Texture, T – Taste.

were recruited through convenience sampling, which could introduce bias and limit the conclusions of the findings to other populations. Another limitation is that data on personality traits and attitudes such as familiarity, meat attachment, food neophobia and others were not collected and could provide additional insights into consumer preferences and perceptions.

5 Conclusions

Through a repeated exposure approach, this study offers significant insights into the acceptance and sensory perception of insect-based products among Portuguese consumers. The results indicate that although initial consumer scepticism regarding insect-based products remains, repeated exposure significantly influences overall liking and sensory perception, with differences based on the product type. It is interesting to note that products with strong, familiar flavours such as 'Falafel' and 'Umami Paste' showed greater consumer acceptance compared with other innovative options, highlighting the importance of flavour masking and ingredient familiarity to increase the appeal of insect-based foods.

In comparing insect-based goods to plant-based alternatives, the latter typically earned higher ratings, presumably because of their market accessibility and sophisticated formulations. The prototype status of insect-based goods highlights the necessity for more product development, especially in concealing unpleasant tastes often linked to elevated protein levels from insects. These findings emphasize the significance of product familiarity and the possible impact of consumers' repeated exposure to novel meals in altering preferences.

Despite certain limitations, such as the small sample size and the lack of data on individual traits like food neophobia, this study establishes a foundation for future research. It suggests that focusing on product familiarity, taste interventions, and continuous consumer education could significantly reduce the stigma

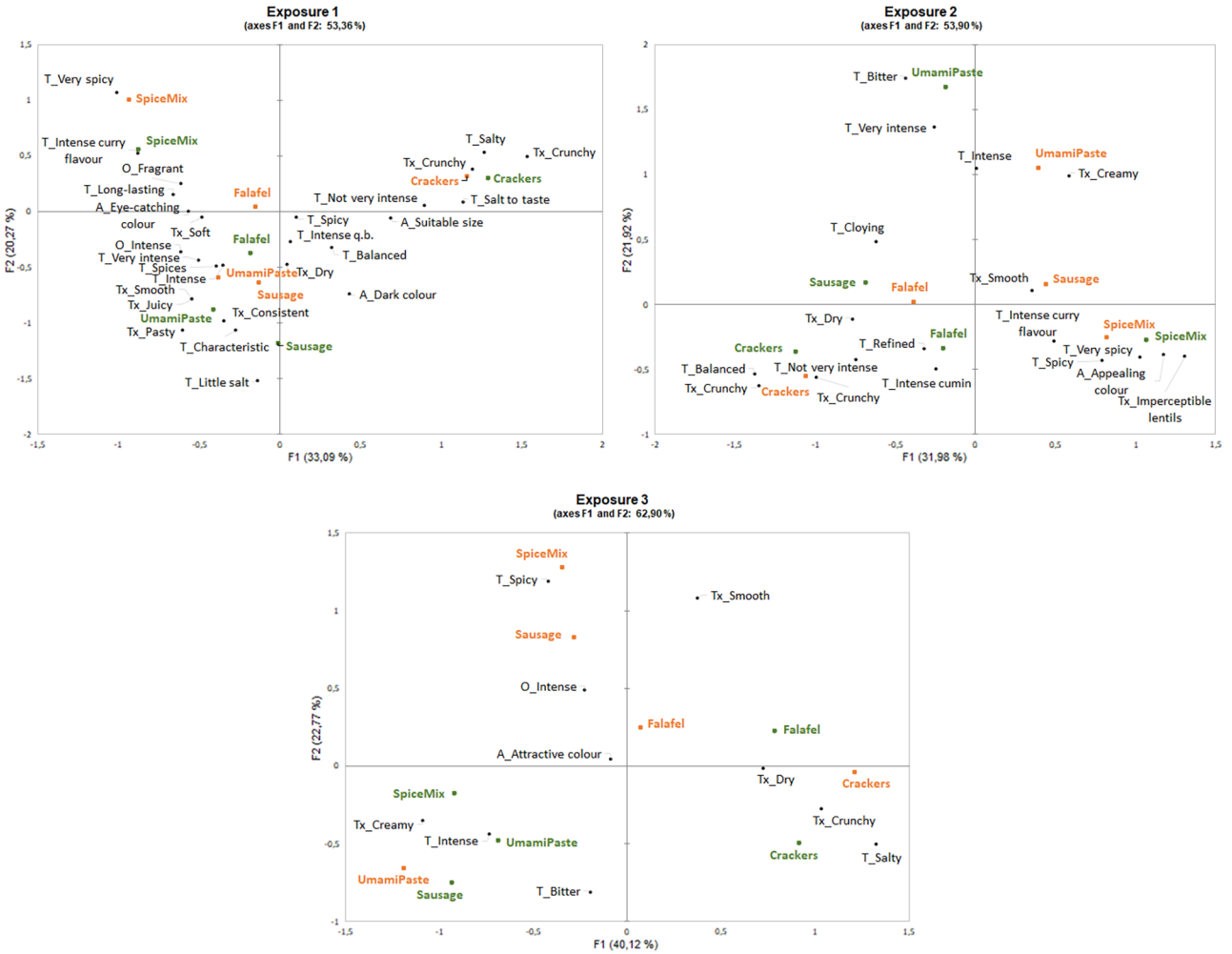

FIGURE 4 Correlation of the veggie samples evaluated by the intervention (shown in green) and non-intervention (shown in orange) groups in the first, second and third exposure session. The initials stand for: A – Appearance, O – Odour, Tx – Texture, T – Taste.

around edible insects. Further research should focus on investigating long-term consumer behaviour, individual psychological characteristics, and the possible scalability of these formulations within a wider market.

Acknowledgements

Author B. Barbosa acknowledges Doctoral Grant No. 2023.03467.BDANA, funded by the Portuguese Foundation for Science and Technology (FCT). Authors Barbosa, Rocha, Ribeiro Cunha also acknowledge support to GreenUPorto from FCT through the Strategic Projects UIDB/05748/2020 (https://doi.org/10.54499/UIDP/05748/2020) and UIDP/05748/2020 (https://doi.org/10.54499/UIDB/05748/2020). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 861976. Authors thank the project partners for providing the products: Lucia Aquilanti and Andrea Osimani from the Universitá Politecnia Delle Marche (Crispbread); Marian Peters, from the New Generation Nutrition (Falafel); Irina Elena Chiriac, from Leitat (Sausage); Roberto Flore, from the Technical University of Denmark (Spice Mix); Jakob Rukov from Bugging Denmark (Umami Paste).

References

Cruz-Lopez, S.O., Alvarez-Cisneros, Y.M., Dominguez-Soberanes, J., Escalona-Buendia, H.B. and Sanchez, C.N., 2022. Physicochemical and sensory characteristics of sausages made with grasshopper (*Sphenarium purpurascens*) flour. Foods 11: 704. https://doi.org/10.3390/foods11050704

FAO, IFAD, UNICEF, WFP and WHO, 2023. The state of food security and nutrition in the world 2023 – Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Food and Agriculture Organi-

zation of the United Nations, Rome, Italy. https://doi.org/10.4060/cc3017en

Hartmann, C. and Siegrist, M., 2018. Development and validation of the Food Disgust Scale. Food Quality and Preference 63: 38-50. https://doi.org/10.1016/j.foodqual.2017.07.013

House, J., 2016. Consumer acceptance of insect-based foods in The Netherlands: academic and commercial implications. Appetite 107: 47-58. https://doi.org/10.1016/j.appet.2016.07.023

Köster, E.P., 2003. The psychology of food choice: some often encountered fallacies. Food Quality and Preference 14: 359-373. https://doi.org/10.1016/S0950-3293(03)00017-X

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

Lesschaeve, I. and Noble, A.C., 2005. Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. The American Journal of Clinical Nutrition 81: 330S-335S. https://doi.org/10.1093/ajcn/81.1.330S

Lévy, C.M. and Köster, E.P., 1999. The relevance of initial hedonic judgements in the prediction of subtle food choices. Food Quality and Preference 10: 185-200. https://doi.org/10.1016/S0950-3293(99)00016-6

MacFie, H.J., Bratchell, N., Greenhoff, K. and Vallis, L.V., 1989. Designs to balance the effect of order of presentation and first-order carry-over effects in Hall tests. Journal of Sensory Studies 4: 129-148. https://doi.org/10.1111/j.1745-459X.1989.tb00463.x

Megido, R.C., Sablon, L., Geuens, M., Brostaux, Y., Alabi, T., Blecker, C., Drugmand, D., Haubruge, E. and Francis, F., 2014. Edible insects acceptance by Belgian consumers: promising attitude for entomophagy development. Journal of Sensory Studies 29: 14-20. https://doi.org/10.1111/joss.12077

Megido, R.C., 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

Peryam, D.R. and Pilgrim, F.J., 1957. Hedonic scale method of measuring food preferences. Food Technology 11: 9-14.

Pineau, N., Schlich, P., Cordelle, S., Mathonnière, C., Issanchou, S., Imbert, A., Rogeaux, M., Etiévant, P. and Köster, E., 2009. Temporal dominance of sensations: construction of the TDS curves and comparison with time–intensity. Food Quality and Preference 20: 450-455. https://doi.org/10.1016/j.foodqual.2009.04.005

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

Pliner, P., 1982. The effects of mere exposure on liking for edible substances. Appetite 3: 283-290. https://doi.org/10.1016/s0195-6663(82)80026-3

Ribeiro, J.C., Gonçalves, A.T.S., Moura, A.P., Varela, P. and Cunha, L.M., 2022. Insects as food and feed in Portugal and Norway – cross-cultural comparison of determinants of acceptance. Food Quality and Preference 102: 104650. https://doi.org/10.1016/j.foodqual.2022.104650

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: 1-45. https://doi.org/10.1111/1541-4337.13247

Ribeiro, J.C., Lima, R.C., Maia, M.R.G., Almeida, A.A., Fonseca, A.J.M., Cabrita, A.R.J. and Cunha, L.M., 2019. Impact of defatting freeze-dried edible crickets (*Acheta domesticus* and *Gryllodes sigillatus*) on the nutritive value, overall liking and sensory profile of cereal bars. LWT 113: 108335. https://doi.org/10.1016/j.lwt.2019.108335

Ribeiro, J.C., Santos, C., Lima, R.C., Pintado, M.E. and Cunha, L.M., 2022b. Impact of defatting and drying methods on the overall liking and sensory profile of a cereal bar incorporating edible insect species. Future Foods 6: 100190. https://doi.org/10.1016/j.fufo.2022.100190

Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., Matthews, E. and Klirs, C., 2019. Creating a sustainable food future: a menu of solutions to feed nearly 10 billion people by 2050. World Resources Institute, Den Haag, the Netherlands.

Sogari, G., Riccioli, F., Moruzzo, R., Menozzi, D., Tzompa-Sosa, D.A., Li, J. 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.2022.104764

Ssepuuya, G., Mukisa, I.M. and Nakimbugwe, D., 2017. Nutritional composition, quality, and shelf stability of processed *Ruspolia nitidula* (edible grasshoppers). Food Science & Nutrition 5: 103-112. https://doi.org/10.1002/fsn3.369

Stein, L.J., Nagai, H., Nakagawa, M. and Beauchamp, G.K., 2003. Effects of repeated exposure and health-related information on hedonic evaluation and acceptance of a bitter beverage. Appetite 40: 119-129. https://doi.org/10.1016/s0195-6663(02)00173-3

Sulmont-Rossé, C., Chabanet, C., Issanchou, S. and Köster, E.P., 2008. Impact of the arousal potential of uncommon drinks on the repeated exposure effect. Food Quality and Preference 19: 412-420. https://doi.org/10.1016/j.foodqual.2007.12.003

van Huis, A., Rumpold, B., Maya, C. and Roos, N., 2021. Nutritional qualities and enhancement of edible insects. Annual Review of Nutrition 41: 551-576. https://doi.org/10.1146/annurev-nutr-041520-010856

van Huis, A. and Oonincx, D.G., 2017. The environmental sustainability of insects as food and feed. A review. Agronomy for Sustainable Development 37: 43. https://doi.org/10.1007/s13593-017-0452-8

Woolf, E., Maya, C., Yoon, J., Shertukde, S., Toia, T., Zhao, J., Zhu, Y., Peter, P.C. and Liu, C., 2021. Information and taste interventions for improving consumer acceptance of edible insects: a pilot study. Journal of Insects as Food and Feed 7: 129-139. https://doi.org/10.3920/JIFF2020.0057