Influence of cricket powder content and placebo effect on consumers' acceptance of sweet biscuits*

Influencia del contenido de polvo de grillo y efecto placebo en la aceptación de galletas dulces por parte de los consumidores

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Abstract

Introduction. Insect-based foods represent an emerging alternative to conventional food products. Insect powders are an important protein source with reduced ecological impact, though its incorporation into foods should consider effects on sensory properties and nutritional profiles. **Objective.** To assess consumer acceptance of sweet biscuits with cricket powder in Costa Rica, and evaluate the nutritional profiles of the products developed. **Materials and methods.** The study was conducted at the Universidad de Costa Rica, San José, Costa Rica in 2023. Sweet biscuits containing varying proportions of cricket powder (0.0, 12.5, and 26.0 %) were manufactured to evaluate both placebo effect and effect of cricket powder content influence on consumer acceptance, using two distinct panel groups. Demographic information, attitudes towards entomophagy, and perceived importance of protein consumption were collected via questionnaire. Proximate analysis and detailed fatty acid composition were performed on the three tested formulations with cricket powder. **Results.** Study populations demonstrated positive attitude towards insect consumption. The overall acceptance of the "No cricket" sample was significantly lower compared to both "Cricket" and "Commercial" samples. Biscuits containing 12.5% cricket powered achieved significantly higher overall sensory acceptance compared to the "26.0 % cricket powder" sample and showed no significant difference from the "Commercial" sample. Consumer segmentation was accomplished through Agglomerative Hierarchical Clustering. Primary nutritional differences between samples were observed in crude fat and specific fatty acids contents. **Conclusions.** Results indicate high consumer acceptance of sweet biscuits with cricket powder in Costa Rica. Nutritional analysis revealed progressive increases in crude fat and specific fatty acids contents corresponding to increased cricket powder incorporation.

Keywords: **entomophagy, product development, sensory properties, protein content.**

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Resumen

Introducción. Los alimentos con insectos son una alternativa a los alimentos tradicionales. Los polvos de insectos son una fuente importante de proteína con un menor impacto ecológico, pero su inclusión en los alimentos debe considerar efectos sensoriales y nutricionales. **Objetivo.** Evaluar la aceptación de galletas dulces con polvo de grillo en Costa Rica y sus perfiles nutricionales. **Materiales y métodos.** El estudio se desarrolló en la Universidad de Costa Rica, San José, Costa Rica, en 2023. Galletas dulces con diferentes contenidos de polvo de grillo (0,0, 12,5 y 26,0 %) se produjeron para valorar el efecto placebo y el contenido de polvo de grillo en la aceptación, empleando dos grupos de panelistas. Se recolectó mediante un cuestionario información demográfica, actitudes hacia el consumo de insectos y la importancia percibida del consumo de proteína. Se determinó la composición proximal y detallada de ácidos grasos en las tres formulaciones con polvo de grillo evaluadas. **Resultados.** Las poblaciones analizadas mostraron una aparente actitud positiva hacia el consumo de insectos. La aceptación general de la muestra "Sin grillo" fue significativamente menor que la de las muestras "Con grillo" y "Comercial". El agrado sensorial general de la muestra "12,5 % polvo de grillo" fue significativamente mayor que el de la muestra "26,0 % polvo de grillo" y no fue significativamente diferente del de la muestra "Comercial". Se identificaron segmentos de consumidores a través de la Agrupación Jerárquica Aglomerativa. Las principales diferencias significativas entre muestras en el análisis nutricional correspondieron a los contenidos de grasa cruda y ácidos grasos específicos. **Conclusiones.** Existe una aparente alta aceptación de galletas dulces con polvo de grillo en Costa Rica. La valoración de los perfiles nutricionales reveló diferencias en los contenidos de grasa cruda y ácidos grasos en las formulaciones evaluadas, los cuales aumentaron conforme se incrementó el nivel de polvo de grillo en las formulaciones.

Palabras clave: entomofagia, desarrollo de producto, propiedades sensoriales, contenido proteico.

Introduction

Feeding the planet without destroying it is a global challenge. Considering the increase in the world's population and the ecological problems humanity is facing, new questions are being raised about human food production systems. Under this context, the production of macro- and micronutrients in appropriate proportions for human needs currently is an important research issue (Berners-Lee et al., 2018).

Compared with traditional farming, insects are a protein source with a lower ecological impact. Rearing insects demands smaller physical space, lower water consumption, and less economic resources, as they can have a waste-based diet (Hénault-Ethier et al., 2024; Van Huis & Oonincx, 2017).

The cricket species Acheta domesticus presents interesting nutritional properties for producing flour supplements, meat substitute enhancers, or animal nutrition solutions. A. domesticus provides important levels of essential amino acids for human health and bioactive peptides (Udomsil et al., 2019). In fact, cricket powder of A. domesticus is regarded as a protein source (Acosta-Estrada et al., 2021). Also, nutritional analyses have shown crickets to have low-fat contents when compared with other edible insects, and to contain essential fatty acids such as alpha linolenic and linolenic acid. Finally, cricket powder is considered a good source of minerals (Udomsil et al., 2019).

The application of edible insects in cookies and biscuits has been addressed in recent studies, where insects such as *A. domesticus* (Aleman et al., 2022), *Tenebrio molitor* and *Alphitobius diaperinus* (Ortolá et al., 2022), *Gryllus bimaculatus* (Arama et al., 2023), *Ruspolia differens* (Ochieng et al., 2023), and *T. molitor* and *Zophobas atratus* (Sriprablom et al., 2022) were evaluated. Overall, results indicate that edible insects are a good alternative to nutritionally enriched bakery products (including cookies, biscuits, and crackers). Also, reports indicate that results concerning sensory evaluations are promising, but at the same time, the main limitation is to introduce the product in new markets (Yazici & Ozer, 2021).

It is common knowledge that food sensory characteristics drive acceptability, but in this case, other factors can affect food acceptance, including familiarity, cultural aspects, and disgust (Castro & Chambers, 2019). Although there is evidence of insect consumption throughout human history, the potential use of insects as food for humans in the Western world was realized only a few decades ago (Van Huis & Rumpold, 2023). Limitations in consumer acceptance could be associated mainly to these cultural barriers leading to rejection of insect consumption (Ortolá et al., 2022).

In Costa Rica, insect consumption is not widespread; nevertheless, positive consumer perception towards the practice is encouraging. The Costa Rican population shows general approval towards the use of insects as food (Bermúdez-Serrano et al., 2023). The goal of this study was to evaluate the consumers' acceptance level of sweet biscuits with cricket powder in Costa Rica, and to assess the nutritional profiles of the products developed.

Materials and methods

The study was conducted at the National Center of Food Science and Technology (CITA) and the Department of Food Technology of the Universidad de Costa Rica (UCR), San José, Costa Rica, between June and August 2023.

Raw materials, formulations, and process description

The raw materials for the production of sweet biscuits were wheat flour (Nacarina), butter (Numar), egg (Yema), brown sugar (Doña María), white sugar (Doña María), vanilla extract (Vainol), baking powder (Parapan), and baking soda (Ancla). Materials were purchased from a local supermarket. Acheta domesticus cricket powder was purchased from producer EXO Protein.

Cricket powder was used as a substitute for wheat flour, and its contents in the treatments was expressed as a percentage of wheat flour substitution. Three formulations were tested throughout the study, which consisted of a control treatment (0.0 % cricket powder) and two additional treatments with 12.5 % and 26.0 % cricket powder. The formulations tested are shown in Table 1.

Table 1

Tested formulations of sweet biscuits. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Raw material	Formulation 1: 0.0 % cricket powder biscuit	Formulation 2: 12.5 % cricket powder biscuit	Formulation 3: 26.0 % cricket powder biscuit
Wheat flour (g)	125	109	93
Cricket powder (g)	0	16	33
Butter (g)	13	13	13
Egg (g)	10	10	10
Brown sugar (g)	7	7	7
White sugar (g)	7	7	7
Vanilla extract (g)	0.3	0.3	0.3
Baking powder (g)	0.3	0.3	0.3
Baking soda (g)	0.1	0.1	0.1

Cuadro 1. Formulaciones evaluadas de galletas dulces. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

The process for the production of sweet biscuits was carried out as follows. Brown and white sugar were mixed with melted butter until homogeneous. Egg was incorporated while mixing. The rest of the ingredients (flour, cricket powder, baking powder, baking soda, and vanilla extract) were incorporated while mixing until homogeneous. The resulting dough was rested between 1 and 3 h in refrigeration. The rested dough was rolled until a 0.6 cm thickness was achieved. A round, 4 cm diameter cookie cutter was used to cut the biscuits. Biscuits were placed on a baking sheet covered with parchment paper. Biscuits were baked for 6 min and 30 s at 170 °C and cooled on a rack until they reached room temperature.

The final products used for the experiments were individually packed in labeled plastic bags and sealed. Sweet biscuits were produced two days before each sensory analysis experiment and were kept at room temperature until the evaluation session. A commercially available sweet biscuit, which was used in the sensory analysis experiments, was purchased from a local supermarket. The ingredients listed in the commercial biscuit were: wheat flour, sugar, butter, baking powder, and baking soda. Preliminary trials were carried out so that the formulated sweet biscuits resembled the commercial product in terms of size and color.

Nutritional analyses

The proximate and detailed fatty acid composition was determined in the three tested formulations. Each analysis was carried out in triplicate samples, with each replicate corresponding to one independent production batch of the sweet biscuits. Moisture and protein analyses were carried out following the methods described by Cortés-Herrera et al. (2021). Nitrogen analyses were performed using a combustion analyzer rapid N exceed® (Elementar), with a conversion factor from nitrogen to protein of 6.25. A thermogravimetric analyzer (LECO, TGA 801) was used for moisture determination.

Crude fat and ash were determined following Association of Official Analytical Chemists standard methods 920.85 and 935.39B (Association of Official Analytical Chemists [AOAC], 2019). Equipment used were Extraction unit E-816 SOX (Büchi) and Furnace Lamdberg Blue M BF51894C-1 (Thermo Scientific) for

crude fat and ash, respectively. Total carbohydrates were calculated by difference, from calculations of moisture, protein, crude fat, and ash contents. Saturated, monounsaturated, polyunsaturated, and trans fatty acids contents were determined following a methodology based on standard methods 996.06 (AOAC, 2019) and Ce 1e-91 (American Oil Chemists' Society [AOCS], 2012). Further details concerning the methodologies can be found elsewhere (Artavia & Granados-Chinchilla, 2021).

Panelist selection for sensory analyses

Two groups of consumers were selected among students, employees, and visitors at the Universidad de Costa Rica (UCR), San José, Costa Rica. Each group of panelists was used for one of the two sensory analysis experiments. The recruitment was performed according to the following inclusion criteria: be a frequent consumer of biscuits (more than three times a week), be over 18 years of age, not having food allergies, and not being pregnant. Before the sensory analyses, panelists were informed about the details of the study and were made aware that foods containing insects could be part of the samples to taste. A consent form was read and signed by each participant before tests were performed.

Before sensory evaluations, a questionnaire was used to collect relevant demographic information from participants, including gender, age, nationality, and general area of residence (urban or rural). The questions were also designed to request information concerning food neophobia, experience and perception of insect consumption, expectation of biscuits to be sampled, perceived importance of protein consumption, and willingness to include insects in their diet in order to increase protein consumption. The Microsoft Forms platform was used to create and apply the questionnaire. To check its clarity and usability, four people were interviewed and suggested minor changes, which were implemented in the final version. The questionnaire was completed by 161 participants of the study.

Sensory experiment 1: placebo effect on consumer acceptance

The first experiment was carried out to understand the influence of informing the panelists about the cricket powder and protein content of the samples on the overall sensory acceptability of biscuits. A description of samples presented to the panelists (n = 81) is shown in Table 2.

Table 2

Samples of sweet biscuits subjected to sensory evaluation on experiment 1. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Sample	Sample identity	Sample label
Commercial	Commercially available sweet biscuit	Three-digit code This biscuit contains: wheat flour, sugar, butter, baking powder, baking soda, and salt. Protein content: 5.3 %
No cricket	0.0 % cricket powder biscuit	Three-digit code This biscuit contains: wheat flour, butter, egg, sugar, vanilla extract, baking powder, and baking soda. Protein content: 6 %
Cricket (placebo sample)	0.0 % cricket powder biscuit	Three-digit code This biscuit contains: wheat flour, cricket powder, butter, egg, sugar, vanilla extract, baking powder, and baking soda. Protein content: 10 %

Cuadro 2. Muestras de galletas dulces sujetas a evaluación sensorial en el experimento 1. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

All the samples were coded with randomized three-digit codes and balanced before being presented to the panelists. Each panelist received a tray with three samples, a glass of water, a napkin, a pencil, and a printed

form that included instructions and three scales for evaluation of the samples. The hedonic scale used was 10 points, linear and unstructured. Panelists were instructed to evaluate overall acceptability and score the samples from left to right as presented, by drawing a vertical line on the scale. The printed form also featured a QR code which directed the panelists to the Microsoft Forms questionnaire (they were instructed to complete the questionnaire first and then evaluate the samples).

Sensory experiment 2: effect of cricket powder content on consumer acceptance

The second experiment was carried out to assess overall sensory acceptability of biscuits with varying contents of cricket powder. The following samples were presented to the panelists (n = 80): (a) commercially available sweet biscuit, (b) 12.5 % cricket powder biscuit, (c) 26.0 % cricket powder biscuit. The sample presentation and experimental conditions were similar to those described in the previous section. The only difference corresponded to the scale, which was a 9-point hedonic scale. Panelists were instructed to score the samples by marking the scale that best described their perception of the sample.

Statistical analyses

For nutritional analyses, results were expressed as mean values of triplicate measurements with the corresponding standard deviation. ANOVA followed by Tukey's HSD post hoc test were used to identify significant differences in means of three tested treatments. For the trans fatty acids content analysis, Student's t test was applied to identify differences between two treatments, since no trans fatty acids were detected in any sample of 0.0 % cricket powder biscuit. The level of statistical significance (alpha-value) was set at 0.05.

For both sensory analysis experiments, information obtained from panelists through the applied questionnaires was tabulated as percentage values for each item's category. Agglomerative Hierarchical Clustering (CAH) was used to identify potential consumer clusters or segments. Afterwards, a one-way ANOVA per cluster was performed to identify differences between the samples. The results were also compared with a one-way ANOVA using the whole data set, per experiment. Mean comparisons using Fisher's LSD post hoc test were performed when significant differences were found among samples. The level of statistical significance (alpha-value) was set at 0.05. The software XLSTAT (2023.1.6 1410) was used to perform all statistical calculations.

Results

Nutritional analyses

The main statistically significant differences (p < 0.05) between samples regarding nutritional analysis correspond to contents of crude fat and specific fatty acids. Mean protein contents increased as the cricket powder content rose in the formulation, but no statistically significant differences were found due to the high variability of the tested samples, particularly the 0.0 % and 12.5 % cricket powder biscuits (Table 3).

Table 3

Proximate and detailed fatty acid composition of three tested sweet biscuit formulations. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Component	Content (g / 100 g) *		
	0.0 % cricket powder biscuit	12.5 % cricket powder biscuit	26.0 % cricket powder biscuit
Moisture	9.1 ± 0.2 [a]	7.9 ± 0.2 [b]	6.4 ± 0.2 [c]
Protein	9 ± 4 [a]	13 ± 5 [a]	14.1 ± 0.5 [a]
Crude fat	20.6 ± 0.4 [c]	21.5 ± 0.2 [b]	23.6 ± 0.1 [a]
Ash	1.4 ± 0.1 [a]	1.5 ± 0.1 [a]	1.4 ± 0.3 [a]
Total carbohydrates	60 ± 4	56 ± 5	54.5 ± 0.5
Saturated fatty acids	13.7 ± 0.2 [b]	13.9 ± 0.1 [b]	15.13 ± 0.06 [a]
Monounsaturated fatty acids	5.9 ± 0.1 [b]	6.1 ± 0.1 [b]	6.59 ± 0.03 [a]
Polyunsaturated fatty acids	1.02 ± 0.05 [c]	1.41 ± 0.02 [b]	1.84 ± 0.03 [a]
Trans fatty acids	ND **	0.006 ± 0.001 [b]	0.076 ± 0.002 [a]

* Mean value ± standard deviation (n = 3); values with different superscript letters denote statistically significant differences between treatments according to Tukey's post hoc test. ** **ND:** Not detected (<0.010 g/100 g fat). / * Valor promedio ± desviación estándar (n = 3); valores con letras superíndices diferentes denotan diferencias estadísticamente significativas entre tratamientos de acuerdo con la prueba post hoc de Tukey. ** **ND:** No detectado (<0.010 g/100 g grasa).

Cuadro 3. Composición proximal y detallada de ácidos grasos de tres formulaciones de galletas dulces evaluadas. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Sensory analyses

A summary of the demographic information, attitudes towards insect consumption and perceived importance of protein consumption in both populations is presented in Table 4. Both populations were balanced in terms of gender distribution. Most participants were from Costa Rica and were between 19 and 30 years old. More than 90 % of respondents considered themselves to be people who like to try new foods. Over 80 % of participants mentioned protein as a priority or an important aspect of their diet. In general, a positive attitude towards insect consumption was observed in both populations.

Table 4

Percentage distribution of tested populations' demographic information and perceptions related to insect and protein consumption. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Questionnaire item		% of responses	
		Sensory experiment 1 (*n* = 81)	Sensory experiment 2 (*n* = 80)
Gender (single choice)	Female	55.56	40.00
	Male	43.21	57.50
	Prefer not to say	1.23	2.50
Age (single choice)	19-30	65.43	67.50
	31-50	25.93	21.25
	51-60	8.64	5.00
	Prefer not to say	0.00	6.25
Nationality (single choice)	Costa Rican	96.30	95.00
	Nicaraguan	2.47	0.00
	Other	1.23	5.00
General area of residence (single choice)	Urban	77.78	80.00
	Rural	22.22	20.00
Would you describe yourself as someone who likes to try new foods?	Yes	93.83	92.5
	No	6.17	7.5
Have you ever eaten insects before?	Yes	49.38	37.50
	No	50.62	62.50
Do you identify with any of the following statements?	The idea of eating food with insects disgusts me	25.93	20.99
	The idea of eating whole insects disgusts me	80.25	22.22
What is your expectation about the insect cookies you will taste?	Cookies are delicious	88.89	NC
	Cookies are not delicious	11.11	NC
How important is protein consumption for you?	A priority	43.21	41.25
	Important but not a priority	49.38	41.25
	Indifferent	7.4	17.50
Would you be keen to include insects into your diet to increase your protein consumption?	Definitely yes	37.04	NC
	I would consider it depending on the product	62.96	NC
	Definitely no	0.00	NC

n: number of panelists. **NC:** not collected. / **n:** número de panelistas. **NC:** no recolectado.

Cuadro 4. Distribución porcentual de la información demográfica y percepciones relacionadas con el consumo de insectos y proteína de las poblaciones evaluadas. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Concerning sensory experiment 1, which assessed the placebo effect on consumers' acceptance, significant differences (p = 0.002) were found among the tested samples. The overall sensory liking score of the "No cricket" sample was significantly lower than those of the "Cricket" and "Commercial" samples, which did not differ significantly from each other (Figure 1). Both the "No cricket" and "Cricket" samples were 0.0 % cricket powder biscuits. The difference in their labels corresponded to the indication that the "No cricket" sample does not contain cricket powder and has a protein content of 6 %, whereas the "Cricket" sample's label indicated that it contains cricket powder and has a protein content of 10 %. The "Cricket" sample was

considered the placebo stimulus, since it appeared to contain cricket powder but in fact had none, and its formulation was identical to that of the "No cricket" sample.

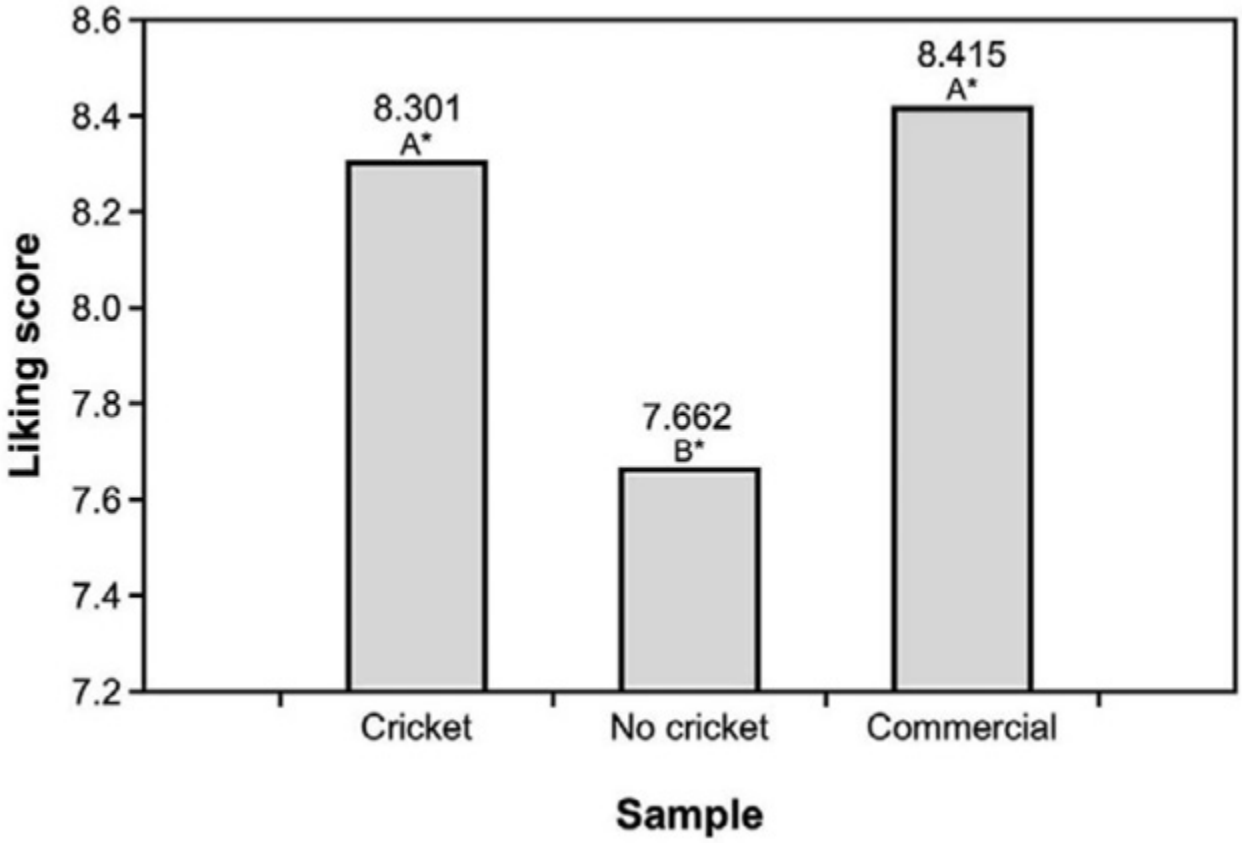

Figure 1

Mean general liking scores obtained from sensory evaluation of sweet biscuit samples on experiment 1. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

* Mean general liking scores with different superscript letters denote statistically significant differences between samples according to Fisher's LSD post hoc test.

Figura 1. Calificaciones de agrado general promedio obtenidas a partir de la evaluación sensorial de muestras de galletas dulces en el experimento 1. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

* Calificaciones de agrado general promedio con letras superíndices diferentes denotan diferencias estadísticamente significativas entre muestras de acuerdo con la prueba post hoc de Fisher.

In sensory experiment 1, five consumer segments were identified through Agglomerative Hierarchical Clustering. Cluster 5 was the largest and most influential segment overall (Figure 2). When analyzing only the data from cluster 5 (n = 60), results were indistinguishable from those obtained from the entire set of panelists (n = 81): significant differences (p = 0.044) were observed among the samples, with the "No cricket" sample scoring significantly lower in overall sensory liking compared to the others.

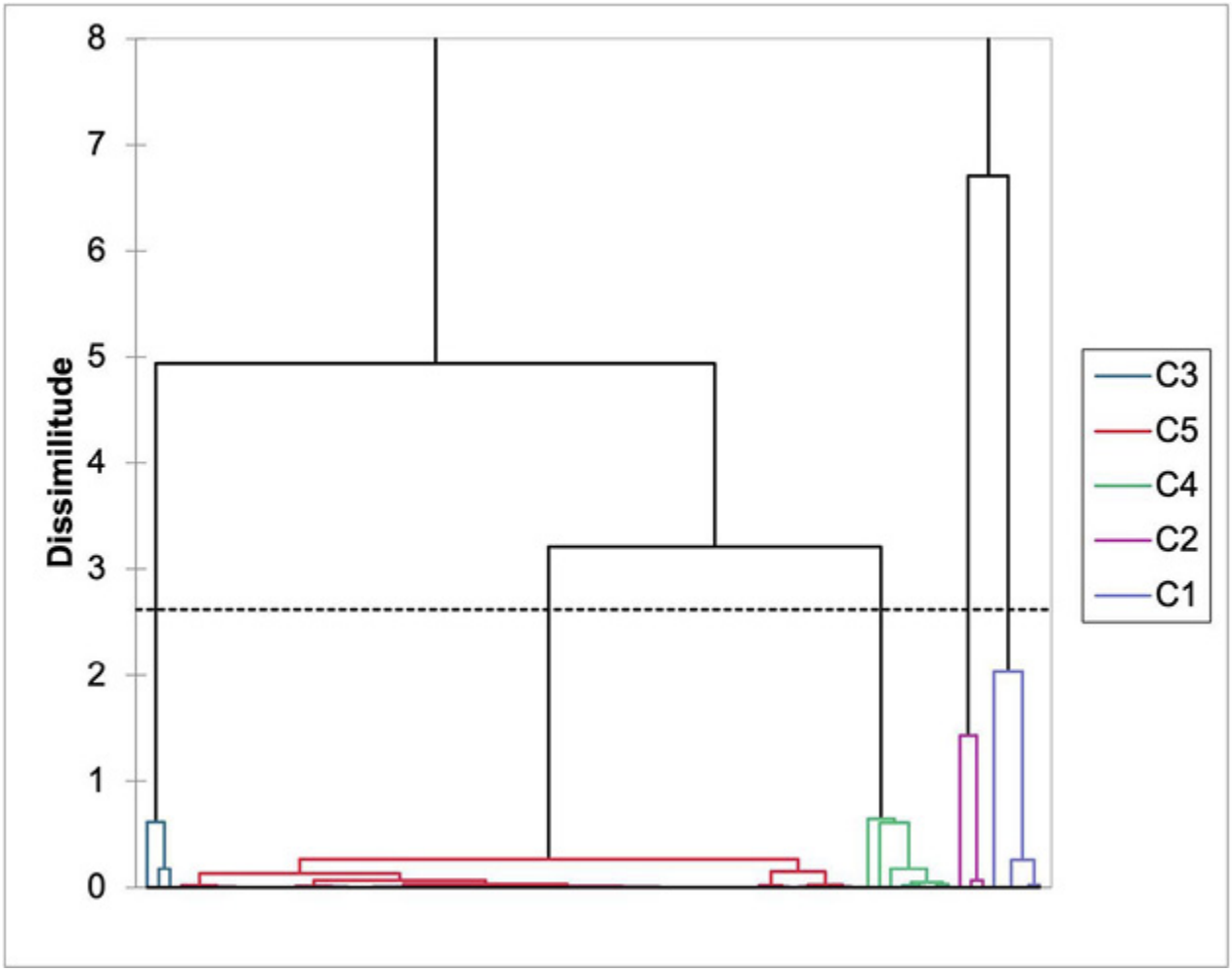

Figure 2

Consumer segments obtained from sensory evaluation of sweet biscuit samples on experiment 1: C1 (n = 5), C2 (n = 3), C3 (n = 3), C4 (n = 8), C5 (n = 60). Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Figura 2. Segmentos de consumidores obtenidos a partir de la evaluación sensorial de muestras de galletas dulces en el experimento 1: C1 (n = 5), C2 (n = 3), C3 (n = 3), C4 (n = 8), C5 (n = 60). Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

In sensory experiment 2, related to the effect of cricket powder content on consumers' acceptance, significant differences (p = 0.008) were found among the tested samples. The overall sensory liking score of the "12.5 % cricket powder" sample was significantly higher than that of the "26.0 % cricket powder" sample, and not significantly different from the "Commercial" sample (Figure 3).

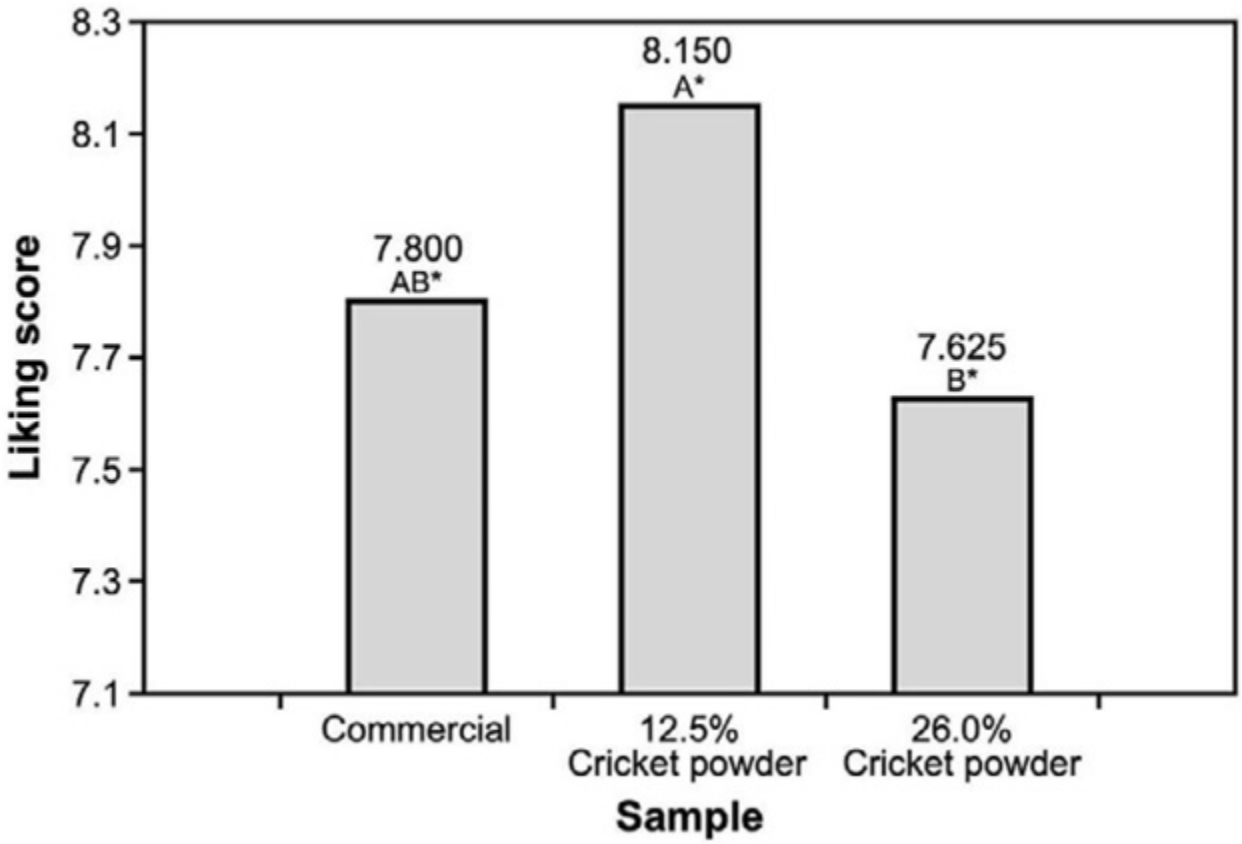

Figure 3

Mean general liking scores obtained from sensory evaluation of sweet biscuit samples on experiment 2. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

* Mean general liking scores with different superscript letters denote statistically significant differences between samples according to Fisher's LSD post hoc test.

Figura 3. Calificaciones de agrado general promedio obtenidas a partir de la evaluación sensorial de muestras de galletas dulces en el experimento 2. Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

* Calificaciones de agrado general promedio con letras superíndices diferentes denotan diferencias estadísticamente significativas entre muestras de acuerdo con la prueba post hoc de Fisher.

In sensory experiment 2, three consumer segments were identified through Agglomerative Hierarchical Clustering. Cluster 1 was the largest and most influential segment overall. The consumer segments obtained from the sensory evaluation are shown in Figure 4. Data from cluster 1 (the largest, n = 38) determined the product differentiation pattern (p = 0.020): the overall sensory liking score of the "12.5 % cricket powder" sample was significantly higher than that of the "26.0 % cricket powder" sample, and not significantly different from the "Commercial" sample.

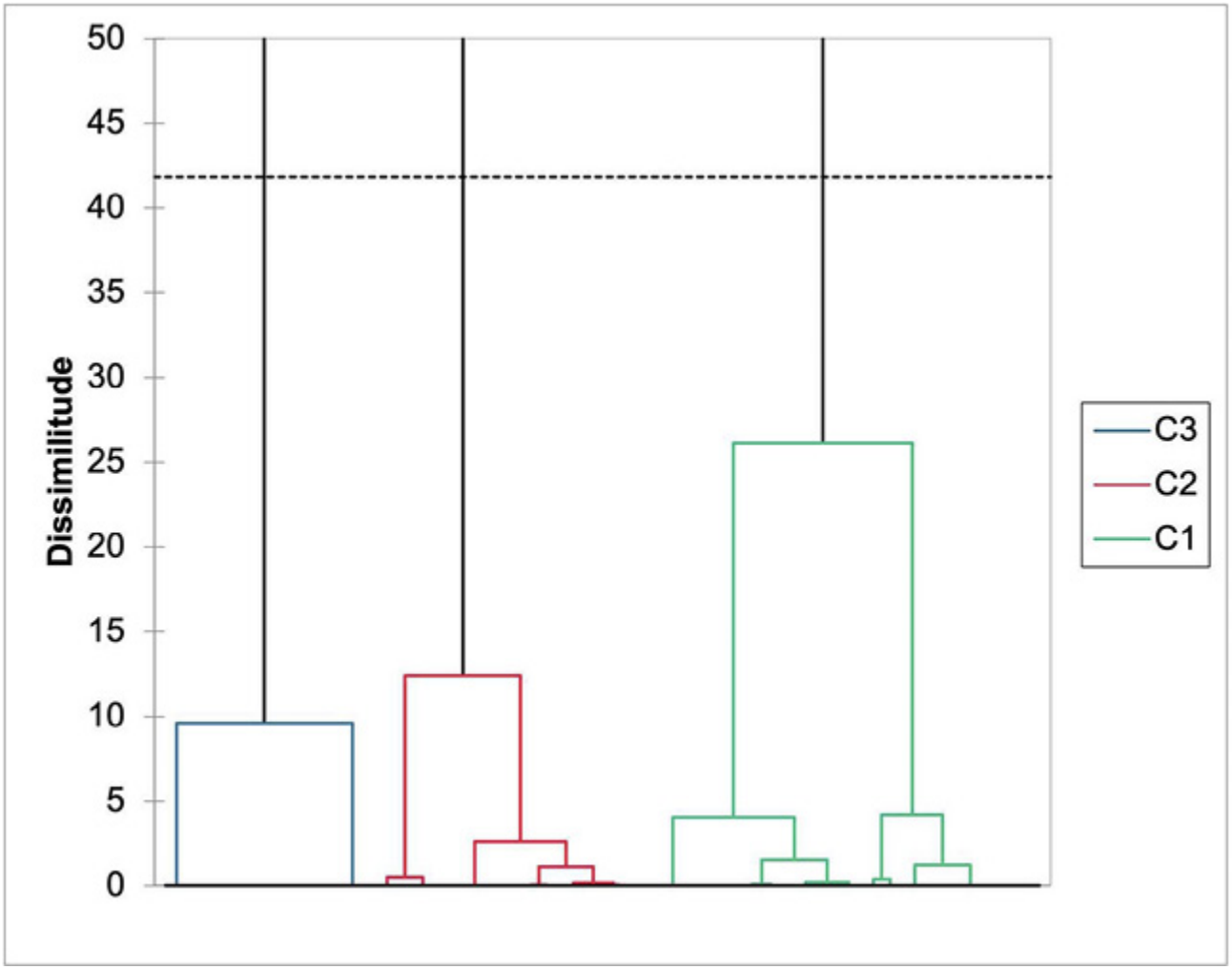

Figure 4

Consumer segments obtained from sensory evaluation of sweet biscuit samples on experiment 2: C1 (n = 38), C2 (n = 22), C3 (n = 20). Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Figura 4. Segmentos de consumidores obtenidos a partir de la evaluación sensorial de muestras de galletas dulces en el experimento 2: C1 (n = 38), C2 (n = 22), C3 (n = 20). Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Universidad de Costa Rica (UCR), San José, Costa Rica. 2023.

Discussion

Demographic information and perceptions related to insect and protein consumption for both tested populations suggest they are an ideal target for introducing insects as food. There seems to be an optimistic view of new foods and previous experience related to insect consumption (Hopkins et al., 2023; La Barbera et al., 2018; Ruby et al., 2015; Tan et al., 2015). It is important to clarify that in this study no information was collected describing whether these past experiences were positive or negative, which could help understand how experiences influence participants' behavior in the present (Deroy et al., 2015).

The main difference between populations is that 80.25 % of population 1 identifies with the statement "The idea of eating whole insects disgusts me", while only 22.22 % of population 2 does. Results in Table 4 show that only about 20 % of both populations seem to be disgusted by eating food with insects. This is a positive indicator compared to findings reported in other studies, where more than 50 % of the population rejected the idea of eating insects or foods containing insects (Jensen & Lieberoth, 2019).

Concerning sensory experiment 1, the placebo stimulus helps reveal two important aspects: 1) the sensory stimulus corresponding to what is actually perceived during the sensory test, and 2) the mental imagery related to images and conceptual constructions that can influence hedonic scores even before tasting (Fish, 2018). In this experiment, the sensory stimulus was fixed to evaluate the effect of mental imagery triggered by the apparent insect and protein content indicated on the sample's label. Overall acceptance of the "No cricket" sample was significantly lower than that of the "Cricket" and "Commercial" samples (which are not significantly different from each other), when analyzing both the whole set of panelists (n = 81) as well as data from cluster 5 (n = 60).

It can be assessed that mental images and conceptual constructions related to insect and protein content are inducing positive effects on hedonic rates. This is a surprising finding considering that 80.25 % of population 1 identifies with the statement "The idea of eating whole insects disgusts me". It is difficult to conclude at this point whether this positive effect is caused by having insects as a non-visible ingredient, the good reputation of crickets, or informing about their superior protein content.

Several authors have documented how insect presentation affects the perception of edible insects, and how processing them into powder or incorporating them into more familiar food products can help mitigate food neophobia (Van Huis & Rumpold, 2023; Castro & Chambers, 2019; La Barbera et al., 2008; Deroy et al., 2015). Authors such as Arama et al. (2023), Aleman et al. (2022), and Udomsil et al. (2019) have observed that crickets, specifically, are insects with a good level of consumer acceptability, being perceived as nutritious and sustainable. Moreover, Arama et al. (2023) demonstrated that consumers are willing to pay more for bakery products enriched with cricket powder.

Other studies have shown that highlighting the protein and nutritional content of insect products increases their acceptability and attractiveness (Amoah et al., 2023; Aleman et al., 2022; Van Huis & Oonincx, 2017). Based on the results of this study, it is possible to say that communicating these aspects together, in comparison with a product such as the commercial control, produces positive effects on liking scores (Delwiche, 2023). This indicates that the perceived value of insect products can be shaped by presenting them to consumers in the right way and emphasizing their benefits, even before the product is tasted.

Even though mental imagery is important for acceptance, the factual sensory experience remains determinant. By confirming or disconfirming expectations toward the insect product, acceptability scores can be modified, and product perception can be affected. Jensen & Lieberoth (2019) demonstrated the impact of taste experiences on willingness to eat insects, showing that negative first impressions significantly reduce acceptance. Insect products must therefore be carefully formulated by controlling and optimizing all sensory aspects that drive acceptability. Considering this, the study aimed to determine the acceptable concentrations of cricket powder for this specific product and consumer population.

Regarding sensory experiment 2, significantly higher scores for the "12.5 % cricket powder" sample compared to the "26.0 % cricket powder" sample, and non-significant differences compared to the "Commercial" sample, indicate that any biscuit with cricket powder below 12.5 % will be as acceptable as the "Commercial". This result aligns with other studies, where contents of 10 % cricket powder were well accepted in milk biscuits (Homann et al., 2017). It can also be observed that consumers start lowering their hedonic scores when cricket powder contents range between 12.5 % and 26.0 %.

Hedonic experience is generally unconscious. Hedonic experience is generally unconscious. According to Gestalt theories, people perceive food as a whole rather than as the sum of individual attributes, which makes it difficult to identify the specific reasons behind their liking or disliking of a product. Despite this, some general patterns of food preference are evident. For example, the "mere exposure effect" stimulates higher hedonic scores (Zajonc, 2001).

Populations such as the Costa Rican population, with no tradition and low levels of insect consumption (Table 4), could initially show limited acceptance of higher concentrations of insects in food; however, this acceptance is likely to improve with increased exposure. To better understand the factors influencing the

decline in liking as cricket powder concentration increases, additional qualitative research is required. Methods such as focus groups or in-depth interviews are appropriate for collecting this type of information, as qualitative approaches are particularly effective for exploring the reasons behind behaviors, identifying unexpected issues, and understanding the context in which decisions and actions occur; while quantitative data can indicate what happens and how frequently, qualitative inquiry provides insights into why these patterns occur (Patton, 2015).

Further research is required to determine the precise cricket powder content at which consumer acceptance begins to decline. Although the 26.0 % cricket powder sweet biscuit scored significantly lower than the 12.5 % cricket powder sweet biscuit, no difference was observed compared to the "Commercial" sample. This suggests that the 26.0 % sample could be accepted by the market regardless its lower hedonic score relative to the 12.5 % sample. It is advisable to repeat this experiment using this concentration with additional market control samples, while also comparing results with the 0.0 % cricket powder biscuit.

The importance of enriching products with edible insects to improve their nutritional composition has been previously reported (Amoah et al., 2023). Results presented in Table 3 do not show relevant significant differences among the tested samples. Statistically significant differences were observed in moisture content; however, these variations are not of practical relevance, as all values remained below the critical moisture threshold of 10 % for crispy cereal-based foods (Guillard et al., 2004). An increase in protein content with higher cricket powder incorporation was expected, but no statistically significant differences were detected, likely due to the high variability of the tested samples.

The non-significant decrease in total carbohydrate content as cricket powder increased in the formulation may be related to variations in protein and crude fat contents. This result is consistent with the fact that cricket powder is mainly composed of protein and fat (Ververis et al., 2022), and carbohydrate content is calculated by difference from other macronutrients. The main statistical and practical differences between samples were observed in crude fat and specific fatty acids. As expected, crude fat and fatty acids contents increased significantly with higher cricket powder levels. Variations in fatty acids composition can affect the nutritional profile, sensory characteristics, and shelf life of bakery products (Gutiérrez-Luna et al., 2022).

Conclusions

The evaluation of the nutritional profiles of the developed products revealed the expected results, mainly differences in crude fat and specific fatty acids contents, since fat and protein are the main components of cricket powder. Significant differences between the tested formulations indicated opportunities for developing nutrient-enriched products, such as protein-rich foods. The use of cricket powder in processed foods can promote the development of the entire value chain, which includes the primary production of insects for human consumption.

There is an apparent high consumer acceptance of sweet biscuits with cricket powder in Costa Rica, as the perception of insect powder content increased overall acceptance, and samples with 12.5 % cricket powder scored similarly to commercially available products. In general, consumers perception denotes an optimistic view of novel foods and previous experience related to insect consumption. The presence of segments in the evaluated population highlights the need for further studies on product optimization and in-depth sensory and consumer science analyses.

An optimistic scenario exists for introducing biscuits with cricket powder to the Costa Rican market, considering a young target population that may be open to trying new foods and possibly values higher protein content. Future research should focus on understanding why the population does not accept higher concentrations of cricket powder, as well as experimentation to evaluate the "mere exposure effect".

Interests conflict

The authors declare that there is no conflict of interest related to this study.

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Notes

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Influence of cricket powder content and placebo effect on consumers' acceptance of sweet biscuits*
Influencia del contenido de polvo de grillo y efecto placebo en la aceptación de galletas dulces por parte de los consumidores

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