Current Research in Food Science 12 (2026) 101288

Contents lists available at ScienceDirect

Current Research in Food Science

journal homepage: www.sciencedirect.com/journal/current-research-in-food-science

Neuroscience meets food choice: Implicit and explicit consumer responses to plant-based vs animal-based foods

Bianca Maria Serena Inguscio [a,b,*], Giulia Carcaterra [a], Patrizia Cherubino [b], Dario Rossi [a,b], Gaia Madini [a], Luca Fraccascia [c], Fabio Babiloni [d,e,b], Giulia Cartocci [f,b]

[a] Department of Molecular Medicine, Sapienza University of Rome, Viale Regina Elena 291, Rome, 00161, Italy
[b] BrainSigns Ltd, Via Tirso 14, Rome, 00198, Italy
[c] Department of Computer, Control, and Management Engineering "Antonio Ruberti", Sapienza University of Rome, Via Ariosto 25, Rome, 00185, Italy
[d] Department of Physiology and Pharmacology, "Vittorio Erspamer", University of Rome Sapienza, Piazzale Aldo Moro, 5, Rome, 00185, Italy
[e] College of Computer Science, Hangzhou Dianzi University, Hangzhou, 310018, China
[f] UniCamillus – Saint Camillus International University of Health Sciences, Via di Sant'Alessandro, 8, Rome, 00131, Italy

ARTICLE INFO

Keywords:
Plant-based alternatives
Animal-based foods
Electroencephalography
Sensory evaluation
Sustainability
Consumer neuroscience
Neophobia
Implicit and explicit responses

ABSTRACT

Understanding consumer acceptance of plant-based (PB) alternatives is essential for fostering sustainable dietary transitions. This study combined electroencephalography (EEG) and self-reported measures to examine implicit and explicit responses to PB alternatives versus animal-based (AB) traditional foods — belonging to meat, fish, and dairy food types—across visual, olfactory, and gustatory experimental phases. Thirty-six participants evaluated matched PB and AB foods while EEG indices of approach–withdrawal (AW) and mental workload (WL) were recorded.

Results showed AB products globally received higher ratings for taste, familiarity, and purchase intention, whereas PBs were rated as more sustainable. From a neurophysiological point of view, tasting PB foods induced higher WL, which negatively correlated with liking and purchase intention, suggesting that greater cognitive effort reduced explicit acceptance. Conversely, AW positively correlated with tastiness, and purchase intention for PB alternatives and was also higher for AB products during the visual-olfactory presentation phase, reflecting greater familiarity.

Psychographic traits modulated responses: a lifestyle of health and sustainability (LOHAS scores) was associated with more favorable PB ratings, although without corresponding EEG indices, while food neophobia was linked to increased WL and reduced AW across both PB and AB products, indicating lower cognitive engagement despite unchanged self-reports.

By combining neuroscience and behavioral measures, this multi-method approach offers novel insights into consumers' perceptions of plant-based foods. Findings emphasize the dual roles of cognitive effort and approach motivation in food evaluations and highlight practical implications for developing and marketing plant-based products aligned with consumer expectations.

1. Introduction

In recent decades, environmental sustainability has become an urgent global priority, driven by the intensifying ecological consequences of agri-food systems (IPCC, 2022; Hong et al., 2025). Food production contributes significantly to greenhouse gas (GHG) emissions, with livestock-based foods (meat and dairy) production accounting for about 57–60 % of food system emissions worldwide (FAO, 2024; Xu et al., 2021).

More broadly, animal-source foods are responsible for the majority of negative impacts on land and water use, biodiversity, and GHG emissions in global food systems (Kozicka et al., 2023). Climate change linked to GHG emissions represents one of the most significant challenges of our time, with numerous risks to natural and human systems

* Corresponding author. Department of Molecular Medicine, Sapienza University of Rome, Viale Regina Elena 291, 00161, Rome, Italy.
E-mail addresses: biancams.inguscio@uniroma1.it (B.M.S. Inguscio), carcaterra.1837339@studenti.uniroma1.it (G. Carcaterra), patrizia.cherubino@brainsigns.com (P. Cherubino), dario.rossi@uniroma1.it (D. Rossi), madini.2049713@studenti.uniroma1.it (G. Madini), luca.fraccascia@uniroma1.it (L. Fraccascia), fabio.babiloni@unirolm1.it (F. Babiloni), giulia.cartocci@unicamillus.org (G. Cartocci).

https://doi.org/10.1016/j.crfs.2025.101288
Received 18 October 2025; Received in revised form 22 December 2025; Accepted 24 December 2025
Available online 30 December 2025

expected to intensify after 2040 (IPCC, 2022).

Among agri-foods sector, the animal-based foods supply chain is widely recognized as one of the leading contributors to anthropogenic GHG, as well as a major driver of deforestation and excessive freshwater use (Crippa et al., 2021; FAO, 2022). Recent studies estimate that the global agri-food system accounts ~34 % of total GHSs, with livestock production alone contributing ~57 % of the food sector's emissions (Crippa et al., 2021; Adelodun et al., 2025 for a review).

In light of this evidence, the scientific community increasingly advocates for a transition toward more sustainable dietary patterns—such as plant-based or flexitarian diets—as one of the most effective strategies to reduce the environmental footprint of the food sector (Clark et al., 2022; Willett et al., 2019; Tirion et al., 2025). Within this context, plant-based (PB) meat alternatives – products designed to mimic meat in terms of texture, taste, aroma, appearance, and chemical properties (Majcher, 2025) – have gained growing attention. These products show the potential to reduce GHGs by up to 90 %, land use by 89 %, and water consumption by 95 %, compared to their animal-based counterparts (Poore and Nemecek, 2018; Heller and Keoleian, 2018).

Beyond environmental benefits, plant-based diets are also associated with direct human health advantages (Rockström et al., 2025). High consumption of red and processed meat has been linked to an increased risk of non-communicable diseases, including type 2 diabetes, colorectal cancer, and reduced life expectancy (González et al., 2020; Harguess et al., 2020; Duan et al., 2025). Despite these well-documented benefits, however, significant barriers continue to hinder dietary transitions, particularly among non-vegetarian consumers. Obstacles include issues of availability, accessibility, and cultural, religious, social, economic, and legal constraints, that critically shape food choices (Abe-Inge et al., 2024). In fact, even when plant-based meat alternatives achieve sensory attributes and pricing comparable to conventional meat, many consumers still express a marked preference for animal-based options (Slade, 2018; Michel et al., 2021a,b). Specifically, using a theoretical consumer choice model, Slade (2018) found that even when price and taste were held constant, 65 % of consumers still preferred traditional meat, while only 21 % opted for a plant-based alternative. These findings suggest that food choices are not always driven by rational but often by automatic processes, habitual behaviors, and deeply embedded cognitive mechanisms. Furthermore, these findings highlight a critical paradox in sustainable consumption: although plant-based alternatives are often explicitly endorsed for their environmental and ethical benefits, they are frequently rejected in a real choice context. This discrepancy reflects the well-documented divergence between *explicit* attitudes and *implicit* evaluative processes in consumer decision making (Plassmann et al., 2015; Panteli et al., 2024). Indeed, human choices are often governed by automatic, affective, and habitual processes rather than fully rational deliberation (Kahneman, 2011). Furthermore, according to dual-process models of cognition, human judgments and decisions are governed by two interacting system: a fast, automatic, and implicit processing system (System 1), and slower, reflective and controlled processing system (System 2), which supports deliberate evaluation and value-based reasoning (Evans and Stanovich, 2013).

This implicit-explicit divergence is particularly relevant in the context of novel or controversial foods, such as PB alternatives, where sustainability motivations coexist with sensory skepticism and cultural resistance.

Recent research has shown that consumer acceptance of alternative proteins is influenced not only by rational evaluations of healthiness and sustainability, but also by psychological and contextual factors that shape perceived familiarity and comfort. For example, the work of Abdul Kareem and colleagues (Abdul Kareem et al., 2025) highlight that affective reactions, neophobia, perception of naturalness, and expectations regarding sensory quality are among the strongest predictors of acceptance, often outweighing objective nutritional or environmental considerations. Extending this perspective, recent work demonstrates that favorable stated attitudes may mask underlying psychological barriers that emerge during experiential or sensory evaluation, reinforcing the need to examine conscious and implicit responses (Yuan et al., 2025; Wang et al., 2026).

Specifically, Yuan et al. (2025) demonstrated that psychological distance and perceptions of "eeriness" significantly contribute to consumer reluctance toward alternative proteins, and that reducing this distance through transparency mechanisms, such as blockchain, can mitigate negative attitudes. Similarly, Wang et al. (2018) found that acceptance of unconventional food sources, such as insect-based products, varies as a function of social framing, highlighting the role of perceived credibility and perceived healthiness in shaping consumer responses. Together, these findings suggest that explicit endorsement of sustainable food innovations may coexist with underlying forms of hesitation or discomfort driven by perceptions of novelty, unfamiliarity, and symbolic incongruence. This tension—consistently documented in recent research on alternative proteins (Stubelj et al., 2025; Onwezen et al., 2025 Nguyen et al., 2022 for reviews) highlights the importance of investigating both conscious evaluations and deeper evaluative processes in the study of plant-based food acceptance.

Globally, consumer food choices are influenced by a wide range of variables, some of which are captured within consumer decision-making frameworks such as the Engel-Blackwell-Miniard model, (Blackwell et al., 2006) which describes how internal cognitive and affective processes interact with external influences to shape food choices. Moreover, as Casiraghi and colleagues (2025) observe, the eating experience is a complex and multisensory process shaped by social, cognitive, emotional, and physiological factors. Taken together, this body of evidence highlights the importance — and even the urgency — of incorporating implicit (automatic) mental measures into analyses of the psychological and behavioral mechanisms shaping consumer acceptance of plant-based alternative products.

Within this context, consumer neuroscience (Song et al., 2025) offers a valuable contribution. This emerging field investigates consumers' cognitive and emotional responses beyond conscious awareness, using neurophysiological methods such as electroencephalography (EEG) (Plassmann et al., 2015; Harris et al., 2020). While EEG has been applied extensively in advertising and branding research (Alsharif and Isa, 2025 for a review), its application within food-related contexts remains limited, particularly concerning plant-based alternatives (Casiraghi et al., 2025) despite the fact that it can provide useful and detailed data to support the understanding of consumer responses to food (Songsamoe et al., 2019), and even more so in studies on PBMAs. Indeed, EEG enables the detection of implicit brain responses—such as affective reactions, attention, motivational tendencies, and rejection—that are not accessible through self-report measures, making it a particularly suitable tool for investigating consumers' acceptance of PBMAs (Casiraghi et al., 2025).

Moreover, recent studies show that EEG can neurally discriminate between different taste modalities (e.g., sweet, bitter) and assess the hedonic valence of food in real time, which is highly valuable for evaluating reactions to plant-based formulations (Yang et al., 2023).

Furthermore, a recent systematic review of EEG-based neuromarketing highlights that EEG offers superior temporal resolution, greater objectivity, and more robust predictive power for consumer preferences and purchase intentions compared with traditional self-report methods (Khondakar et al., 2024).

Among EEG-derived metrics, frontal alpha asymmetry—also termed the approach-withdrawal (AW) index—has become a well-established marker of motivational orientation toward stimuli (Davidson, 1992; Harmon-Jones et al., 2010). It reflects a preconscious tendency toward approach or avoidance and has been linked to food pleasantness and purchase intention (Di Flumeri et al., 2017; Modica et al., 2018).

By contrast, EEG-based measures of mental workload (WL), indexing cognitive effort and information processing demands, remain largely underexplored in food neuroscience. WL has primarily been employed in ergonomics and cognitive load research (Borghini et al., 2012) with scarce applications to food evaluation and almost no systematic investigation in PBMA studies (e.g., Stuldreher et al., 2022; Martinez-Levy et al., 2019). This represents a *critical gap*, as workload may significantly influence consumers' tolerance toward novel food by imposing cognitive strain that undermines sensory enjoyment and acceptance (see for example van Meer et al., 2023). Furthermore, psychographic traits, as previously noted, contribute to shaping these implicit and explicit responsesFood neophobia—the reluctance to try unfamiliar foods (Ozturk and Dikmen, 2023) —has been shown to negatively affect willingness to adopt novel protein sources, including insect-based and, to a lesser extent, plant-based alternatives (Sogari et al., 2019; Bryant et al., 2019). It is often rooted in evolutionary protective mechanisms and is triggered by novel ingredients, unorthodox preparation methods, or atypical appearance (Barrena and Sánchez, 2013). Individuals with high levels of food neophobia tend to favor conventional, highly processed, and familiar products, placing greater importance on safety-related cues such as product standardization and visual flawlessness (Welk et al., 2025). Therefore, food neophobia is likely to negatively influence consumers' willingness to adopt innovative food products. Conversely, value-driven orientations such as Lifestyles of Health and Sustainability scale – LOHAS (Choi and Johnson, 2021) are associated with greater openness to alternative proteins (Graça et al., 2019; Hoek et al., 2011). LOHAS individuals are indeed characterized by cognitively grounded ecological and rational values, which guide their consumption choices toward sustainability, ethical production, and long-term environmental responsibility (Pícha, et al., 2019) Therefore, from a theoretical perspective, food neophobia aligns with automatic avoidance process (System 1), whereas LOAHS reflects more deliberate, reflective motivation (System 2), highlighting their relevance within dual-process and motivational system frameworks. Furthermore, recent studies reiterate that the psychological drive to explore new products and experiences is the main catalyst for the adoption of eco-friendly products (Zhao et al., 2025). Despite this, little is known about how such psychographic traits shape implicit neural responses and whether they align with or diverge from explicit attitudes in the evaluations of PB products.

Therefore, the present study aims to address these gaps by integrating EEG recordings with self-report measures to systematically examine implicit and explicit responses to plant-based versus animal-based foods across three experiential phases: packaging observation, combined visual-olfactory presentation, and tasting. Specifically, the research pursued three objectives: (1) to compare explicit and neural responses to PB and traditional foods; (2) to examine the relationship between self-reported evaluations and EEG-derived indices, such as AW and mental workload (WL); and (3) to explore how individual differences in food neophobia and LOHAS orientation shape both explicit and implicit responses.

By explicitly addressing the implicit–explicit gap highlighted in recent alternative-protein research combining behavioral and neurophysiological data, the present study aims to advance current knowledge on implicit food evaluation. In doing so, it contributes to ongoing debates on the psychological barriers hindering the adoption of sustainable diets, while also providing a more robust foundation for product development, positioning, and communication strategies within the food sector.

2. Materials and methods

2.1. Participants

Thirty-six healthy volunteers (Mean age = 23.9, St. Dev. = 2.3 years; 66.7 % female, 30.6 % male, and 2.8 % non-binary) took part in the study. Most were university students (75 %), among the remainder employed (16.6 %), unemployed (5.6 %), or combining work and study (2.8 %). All participants were Italian nationals, reported normal or corrected-to-normal vision, and intact olfactory and gustatory function. Exclusion criteria included vegetarian or vegan diets (due to tasting of animal-based foods), self-report food allergies or intolerance, and recent intake of caffeine, alcohol, nicotine, or other stimulants within 4 h of testing, as these can alter EEG spectral activity and sensory perception, particularly in young adults (Foxe et al., 2012; Mento et al., 2020). All participants provided written informed consent prior to taking part in the study. The study protocol was approved by the local ethics committee and complied with the Declaration of Helsinki (1975, revised 2013).

2.2. Food stimuli

Six commercially available food products were selected and grouped into three categories: Meat, Fish, and Dairy. Each category included one animal-based (AB) traditional product and one plant-based (PB) alternative, yielding three matched pairs for comparison. Selection criteria emphasized visual and packaging similarity, in order to reduce the potential influence of the different saliency between pairs of products, instead of the characteristics of them, and to enhance the ecological validity and reduce confounding factors (Köster, 2009; Fernqvist et al., 2024). All products were sourced from major retailers and represented widely available items. All products were stored under manufacturer-recommended conditions and served at room temperature before testing.

During the packaging phase (see *2.3* for protocol details), products were shown in their original commercial form. For presentation and tasting phases, standardized portions were served on neutral white plates to minimize brand or presentation -driven bias (Lawless and Heymann, 2010). On each day of testing, food samples were prepared in advance, covered, and stored in a refrigerator (~4 °C) until needed. They were removed from the refrigerator and served to participants within 25 min (Jaeger et al., 2025). The selected pairs are shown in Fig. 1).

2.3. Experimental design and protocol

The experiment followed a within-subject design and was structured into two sessions. During the "*neuro-taste session*", each participant was exposed to each of the six food products included in the study (three AB, three PB). The order of food categories (Meat, Fish, Dairy) and the starting condition (AB vs. PB) were pseudo-randomized among participants, with the aim of mitigating eventual order effects, while matched pairs (e.g., PB meat vs. AB meat) were always presented consecutively to allow controlled comparisons. Each product was evaluated through a structured four-phase sequence, details below, established based on the literature on sensory evaluation of food (Lawless and Heymann, 2010), and follows the natural order of food consumption, from initial observation to tasting and cleansing the palate.

Phase 1: *Packaging observation* (10 s): participants viewed the packaged product, then rated: aesthetic appeal, expected taste, familiarity, healthiness, sustainability, and purchase intention on 0–100 Visual Analogue Scale (VAS).

Phase 2: *Presentation* (visual olfactory experience) (10 s): the unwrapped product was observed and smelled, followed by the same VAS ratings described in Phase1. This phase provided full access to visual and olfactory cues prior to tasting.

Phase 3: *Tasting* (≥10 s): participants tasted the product and completed the VAS again, adapted for gustatory evaluation. As visual and olfactory information had already been provided in phase 2, this phase constituted a full multisensory tasting experience in line with published literature (Auvray and Spence, 2008; Prescott, 2015; Spence et al., 2015).

Phase 4: *Palate cleansing*: unsalted crackers and still water were consumed between samples to minimize carryover effects.

Fig. 1. Food stimuli used in the experiment. Left: Commercial food products used in the experiment, categorized by product type (Meat, Fish, Dairy) and source (Plant-Based-PB vs Animal-Based-AB). Meat PB: Valsoia Plant-Based Bresaola - Meat AB: Beretta Bresaola, Fish PB: Insuperabile Plant-Based Tuna Trancetti - Fish AB: Rio Mare Tuna in Olive Oil, Dairy PB: Vegetal Grattaveg Cheese Alternative - Dairy AB: Parmigiano Reggiano DOP. Right: Food products as proposed during the experimental protocol (in packaging and plated).

After the *neuro-tasting session*, participants completed a demographic module and validated psychometric questionnaires assessing food neophobia (Pliner and Hobden, 1992) and sustainability-oriented values (LOHAS; Choi and Johnson, 2021) (*tests session*). The experimental protocol is summarized in Fig. 2.

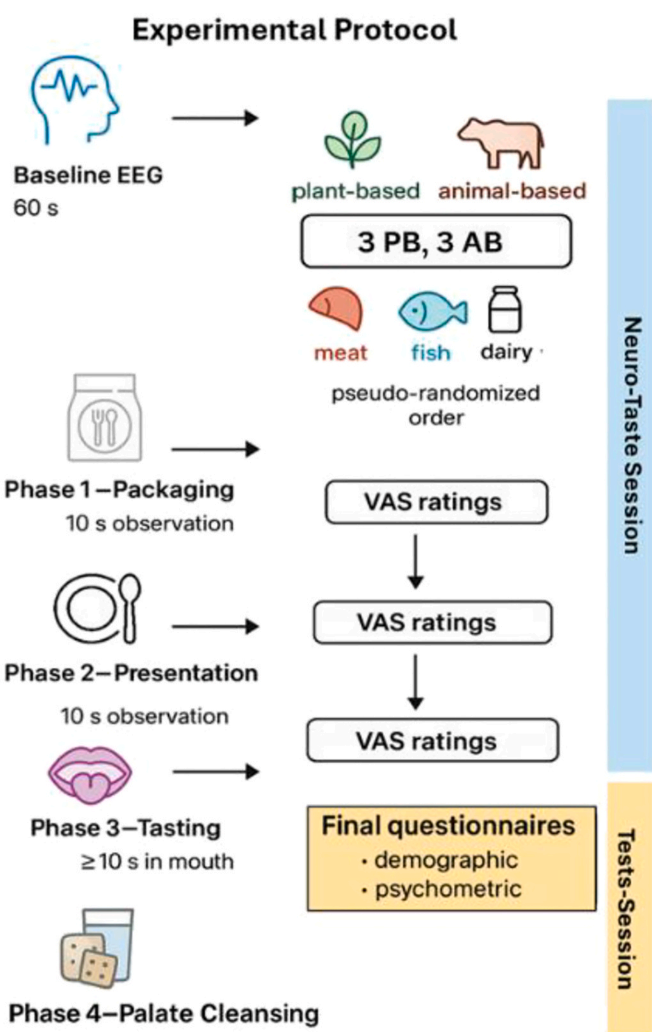

Fig. 2. Graphical representation of the experimental protocol employed.

2.4. Experimental measures

2.4.1. Psychometric questionnaires

To capture individual differences in food-related attitudes, two validated instruments were administered at the end of the experiment: the Food Neophobia Scale (FNS; Pliner and Hobden, 1992), and the LOHAS scale (Hsu, 2020; Choi and Johnson, 2021). The FNS measures reluctance to try novel foods, a trait linked to negative taste expectations (Sogari et al., 2019) and perceived risks of contamination (Martins and Pliner, 2006); LOHAS scale measures sustainability-oriented values capturing health- and environment-driven consumption patterns.

2.4.2. EEG acquisition and signal processing

Electroencephalographic (EEG) data were continuously recorded throughout the Mindtooth Touch EEG headset (https://www.mindtooth-eeg.com/) (accessed on october 2025), which has already been used for the assessment of psychophysiological variables in cognitive neuroscience protocols (Sciaraffa et al., 2022; Inguscio et al., 2024). The system has 8 electrodes, placed, according to the 10–10 system (Oostenveld and Praamstra, 2001) in frontal (AFz, AF3, AF4, AF7, AF8) and parietal (Pz, P3, P4) cortices plus ground (left mastoid) and reference (right mastoid) all recorded at a sampling frequency of 250Hz through the use of the proprietary software. The acquired EEG signal was then processed off-line. We used a fifth-order Butterworth band-pass filter (2–30Hz interval) to remove all the non-relevant frequencies and all the segments of interest for the investigation have been identified to prepare the data to the subsequent analysis. Next, the artifact removal involved two steps: in the first one, ocular artifacts were detected by employing the O-clean method that uses Multichannel Wiener Filters (MWF) to correct contaminated EEG data, that allows to retain more physiological data in settings where a limited number of EEG channels is used (Ronca et al., 2024); in the second step to remove other sources of artifacts, we split the data into 1 s epochs and with a threshold method we labeled as artifact contaminated all the epochs where EEG exceeded the value of $\pm 80\ \mu V$ and discarded from the analysis (Hubbard et al., 2019). Finally, the Global Field Power (GFP) was calculated from the artifact-free EEG with a focus on the frequency band of interest for the aim of this study, Alpha and Theta over the frontal area of interest (AOI), channels AFz, AF3, AF4, AF7, and AF8 and the parietal AOI (channels Pz, P3, P4). These bands were defined accordingly with the Individual Alpha Frequency (IAF) value. Specifically, the IAF corresponds to the peak in the alpha band (typical IAF value is 10 Hz) obtained from the power spectrum of individual EEG signals over parietal sites during a rest condition (Klimesch, 1999), so we estimated it specifically from each subject through 1 min of eyes closed, which was recorded before starting the experiment. Therefore, frequency bands were determined individually for each participant by using the IAF as the cutoff point between the lower and upper alpha band: alpha (IAF − 2 ÷ IAF + 2), and theta (IAF - 6 ÷ IAF - 2). The GFP was chosen because it describes brain EEG activity with the advantage of representing, in the time domain, the degree of synchronization of a specific cortical region of interest in a specific frequency band (Di Flumeri et al., 2023).

Moreover, prior to the beginning of the experimental session, a 1 min with open eyes recording has been acquired with participants looking at the desk in front of them, where the experimental session will later take part, in order to obtain a reference baseline period used to normalize data across participants.

2.4.3. EEG indices

From the GFP data, two neurometric indices were computed.

The first index–AW–reflects hemispheric asymmetry in frontal alpha activity, calculated as:

$$AW = \log(GFP\alpha_{\text{right}}) - \log(GFP\alpha_{\text{left}})$$

Positive values indicate stronger left frontal (AF3 and AF7 electrodes) activation or approach-related motivation, whereas negative values reflect right frontal (AF4 and AF8 electrodes) dominance or avoidance, consistent with affective neuroscience models in normal and clinical populations (Davidson, 1992; Inguscio et al., 2021; Cartocci et al., 2016).

The second index–WL–quantifies the ratio of frontal theta activity (AFz, AF3, AF4, AF7 and AF8 electrodes) to parietal alpha activity (Pz, P3 and P4 electrodes):

$$WL = \frac{GFP\theta_{\text{frontal}}}{GFP\alpha_{\text{parietal}}}$$

Higher values reflect increased cognitive effort or task demand, in line with established workload models (Gevins and Smith, 2000; Inguscio et al., 2022).

Both indices were then normalized using each participant's baseline EEG activity. A z-score transformation was applied to account for inter-individual variability and ensure comparability across tasks and participants:

$$Z = \frac{X_{\text{task}} - \mu_{\text{baseline}}}{\sigma_{\text{baseline}}}$$

where X_{task} is the GFP calculated index (AW or WL) during a given task phase, μ_{baseline} is the average GFP calculated index during the baseline, and σ_{baseline} is the corresponding standard deviation.

For clarity, the EEG-derived indices used in this study can be summarized as follows: the approach–withdrawal (AW) index reflects implicit motivational orientation toward the stimulus, with higher values indicating stronger approach-related motivation, whereas the workload (WL) index reflects cognitive effort, with higher values indicating more demanding information processing.

2.5. Statistical analysis

Inferential statistical analyses were conducted on implicit neurophysiological (approach-withdrawal, AW; mental workload, WL), psychographics (LOHAS; food neophobia), and explicit declared (liking; familiarity; tastiness; purchase intention; healthiness; sustainability) variables to assess within-subject differences between AB and PB products across the three experimental phases (*packaging; presentation*; *tasting*). All comparisons were phase-specific, meaning that each measure was analyzed only within the corresponding phase (e.g., AW during tasting was compared with liking ratings during tasting). No cross-stage comparisons were performed to maintain consistency of sensory and cognitive context. To address the main objective—identifying generalized patterns in responses to PB versus AB foods —data were aggregated by product category. Ratings for the three PB alternatives (meat, fish, dairy) were averaged to create a composite PB score, and the same procedure was applied to AB products.

Statistical tests were used to compare PB and AB scores. When the normality assumption (Shapiro-Wilk test, Shapiro and Wilk, 1965) was met, paired t-tests were applied; otherwise, Wilcoxon signed-ranked tests were used. For all comparisons, effect sizes (matched pairs rank-biserial correlations r_{rb} or Cohen's d) were reported to quantify the magnitude and practical relevance of the observed differences. No multiple-comparison correction was applied, given the exploratory nature of the study and the relatively small sample size, a choice made to avoid inflating Type II errors. Associations between implicit (EEG) and explicit (self-reported) responses were explored using correlations analyses. Pearson's correlation coefficient (r) were calculated to test linear relationships, while Spearman's coefficient rho (ρ) was included to capture non-linear associations. Finally, psychographic variables (food neophobia and LOHAS) were correlated with both EEG indices and explicit behavioral responses to examine how attitudes toward food novelty and sustainability influenced product perception. Statistical analyses were performed using the software JASP version 0.19.3.0. $\alpha = 0.05$ was the threshold value used to determine the statistical significance of the tests.

3. Results

3.1. Declarative and neurophysiological responses to plant-based vs. animal-based foods

Comparisons between plant-based (PB) alternatives and animal-based (AB) foods revealed significant differences at both declarative and neurophysiological levels.

At the declarative level, AB products were rated more positively than PB alternatives in terms of liking, tastiness, familiarity, and purchase intention across all experimental phases (all $p < 0.001$; $0.850 \leq r_{rb} \leq 1$). Conversely, PB products received higher ratings for perceived sustainability across all phases ($0.001 < p \leq 0.006$; $0.529 \leq r_{rb} \leq 0.911$) (Fig. 3). No significant differences were observed in perceived healthiness during presentation and packaging phases, while a significant effect emerged during the *tasting phase* ($p = 0.01$): AB products were perceived as healthier than PB (Fig. 4).

At the neurophysiological level, EEG-based measures revealed distinct patterns between product types. The **WL index was significantly higher during the *tasting phase*** of plant-based alternatives compared to animal-based foods (t (35) = −2.34, $p = 0.02$; $d = 0.16$), indicating increased cognitive effort during PB evaluation (Fig. 5). Regarding implicit motivational responses, the AW index was higher during the visual exposure (*presentation phase*) to animal-based foods (t (35) = 2.01, $p = 0.05$; $d = 0.18$), suggesting a stronger early approach-related activation for traditional (Fig. 6).

3.2. Correlations between neurophysiological responses and declarative product evaluations

Correlation analyses were performed between EEG indices (WL, AW) and self-report ratings across the three protocol phases.

For implicit mental workload, significant associations emerged only for plant-based products during the *presentation phase*. WL showed a negative correlation with both aesthetic liking ($r = -0.45$, $p = 0.005$) and purchase intention ($r = -0.34$, $p = 0.03$) (Fig. 7), indicating that increased cognitive effort at the initial visual stage was linked to less favorable evaluations of plant-based foods. No significant WL correlations were found for animal-based products.

AW index showed several positive associations, particularly for plant-based products. During the tasting phase, AW was positively associated with perceived tastiness ($r = 0.40$, $p = 0.01$) and purchase intention ($r = 0.41$, $p = 0.01$) (Fig. 8), suggesting that stronger left-frontal activation (approach motivation) reflected more favorable

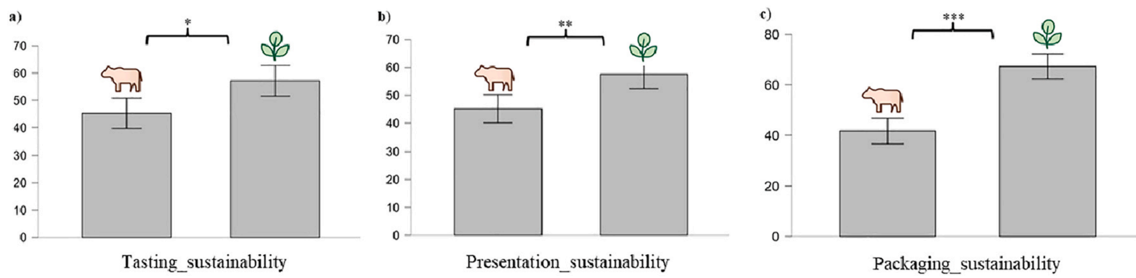

Fig. 3. Comparisons between self-reported evaluation on sustainability for animal-based vs. plant-based products across the 3 protocol phases (tasting; presentation; packaging). (*p-value ≤ 0.05; **p-value < 0.01; ***p-value < 0.001).

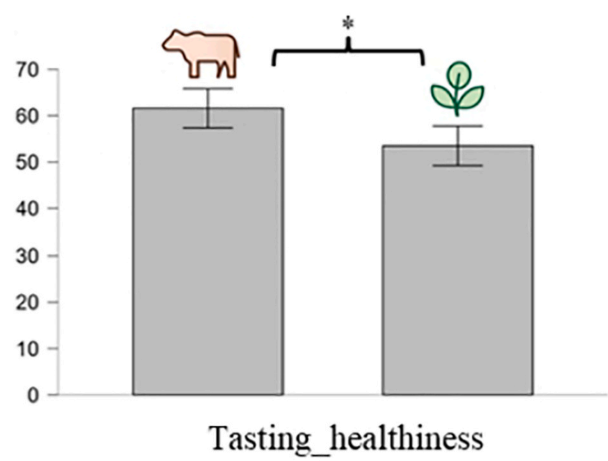

Fig. 4. Comparison of self-reported evaluations of healthiness for animal-based vs. plant-based products during the tasting phase ($p \leq 0.05$).

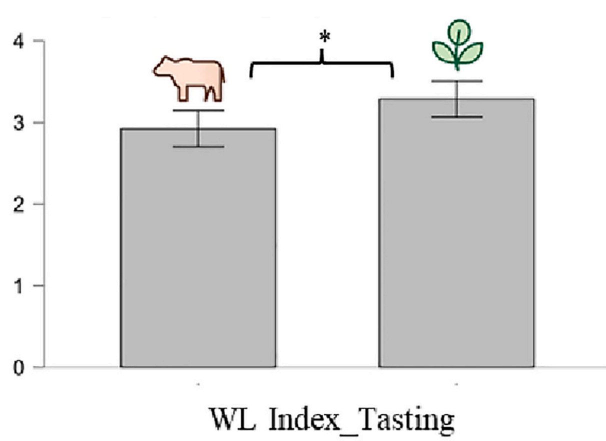

Fig. 5. Mental workload values during the tasting phase for plant-based vs. animal-based products. (*p-value ≤ 0.05).

gustatory evaluations.

For AB foods, a significant positive correlation was found only during the *packaging phase*, between AW and aesthetic liking ($r = 0.37$, $p = 0.02$), suggesting that familiar and visually attractive traditional products elicited higher approach-related neural engagement during early visual exposure (Fig. 9).

3.3. Correlations between psychographic variables and both declarative, and neurophysiological responses

The analysis of psychographic traits revealed distinct patterns of

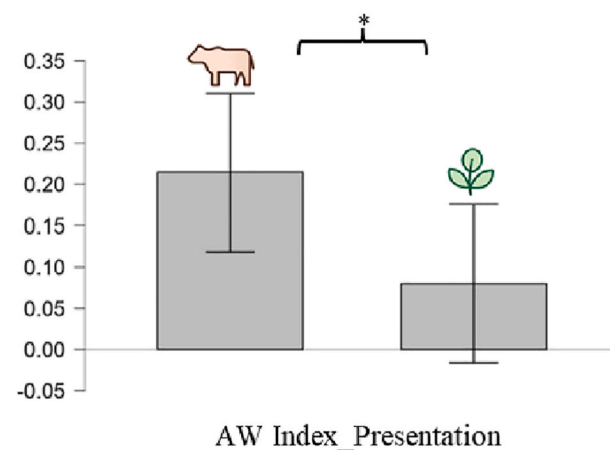

Fig. 6. Approach–Withdrawal (AW) values during the presentation phase for PB vs. AB products (*p-value ≤ 0.05).

association with both self-report evaluations and EEG-derived neurometrics.

Regarding food Neophobia, no significant correlations were observed with self-report ratings ($p > 0.05$). However, higher neophobia scores were positively correlated with increased WL during the *presentation phase*, for both AB ($r = 0.41$, $p = 0.001$), and PB alternatives ($r = 0.35$, $p = 0.03$), and during *packaging phase* for AB foods ($r = 0.424$, $p = 0.010$), (Fig. 10). In addition, food neophobia was negatively correlated with the AW index during the *tasting phase*, for both PB ($r = -0.38$, $p = 0.02$), and AB ($r = -0.35$, $p = 0.03$), products ($p < 0.05$) (Fig. 11).

In contrast, the LOHAS scores showed consistent positive associations with declarative measures, particularly for PB products. Higher LOHAS values were related to greater ratings of liking, tastiness, and purchase intention during the *packaging phase,* and with liking during the *presentation phase* and in tastiness during the *tasting phase*. For animal-based products, LOHAS scores correlated positively with taste and liking during, respectively, the *tasting* and *presentation* phases ($p < 0.05$) and during the *packaging phase* with the intention to buy (see Table 1).

Finally, no significant associations were found between LOHAS scores and EEG indices.

4. Discussion

By combining declarative and implicit neurophysiological measures, this study offers a nuanced understanding of how consumers perceive and respond to PB alternatives compared to AB traditional foods.

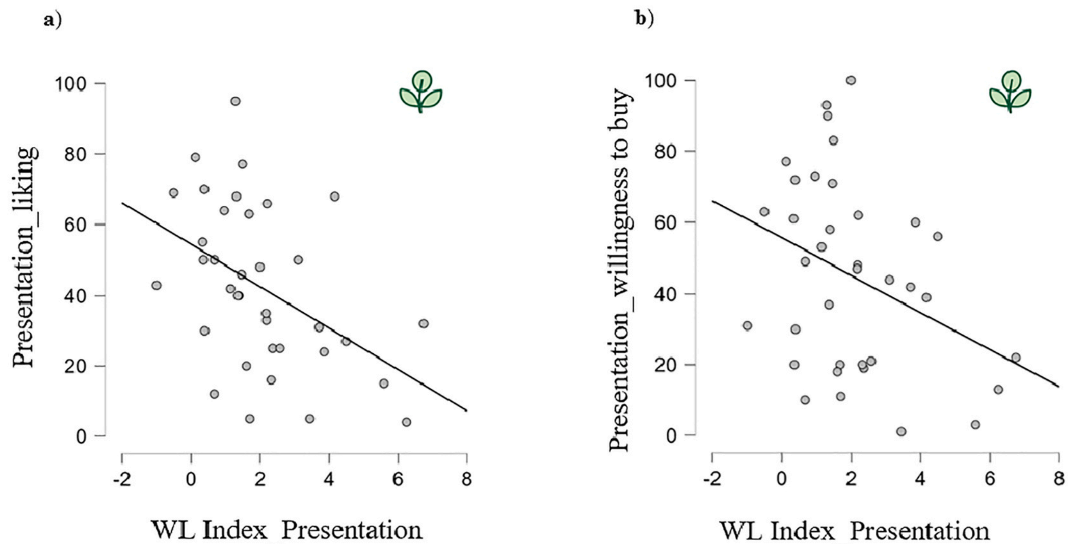

Fig. 7. Associations between Mental Workload (WL) Index during the presentation phase of plant-based products. The scatter plot shows the Pearson correlation between WL and liking (a) and willingness to buy (b) during the presentation phase of experimental protocol.

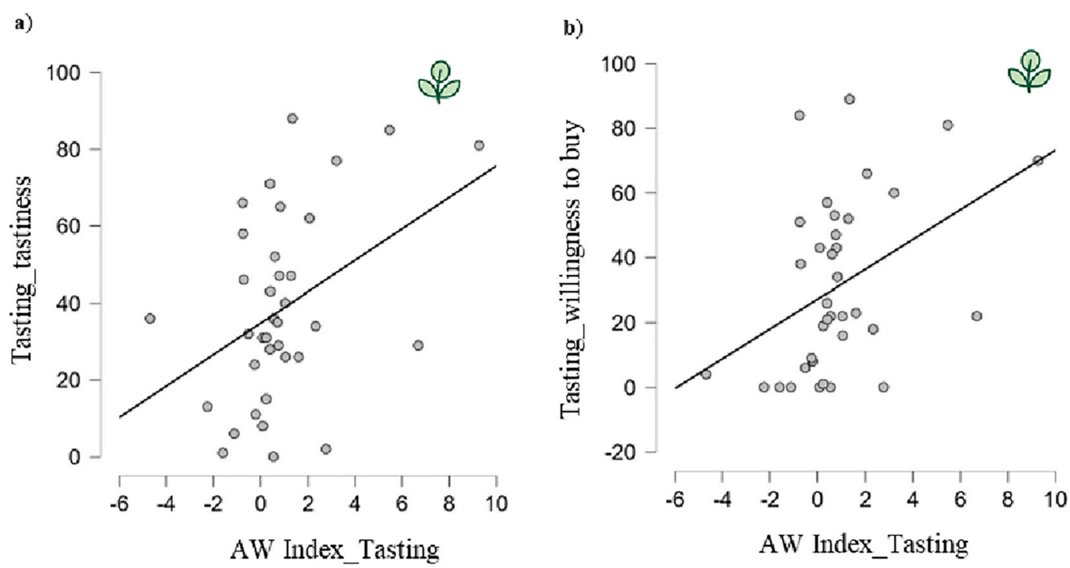

Fig. 8. Associations between the Approach-Withdrawal Index (AW) during the tasting phase of plant-based products. The scatter plot shows the Pearson correlation between AW and tastiness (a) and willingness to buy (b) during the tasting phase of the experimental protocol.

4.1. Implicit and explicit evidences

Participants consistently rated traditional AB foods higher than PB alternatives in terms of aesthetic appeal, perceived taste, familiarity, and purchase intention ($p < 0.001$), confirming prior research linkingexplicit preference to familiarity and sensory expectations (Michel et al., 2021a,b; Elzerman et al., 2011; Hoek et al., 2011; Bryant and Barnett, 2020). In contrast, PB alternatives were systematically perceived as more sustainable (Fig. 3), highlighting sustainability as a key advantage (Ares et al., 2021; Lazzarini et al., 2016).

Interestingly, no significant differences in perceived healthiness emerged between AB and PB during packaging and visual-olfactory presentation phases, whereas AB products were considered healthier during tasting phase (Fig. 4). This may reflect a growing consumer awareness of the so-called “health halo effect”, in which specific positive features lead to an overestimation of a product's health value (Aschemann-Witzel et al., 2020). In fact, the perception of PB products as highly processed or artificial, being the selected PB alternative foods mimicking traditional AB ones, could also attenuate their perceived health benefit (Czado et al., 2022), suggesting that sustainability messaging alone is insufficient to build comprehensive positive attitudes toward these alternatives.

EEG data mirrored these explicit preferences. During the presentation phase (following the packaging phase), AW was higher for AB products (Fig. 6), indicating stronger implicit approach motivation driven by and cultural embedding (Reimann et al., 2010). By contrast, PB alternatives —being relatively recent and less symbolically coded—elicited weaker affective responses (Aschemann-Witzel et al., 2021; Vogel et al., 2022). These results align with the findings of Li and colleagues (2024), who showed that packaging elements strongly shape consumer perceptions by mediating the trade-off between taste and healthiness. Together, these findings highlight how targeted packaging strategies can effectively influence consumer evaluations by balancing health-related and hedonic cues. This finding aligns with recent work by Wang et al., (2026), who demonstrated that acceptance of unconventional food sources is strongly modulated by social and informational

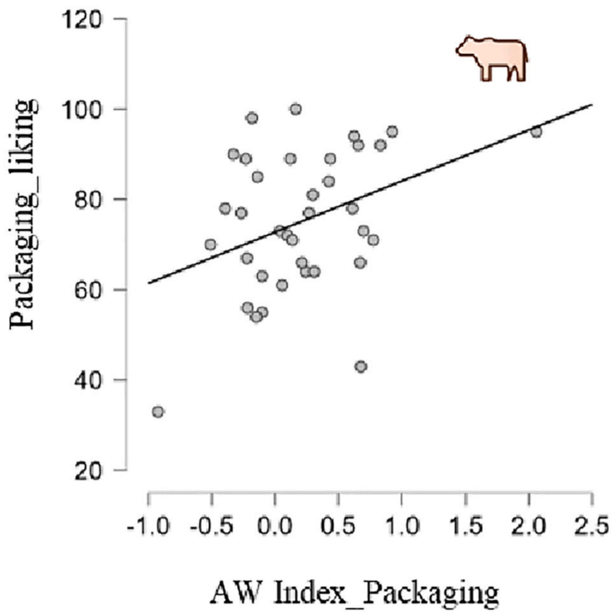

Fig. 9. Associations between the Approach-Withdrawal (AW) Index during the packaging phase of AB products. The scatter plot shows the Pearson correlation between AW and tastiness and declared liking during the packaging phase of experimental protocol.

framing, particularly through perceived credibility and healthiness. Our results extend this perspective by showing that such framing effects are also detectable at the implicit neurophysiological level, influencing both approach motivation and cognitive workload.

During the tasting phase, WL was significantly higher for PB foods than for AB ones (Fig. 5), suggesting that evaluating PB items involved greater cognitive effort. While previous research has associated novel or incongruent stimuli with increased theta activity and decreased parietal alpha (Liu et al., 2020), such patterns have rarely been observed in direct gustatory contexts. From a theoretical perspective, the increase WL can be interpreted as the activation of controlled cognitive processing required to resolve the mismatch between expected and actual sensory proprieties of unfamiliar foods, in line with studies showing that theta and alpha band activity reflect functionally related processes involved in response inhibition under perceptual conflict (Pscherer et al., 2023). This interpretation is consistent with recent evidence showing that psychological distance and feeling "earrings" toward alternative proteins increase cognitive discomfort and resistance, particularly when products deviate from established sensory and cultural schemas (Yuan et al., 2025). Similarly, Vanutelli et al. (2025) found that, even when plant-based foods are evaluated positively at the explicit level, older adults exhibited negative automatic attitudes and lower intention to consume, indicating that implicit resistance can arise independently of conscious preference. In this sense, elevated WL may reflect an implicit manifestation of such psychological distance, emerging prior to explicit rejection.

Within this framework, cognitive workload operates as a mediating mechanism linking product unfamiliarity to reduced explicit liking: when PB products deviate from established sensory schemas, consumers must invest greater mental resources to interpret and evaluate them, which subsequently diminishes hedonic appreciation and purchase intention. For example, EEG studies have shown that tasting foreign products elicits higher mental effort and less familiar perception compared to local products (Martinez-Levy et al., 2019). Similarly, Modica and colleagues (2018) reported increased mental effort during interactions with foreign products. Consistent with this, WL was also negatively associated with liking and purchase intentions for PB products (Fig. 7) during the presentation phase. Similar effects have been reported in other domains such as media and advertising—for instance, Vecchiato et al. (2011) showed that high cognitive workload during TV commercial viewing was linked to reduced activation in brain regions associated with emotional engagement and pleasantness perception. Furthermore, regarding the mediation of cognitive load in food perception, previous studies have demonstrated that cognitive load can interfere with the sensory processing of food and beverages. For instance, van der Wal and van Dillen (2013) found that the perceived intensity of certain substances diminished as cognitive load increased. Similarly, Liang et al. (2018) showed that high cognitive load reduces taste sensitivity. Additionally, a study by van Meer et al. (2023) suggests that cognitive load attenuates the sensory processing of foods, as evidenced by both behavioral responses and neuroimaging data. Finally, Lim and colleagues (2023), using EEG, propose that during the processing of food images, a reduction in perceived pleasure may be linked to the brain's effort to automatically retrieve and process taste-related information from these images, which in turn influences food liking and preferences. Thus, the higher WL observed for PB products reflects a reduction in perceptual fluency, whereby consumers experience increased cognitive friction that weakness the automatic hedonic processing typically associated with food enjoyment. Taken together, these findings suggest that the unfamiliar visual-olfactory profiles typical of many plant-based foods may elevate cognitive load, which in turn is associated with less favorable evaluations—extending prior evidence from domains like advertising and branding into the context of real-world food consumption.

Conversely, for PB alternatives, AW positively correlated with tastiness and purchase intention (Fig. 8), in line with previous literature showing that increased left-prefrontal activation—reflecting implicit approach motivation—is associated with favorable stimulus evaluation (Davidson, 1998). This neurophysiological pattern has been linked to higher perceived pleasantness in gustatory tasks (Di Flumeri et al., 2017)

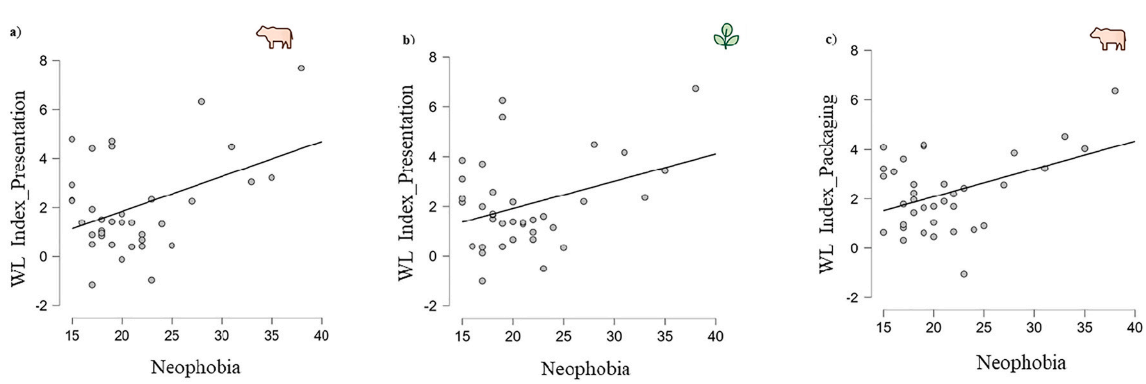

Fig. 10. Associations between Neophobia and Workload Index (WL). The scatter plot shows the Pearson correlation between WL Index and neophobia trait during the presentation phase for AB products (a) and PB alternatives (b) and during the packaging phase (c).

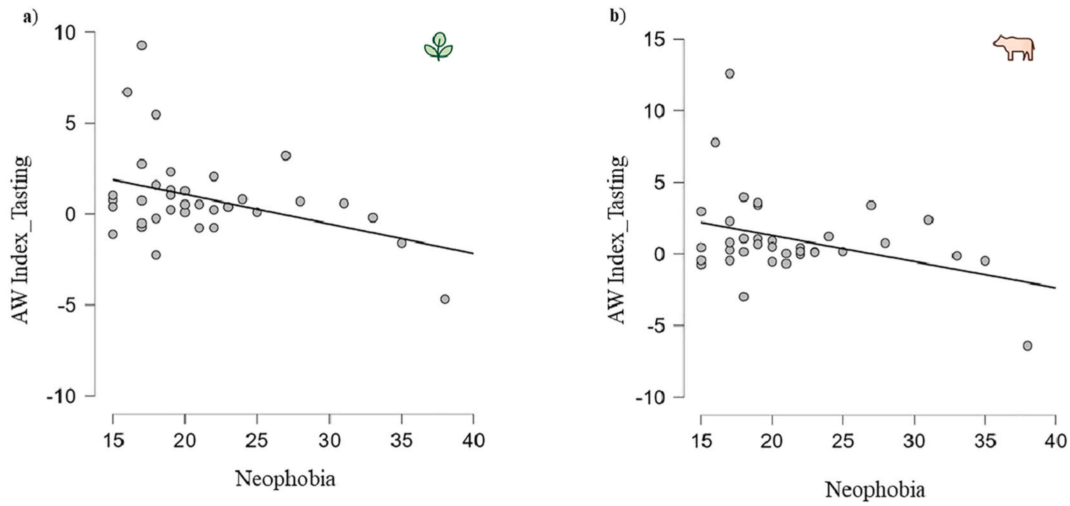

Fig. 11. Associations between Neophobia and Approach-Withdrawal (AW) Index. The scatter plot shows the Pearson negative correlation between AW Index and Neophobia trait during the tasting phase for PB products (a) and AB products (b).

Table 1
Significant Pearson's correlations between LOHAS scores and declarative ratings (liking, taste, purchase intention) during different sensory phases for plant-based (PB) and animal-based (AB) products (*p-value ≤0.05; **p-value <0.01; ***p-value <0.01).

Psychographic Variable	Protocol Phase	Product Type	Evaluation Variable	Pearson's r
LOHAS	Presentation	AB	Willingness to buy	0.53***
	Tasting	AB	Tastiness	0.34*
	Packaging	AB	Tastiness	0.36*
	Presentation	PB	Liking	0.33*
	Tasting	PB	Tastiness	0.47*
	Packaging	PB	Liking	0.59***
	Packaging	PB	Tastiness	0.49**
	Packaging	PB	Willingness to buy	0.49**

and shown to predict purchase intention in broader marketing contexts (Ravaja et al., 2013; Ramsøy et al., 2018). This interpretation is also in line with the correlation found between AW and liking during the packaging phase for AB foods (Fig. 9). In fact, there is a tendency to prefer traditional or familiar packaging because it elicits more positive neural approach responses and reduces mental workload, making the consumption experience cognitively easier and emotionally rewarding. This is in line with the theoretical framework of perceptual fluency applied to the context of food packaging (Su and Wang, 2024). *Perceptual fluency* refers to the cognitive experience associated with the ease or speed with which individuals process an object or piece of information (Reber et al., 1998). In our experimental context, it may be that the packaging of AB foods exhibits a higher level of perceptual fluency than their PB counterparts, as these products are recognized or identified more effortlessly. This, in turn, may elicit more positive emotions and preferences, explaining the association between implicit (AW index) and explicit pleasantness. However, these associations should be interpreted with caution, as the correlational nature of the data—and the modest sample size—does not permit drawing causal conclusions about the direction or magnitude of the relationship between AW and explicit evaluations. Furthermore, the observed gap between explicit and implicit responses to AB and PB products may reflect an underlying tension between perceived healthiness, sustainability, and the degree of industrial processing associated with these foods. Although plant-based alternatives are generally associated with positive sustainability values, they are also often perceived as highly processed and less natural (Varela et al., 2022). This ambivalence may reduce their affective appeal and limit their potential to motivate omnivorous consumers to shift toward more plant-based dietary patterns. Consequently, the effectiveness of meat substitutes as a strategy for promoting sustainable eating behaviors might depend on reducing perceived processing and enhancing sensory and emotional acceptance.

So EEG evidence supports that familiarity plays a significant role in shaping implicit food packaging preferences in consumers (Moya et al., 2020).Furthermore, while previous studies (Lee et al., 2014; Balconi et al., 2019) focused on individual environmental sensitivity, showing that consumers with stronger ecological values exhibit greater neural engagement with sustainable content, our findings indicate that approach-related responses may also be associated with sustainability as a perceived attribute of the product itself, regardless of the consumer's dispositional profile. Importantly, this suggests that perceptual and cognitive mechanisms—such as familiarity and processing fluency—may override dispositional sustainability values at the implicit level, reinforcing the idea that automatic affective responses are primarily driven by sensory expectations and schema congruence rather than moral or ideological considerations. This extends the application of the AW index to value-based stimulus attributes, such as sustainability, which remain underexplored in consumer food neuroscience.

Finally, the presence of significant correlations between EEG indices and self-reported evaluations in relation to PB products supports the view that neurophysiological measures such as AW and WL are particularly sensitive to novel, ambiguous, or culturally transitional stimuli (Khushaba et al., 2013; Cherubino et al., 2019), offering valuable insights into consumer adaptation to emerging food categories. From a managerial perspective, these findings highlight practical strategies to mitigate cognitive load and enhance PB acceptance. Designing packaging that increases perceptual fluency—through familiar visual codes, reassuring sensory cues, and clear taste-related information—may reduce the cognitive effort required to evaluate PB products. Moreover, incorporating multisensory elements (e.g. appetizing imagery, textured materials, or flavor-descriptive language) can facilitate automatic approach responses and improve consumer readiness to adopt these alternatives.

Building on these considerations, recent literature further corroborates the relevance of dual-process mechanisms and sensory-contextual modulation in shaping consumer responses to PB alternatives. Heuristic and familiarity biases have been shown to strongly influence the evaluation of novel or alternative products, even among individuals who explicitly endorse sustainability-oriented values, suggesting that under conditions of uncertainty consumers may rely on simplified cognitive shortcuts rather than reflective reasoning (Siegrist et al., 2024). Likewise, studies on multisensory perception show that packaging design, color properties, and congruent flavor descriptions can enhance perceived tastiness and acceptance of PB products by reducing cognitive uncertainty and increasing processing fluency (Zandstra et al., 2025). Additionally, emerging evidence highlights that perceived excessive industrial processing or artificial formulation remains a critical psychological barriers to plant-based food adoption, generating tension between ethical motivations and sensory expectations (Kershaw et al., 2025). This pattern aligns with our overall findings reinforcing the role of WL as a possible key mediator in the relationship between familiarity and explicit liking. As familiarity increases, cognitive effort required for interpretation decreases, thereby facilitating more positive conscious (self-reported) evaluations.

4.2. Psychographic contributions

Beyond stimulus-related effects, we explored whether individual psychographic traits further shaped food perception LOHAS orientation showed consistent positive correlations with self-reported evaluations (Table 1), particularly for plant-based products, but no significant association with AW or WL indices. This dissociation can be theoretically interpreted through dual-process models of cognition, which distinguish between reflective, controlled processing and automatic and implicit processing (System 1) (Evans and Stanovich, 2013; Kahneman, 2011). From this perspective, LOHAS values appear to primarily influence explicit judgments through reflective and controlled evaluation processes (System 2), in which individuals consciously activate ethical and sustainability-related beliefs when formulating their liking and purchase intentions. This pattern reflects the idea that many ethically driven decisions often rely on deliberate, value-based, reflective (System 2) reasoning that do not necessarily translate into immediate, implicit engagement during sensory exposure (Plassmann et al., 2015; Panteli et al., 2024).

Conversely, implicit neural responses such as AW and WL align with fast, automatic and implicit processing (System 1) mechanisms that are primarily driven by perceptual fluency and familiarity, rather than reflective, value-based considerations. The perceptual-fluency literature establishes the affective impact of ease of processing (Reber et al., 1998), while EEG-event-related potentials studies demonstrate that fluency and familiarity elicit early neural signatures and discriminable brain responses, supporting the notion that neurophysiological indices capture fast, implicit processing (Wang et al., 2018).Moreover, consumer-neuroscience work shows that multisensory product exposure and familiarity modulate EEG and autonomic responses in ways predictive of liking (Modica et al., 2018). Therefore, while LOHAS-oriented individuals may consciously endorse plant-based products due to their alignment with personal values, this endorsement does not necessarily translate into automatic approach motivation or reduced cognitive load at the neurophysiological level. This discrepancy reinforces the notion that ethical consumption often operates as a deliberate self-regulatory behavior rather than an intrinsic affective response (Syed et al., 2024)

In contrast, food neophobia showed no significant association with explicit evaluations but was positively related to WL in early stages (Fig. 10) and negatively associated with AW during tasting (Fig. 11)—indicating heightened cognitive effort and reduced implicit motivational engagement. These effects emerged for both AB and PB products, suggesting that neophobia reflects a generalized dispositional processing style, rather than stimulus-driven responses to specific product categories. This interpretation aligns with findings by Stuldreher and colleagues (Stuldreher et al., 2023a,b), who reported increased attentional engagement (*via* Late Positive Potential -LPP and EEG synchrony) and heightened anticipatory arousal (*via* electrodermal activity) in neophobic individuals, confirming that such trait modulate autonomic processing mechanisms involved in sensory evaluation.

Importantly, these findings offer theoretical clarification of the mediating role of cognitive workload in the relationship between product familiarity and explicit liking. Less familiar products, such as PB alternatives, require greater cognitive resources to be processed and interpreted, resulting in elevated WL (Liu et al., 2020; van Meer et al., 2023). This increased workload interferes with smooth sensory integration and reduces perceptual fluency, which in turn weakens explicit liking and purchase intention (Reber et al., 1998; Alter and Oppenheimer, 2009; Su and Wang, 2024). In this sense, WL acts as a “cognitive bottleneck” linking unfamiliarity to reduced acceptance: the more cognitively demanding the evaluation process, the less positively the product is consciously assessed. Familiar products, by contrast, benefit from fluent processing that simultaneously enhances implicit approach motivation, and explicit preference, supporting a more coherent and rewarding consumption experience (Winkielman et al., 2003; Zandstra et al., 2025).

4.3. Managerial implications

These results could carry direct implications for strategic positioning of plant-based alternatives. From a managerial perspective, enhancing perceptual fluency and reducing cognitive workload emerge as critical levers for improving PB alternatives acceptance (Li and Li, 2024; Zandstra et al., 2025). Packaging design, product naming and multisensory cues should be structured to evoke familiarity and sensory coherence with traditional animal-based products. For instance, visual elements recalling conventional meat textures, color palettes associated with freshness and naturalness, and olfactory cues consistent with expected flavor profiles may reduce cognitive effort and facilitate more automatic positive responses (Zandstra et al., 2025; Spence, 2020). Additionally, simplifying informational load and avoiding overly technical descriptions of processing methods may mitigate perceptions of artificiality and over-processing, which are known to negatively impact PB acceptance (Varela et al., 2022; Melendrez-Ruiz et al., 2025). Sustainability messaging, although effective in activating reflective approval among LOHAS-oriented consumers, should be integrated in a way that does not increase perceived complexity or distance the product from familiar sensory schemas (Aschemann-Witzel et al., 2021). Multisensory retail environments and packaging strategies that enhance experiential congruence may thus contribute to aligning ethical motivation with affective acceptance, bridging the gap between explicit endorsement and implicit engagement. Integrating explicit and neurophysiological metrics allows managers to design interventions that align ethical motivation with affective acceptance. Collectively, these findings underscore the critical value of integrating explicitand neurophysiological metrics in consumer research. While explicit data reflects rational evaluations rooted in personal values and sociocultural norms, EEG indices provide insight into the automatic processes that often guide spontaneous preferences (Panteli et al., 2024).

4.4. Limitations and future directions

Notwithstanding the robustness of the methodological approach and the novelty of integrating EEG and declarative measures, several limitations should be acknowledged when interpreting our findings. The sample consisted exclusively of young Italian adults (aged 18–32), which restricts the generalizability of the results to broader populations differing age, cultural background and dietary habits. Given that attitudes toward plant-based foods and sustainability values are known to vary substantially across generations and cultural contexts, future studies should aim to include more heterogeneous samples to capture a wider spectrum of consumer profiles. Furthermore, the relative sample size limited the possibility of stratifying participants according to psychographic characteristics such as food neophobia and LOHAS orientation. As a result, the present study could only explore correlational patterns rather than conducting more fine-grained comparisons between distinct consumer segments. Future research with larger samples should enable cluster-based or profile-based analyses, allowing for a more precise understanding of how specific psychographic profiles modulate both implicit and explicit responses to innovative food products. Accordingly, the observed patterns for LOHAS orientation and food neophobia should be interpreted as preliminary, pending replication in larger, more segmented samples. Moreover, the experimental stimuli covered only a narrow selection of plant-based and animal-based products, potentially not representative of contemporary food markets. Expanding product variety would enhance the ecological validity and predictive power of the findings. Furthermore, the consumption experience took place in a controlled laboratory environment which, despite methodological rigor, may have affected participant's implicit responses by reducing the spontaneity of interaction with the product. Future studies should incorporate a wider range of food items, recruit more demographically and culturally diverse samples, and employ more naturalistic testing settings—such as supermarkets or in-home environments—to enhance external validity and practical applicability. Finally, although this study primarily focused on cognitive and motivational mechanisms, a more detailed exploration of emotional dynamics — potentially supported by additional neurophysiological signals such as heart rate (HR) and galvanic skin response (GSR) — represents a valuable future extension of this research. Future research should also consider recent developments in the European regulatory framework restricting the use of meat-related terminology for plant-based products (European Parliament, 2025). Such regulatory changes may alter consumer expectations and reduce perceptual fluency during product evaluation, potentially increasing cognitive workload and further shaping the implicit–explicit divergence observed in plant-based food acceptance. Overall, addressing these limitations will support the development of more generalizable, ecologically valid, and theoretically grounded models for understanding consumer acceptance of plant-based and other innovative food products.

5. Conclusions

This study provides new evidence that plant-based (PB) alternative foods elicit distinct cognitive, affective, and motivational responses compared to traditional animal-based (AB) counterparts, highlighting the pivotal role of familiarity and cognitive effort in shaping consumer experience.

At the explicit level, AB foods received higher ratings in terms of liking and purchase intention, confirming that familiarity operates as a powerful heuristic facilitating positive evaluations and preference formation in food choice contexts (Tan et al., 2016; Pagliarini et al., 2021).

At the implicit level, AB foods evoked stronger approach-related asymmetry (AW), whereas PB alternatives generated significantly higher cognitive workload (WL), particularly during tasting. These findings support a theoretical framework in which cognitive workload mediates the relationship between product familiarity and explicit liking; unfamiliar or weakly assimilated products require increased cognitive resources to be processed and interpreted, which reduces perceptual fluency and, consequently, diminishes hedonic appraisal and purchase propensity. In this perspective, elevated WL associated with PB alternatives reflects a disruption of automatic sensory schemas, translating into less favorable conscious evaluations. Conversely, stronger AW responses indicate implicit motivational engagement, suggesting that positive approach tendencies depend on the ease with which sensory and semantic information is integrated. This dual pattern reinforces the importance of perceptual fluency as a central mechanism linking neural processing efficiency to affective preference (Su and Wang, 2024).

The dissociation observed between psychographic variables and neurophysiological indices further clarifies the multi-layered nature of consumer decision-making. LOHAS orientation was positively associated with explicit evaluations of PB foods but did not correlate with EEG measures, indicating that sustainability-driven attitudes predominantly operate within reflective cognitive systems, involving conscious reasoning, moral evaluation, and identity expression. These processes contrast with implicit neural responses, which primarily capture automatic, affective, and familiarity-driven mechanisms (Verain et al., 2012; White et al., 2019; Plassmann et al., 2015; Panteli et al., 2024). This divergence aligns with dual-process theories distinguishing between deliberate (System 2) and automatic (System 1) pathways in consumer judgment.

Overall, the integration of EEG and self-report measures provides a comprehensive and theoretically grounded framework for understanding consumer responses to innovative food products. Finally, this innovative multimethod approach captures both the reflective and autonomic dimensions of food choice, offering valuable insights for the design, communication, and positioning of sustainable food innovations. Future research should include more diverse populations and real-world consumption contexts to better understand the dynamic interplay between familiarity, cognitive load, and sustainability and support — through neurosciences—the development of more effective strategies for promoting sustainable food innovations.

CRediT author statement

Conceptualization: G.Cartocci, B.M.S.I, P.C.; Data curation: G.Carcaterra, D.R., G.M., ; Formal Analysis: G.Carcaterra, D.R., B.M.S.I.; Investigation: B.M.S.I.; G.Carcaterra, Methodology: G.C artocci, P.C., D. R., B.M.S.I.; Project administration: F.B., G.Cartocci; B.M.S.I, P.C., Resources F.B; Software: D.R., G. Carcaterra, B.M.S.I.; Supervision: G. Cartocci, F.B, L.F; Validation: B.M.S.I., G.Cartocci; Visualization: B.M.S. I; G.Carcaterra Writing – original draft: B.M.S.I., G.Carcaterra; Writing – review & editing: B.M.S.I., G.Cartocci, P.C.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Funding

This research was partially funded by RTD-A project “Pensiamo e compriamo in maniera sostenibile? Uno studio neurofisiologico delle reazioni di genere implicite ed esplicite a concetti e scelte di consume green e sostenibile da parte dei consumatori italiani” funded by PNRR and conducted by Dr. Giulia Cartocci, Scientific Responsible Prof. Fabio Babiloni, Sapienza University of Rome.

Declaration of competing interest

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

Acknowledgements

The authors would like to sincerely thank all participants who volunteered their time and effort to take part in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crfs.2025.101288.

References

Abdul Kareem, F.B., Nicholles, B., Bryant, C., 2025. Consumer acceptance of alternative proteins: a Re-Review. Food Rev. Int. 41 (2), 521–542.

Abe-Inge, V., Aidoo, R., de la Fuente, M.M., Kwofie, E.M., 2024. Plant-based dietary shift: current trends, barriers, and carriers. Trends Food Sci. Technol. 143, 104292.

Adelodun, B., Agbelusi, O.O., Soma, T., Odey, G., Adeyi, Q., Kumar, P., et al., 2025. Rethinking food loss and waste to promote sustainable resource use and climate change mitigation in agri-food systems: a review. Waste Manag. Res. 43 (4), 490–506.

Alsharif, A.H., Isa, S.M., 2025. Electroencephalography studies on marketing stimuli: a literature review and future research agenda. Int. J. Consum. Stud. 49 (1), e70015.

Alter, A.L., Oppenheimer, D.M., 2009. Suppressing secrecy through metacognitive ease: cognitive fluency encourages self-disclosure. Psychol. Sci. 20 (11), 1414–1420.

Ares, G., Antúnez, L., Vidal, L., Giménez, A., Maiche, A., 2021. Consumers' associations with plant-based foods: Health-related and ethical concerns. Appetite 163, 105212. https://doi.org/10.1016/j.appet.2021.105212.

Aschemann-Witzel, J., Gantriis, R.F., Fraga, P., Perez-Cueto, F.J.A., 2020. Plant-based food and protein trend from a consumer perspective: a cross-country analysis. Foods 9 (9), 1316. https://doi.org/10.3390/foods9091316.

Aschemann-Witzel, J., Varela, P., Peschel, A.O., 2021. Consumers' categorization of food ingredients: do plant-based alternatives fit in? Food Qual. Prefer. 93, 104256.

Auvray, M., Spence, C., 2008. The multisensory perception of flavor. Conscious. Cognit. 17 (3), 1016–1031. https://doi.org/10.1016/j.concog.2007.06.005.

Balconi, M., Fronda, G., Venturella, I., 2019. A neuroscientific approach to explore consumers' intentions towards sustainability within the luxury fashion industry. Sustainability 11 (18), 5105. https://doi.org/10.3390/su11185105.

Barrena, R., Sánchez, M., 2013. Neophobia, personal consumer values and novel food acceptance. Food Qual. Prefer. 27 (1), 72–84.

Blackwell, R.D., Miniard, P.W., Engel, J.F., 2006. Consumer Behavior Mason. Thomson South-Western, Ohio.

Borghini, G., Vecchiato, G., Toppi, J., Astolfi, L., Maglione, A., Isabella, R., et al., 2012. Assessment of mental fatigue during car driving by using high resolution EEG activity and neurophysiologic indices. In: 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE, pp. 6442–6445.

Bryant, C.J., Szejda, K., Parekh, N., Deshpande, V., Tse, B., 2019. A survey of consumer perceptions of plant-based and clean meat in the USA, India, and China. Front. Sustain. Food Syst. 3, 11. https://doi.org/10.3389/fsufs.2019.00011.

Bryant, C.J., Barnett, J.C., 2020. Consumer acceptance of cultured meat: a systematic review. Meat Sci. 143, 8–17. https://doi.org/10.1016/j.meatsci.2018.04.008.

Cartocci, G., Modica, E., Rossi, D., Maglione, A.G., Venuti, I., Rossi, G., et al., 2016. A pilot study on the neurometric evaluation of "effective" and "ineffective" antismoking public service announcements. In: 2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). IEEE, pp. 4597–4600.

Casiraghi, C., Fici, A., Bilucaglia, M., Rossi, C., Zito, M., Russo, V., 2025. Processing every bite: a neuroscientific analysis of the eating experience and its cognitive and emotional dynamics. Curr. Psychol. 1–17.

Cherubino, P., Martinez-Levy, A.C., Caratù, M., Cartocci, G., Modica, E., Rossi, D., Babiloni, F., 2019. Consumer behaviour through the eyes of neurophysiological measures: State-of-the-art and future trends. Comput. Intell. Neurosci. 2019, 1–41.

Choi, D., Johnson, K.K.P., 2021. Influences of LOHAS values and attitudes toward sustainable fashion on consumer behavior. Sustainability 13 (7), 3887. https://doi.org/10.3390/su13073887.

Clark, M.A., Springmann, M., Hill, J., Tilman, D., 2022. Multiple health and environmental impacts of foods. Proc. Natl. Acad. Sci. 119 (33), e2120584119.

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N., Leip, A., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat. Food 2 (3), 198–209. https://doi.org/10.1038/s43016-021-00225-9.

Czado, N., Christoph-Schulz, I.B., Salm, L., 2022. "Healthy", "natural", "highly processed"? How consumers perceive plant-based meat alternatives in Germany. Food Qual. Prefer. 102, 104635.

Davidson, R.J., 1992. Anterior cerebral asymmetry and the nature of emotion. Brain Cognit. 20 (1), 125–151. https://doi.org/10.1016/0278-2626(92)90065-T.

Davidson, R.J., 1998. Affective style and affective disorders: perspectives from affective neuroscience. Cognit. Emot. 12 (3), 307–330. https://doi.org/10.1080/026999398379628.

Di Flumeri, G., Arico, P., Borghini, G., Sciaraffa, N., Lanzi, P.L., Pozzi, S., Babiloni, F., 2017. EEG-based approach–withdrawal index for the pleasantness evaluation during taste experience in realistic settings. IEEE (Inst. Electr. Electron. Eng.) Trans. Biomed. Eng. 64 (12), 2739–2749. https://doi.org/10.1109/TBME.2017.2654463.

Di Flumeri, G., Giorgi, A., Germano, D., Ronca, V., Vozzi, A., Borghini, G., Tamborra, L., Simonetti, I., Capotorto, R., Ferrara, S., et al., 2023. A neuroergonomic approach fostered by wearable EEG for the multimodal assessment of drivers trainees. Sensors 23, 8389.

Duan, M.-J., Poelman, M.P., Biesbroek, S., 2025. Non-communicable disease burden through adhering to Dutch dietary guidelines: a modeling study to estimate future reductions. eClinicalMedicine 82, 103170. https://doi.org/10.1016/j.eclinm.2025.103170.

Elzerman, J.E., Hoek, A.C., van Boekel, M.A.J.S., Luning, P.A., 2011. Consumer acceptance and appropriateness of meat substitutes in a meal context. Food Qual. Prefer. 22 (3), 233–240. https://doi.org/10.1016/j.foodqual.2010.10.006.

European Parliament, 2025. European Parliament resolution of 8 October 2025 on the transparency and sustainability of the food system (2024/2122(INI)). https://www.europarl.europa.eu/doceo/document/TA-10-2025-10-08_EN.html.

Evans, J.S.B., Stanovich, K.E., 2013. Dual-process theories of higher cognition: advancing the debate. Perspect. Psychol. Sci. 8 (3), 223–241.

FAO, 2022. Greenhouse gas emissions from agrifood systems: global, regional and country trends, 2000–2022. FAOSTAT Anal. Br. Ser., 50, 1-12. Food and Agriculture Organization of the United Nations.

FAO, 2024. World Food and Agriculture: Statistical Yearbook 2024. Food and Agriculture Organization of the United Nations, Rome. Available at: https://www.fao.org/statistics/yearbook. (Accessed 3 October 2025).

Fernqvist, F., Spendrup, S., Tellström, R., 2024. Understanding food choice: a systematic review of reviews. Heliyon 10 (12), e32492.

Foxe, J.J., Morie, K.P., Laud, P.J., Rowson, M.J., de Bruin, E.A., Kelly, S.P., 2012. Assessing the effects of caffeine and alcohol on human neurophysiology using EEG. Front. Hum. Neurosci. 6, 200. https://doi.org/10.3389/fnhum.2012.00200.

Gevins, A., Smith, M.E., 2000. Neurophysiological measures of cognitive workload during human-computer interaction. Theor. Issues Ergon. Sci. 1 (1), 1–18. https://doi.org/10.1080/146392200364063.

González, N., Marquès, M., Nadal, M., Domingo, J.L., 2020. Meat consumption: which are the current global risks? A review of recent (2010-2020) evidences. Food Res. Int. 137, 109341. https://doi.org/10.1016/j.foodres.2020.109341. Epub 2020 May 29. Erratum in: Food Res Int. 2020 Nov;137:109620. doi: 10.1016/j.foodres.2020.109620. PMID: 33233049; PMCID: PMC7256495.

Graça, J., Calheiros, M.M., Oliveira, A., 2019. Situating protein consumption within a value–attitude–behavior framework: the role of personal values and eating contexts in meat consumption. Appetite 132, 132–139. https://doi.org/10.1016/j.appet.2018.10.012.

Harguess, J.M., Crespo, N.C., Hong, M.Y., 2020. Strategies to reduce meat consumption: a systematic literature review of experimental studies. Appetite 144, 104478.

Harmon-Jones, E., Gable, P.A., Peterson, C.K., 2010. The role of asymmetric frontal cortical activity in emotion-related phenomena: a review and update. Biol. Psychol. 84 (3), 451–462. https://doi.org/10.1016/j.biopsycho.2009.08.010.

Harris, A., Ciorciari, J., Gountas, J., 2020. Consumer neuroscience for marketing researchers. J. Consum. Behav. 19 (4), 299–302. https://doi.org/10.1002/cb.1816.

Heller, M.C., Keoleian, G.A., 2018. Beyond Meat's Beyond Burger Life Cycle Assessment. University of Michigan, Center for Sustainable Systems.

Hoek, A.C., Luning, P.A., Weijzen, P., Engels, W., Kok, F.J., de Graaf, C., 2011. Replacement of meat by meat substitutes: a survey on person- and product-related factors in consumer acceptance. Appetite 56 (3), 662–673. https://doi.org/10.1016/j.appet.2011.02.001.

Hong, C., Zhong, R., Xu, M., He, P., Mo, H., Qin, Y., et al., 2025. Interactions among food systems, climate change, and air pollution: a review. Engineering 44, 215–233.

Hsu, C.L., 2020. Investigating the role of LOHAS lifestyle on organic food purchase intentions. Int. J. Environ. Res. Publ. Health 17 (5), 1834. https://doi.org/10.3390/ijerph17051834.

Hubbard, J., Kikumoto, A., Mayr, U., 2019. EEG decoding reveals the strength and temporal dynamics of goal-relevant representations. Sci. Rep. 9, 9051.

Inguscio, B.M.S., Cartocci, G., Modica, E., Rossi, D., Martinez-Levy, A.C., et al., 2021. Smoke signals: A study of the neurophysiological reaction of smokers and non-smokers to smoking cues inserted into antismoking public service announcements. Int. J. Psychophysiol. 16, 22–29. https://doi.org/10.1016/j.ijpsycho.2021.06.010.

Inguscio, B.M.S., Mancini, P., Greco, A., Nicastri, M., Giallini, I., et al., 2022. 'Musical effort' and 'musical pleasantness'. Hear. Bal. Commun. 20 (2), 79–88. https://doi.org/10.1080/21695717.2022.2079325.

Inguscio, B.M.S., Rossi, D., Giliberto, G., Vozzi, A., Borghini, G., Babiloni, F., et al., 2024. Bridging the gap between psychophysiological and audiological factors in the assessment of tinnitus: an EEG investigation in the beta band. Brain Sci. 14 (6), 570.

IPCC, 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. IPCC sixth assessment report.

Jaeger, S.R., Jin, D., Roigard, C.M., Cardello, A.V., 2025. Consumer evaluations of commercially available plant-based cheddar cheese alternatives reveal inferior taste, nutrition and emotional appeal. Food Res. Int. 200, 115452.

Kahneman, D., 2011. Thinking, Fast and Slow. Farrar, Straus and Giroux.

Kershaw, J., Nolden, A., Ellinger, L., Dlamini, N.N., 2025. Consumers' perceptions of plant-based alternatives relative to the foods they directly imitate. Food Qual. Prefer. 129, 105519.

Khondakar, M.F.K., Sarowar, M.H., Chowdhury, M.H., Majumder, S., Hossain, M.A., Dewan, M.A.A., Hossain, Q.D., 2024. A systematic review on EEG-based neuromarketing: recent trends and analyzing techniques. Brain Informatics 11 (1), 17.

Khushaba, R.N., Greenacre, L., Kodagoda, S., Louviere, J., Burke, S., Dissanayake, G., 2013. Choice modeling and the brain: a study on the Electroencephalogram (EEG) of preferences. Expert Syst. Appl. 40 (16), 6214–6221.

Klimesch, W., 1999. EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. Brain Res. Rev. 29 (2–3), 169–195.

Kozicka, M., Havlík, P., Valin, H., et al., 2023. Feeding climate and biodiversity goals with novel plant-based meat and milk alternatives. Nat. Commun. 14, 5316. https://doi.org/10.1038/s41467-023-40899-2.

Köster, E.P., 2009. Diversity in the determinants of food choice: a psychological perspective. Food Qual. Prefer. 20 (2), 70–82.

Lawless, H.T., Heymann, H., 2010. Sensory Evaluation of Food: Principles and Practices, second ed. Springer. https://doi.org/10.1007/978-1-4419-6488-5.

Lazzarini, G.A., Zimmermann, J., Visschers, V.H., Siegrist, M., 2016. Does environmental friendliness equal healthiness? Swiss consumers' perception of protein products. Appetite 105, 663–673.

Lee, H., Kim, H.J., Kim, H.J., 2014. The spell of green: can frontal EEG activations identify green consumers? J. Bus. Ethics 122 (3), 511–521.

Li, X., Wang, S., Ruan, Y., Pan, Y., Huang, Y., 2024. Taste or health: the impact of packaging cues on consumer decision-making in healthy foods. Appetite 203, 107636.
Li, R., Li, H., 2024. The impact of food packaging design on users' perception of green awareness. Sustainability 16 (18), 8205.
Lim, M., Park, S., Lee, Y., Kwak, H.S., 2023. Brain responses and connectivity to visual meal compositions: an EEG investigation into food liking. Food Qual. Prefer. 112, 105029.
Liu, Y., Wang, M., Xu, C., Fan, Z., 2020. EEG-based consumer preference prediction using temporal convolutional networks. Front. Neurosci. 14, 168.
Majcher, S., 2025. Consumers' perspective of plant-based meat Alternatives—A systematic literature review and future research agenda. Int. J. Consum. Stud. 49 (2), e70036.
Martinez-Levy, et al., 2019, 2019. In: Longo, L., Leva, C. (Eds.), H-Workload 2019, the 3rd. International Symposium on Human Mental Workload. Work in Progress. Sapienza, University of Rome, 14-15 November, 2019.
Martins, Y., Pliner, P., 2006. "Ugh! that's disgusting!": identification of the characteristics of foods underlying rejections based on disgust. Appetite 46 (1), 75–85. https://doi.org/10.1016/j.appet.2005.09.001.
Melendez-Ruiz, J., Dujourdy, L., Arvisenet, G., Chambaron, S., 2025. Disentangling consumer perceptions regarding plant-based food processing and formulation: insights from a French study. Food Qual. Prefer., 105654
Mento, G., Astle, D.E., Scerif, G., Marchetti, A., 2020. Resting-state EEG signatures of caffeine and nicotine consumption in young adults. Neuropsychologia 146, 107550. https://doi.org/10.1016/j.neuropsychologia.2020.107550.
Michel, F., Knaapila, A., Hartmann, C., Siegrist, M., 2021a. A multi-national Comparison of Meat Eaters' Attitudes and Expectations for Plant-based Foods.
Michel, F., Knaapila, A., Hartmann, C., Siegrist, M., Büttner, O.B., 2021b. Consumers' perception of plant-based alternatives to animal-based food products: a systematic review. Trends Food Sci. Technol. 116, 1115–1129. https://doi.org/10.1016/j.tifs.2021.09.004.
Modica, E., Cartocci, G., Rossi, D., Martinez Levy, A.C., Cherubino, P., Maglione, A.G., et al., 2018. Neurophysiological responses to different product experiences. Comput. Intell. Neurosci. 2018 (1), 9616301.
Nguyen, J., Ferraro, C., Sands, S., Luxton, S., 2022. Alternative protein consumption: a systematic review and future research directions. Int. J. Consum. Stud. 46 (5), 1691–1717.
Onwezen, M.C., Nassar, G., Bouma, J.A., 2025. Change meat resistance: systematic literature review on consumer resistance to the alternative protein transition. Annu. Rev. Food Sci. Technol. 16.
Oostenveld, R., Praamstra, P., 2001. The five percent electrode system for high-resolution EEG and ERP measurements. Clin. Neurophysiol. 112, 713–719.
Ozturk, E.E., Dikmen, D., 2023. Food Neophobia and its Association with Taste Threshold and Food Liking Among Adults.
Pagliarini, E., Proserpio, C., Spinelli, S., Lavelli, V., Laureati, M., Arena, E., et al., 2021. The role of sour and bitter perception in liking, familiarity and choice for phenol-rich plant-based foods. Food Qual. Prefer. 93, 104250.
Panteli, A., Kalaitzi, E., Fidas, C.A., 2024. A review on the use of eeg for the investigation of the factors that affect Consumer's behavior. Physiol. Behav. 278, 114509.
Plassmann, H., Venkatraman, V., Huettel, S., Yoon, C., 2015. Consumer neuroscience: applications, challenges, and possible solutions. J. Mark. Res. 52 (4), 427–435. https://doi.org/10.1509/jmr.14.0048.
Pliner, P., Hobden, K., 1992. Development of a scale to measure the trait of food neophobia in humans. Appetite 19 (2), 105–120. https://doi.org/10.1016/0195-6663(92)90014-W.
Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. Science 360 (6392), 987–992.
Prescott, J., 2015. Multisensory processes in flavour perception and their influence on food choice. Curr. Opin. Food Sci. 3, 47–52. https://doi.org/10.1016/j.cofs.2015.02.007.
Pscherer, C., Wendiggensen, P., Mückschel, M., Bluschke, A., Beste, C., 2023. Alpha and theta band activity share information relevant to proactive and reactive control during conflict-modulated response inhibition. Hum. Brain Mapp. 44 (17), 5936–5952. https://doi.org/10.1002/hbm.26486. Epub 2023 Sep 20. PMID: 37728249; PMCID: PMC10619371.
Ramsøy, T.Z., Skov, M., Christensen, M.K., Stahlhut, C., 2018. Frontal brain asymmetry and willingness to pay. Front. Neurosci. 12, 138. https://doi.org/10.3389/fnins.2018.00138.
Ravaja, N., Somervuori, O., Salminen, M., 2013. Predicting purchase decision: the role of hemispheric asymmetry over the frontal cortex. Journal of Neuroscience, Psychology, and Economics 6 (1), 1–13.
Reber, R., Winkielman, P., Schwarz, N., 1998. Effects of perceptual fluency on affective judgments. Psychol. Sci. 9 (1), 45–48.
Reimann, M., Zaichkowsky, J.L., Neuhaus, C., Bender, T., Weber, B., 2010. Aesthetic package design: a behavioral, neural, and psychological investigation. J. Consum. Psychol. 20 (4), 431–441.
Rockström, J., Thilsted, S.H., Willett, W.C., Gordon, L.J., Herrero, M., Hicks, C.C., et al., 2025. The EAT–Lancet Commission on healthy, sustainable, and just food systems. Lancet 406 (10512), 1625–1700.
Ronca, V., Di Flumeri, G., Giorgi, A., Vozzi, A., Capotorto, R., Germano, D., et al., 2024. o-CLEAN: a novel multi-stage algorithm for the ocular artifacts' correction from EEG data in out-of-the-lab applications. J. Neural. Eng. 21 (5), 056023.
Sciaraffa, N., Di Flumeri, G., Germano, D., Giorgi, A., Di Florio, A., Borghini, G., et al., 2022. Validation of a light EEG-based measure for real-time stress monitoring during realistic driving. Brain Sci. 12 (3), 304.
Shapiro, S.S., Wilk, M., 1965. An analysis of variance test for normality (complete samp). Biometrika 52, 591–611.
Siegrist, M., Michel, F., Hartmann, C., 2024. The shift from meat to plant-based proteins: consumers and public policy. Curr. Opin. Food Sci. 58, 101182.
Slade, P., 2018. If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers. Appetite 125, 428–437. https://doi.org/10.1016/j.appet.2018.02.030.
Sogari, G., Mora, C., Menozzi, D., 2019. The food neophobia scale and young adults' intention to eat insect products. Int. J. Consum. Stud. 43 (1), 68–76. https://doi.org/10.1111/ijcs.12485.
Song, G., Gazi, M.A.I., Waaje, A., Roshid, M.M., Karim, R., Rahaman, M.A., et al., 2025. The neuromarketing: bridging neuroscience and marketing for enhanced consumer engagement. IEEE Access 13, 40331–40353.
Songsamoe, S., Saengwong-ngam, R., Koomhin, P., Matan, N., 2019. Understanding consumer physiological and emotional responses to food products using electroencephalography (EEG). Trends Food Sci. Technol. 93, 167–173.
Spence, C., 2020. Multisensory flavor perception: a cognitive neuroscience perspective. In: Multisensory Perception. Academic Press, pp. 221–237.
Spence, C., Smith, B., Auvray, M., 2015. Confusing tastes and flavours. Perception and its modalities 247, 274.
Stubelj, M., Gleščič, E., Žvanut, B., Širok, K., 2025. Factors influencing the acceptance of alternative protein sources. Appetite 210, 107976.
Stuldreher, I., Kaneko, D., Hiraguchi, H., Brouwer, A.-M., 2022. EEG measures of attention toward food-related stimuli vary with food neophobia. Appetite 179, 106294. https://doi.org/10.1016/j.appet.2022.106294.
Stuldreher, I., van der Laan, L.N., de Graaf, C., 2023a. EEG measures of attention toward food-related stimuli vary with food neophobia. Food Qual. Prefer. 106, 104805.
Stuldreher, I., van der Laan, L.N., de Graaf, C., 2023b. Electrodermal activity as an index of food neophobia outside the lab. Frontiers in Neuroergonomics 2, 1297722.
Su, J., Wang, S., 2024. Influence of food packaging color and foods type on consumer purchase intention: the mediating role of perceived fluency. Front. Nutr. 10, 1344237.
Syed, S., Acquaye, A., Khalfan, M.M., Obuobisa-Darko, T., Yamoah, F.A., 2024. Decoding sustainable consumption behavior: a systematic review of theories and models and provision of a guidance framework. Resources, Conservation & Recycling Advances 23, 200232.
Tan, H.S.G., van den Berg, E., Stieger, M., 2016. The influence of product preparation, familiarity and individual traits on the consumer acceptance of insects as food. Food Qual. Prefer. 52, 222–231.
Tirion, A.S., D'Lima, D., Terlet, J., Rao, R., Gutman, L.M., 2025. Identifying behaviour change techniques for sustainable food consumption: a systematic review using the BCTTv1. Appetite 214, 108057.
van der Wal, R.C., van Dillen, L.F., 2013. Leaving a flat taste in your mouth: task load reduces taste perception. Psychol. Sci. 24 (7), 1277–1284.
van Meer, F., van Steenbergen, H., van Dillen, L.F., 2023. The effect of cognitive load on preference and intensity processing of sweet taste in the brain. Appetite 188, 106630.
Vanutelli, M.E., Adorni, R., Leone, P.A., Luperini, A., D'Addario, M., Steca, P., 2025. Never too late to try something new: attitudes and intention to taste foods from alternative protein sources in a sample of Italian older adults. Front. Nutr. 12, 1712358. https://doi.org/10.3389/fnut.2025.1712358.
Varela, P., Arvisenet, G., Gonera, A., Myhrer, K.S., Fifi, V., Valentin, D., 2022. Meat replacer? No thanks! the clash between naturalness and processing: an explorative study of the perception of plant-based foods. Appetite 169, 105793.
Vecchiato, G., Astolfi, L., De Vico Fallani, F., Cincotti, F., Mattia, D., Babiloni, F., 2011. Changes in brain activity during the observation of TV commercials by using EEG, GSR and HR measurements. Brain Topogr. 23 (2), 165–179. https://doi.org/10.1007/s10548-010-0148-6.
Vogel, C., Nordgren, A., Bonke, J., 2022. The cultural embedding of meat consumption: a cross-national Study. Appetite 172, 105967.
Wang, W., Li, B., Gao, C., Guo, C., 2018. The temporal dynamics of perceptual and conceptual fluency on recognition memory. Brain Cognit. 127, 1–12. https://doi.org/10.1016/j.bandc.2018.07.002. Epub 2018 Sep 1. PMID: 30176534.
Wang, Z., Nguyen, M., Park, J., Yuan, Y., 2026. From perceived healthiness to acceptance: how influencer type shapes consumer acceptance of insect-based foods. Food Qual. Prefer., 105719
Welk, A.K., Mehlhose, C., Daum, D., Enneking, U., 2025. From emotion to intention: how mood, food neophobia, and purchase motives shape willingness to buy new broccoli leaf products. Br. Food J. 127 (13), 781–802.
Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., et al., 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 393 (10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4.
Winkielman, P., Schwarz, N., Fazendeiro, T., Reber, R., 2003. The hedonic marking of processing fluency: implications for evaluative judgment. In: Musch, J., Klauer, K.C. (Eds.), The Psychology of Evaluation: Affective Processes in Cognition and Emotion, pp. 189–217.
Xu, X., Sharma, P., Shu, S., Lin, T.S., Ciais, P., Tubiello, F.N., et al., 2021. Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. Nat. Food 2 (9), 724–732.

Yang, T., Zhang, P., Xing, L., Hu, J., Feng, R., Zhong, J., et al., 2023. Insights into brain perceptions of the different taste qualities and hedonic valence of food via scalp electroencephalogram. Food Res. Int. 173, 113311.

Yuan, Y., Nguyen, M., Zhang, Y., Cheah, I., 2025. The roles of psychological distance and digital blockchain technology in mitigating consumer reluctance toward alternative proteins. Appetite 211, 108008. https://doi.org/10.1016/j.appet.2025.108008.

Zandstra, E.H., Van Os, D.E., Van der Burg, E., Stuldreher, I.V., Toet, A., Velut, S., et al., 2025. Multisensory contextual cues and information affect plant-based food choices and taste perception. Food Qual. Prefer. 126, 105385.