

TESIS



Universidad de Jaén

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**SENSORY AND DECISION PROCESS DYNAMICS
IN THE SENSORY ANALYSIS OF
EXTRA VIRGIN OLIVE OIL ATTRIBUTES**

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Sensory and Decision Process Dynamics in the Sensory Analysis of Extra Virgin Olive Oil Attributes

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1. Abstract

Extra virgin olive oil (EVOO) provides numerous health benefits, including reducing cardiovascular disease risk, mortality, type 2 diabetes, and certain cancers. It also improves cognitive function, prevents Alzheimer's disease, strengthens bone health, and supports weight management. Additionally, EVOO enhances intestinal microbiota, glycemic control, and lowers LDL cholesterol due to its rich polyphenol and oleocanthal content, which also aids in preventing age-related diseases. Despite these benefits, promoting EVOO as a functional food faces challenges due to its bitterness and pungency, often disliked by consumers. This dissertation explores the factors influencing consumer preferences and decision-making regarding EVOO. The study's objectives focus on three key areas: understanding the role of consumer familiarity with EVOO culture, assessing sensory analysis through consumer panels, and comparing expert and consumer perceptions.

The first objective examines how familiarity with EVOO culture affects consumer perception, using country of residence as a proxy for familiarity. Findings suggest that consumers from EVOO-producing regions show a higher tolerance for bitterness and pungency, while those from non-producing regions tend to reject these attributes. Certifications such as PGI and organic labels play a significant role in consumer choices, often reflecting ethnocentrism. These insights provide a framework for targeted marketing strategies to promote EVOO globally.

The second objective evaluates the use of Signal Detection Theory (SDT) and the Additive Double Dissociation Test (DDAT) to analyze sensory and decision-making processes in untrained consumers. Two experimental studies were conducted, with the first validating SDT's applicability in assessing sensory evaluation. Results showed that decision-making processes are influenced by expectations rather than sensory discrimination alone. In the second study, a manipulation introduced to separate sensory and decision-making processes confirmed their independence, supporting SDT's theoretical framework. An additional finding revealed a discrepancy between expressed preferences and willingness to pay (WTP). Consumers could detect quality differences and preferred high-quality EVOOs but were unwilling to pay more for them, highlighting a gap between sensory appreciation and economic decisions.

The third objective compares expert and consumer evaluations within the same experimental setting. Experts exhibited greater sensitivity to sensory attributes than consumers. Both groups responded to experimental manipulations similarly, although experts demonstrated a more refined perception of green EVOO. Confidence levels were high among both groups, with no statistically significant differences, suggesting that training and familiarity may help align consumer evaluations with expert assessments.

This dissertation's findings offer valuable contributions to Sensory and Consumer Science, integrating sensory methodologies with consumer behavior research. By combining SDT and DDAT, the study provides a robust framework for analyzing sensory and decision-making processes. The results highlight the importance of targeted consumer education and familiarity in shaping preferences, supporting efforts to promote EVOO consumption and improve public health.

Keywords: EVOO, Consumer preferences, Methodology of Sensory analysis

1.1. Abbreviations list

- DDAT Double Dissociation Additive Test
- EU European Union
- EVOO Extra Virgin Olive Oil
- IOC International Olive Council
- LDL: Low-Density Lipoprotein
- OO Olive Oil
- ROC Receiver Operating Characteristic curve
- SDT Signal Detection Theory
- UNESCO United Nations Educational, Scientific and Cultural Organization;
- WOS Web of Science
- WTP Willing To Pay

2. Challenges in sensory evaluation of EVOO

As highlighted by Medeiros and Hampton (2020), interest in healthy eating and the nutritional value of foods has grown significantly in recent years, increasing the relevance of terms such as *nutraceutical* and *functional foods*. According to FUFOSE (Functional Food Science in Europe), functional foods are those that offer health benefits beyond basic nutrition (European Commission, 2010). In contrast, nutraceuticals—a term combining "nutritional" and "pharmaceutical"—are defined as foods used for therapeutic purposes (Casini et al., 2014). Thus, food has emerged as a strategy for preventing or treating various diseases.

Medeiros and Hampton (2020) highlight that the relatively low prevalence of cardiovascular disease, chronic disease, and cancer in Mediterranean countries has spurred increased interest in the health benefits of Extra Virgin Olive Oil (EVOO) consumption. The authors note that phenolic compounds in EVOO can lower both systolic and diastolic blood pressure and emphasize that the Mediterranean diet, which incorporates EVOO, is an effective approach to preventing metabolic syndrome. This condition is linked to several pathologies, including hypertension, insulin resistance, abdominal obesity, and elevated uric acid levels. Recognizing its health benefits, the Mediterranean diet was inscribed as Intangible Cultural Heritage of Humanity by UNESCO in Nairobi, Kenya, on November 16, 2010 (Trichopoulou, 2021; UNESCO, 2010, ITH/10/5.COM/CONF.202/6 - p. 52).

Within the Mediterranean diet, EVOO stands out for its high content of monounsaturated fatty acids and its abundance of natural antioxidants, including tocopherols (vitamin E) and phenolic compounds such as hydroxytyrosol, tyrosol, and oleuropein. These compounds confer superior antioxidant properties to EVOO, such as preventing LDL cholesterol, oxidation and the neutralizing free radicals (e.g., Francisco

et al., 2019). These effects are notably more potent than those of synthetic antioxidants or vitamins like C and E (Medeiros & Hampton, 2020).

The health benefits of regular EVOO consumption extend far beyond these findings. Numerous studies have identified a protective association between olive oil consumption and lowering the risk of cancer, particularly breast, colorectal, and prostate cancers. The bioactive polyphenols in EVOO play a pivotal role in preventing cancer development and progression (e.g., González-Rodríguez et al., 2023; Markellos et al., 2022). Moreover, EVOO has been shown to aid in the prevention or resolution of liver damage, protect against age-related cognitive decline, and reduce the risk of Alzheimer's disease (Snodgrass & Corwin, 1988) by enhancing the gut microbiota, thereby conferring benefits to cardio metabolic and cognitive health through the gut-brain axis (e.g., Millman et al., 2021; Tzekaki et al., 2021; Valls-Pedret et al., 2015). Xia et al. (2022) discovered that EVOO consumption was linked to a notable reduction in the likelihood of developing cardiovascular disease and mortality (see also, García & Claros, 2023). They ascribe this to the anti-inflammatory and antioxidant properties of EVOO, as well as its high content of monounsaturated fatty acids and phenolic compounds. A higher intake of EVOO has been associated with a reduced risk of developing type 2 diabetes (Martínez-González et al., 2022). This benefit is attributed to EVOO's ability to enhance insulin sensitivity and reduce chronic inflammation. Additionally, García-Gavilán et al. (2018) suggest that EVOO enhances bone health, evidenced by increased bone density and a reduced risk of fractures. These effects are likely due to EVOO's polyphenol content and its ability to facilitate better calcium absorption (see also Flynn et al., 2023).

Given the scientific evidence supporting the health benefits of EVOO in preventing and treating cardiovascular, metabolic, and neurodegenerative diseases, as well as its potent antioxidant and anti-inflammatory properties, promoting its

consumption could significantly enhance public health. Increased EVOO consumption would likely reduce the incidence of chronic diseases, improve the overall quality of life for the population, and alleviate the burden on healthcare systems. However, the volatile compounds and phenols in EVOO, which contribute to its health benefits, are associated with bitter, pungent, and astringent flavors. These are often perceived negatively by consumers, who associate them with toxicity, whereas experts tend to appreciate these qualities (Cavallo et al., 2018; Delgado & Guinard, 2011; Valli et al., 2014). Consequently, the bitterness and spiciness, considered positive attributes by experts, pose a significant challenge to promoting EVOO's acceptance as a functional food among novice consumers (Barbieri et al., 2015; Caracciolo et al., 2020; Cavallo et al., 2019; Clicerì et al., 2021; Delgado & Guinard, 2012; Salazar-Ordóñez et al., 2018; Santosa et al., 2013; Zamuz et al., 2020). In this context, labeling a food as healthy or nutraceutical does not necessarily ensure its acceptance by consumers (Casini et al., 2014).

This PhD dissertation aims to evaluate the sensory perception EVOO from the consumer's perspective, with the ultimate goal of identifying processes that could promote its consumption as a nutraceutical food among the general public. The first section explores how the perception of EVOO attributes varies depending on whether the consumer resides in a producer area, offering insights into bridging the gap between expert and consumer evaluations through tailored marketing strategies. The second section presents two experimental studies that introduce methodological innovations in the sensory evaluation of EVOO by regular consumers, enabling the dissociation of sensory and decision-making processes within an EVOO tasting panel.

A similar observation can be made when considering recent advancements in sensory and consumer science and Psychophysics. These advancements demonstrate a congruence with the trajectory of this doctoral thesis. According to Jaeger et al. (2025),

sensory and consumer science is defined as an interdisciplinary field that integrates sensory research with the analysis of consumer behavior. The objective of this field is to examine how products are perceived through the senses and how consumers respond to them. To this end, it employs a variety of research methods and approaches to understand the interaction between sensory experience and consumer decisions. As we have previously stated (Ramos-Álvarez et al., 2013), the study of the dynamics of these two processes in sensory evaluation could be optimized by the application of contemporary psychophysical theories such as Signal Detection Theory (SDT).

Meiselman et al. (2022) review nearly 100 years of advances in sensory and consumer science, discuss the evolution of sensory methodologies, the integration of consumer psychology, and the impact of new technologies on food preference research. The authors also discuss current issues, including the need for more holistic approaches, individual variability in sensory perception, and sustainability in the food industry. They conclude by underscoring the importance of continuing to innovate in interdisciplinary methods and approaches to improve understanding of consumer behavior and product quality. In contrast, Lee et al. (2024) used SDT to assess consumer perceptions of food sensory attributes, as well as to support product optimization, consumer acceptance, and market impact. In a similar vein, Choi et al. (2023) emphasize the critical role of product familiarity in ensuring the accuracy of SDT analysis. In the following section, the theoretical and methodological foundations supporting the studies derived from this thesis will be presented. Subsequently, a review will be provided that offers a general framework of how consumer preferences have evolved from perception of attributes and their interaction with product familiarity. These precepts are then taken to the experimental phase where two empirical studies are carried out in which a consumer panel is created to evaluate pure oils, focusing on their subtle attributes, and then contrast it

with the evaluation made by experts, generating a bridge between sensory and consumer science and SDT.

2.1. Sensory evaluation of EVOO

To assess food quality—specifically in the case of EVOO—highly specialized tasting panels conduct sensory analysis. Sensory analysis is defined as "the method for measuring, analyzing, and interpreting human responses perceived by the senses" (Stone and Sidel, 2004). This method evaluates the sensations inherent in food both qualitatively and quantitatively, describing its attributes and organoleptic characteristics. To reduce errors or biases, sensory analysis is carried out by specialized panels (Martin-Guerrero et al., 2014).

For EVOO, the International Olive Oil Council (IOC) defines the protocols for sensory analysis, specifying the oil varieties, positive attributes, and defects to be assessed. The organoleptic properties of EVOO include physical characteristics such as taste, smell, texture, and color, along with positive attributes like fruity, bitter, and spicy flavors, and potential defects such as musty, metallic, or rancid notes. These evaluations establish quality standards, enabling the classification of oils into categories such as lampante, olive, virgin, or extra virgin (IOC, 2018, 2023).

The sensory analysis of EVOO is inherently a psychological process. Tasters use their senses as tools to assess and evaluate the food's characteristics, leveraging their ability to discriminate between compounds or elements based on attributes or organoleptic properties. The scientific field bridging psychology and food science in this context is psychophysics, which studies the relationship between physical stimuli and their subjective perception (Allan and Siegel, 2002; Macmillan, 1993; Ramos-Álvarez et al., 2013). Sensory analysis, as a psychophysical process, allows for the determination of

EVOO quality, where the taster's senses serve as precise measuring instruments (Paredes-Olay et al., 2010).

2.1.1. Classical psychophysics as the basis of tasting

Classical psychophysics is predicated on the concept of threshold, which can be conceptualized as a dichotomy between sensation and no sensation. The absolute threshold represents the moment at which the individual becomes aware of the presence of a stimulus, whereas the differential threshold delineates the extent to which a stimulus must increase for that change to be detected. In probabilistic terms, the first seeks a hit rate of 50%, while the second seeks a hit rate of 75% (Fechner, 1966; Macmillan, 1993; Martin-Guerrero et al., 2014; McNicol, 2005). A variety of tests, including yes-no tasks, same-different tasks, triangular tests, paired tests, duo-trio tests, and forced-choice tests, are based on classical psychophysics, particularly the theories of thresholds. These theories posit that sensations depend on the intensity of stimuli, such that the stimulus is perceived only when it exceeds the absolute threshold (Paredes-Olay et al., 2010).

The International Olive Council (IOC, 2023) has developed a procedure aligned with ISO standards for the selection, training, and evaluation of virgin olive oil tasters, grounded in the principles of classical psychophysics. Classical psychophysics is founded on the concept of thresholds, which distinguish between the presence and absence of sensation. The absolute threshold refers to the point at which an individual first becomes aware of a stimulus, while the differential threshold defines the degree of change in a stimulus required for the individual to detect that change. In probabilistic terms, the absolute threshold corresponds to a 50% hit rate, and the differential threshold corresponds to a 75% hit rate (Fechner, 1966; Martin-Guerrero et al., 2014; McNicol, 2005).

Various sensory evaluation tests are derived from classical psychophysics and its threshold theories, including yes-no tasks, same-different tasks, triangle tests, paired comparison tests, duo-trio tests, and forced-choice tests. These theories propose that sensations are dependent on stimulus intensity, with stimuli being perceived only when their intensity exceeds the absolute threshold (Paredes-Olay et al., 2010).

The IOC (2023) procedure involves an initial screening through interviews to evaluate candidates' motivation and descriptive abilities, followed by sensory tests to establish detection thresholds. The selection phase identifies the most suitable candidates based on their ability to discriminate specific attributes. Selected candidates undergo comprehensive training, covering the theoretical and practical aspects of oil characteristics, defect and attribute recognition, and the use of technical terminology. Additionally, panel members are continuously monitored, and if their performance declines, they undergo retraining before reinstatement. This rigorous process ensures high quality and accuracy in sensory evaluations.

Classical psychophysics and threshold theory have notable limitations, as they do not effectively separate the measurement of sensory attributes from other factors related to the stimulus or the evaluator's abilities (Hautus et al., 2021; Martin-Guerrero et al., 2014). While these methodologies adhere to rigorous standards and incorporate training to address certain challenges, they remain primarily focused on sensory performance. Consequently, they overlook psychological attributes of the evaluator, such as expectations, beliefs, and motivation, which can introduce bias. This issue is particularly pronounced among inexperienced tasters, although it can also affect experts (Paredes-Olay et al., 2010).

2.1.2. Contemporary psychophysics applied to tasting: SDT

Contemporary psychophysics posits that sensations are best conceptualized as a continuum, contingent upon the properties of the stimulus (Lawless & Heymann, 1988), the sensitivity of the perceiver, and a range of subjective factors, including motivations, beliefs, and expectations (Schifferstein, 1996). The most prominent model of modern psychophysics is the Signal Detection Theory (SDT).

The SDT has been applied in a variety of fields, including engineering and technology, particularly in the field of telecommunications. In radar and sonar, SDT improves detection accuracy by discriminating between authentic signals (objects) and ambient noise (Richards, 2005). In forensic science, SDT is used to distinguish signals (e.g., relevant evidence) from noise (i.e., irrelevant information). In addition, SDT is used to assess the likelihood of evidence being true versus the possibility of error, to quantify decision errors (e.g., false positives or negatives), and to adjust decision thresholds according to the circumstances of the case (Phillips et al., 2001). In medicine, particularly radiology, it has been used to improve diagnostic accuracy by facilitating the differentiation between positive signals associated with specific diseases and noise, taking into account normal variation (Swets, 1996). In the context of disease detection, such as breast cancer, it has been used to distinguish false positives from negatives (Zweig & Campbell, 1993); in psychology, to distinguish stimuli from cognitive processes in research focused on attention, memory, and decision making (Hautus et al., 2021).

The SDT in sensory evaluation allows for the measurement of the sensitivity of the perceiver and the consideration of biases in their responses (Hautus et al., 2021; Solovey et al., 2014), although it has been applied sparingly to the context of olive oil evaluation. As we have previously stated, this approach enables the calculation of differentiated sensory and decisional indexes, thereby facilitating a more comprehensive

understanding of the tasting process in general and EVOO tasting in particular (Moreno-Fernández et al., 2012).

Table I.1

Confusion Matrix in a Detection Task

		Stimulus	
		Signal (S)	Noise(N)
Response	“Yes, Signal present”	(H: Hits)	(FA: False Alarms)
	“No, Signal absent”	(M: Misses)	(CR: Correct Rejections)
		Signal Trials	Noise Trials
		$P(SN) = H/H+M$	$P(N) = FA/FA+CR$

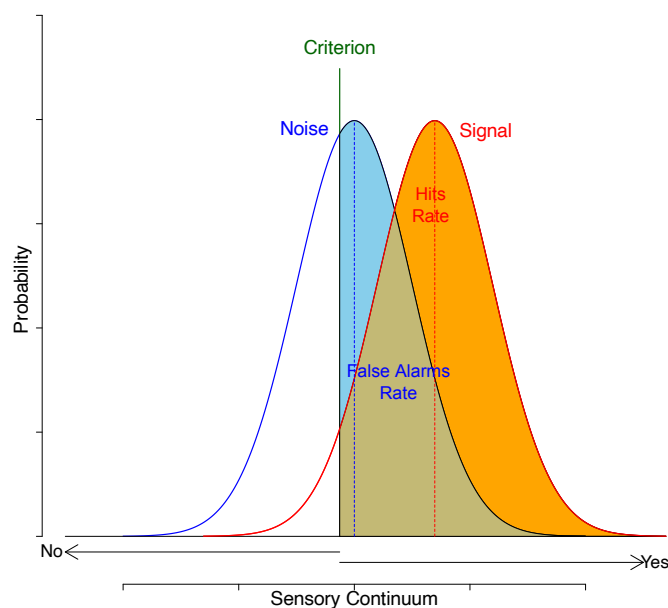
Note. Adapted from Martin-Guerrero et al. (2014).

SDT is designed to assess an individual's perceptual and cognitive judgment capabilities, specifically their sensitivity to stimuli, independent of response biases. To achieve this, two types of stimuli are used: signals (target stimuli) and noise (distractor stimuli). Participants are tasked with determining the presence or absence of a specific attribute or stimulus. This requires sensory discrimination between stimuli, enabling them to respond accordingly. In a classic taste perception task with binary response options (yes/no), participants must determine the presence or absence of a target stimulus (signal). Trials involve two sample types: signal (Signal+Noise or S) and noise (N). Four possible outcomes arise: Hit (correct positive response to signal), Correct Rejection (correct negative response to noise), Miss (incorrect negative response to signal), and False Alarm (incorrect positive response to noise) (Hautus et al., 2021). Performance is typically assessed by calculating hit and false alarm rates (Green & Swets, 1966; Hautus et al.,

2021; Swets, 1996). While correct rejections and failures can also be considered, the standard approach focuses on hit and false alarm rates. Table I.1 illustrates the confusion matrix used in SDT-based detection tasks, as described by Martin-Guerrero et al. (2014).

Figure I.1

Sensory Continuum and Probability Associated with Signal and Noise



Note. The Y-axis depicts the probability of signal and noise, whereas the X-axis illustrates the response biases (conservative, lenient, neutral) and their correlation with the aforementioned probabilities.

SDT depicts a sensory continuum with two overlapping normal distributions representing the signal and noise (see Figure I.1). The Y-axis indicates the probability of signal or noise presentation, while the X-axis shows decision criteria ranging from conservative to lenient. When stimuli are distinct, the dominant one is easily perceived. However, discrimination becomes challenging when stimuli are similar. A perceiver

response depends on their assumed decision criterion: a conservative criterion leads to more "no" responses, a lenient criterion to more "yes" responses, and a neutral criterion to equal responses. Experimental manipulation of expectations, instructions, or payoff matrices can influence the decision criterion. The sensory criterion, influenced by factors like stimulus contrast and the taster's physiological state, tends to remain stable under consistent conditions (Hautus et al., 2021; Martin-Guerrero, 2015).

According to the principles of SDT, O'Mahony and Hautus (2008) introduced the Receiver Operating Characteristic (ROC) curve as a graphical tool. This instrument facilitates the analysis of cognitive strategies used by experimental subjects, the assessment of tasters' performance and response biases (Paredes-Olay et al., 2010), and the investigation of the underlying mechanisms that shape sensory perception. Apart from SDT, there are other models that can be applied to the sensory context such as the one referred to by Angulo and O'Mahony (2009) who report how the model developed by Thurstone allows observing the decision-making process when the differences between the stimuli are subtle, in this sense the perception of the stimuli can be considered from the probability, evidencing the differences detected between the stimuli.

As SDT allows for a separate evaluation of sensory and decision processes, it appears to have potential applications in tasting evaluations, particularly when conducted with untrained consumers, as will be the case in the studies included in this dissertation.

Paredes-Olay et al. (2010) conducted a seminal study exploring the potential application of SDT to the organoleptic evaluation of EVOO. The study included two experiments with novice tasters. Experiment 1a employed the same-different test, rooted in classical psychophysics, to select the concentrations of EVOO in sunflower oil that would be used in Experiment 1b (1.6%, 3.2%, and 12.8%). In Experiment 1b, SDT was

applied to calculate sensory and decision indices, which were subsequently plotted on a receiver operating characteristic (ROC) graph. Participants were tasked with indicating whether the sample contained olive oil.

In both experiments, the proportion of correct answers increased with higher concentrations of olive oil, demonstrating enhanced sensitivity at greater stimulus intensities. Experiment 1b further complemented this finding by providing a decision criterion index, which remained consistent across varying levels of olive oil concentration. This consistency highlighted the ability of SDT to disentangle sensory sensitivity from decision-making processes in the context of tasting evaluations. Martín-Guerrero et al. (2016) found equivalent results in a task in which basic tastes (salt concentration) were manipulated.

In a follow-up study, Moreno-Fernández et al. (2012) compared the results of two types of training methods to explore how experience and training could lead to above-average performance. Specifically, they evaluated whether the easy-to-hard effect could be obtained within the context of tasting. This effect occurs when learning a difficult discrimination is facilitated by gradually increasing the difficulty of the discrimination compared to a group trained directly with the difficult discrimination. Progressive training led to significantly better performance than training conducted with the difficult discrimination from the start. However, participants who received progressive training also exhibited a conservative bias, which would have gone unnoticed without the use of SDT methodology.

2.1.3. Methodological constraints of the use of SDT in the tasting context: DDAT

The studies briefly summarized above confirm both the usefulness and the necessity of applying SDT methodology in the context of training. However, they also present methodological challenges. The limited number of trials employed in tasting tasks, designed to prevent sensory saturation, makes it unlikely to meet the parametric requirements of SDT, such as normality of data and equivalent variances (e.g., Wickens, 2002).

This constraint has been addressed by adopting nonparametric alternatives to compute sensory and decision indexes, namely A' (sensitivity index) and B' (decision index) (see Stanislaw & Todorov, 1999). Building on this approach, Ramos-Álvarez et al. (2013) compared various nonparametric and parametric indices, as well as different statistical approaches. Their findings indicated that the nonparametric sensitivity index A' (Grier, 1971) and the bias index B'_D (Donaldson, 1992), along with robust analysis of variance, were conceptually and methodologically the most suitable for separately measuring sensory and decision processes in the context of olive oil tasting.

A fundamental issue when using SDT is ensuring that the chosen indices allow for a clear dissociation between sensory and decision processes (Hautus et al., 2021). To address this, Ramos-Álvarez et al. (2013) developed the Double Dissociation Additive Test (DDAT), based on Sternberg's (1998) methodology. In DDAT, at least one factor from each process (sensory and decision) is manipulated within a multifactorial design, enabling the evaluation of whether changes in sensory performance influence decision criteria and vice versa. Using the DDAT methodology, Ramos-Álvarez et al. (2013) found that for untrained consumers, changes in olive oil concentration affected sensory processes without impacting decision processes. Conversely, instructions prompting

participants to adopt conservative or lenient response strategies influenced decision-making without altering sensory performance.

Martín-Guerrero et al. (2016) applied DDAT to examine the impact of variations in signal intensity and response incentives on sensitivity and decision-making during the evaluation of basic flavors. Signal intensity was manipulated by altering the salt concentration in a sour compound (0.07%, 0.1%, and 0.75%), while response incentives were modified using payoff matrices designed to encourage lenient, conservative, or neutral response strategies. Signal intensity manipulations affected only the sensory process, whereas payoff manipulations influenced only the decision index, thus extending the findings of Ramos-Álvarez et al. (2013) to include basic flavor evaluations and response incentives.

In a recent study, Ramos-Álvarez et al. (2024) investigated decision-making processes in a tasting task involving mixtures of salty and sour basic tastes by inducing neutral, conservative, or lenient expectations through variations in signal-to-noise base rates (neutral: 12 SN and 12 N; conservative: 4 SN and 20 N; lenient: 20 SN and 4 N). They also manipulated the presence or absence of feedback, as well as the intensity of the concentration. Participants' ability to discriminate improved with increasing salt concentrations, independent of any induced bias or the presence of feedback. However, the inclusion of feedback resulted in an overall enhancement of sensitivity. Both the base rates of signal-noise stimuli and the presence of feedback significantly impacted the decision-making process. Specifically, when feedback was provided, participants' detection judgments corresponded more closely with the actual base rates of signal and noise stimuli. Conversely, in the absence of feedback, the relationship between base rates and response bias was inverted.

These methodological advances enhance the accuracy and reliability of evaluations while overcoming the inherent limitations posed by the tasting process.

2.2. Goals of the dissertation

Despite significant advancements in understanding the sensory and decision-making processes involved in EVOO tasting, several unresolved issues remain that merit further investigation. These challenges are particularly relevant in the context of promoting EVOO as a functional food and enhancing its acceptance among consumers. Consequently, they will shape the general and specific objectives to be addressed in this dissertation.

General goal

The primary objective of this dissertation is to enhance understanding of the factors influencing consumer preferences and decision-making regarding EVOO choices. It aims to develop conceptual and methodological tools to bridge the gap between expert evaluations and consumer perceptions. The ultimate aim is to foster greater acceptance and consumption of EVOO as a functional food, given its significant potential benefits for public health.

Specific goals and hypotheses

Specific goal 1. The role of familiarity in EVOO perception. Promoting EVOO as a functional food relies heavily on consumer preferences. This issue has been addressed in

numerous studies and systematic reviews evaluating the importance of various intrinsic and extrinsic attributes of olive oil in consumer purchasing decisions (e.g., Cavallo et al., 2019; Cicerale et al., 2016; Del Giudice et al., 2015; Erraach et al., 2021; Fernandes et al., 2018; Jiménez-Guerrero et al., 2012). Of particular interest are intrinsic attributes such as bitterness and pungency, which are positively valued by expert tasters but often rejected by consumers, as these attributes are associated with unfavorable taste perceptions (e.g., Caracciolo et al., 2020; Delgado & Guinard, 2012; Predieri et al., 2013).

One factor that seems to influence consumer perceptions, leading either to alignment or divergence from expert evaluations, is familiarity with EVOO consumption and culture (e.g., Delgado & Guinard, 2011). Unfortunately, the role of familiarity in shaping consumer perceptions is inconsistently defined and often underreported in studies, making it difficult to determine its precise influence.

The first specific goal of this dissertation is to evaluate how familiarity with EVOO, influenced by cultural and geographical factors, affects the perception and evaluation of its sensory attributes. Specifically, the research will investigate whether the country of residence serves as a valid proxy for evaluating the interaction between familiarity and consumer preferences for olive oil attributes.

This goal will be pursued through a systematic review of consumer perceptions of intrinsic and extrinsic EVOO attributes, under the hypothesis that consumers from EVOO-producing regions will exhibit greater tolerance for and preference toward bitterness and pungency compared to consumers from non-producing regions, due to higher familiarity and exposure.

Specific goal 2. Dynamics of sensory and decision-making processes in EVOO tasting conducted by a consumers panel. As demonstrated in the introductory section,

our research team has conducted numerous studies applying Signal Detection Theory (SDT) to the sensory analysis of EVOO. These studies have provided valuable methodological and practical insights into the dynamics of sensory and decision-making processes in tasting contexts (Martín-Guerrero et al., 2014; Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010; Ramos-Álvarez et al., 2013). However, a limitation of these studies is that they were conducted either with basic flavors (Martín-Guerrero et al., 2015, 2016; Ramos-Álvarez et al., 2024) or by detecting the presence or absence of oil in other substances, such as sunflower oil or alimentary paraffin (Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010). While these methodologies are valid, the applicability of SDT to the assessment of natural EVOO—characterized by its complex composition—remains unexplored.

The second goal of this dissertation is to validate SDT and the Double Dissociation Additivity Test (DDAT) as tools to independently assess the sensory and decision-making processes of untrained consumers when differences between signal and noise are based on subtle attributes of natural oils, rather than on the presence or absence of EVOO.

This objective will be addressed through an experimental study designed to test the hypothesis that SDT-based evaluation methodologies, such as DDAT, can effectively evaluate the independence or interaction of sensory and decision-making processes in the evaluation of oils based on their sensory attributes, rather than their mere presence or absence.

Specific goal 3. Experts and consumers. Although research has been conducted comparing tasters (experts and novices), sensory analysis is typically performed with

experts, while tasting, surveys, focus groups, or interviews are conducted with consumers (Caracciolo et al., 2020, Casini et al., 2014; Dekhili et al., 2011; El Riachy et al., 2018; Hassine et al., 2014; 2015; Vázquez-Araújo et al., 2015). Some studies have included sensory analysis sessions involving both experts and consumers (Delgado et al., 2013; Predieri et al., 2013; Valli et al., 2014); however, a meaningful bridge between the two has yet to be established. This disconnect arises because the perception of EVOO is influenced by whether the evaluator is a consumer or a highly trained taster. Evidence suggests that both consumers and experts are influenced by subjective factors such as prior experience, expectations, and motivation., yet these factors have not been thoroughly evaluated. SDT and DDAT offer promising methodological approaches to disentangle sensory and subjective influences in the sensory evaluation of olive oil.

The third goal of this dissertation was to compare the assessments of regular EVOO consumers and experts. Building upon on the research conducted to reach goal two above (Arbeláez-Mejía et al., 2025b, this study replicated those findings with panels of Italian experts and regular consumers evaluating different EVOOs. The aim was to determine whether the interaction between sensitivity and decision processes remains consistent under these conditions, as well as establishing whether the differences between consumers and experts in sensory evaluation is a matter of degree or quality.

Given that the review in goal one found that the appreciation of bitter and spicy flavors tend to increase with familiarity, and the findings by Dos Santos et al. (2023) demonstrating that basic EVOO tasting training enables novice consumers to approach expert evaluations, we expected that differences between experts and familiar consumers would be limited to sensitivity levels rather than evaluation quality. Regarding the independence or interaction between sensory and decision processes, the hypotheses remained open. The study conducted in goal two found that interaction between these

processes might occur in regular consumers. However, previous research on perception (e.g., Howe et al., 1993; Huang & Ferreira, 2020; Swets, 1996; Wright & Skagerberg, 2009) and tasting evaluations involving basic flavors (Ramos-Álvarez et al., 2025) or the detection of olive oil in dilutions (Ramos-Álvarez et al., 2013) suggests that sensory and decision processes are generally independent.

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3. Specific Goal 1. The Role of Familiarity in EVOO Perception

Interaction Between Attributes and Familiarity in Consumer Preferences for Olive Oil using the Country of Residence as a Proxy for Familiarity

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Keyword List (portal):	
Free-text Keywords (portal):	
Keywords:	Consumer preferences, extrinsic and intrinsic attributes, familiarity, Olive Oil
Search Terms:	consumer behavior, nutraceuticals, functional food

OLIVE OIL FAMILIARITY AND CONSUMER PREFERENCES 1

1 **Interaction Between Attributes and Familiarity in Consumer Preferences for Olive**
2 **Oil using the Country of Residence as a Proxy for Familiarity**

3

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15 SHORT TITLE: OLIVE OIL FAMILIARITY AND CONSUMER PREFERENCES

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OLIVE OIL FAMILIARITY AND CONSUMER PREFERENCES 2

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For Peer Review

OLIVE OIL FAMILIARITY AND CONSUMER PREFERENCES 4

58

Abstract

59

60 Consumer perception of olive oil attributes appears to be influenced by their familiarity
61 with olive oil culture. However, familiarity is often either unreported or defined
62 inconsistently across studies. This review found that residing in a producer country can
63 serve as a valid proxy for familiarity in order to assess the interaction between
64 familiarity and the preferred attributes of olive oil among regular consumers. It suggests
65 that providing consumers with information that links the bitter and pungent flavors to
66 the health benefits of Extra Virgin Olive Oil (EVOO) consumption will be a key
67 strategy in overcoming the challenge of promoting its consumption in non-producer
68 regions.

69

70 **Key-words:** Consumer preferences, extrinsic and intrinsic attributes, familiarity, Olive
71 Oil

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74 1. Introduction

75 The Mediterranean diet, recognized as an intangible cultural heritage by UNESCO in
76 2010 due to its health benefits, features Extra Virgin Olive Oil (EVOO) as a key
77 component (Trichopoulou, 2021). EVOO, a functional food (e.g., Quiles et al., 2006),
78 offers numerous health benefits, including cardioprotective effects, improved lipid
79 profiles and blood pressure, and reduced cardiovascular events (González et al., 2023).
80 The chlorophyll and carotenoids that give EVOO its color have been associated with
81 antioxidant activity and the prevention of eye disorders (Moyano et al., 2010).
82 Similarly, oleocanthal in EVOO possesses anti-inflammatory and antioxidant
83 properties, helping to prevent aging-related diseases (Francisco et al., 2019). It also
84 improves gut microbiota, contributing to cardiometabolic and cognitive health (Millman
85 et al., 2021). Compared to other fats, EVOO lowers LDL cholesterol and improves
86 glycemic control. Its polyphenol content provides protective effects on general human
87 health (Flynn et al, 2023). These characteristics make promoting EVOO consumption
88 desirable for public health.

89 EVOO's popularity is growing due to its health benefits and culinary value
90 (Cavallo et al., 2018; Menapace et al., 2011). However, its bitter, pungent, and
91 astringent taste, caused by volatile compounds and phenols, can be challenging to
92 promote (e.g., Cicerale et al., 2016). While experts value these flavors (Rébufa et al.,
93 2021), many consumers dislike them due to their association with toxic substances (e.g.,
94 Delgado & Guinard, 2011; Predieri et al., 2013). This highlights the need to explore
95 factors influencing EVOO's acceptance as a functional food, especially considering that
96 not all consumers prioritize health over taste (Verbeke, 2006).

97 Recent reviews have explored consumer preferences for extra virgin olive oil
98 (EVOO) and the attributes influencing these preferences, such as taste, origin, and

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99 labeling. Those reviews show that consumers generally avoid bitter tastes unless
100 contextual factors or educational efforts highlight their benefits (Cavallo et al., 2019),
101 while sweet, floral, and fruity flavors are the most popular (Cicerale et al., 2016). The
102 origin of EVOO strongly affects consumer willingness to pay (WTP) and is often linked
103 to quality, taste, and environmental benefits (Erraach et al., 2021; Del Giudice et al.,
104 2015). Familiarity with local products and cultural knowledge of EVOO enhances
105 perception and trust in its quality (Fernandes et al., 2018; Jiménez-Guerrero et al.,
106 2012), although attributes like pungency and bitterness often require consumer
107 education to be fully appreciated (Tuorila et al., 2014). Preferences for national products
108 reflect ethnocentric tendencies (Thøgersen, 2023), and organic or PGI-certified EVOO
109 is valued for its environmental friendliness and higher WTP (Latino et al., 2022). While
110 these factors are well-documented, the role of familiarity with EVOO in shaping
111 consumer perceptions remains underexplored, a gap that this review seeks to address
112 through a systematic analysis.

113 Defining familiarity with olive oil is challenging. Familiarity has been defined
114 as living in a producing region, residing in countries that follow a Mediterranean diet,
115 being a regular consumer, and possessing knowledge of its properties, certifications,
116 and attributes making it difficult to disentangle its role in shaping consumers'
117 preferences. To address this problem, in this review we considered the region where a
118 study is conducted as a proxy for familiarity. Thus, the goal of this review was to
119 evaluate whether a consumer's country of residence being a producer country can be
120 used as a proxy to assess the potential interaction between familiarity and consumers'
121 evaluation of EVOO attributes. We expected this approach to detect differences in the
122 value consumers assign to various olive oil attributes, thereby guiding the design of
123 promotion campaigns for EVOO consumption in non-producer countries.

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124 **2. Method**

125 This systematic review was conducted using the PRISMA 2020 protocol (Page, et al.,
126 2021a, 2021b) through the process described in Table 1. The Web of Science and
127 Scopus databases were searched using the keywords “Consumer AND Preferences
128 AND Olive Oil.” The search covered publications over the 14 years between January
129 2010 to December 2024 to ensure a balanced review period and topical relevance, as
130 consumer preferences can evolve over time. The year 2010 was chosen as the starting
131 point because the Mediterranean diet, with Olive Oil (OO) as one of its main
132 components, was declared an Intangible Cultural Heritage of Humanity on November
133 16, 2010, fostering research from that date onward (Latino et al., 2022). Papers
134 employing a scientific methodology or published in Journal Citation Reports journals,
135 book chapters, meta-analyses, and systematic or narrative reviews were considered.
136 Articles that addressed OO consumer preferences from the perspective of their intrinsic
137 and extrinsic attributes were included.

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Insert Table 1 about here

Figure 1 presents the PRISMA flowchart followed in this review. In the
identification phase, a total of 315 publications were found in Web of Science and 276
in Scopus. After excluding 366 publications from the preliminary selection phase, 225
publications remained. In the screening phase, 30 duplicates were removed, and 57
publications were excluded after reviewing the abstracts and determining that they did
not align with the topic of interest. Additionally, 9 publications were excluded due to
methodological limitations or nor directly addressing consumer preferences for olive
oil. Finally, 129 publications were selected for this review. A general description of the

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149 selected articles can be access at the following link:

150 [<https://data.mendeley.com/datasets/ftsx8cfnmf/1>]. The supplementary table

151 incorporates an overview of the methodology, key findings, and bias analyses of all the

152 selected studies.

153

154 Insert Figure 1 about here

155

156 **3. Descriptive overview of the selected papers in this systematic review**

157 In general, the interest in consumer perception of OO has increased in the years

158 evaluated (from 2010 to 2024). The biennia from 2018 to 2021 were especially

159 productive as included 45.1% of the publications selected for this review. Italy and

160 Spain, as the main producers worldwide, also concentrate most of the publications.

161 Comparative studies (Croatia, Germany, and UK; Denmark, France, Tunisia, and USA;

162 Chile, UK and Spain; Netherlands and Italy; Tunisia and France; Italy and Denmark;

163 USA and Spain), and other countries where only one publication on consumer

164 preferences was found (Uruguay, Argentina, Poland, Canada, Portugal, Japan, Finland,

165 France, Switzerland and Australia) were also included in the review.

166 A general assessment of biases was performed using the RoB-2 Risk of Bias-2

167 Scale (Cochrane Methods, 2019), which includes: 1) Selection biases (Random

168 sequence generation and allocation concealment), 2) blinding of participants and

169 personnel or performance bias, 3) blinding of outcome assessment or detection bias, 4)

170 incomplete outcome data or attrition bias, 5) selective reporting or reporting bias, and 6)

171 other identified bias. The biases in the selected publications are shown in Figure 2. Low

172 levels of bias prevailed in all categories except for random sequence and attrition biases.

173 The medium and low values in the random sequence bias are related to the mixed

OLIVE OIL FAMILIARITY AND CONSUMER PREFERENCES 9

174 methodologies that combine quantitative and qualitative approaches where random
175 sequence generation does not apply. A similar explanation can be given for the attrition
176 bias, as research into the preferences of OO consumers using qualitative techniques
177 such as focus groups does not take this information into account.

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179 Insert Figure 2 about here

180

181 The General assessment reflects the quality of the publication and it is inversely
182 related to bias. Most of the selected publications are classified as of high (n=67) and
183 medium (n=57) quality. Five studies with a low general assessment were included
184 because they were qualitative studies, survey or narrative reviews that provided
185 information consistent with the goal of this review such as perception of bitterness,
186 intrinsic and extrinsic attributes, stated preferences, sustainability or eco-labels, multi-
187 attribute evaluation, as well as techniques to study preferences in the United States and
188 how the sensory perception of attributes is carried out. Although they do not meet the
189 requirements of the RoB-2 Risk of Bias-2 scale, this scale was designed for
190 experimental studies and is not suitable for assessing the quality of narrative reviews
191 and some qualitative studies.

192

193 4. The Role of familiarity in consumer preferences

194 Santosa et al. (2010) noted that familiarity with olive oil can bias consumer preference
195 studies. Familiarity differs from ethnocentrism, which involves a preference for local
196 products often tied to nationalism. While familiarity and ethnocentrism can be
197 synergistic, as in Italy and Spain, this isn't always the case. For example, in France,
198 national olive oil is used for cooking, but Italian EVOO is preferred for dressing (e.g.,

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199 Erraach & Sayadi, 2020). However, familiarity with OO is not generally reported in
200 most studies. Only 16 out of the 129 papers selected in this review took familiarity into
201 account, and they considered it from different perspectives: knowledge of its healthy
202 properties (Cavallo & Piqueras-Fiszman, 2017), acceptance of spicy flavour (Cavallo et
203 al., 2019), daily use (Contini et al., 2015), closeness between expert and consumer
204 assessments (Fernandes et al., 2018), knowledge certifications (e.g., Dekhili et al.,
205 2011), familiarity with culture and religion (Kitagawa et al., 2020), product knowledge
206 and purchase frequency (e.g., Sgroi et al., 2024).

207 To address the scarcity of reports on the familiarity of the sample, in this review,
208 we approached the issue indirectly by considering whether the country where the study
209 was conducted is a producer of olive oil or not. Three levels of familiarity were
210 established based on recent reports from the IOC on global production (IOC, 2021a,
211 2021b, 2024):

- 212 ○ *High familiarity*: Consumers living in an olive oil-producing country with a
213 Mediterranean diet, such as Italy, Spain, Greece, Portugal, France, Turkey,
214 Tunisia, Croatia, Albania, Jordan, and Lebanon.
- 215 ○ *Medium familiarity*: Consumers living in producing countries that do not follow
216 the Mediterranean diet, such as USA, Chile, Argentina, Uruguay, and Brazil, as
217 well as countries with limited olive oil production, such as Australia, Canada,
218 and Japan, which supplement their domestic supply with imports.
- 219 ○ *Low familiarity*: Consumers living in non-producing countries such as the
220 Netherlands, Germany, the UK, Poland, Switzerland, Denmark, and Finland.

221 This classification is somewhat broad, as olive oil production and consumption
222 vary within countries like Italy and Spain. We chose this classification for its
223 comprehensiveness, with exceptions noted. The hypothesis underlying this review was

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224 that operationalizing consumers' familiarity based on whether the country is a producer
225 or not will be sensitive enough to detect differences in how consumers evaluate the
226 various attributes. If this proves accurate, the results of this systematic review could be
227 used to design promotional campaigns tailored to consumers' perceptions in the specific
228 country or region where such campaigns are planned.

229

230 5. Relevance of intrinsic and extrinsic attributes in consumer preferences

231 When a consumer chooses a product, they need information about its characteristics,
232 which they recognize in the form of quality signals referred to as attributes that can be
233 intrinsic or extrinsic (see Bernués et al., 2003; Flandos & Flavian, 2006). Intrinsic
234 attributes are related to the physical aspects of the product, such as colour and flavour.
235 The IOC (2017, 2018) defines intrinsic attributes for sensory analysis of OO as fruity,
236 bitter, and pungent. Extrinsic attributes of EVOO are not part of the physical product
237 but related to the appearance and the information about the product (Cicerale et al.,
238 2016); examples include price, brand, and certifications. Consumers rely on these
239 extrinsic attributes to assess quality and guide their selection process (e.g., Carzedda et
240 al., 2021).

241 This review considers the attributes listed in Table 2. Intrinsic attributes such as
242 smell, viscosity, and transparency were excluded due to the lack of sufficient studies
243 evaluating them. Interacting attributes have been analyzed together, as is the case with
244 bitterness and pungency, which are often contentious between experts and consumers.
245 Similarly, PDO (Protected Designation of Origin) and PGI (Protected Geographical
246 Indication) certifications are analyzed alongside origin, as they are not treated separately
247 in the reviewed studies.

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Insert Table 2 about here

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6. Interaction between attribute evaluation and degree of familiarity

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The health benefits associated with EVOO consumption also deserve special mention. Health benefits could be considered an intrinsic attribute as they are derived from the intrinsic compounds of EVOO (e.g., Cicerale et al., 2016). However, as these benefits are inferred from the information that appears in the label, health benefits have sometimes been regarded as an extrinsic attribute (e.g., De Gennaro et al., 2021). In this context, we will consider them as a mixed attribute that motivates EVOO consumption, rather than classifying them strictly as intrinsic or extrinsic attributes.

The role of intrinsic and extrinsic attributes on consumer preferences is not homogeneous among consumers, and seems to depend on their level of familiarity with the product. For example, novice consumers may rely on extrinsic cues like brand or price. As familiarity increases, consumers seem to develop a more refined appreciation for the nuances of olive oil, leading to a greater focus on intrinsic attributes (see, for instance, Jiménez-Guerrero et al., 2012; Tuorila & Recchia, 2014). The following sections will analyze consumers' evaluation of each attribute using as a proxy of familiarity whether they live in a producing country or not.

269 6.1. Intrinsic Attributes*270 6.1.1. Color*

271 Taking the country of residence as a proxy for familiarity allowed for differentially
272 establishing consumers' preferences based in the color of the oil. Consumers from
273 high-familiarity countries rate color as one of the most important features of OO.
274 Despite some subtle differences, consumers in these regions generally prefer green
275 rather than yellow OO. This preference is evident in southern Italy (Di Vita et al.,
276 2021a; Di Vita, et al., 2020), Albania (Muça et al., 2016), and Spain (though Spanish
277 consumers also appreciate a hint of yellow, Erraach et al., 2014; Sayadi et al., 2017;
278 Zamuz et al., 2020). In Lebanon (Houmani et al., 2024) and in Tunisia (Ben Ali et al.,
279 2023), both green and yellow are valued colors. In contrast, in the central-northern part
280 of Italy, where olive oil production is absent, consumers tend to dislike the intense color
281 associated with high-quality oils (Barbieri et al., 2015). In countries with a medium
282 level of familiarity with olive oil, there is no clear preference for color (Gámbaro et al.,
283 2014). For instance, consumers in Brazil appreciate the color, but there is no clear
284 distinction between green and yellow (Antonialli et al., 2018); in Uruguay, the yellow
285 oil is considered cheaper, of low quality, and with a soft taste, which they associate with
286 seed oils, though intense green oils were also negatively evaluated, considered
287 defective, with a strange, and strong taste (Gámbaro et al., 2014). Finally, no studies
288 were found on color preferences in nonproducer countries.

289

290 6.1.2. Flavor

291 Flavor appears to be the most important attribute for consumers (Dekhili et al., 2011;
292 De Gennaro et al., 2021; Liberatore et al., 2018). Consumers report that flavor is
293 essential at the time of decision-making, regardless of their level of familiarity (Di Vita

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294 et al., 2020; Oplanić et al., 2022; Wang et al., 2013; Wilson et al., 2023). However, the
295 specific flavors valued by consumers vary depending on their level of familiarity with
296 olive oil.

297

298 *Bitter and Pungent.* Bitter and pungent are EVOO's positive attributes for the
299 International Olive Council (IOC, 2018), but their acceptance depends on the familiarity
300 with olive oil. In general, consumers of countries with high familiarity, including Italy,
301 Spain, and Tunisia, valued bitter and pungent flavors positively (Mtimet et al., 2013;
302 Polenzani et al., 2020). However, its acceptance depends on the region within the
303 country where the study is conducted. For example, in southern Italy, consumers prefer
304 medium-pungent flavors, while in the north-central area, they prefer intense flavors and
305 pungency (Carlucci et al., 2023; Di Vita et al., 2021a Rizzo et al., 2020; c.f., Caracciolo
306 et al., 2020; Piccolo et al., 2013). In Tunisia, the results are mixed, with some
307 consumers preferring an intense taste while others favor a more moderate one (Ben Ali
308 et al., 2023). In Spain, pungent and floral were the attributes most valued by consumers,
309 who rejected high bitterness (Salazar-Ordóñez et al., 2018a; Zamuz et al., 2020).
310 Aversion to the strong flavor of EVOO was observed in some consumers in France
311 (Dekhili et al., 2011) and in earlier studies conducted in Lebanon (El Riachy et al.,
312 2018). However, this rejection has disappeared in more recent studies (Shaalán et al.,
313 2024). General rejection towards bitter and pungent flavors is reported in countries with
314 medium familiarity such as the United States, Argentina, Canada, Brazil, and Uruguay.
315 In Argentina and USA, consumers may also show acceptance of some of the defects of
316 lampante oils (Cicerale et al., 2016; Delgado & Guinard, 2011; De Melo et al., 2021;
317 Pardo et al., 2018; Santosa et al., 2013; Vázquez-Araújo et al., 2015; Wang et al., 2013).
318 In Uruguay, consumers evaluated the bitter olive oil negatively, considering it defective

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319 with a strange and strong taste (Gámbaro et al., 2014). Olive oil bitterness is also
320 rejected in Japan (Cavallo et al., 2019; Kitagawa et al., 2020) and Brazil (dos Santos et
321 al., 2023). Finally, consumers reject the pungent and bitter taste of olive oil in countries
322 with low familiarity, such as Switzerland, the Netherlands, and Finland (Cavallo &
323 Piqueras-Fiszman, 2017; Recchia et al., 2012; Valli et al., 2014). In summary, bitter and
324 pungent flavors are considered as negative features by consumers in countries with low
325 and medium familiarity, as well as in non-producing areas of high familiarity countries.
326 To qualify, we have observed a general trend towards greater acceptance of this flavors
327 over time, as demonstrated by cross cultural studies (e.g., Chrysochouet al., 2021;
328 Fakhreddine et al., 2023).

329

330 *Fruitiness*. Fruitiness appears to have a strong hedonic appeal and it is the attribute in
331 which consumers and experts seem to find the greater agreement (Dos Santos et al.,
332 2023). This is supported by various studies, regardless of whether they were conducted
333 in producing countries or not (Peršurić, 2020; Roselli et al., 2020). Consumers have
334 shown a strong preference for fruity flavor in high familiarity countries such as Spain
335 (Sayadi et al., 2017), France (Dekhili et al., 2011; Erraach & Sayadi, 2020), Tunisia
336 (Hassine et al., 2015; Mtimet et al., 2013), and Italy (Di Vita et al. 2013; Di Vita 2021c;
337 Predieri et al. 2013; Rizzo et al., 2020). It has been also reported in countries with
338 medium familiarity such as Brazil (De Melo et al., 2021) and the USA, where
339 consumers show a high acceptance of various fruity notes, including sweet, ripe,
340 almond, herbal, and fruity green (Cicerale et al., 2016; Delgado et al., 2013; Delgado &
341 Guinard, 2011; Santosa et al., 2013; Vázquez-Araújo et al., 2015). The only exception
342 for this pattern comes from the single study conducted in a low familiarity country
343 (Switzerland) which indicates that consumers do not favor fruity green flavors; rather,

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344 they prefer those that evoke a sense of ripeness (Valli et al., 2014). However, as this
345 result comes from a single study, it should be taken with caution until further research is
346 conducted.

347

348 **6.2. Extrinsic Attributes**

349 *6.2.1. Size*

350 Most olive oil containers range in size from 250 to 5000 ml, with the one-litre bottle
351 being the most common, followed by the 500 ml size and containers larger than one
352 litre (Ballco & Gracia, 2020a). Size selection for olive oil depends on its intended use,
353 and does not depend on whether the market is traditional or emerging (Cicerale et al.,
354 2016; Corbeto-Fabón et al., 2018; Delgado et al., 2014; Di Vita et al., 2013; Romo-
355 Muñoz et al., 2017; Roselli et al., 2018; Sillani et al., 2014; Valli et al., 2014).

356

357 *6.2.2. Type of oil*

358 For consumers in high familiarity countries, the classification of EVOO is the primary
359 and most significant attribute they consider. This preference has been observed in
360 Tunisia (Dekhili et al., 2011; Hassine et al., 2015,2014; Perito et al., 2019), Croatia
361 (Čehić et al., 2021; Oplanić et al., 2022), Greece (Wilson et al., 2023), Portugal
362 (Bernabéu et al., 2020), Spain (Yangui et al., 2014, 2016), and Italy (Menozzi, 2014;
363 Tempesta & Vecchiato, 2019). Furthermore, these consumers are willing to spend more
364 for products labelled as extra virgin (Giannoccaro et al., 2019). Consumers in medium
365 familiarity countries like Brazil (Antonialli et al., 2018), Chile (Romo-Muñoz et al.,
366 2018), and Canada (Menapace et al., 2011) also prefer and regularly consume EVOO.
367 In contrast, consumers in the United States tend to consume EVOO only occasionally,

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368 often combining it with other types of oils and fats. Moreover, many USA consumers
369 are unable to distinguish whether an olive oil is EVOO or not (Delgado et al., 2014). In
370 Argentina, consumer preferences vary depending on the region. For example, in the city
371 of Mendoza, consumers frequently prefer and consume EVOO. However, in cities like
372 Buenos Aires, consumers tend to use a mix of olive oil and other types of oils, often
373 preferring olive oil mixtures or lampante olive oil (Pardo et al., 2018). Finally, there is
374 no clear evidence regarding the preferred type of olive oil in countries with low
375 familiarity: In the UK, there is a general preference for regular olive oil over EVOO
376 (Cicerale et al., 2016), while in Denmark consumers view EVOO as the best type of
377 olive oil (Chrysochou et al., 2021). In summary, although there is generally a low level
378 of knowledge about the different varieties of olive oil (Marano-Marcolini et al., 2015),
379 and most consumers are largely unaware of the differences between various oil types
380 (Torres-Ruiz et al., 2012)—to the extent that some may believe refined olive oil is of
381 higher quality and assume all olive oils are equally healthy (Arriaza et al., 2021;
382 Delgado et al., 2013)—consumers in producing countries clearly show a preference for
383 EVOO, while consumers in medium and low familiarity countries may not distinguish
384 between EVOO and other types of olive oil.

385

386 *6.2.3. Packaging*

387 Consumers of olive oil use packaging as a way to infer the product's quality, regardless
388 of whether the country is a producer country or not (Di Vita et al., 2021a, 2021b,
389 2021c). Ballco and Gracia (2020b) found that olive oil presented in glass bottles led to
390 higher Willing To Pay (WPT) by Spaniard consumers than olive oil presented in plastic
391 bottles. In Italy, consumer preferences vary, with some studies indicating a preference
392 for dark containers (Cavallo & Piqueras-Fiszman, 2017), while others favor transparent

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393 bottles (Di Vita et al., 2021a), similar to findings in Lebanon (Shaalán et al., 2024).
394 Additionally, eye-catching packaging generally increases WTP (Di Vita et al., 2021c).
395 In general, packaging features are among the least important attributes for consumers in
396 Italy (De Gennaro et al., 2021; Panico et al., 2014), the USA (Delgado et al., 2014), and
397 Denmark (Chrysochou et al., 2021). The lack of relevance of the packaging suggested
398 by most studies is probably due to the homogeneity of traditional packaging in the OO
399 market, something that is substantially changing for the highest quality OO in the last
400 decade.

401

402 *6.2.4. Brand*

403 For consumers in high familiarity countries, brand recognition plays a significant role in
404 their purchasing decisions. These consumers tend to prefer well-established, known
405 brands over newer ones. This trend has been observed in Spain (Corbeto-Fabón et al.,
406 2018; Salazar-Ordóñez et al., 2018c; Yangui et al., 2019), Italy (Di Vita et al., 2021a;
407 Liberatore et al., 2018; Panico et al., 2014; Piccolo et al., 2013; Savelli et al., 2021),
408 Turkey (Zulug et al., 2015), France (Erraach & Sayadi, 2020), Lebanon (Chaaban,
409 2012), Albania (Imami et al., 2013), and Greece (Mattas & Tsakiridou, 2017). Brand
410 awareness provides consumers with a certain level of confidence when purchasing and
411 is often associated with product quality and brand loyalty (Baziana & Tzimitra-
412 Kalogianni, 2019). In the USA, familiarity with the brand significantly influences
413 purchasing decisions (Delgado et al., 2013; Dentoni et al., 2013). However, there is a
414 lack of references regarding the impact of brand familiarity on purchasing decisions in
415 other countries with medium familiarity. Finally, a single study conducted in a low
416 familiarity country (Denmark), found that brand was the least valued attribute by
417 consumers when choosing olive oil (Chrysochou et al., 2021). In summary, in olive oil-

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418 producing countries, consumption behavior is largely influenced by well-known brands,
419 while in non-producing countries, brand recognition does not seem to play a significant
420 role, as consumers lack references, knowledge, and loyalty to specific brands.

421

422 *6.2.5. Origin and Certifications*

423 In general, origin information has been found to have a substantial impact on food
424 choices (see Thøgersen, 2023). Accordingly, PDO (Protected Designation of Origin)
425 certification enhances the general acceptance of EVOO and is valued more highly than
426 PGI (Protected Geographical Indication) certification (e.g., Marano-Marcolini et al.,
427 2015; Violino et al., 2019) and the presence of a PDO label often leads to increased
428 purchase intentions and WTP (e.g., Carlucci et al., 2014). However, the relevance of the
429 certificates is modulated by familiarity with olive oil. Consumers in high familiarity
430 countries show a strong preference for oils that are labelled with PDO or PGI
431 certifications. In Italy, consumers associate these certifications with superior quality and
432 authentic regional characteristics (Contini et al., 2016; Di Vita et al., 2021a; Piccolo et
433 al., 2013; Sgroi et al., 2024). In Spain there is a notable increase in WTP for EVOO
434 with PDO and PGI labels, reflecting a strong preference for products that guarantee
435 specific regional attributes (Ballco & Gracia, 2020b; Erraach et al., 2014; Pérez et al.,
436 2023; Pérez et al., 2019; Pérez et al., 2020). Similar trends are observed in Greece
437 (Vlontzos & Duquenne, 2014) and Lebanon (Houmani et al., 2024). The role of origin
438 and certifications in producer countries intertwined with ethnocentrism (Arriaza et al.,
439 2021; Ballco & Gracia, 2020b; Bernabéu et al., 2020; De Gennaro et al., 2021; Romo-
440 Muñoz et al., 2017; Tempesta & Vecchiato, 2019). Ethnocentric tendencies have been
441 reported in Portugal (Bernabéu et al., 2020), Jordan (Al Ganideh, 2012; Al Ganideh &
442 Good, 2016), Spain (Blazquez-Resino et al., 2021), and Italy (Di Vita et al., 2021a,

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443 2021b, 2021c). In Spain and Italy, local production tends to increase WTP (Ballco &
444 Gracia, 2020a; Bimbo et al., 2020; Cappelli et al., 2020; Yanguí, 2014). As an exception
445 to this ethnocentric trend, French consumers prefer national olive oil for frying and
446 cooking (Cicerale et al., 2016), while there is a preference for Italian and Spanish oil for
447 salads and dressings (Erraach & Sayadi, 2020). In medium familiarity countries like the
448 USA, consumers often prioritize factors such as territory, certifications, region, or
449 country of origin when evaluating olive oil, influencing their purchasing decisions
450 (Delgado et al., 2013). WTP is increased by the PGI and PDO certifications,
451 demonstrating the value consumers place on these indicators of quality and authenticity
452 (Dentoni et al., 2013; Roselli et al., 2016). In Canada, consumers prefer oils from Italy,
453 Spain, and then Greece. They value PDO more than PGI (Menapace et al., 2011). In
454 Japan, consumers prefer oils from Italy, Spain, and Tunisia (Kitagawa et al., 2020).
455 Consumers from low-familiarity countries, such as Denmark, give high relevance to the
456 country of origin of EVOO (e.g., Chrysochou et al., 2021).

457

458 *6.2.6. Organic Production*

459 Consumers generally value the organic production of EVOO positively (Delpozo et al.,
460 2024; Latino et al., 2022; Pérez et al., 2023), regardless of whether they reside in a
461 producer country or not, as they consider it to be more environmentally friendly. This is
462 observed in countries like Italy (Aprile et al., 2012; Cavallo et al., 2018; De Gennaro et
463 al., 2021; Di Vita et al., 2021b, 2021c; Pagliuca & Scarpato, 2011; Panico et al., 2014;
464 Piccolo et al., 2013), Portugal (Bernabéu et al., 2020), Greece (Vlontzos & Duquenne,
465 2014), Tunisia (Ghali, 2020), the USA (Roselli et al., 2016), Canada (Menapace et al.,
466 2011), and the Netherlands (Cavallo & Piqueras-Fiszman, 2017). This positive
467 perception is likely tied to a broader belief that organic production indicates attention to

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468 health and the preservation of the natural environment (Cicerale et al., 2016; Vlontzos
469 & Duquenne, 2014), and consumers tend to trust the nutritional value of organic
470 products (Ghali, 2020). The organic label also increases consumers' WTP in Greece
471 (Vlontzos & Duquenne, 2014), Spain (Lami et al., 2023), and Italy (Bimbo et al., 2020;
472 Giannoccaro et al., 2019). Finally, consumers prefer to buy EVOO that has both PDO
473 and organic certifications (Boncinelli et al., 2017; Borrello et al., 2022).

474

475 *6.2.7. Price*

476 Price is a significant factor guiding the purchase and consumption of olive oil regardless
477 of the country. That is the case in producer countries such Italy (Contini et al., 2016;
478 Boncinelli et al., 2017; Liberatore et al., 2018; Sillani et al., 2014; Tempesta &
479 Vecchiato, 2019), Spain (Bernabéu et al., 2020; Bernabéu & Diaz, 2016; Erraach et al.,
480 2014; Salazar-Ordóñez & Rodríguez-Entrena, 2019; Sayadi et al., 2017), France
481 (Erraach & Sayadi, 2020), Tunisia (Mtimet et al., 2013), Albania (Chan-Halbrendt et
482 al., 2010), Greece (Papoutsis, 2023), and Portugal (Bernabéu et al., 2020). In Italy and
483 Spain, consumers often associate price with quality and are more willing to pay higher
484 prices based on their experience and knowledge of the product (e.g., Ballco & Gracia
485 2020b). Similarly, certifications such as PGI, PDO, and organic production have been
486 found to increase the price consumers are willing to pay in Italy (Roselli et al., 2018;
487 Zanchini et al., 2022) and Greece (Albayram et al., 2014; Papoutsis, 2023; Vlontzos &
488 Duquenne, 2014). In Turkey, willingness to pay also increases with local production
489 (Zulug et al., 2015). Finally, Tunisian consumers are willing to pay premium prices for
490 organic production (Ghali, 2020). Consumers in countries with medium familiarity,
491 such as Chile, tend to link higher prices to better quality (Romo-Muñoz et al., 2018;
492 Romo-Muñoz et al., 2017). In the USA, price significantly influences consumers'

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493 decisions regarding the type of olive oil they purchase in relation to the reputation of the
494 region or country of origin (Delgado et al., 2013; Delgado et al., 2014). Finally, in the
495 single study conducted in a non-producer country, Chrysochou et al. (2021) found that
496 in Denmark, "price-conscious consumers" value the price more than the origin or the
497 brand of the product.

498

499 *6.2.8. Label Information*

500 Labelling information serves as a crucial medium for communicating extrinsic attributes
501 such as PGI, PDO, origin, production methods, and organic status, regardless of the
502 country in which the study has been conducted. Consumers in high familiarity countries
503 such as Spain (Ballco & Gracia, 2020a), Italy (Cavallo & Piqueras-Fiszman, 2017; Di
504 Vita et al., 2020; c.f. De Gennaro et al., 2021; Panico, et al., 2014), France (Cicerale et
505 al., 2016), Portugal (Bernabéu et al., 2020), Greece (Mattas & Tsakiridou, 2017), and
506 Turkey (Zulug et al., 2015) consider label information to be relevant at the time of
507 purchase. In Spain, labels are viewed as the best way to make an informed decision
508 (Sayadi et al., 2017). In northern Italy, customers are more attracted to label information
509 compared to those in the southern regions (Di Vita et al., 2021b). As in Spain,
510 willingness to pay increases with detailed labelling (Di Vita et al., 2021a), including
511 labels indicating organic status or extra virgin olive oil (Giannoccaro et al., 2019).
512 Italian consumers also value the inclusion of country and origin information on labels
513 (Pagliuca & Scarpato, 2011, 2014). Similarly, in countries with lower production, such
514 as the USA, generic information and PGI labels enhance consumer confidence and
515 positively influence purchasing decisions (Dentoni et al., 2013). This is also true in low
516 familiarity countries like Poland (Kaczorowska et al., 2019). Perhaps the only
517 familiarity-based difference with respect to the role of the information of the label

518 comes from the fact that consumers in countries with high familiarity with EVOO may
519 disregard label information if it conflicts with their existing knowledge. That could be
520 behind the result reported by Chaaban (2012), whom found that in Lebanon, 28% of
521 consumers report that they do not read labels (Chaaban, 2012). As a more specific
522 example, Nutri-Score initially classified EVOO in the 4th level (D) of its 5-level scale
523 due to its fat content, which could have led to the misconception that EVOO is
524 unhealthy. This prompted protests from various organizations, resulting in a revised
525 classification of EVOO as B. However, Failon et al. (2021) found that the Nutri-Score
526 classification did not affect Spanish consumers' perceptions of EVOO, likely due to
527 their general awareness of its health benefits.

528

529 *7. Perceived health benefits*

530 Most consumers are aware of the health benefits associated with the consumption of
531 EVOO, though they may wrongly ascribe the same properties to any kind of olive oil
532 (Fakhreddine et al., 2023; Fakhreddine & Sánchez, 2023; Di Vita et al., 2021c;
533 Jiménez-Guerrero et al., 2012; Roselli et al., 2018). In fact, many consumers are not
534 familiar with the specific bioactive components of EVOO or the particular polyphenol-
535 related health benefits. A study conducted in Italy comparing early and late harvests and
536 traditional versus organic agriculture found that early and organic harvesting is most
537 effective in improving health outcomes related to oxidative stress (Trombetta et al.,
538 2017). Different studies have highlighted the importance of providing detailed
539 information on consumer behavior, particularly regarding labels that include health
540 claims about polyphenol content and its health impacts (Contini et al., 2016; Barbieri et
541 al., 2015; Boncinelli et al., 2017; Rizzo et al., 2020; Shaalan et al., 2024). The health

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542 benefits of OO are the primarily reason given by consumers for consuming olive oil,
543 regardless of whether the country where the study was conducted is a producer country
544 or not (i.e., Peršurić & Damijanić, 2021). In producer countries such as Spain, Italy,
545 and Greece. In Italy (Casini et al., 2014; Contini et al., 2015, 2016; De Gennaro et al.,
546 2021; Liberatore et al., 2018) and Greece (Baziana & Tzimitra-Kalogianni, 2019;
547 Mattas & Tsakiridou, 2017), health properties are among the most valued attributes of
548 EVOO, with 65.9% of consumers consuming EVOO due to its health benefits. Italian
549 consumers are well-informed about EVOO and its health advantages (Casini et al.,
550 2014), although the increased willingness to pay for EVOO with high polyphenol
551 content is observed primarily among those who are health-conscious (Di Vita et al.,
552 2020). In Spain, individuals with a lifestyle and personality oriented towards health are
553 more likely to include EVOO in their diet (Yangui et al., 2016). In medium familiarity
554 countries such as the USA (Cicerale et al., 2016; Delgado et al., 2014; Santosa &
555 Guinard, 2011), Chile (Fakhreddine et al., 2023) or Australia (Wilson et al., 2023), the
556 health properties of extra EVOO are also the primary motivator for its purchase and
557 consumption. Similar results have been found in low familiarity countries such as the
558 UK and Germany (Peršurić, 2020) and Denmark (Contini et al., 2015). In summary, the
559 perceived impact of EVOO on health is a major reason for consumption regardless of
560 familiarity. However, a key factor is whether consumers can singularize this health
561 benefits to the extra-virgin variety (e.g., Arriaza et al., 2021; Delgado et al., 2013).
562 While many consumers are aware of the general health benefits of olive oil, they may
563 not fully understand the specific advantages of EVOO, such as its higher polyphenol
564 content and associated health benefits.
565

566 8. Discussion and conclusions

567 Promoting EVOO as a functional food is a challenge that requires understanding of how
568 consumers perceive its intrinsic and extrinsic qualities. Research indicates that
569 familiarity with olive oil can significantly influence consumer perceptions of its various
570 attributes (e.g., Cavallo et al., 2020; Erraach et al., 2021; Jiménez-Guerrero et al., 2012).
571 However, the lack of a standardized definition of familiarity across studies hinders
572 definitive conclusions about its impact on consumer perceptions of various attributes.
573 This systematic review aimed to determine if consumers' country of residence could
574 serve as a proxy for familiarity with olive oil and influence their perception of its
575 attributes. The International Olive Council's global production reports (2021a, 2021b,
576 2024) were used to categorize countries into high, medium, or low familiarity levels
577 based on olive oil production. The results demonstrated that country of residence can
578 indeed predict how consumers perceive different attributes, enabling the design of more
579 effective promotional campaigns. Figure 3 summarizes the conclusions regarding the
580 interaction between familiarity and the evaluation of intrinsic and extrinsic olive oil
581 attributes.

582

583

584

Insert Figure 3 about here

585

586

587 Consumers in producer countries, rated as highly familiar with olive oil, exhibit
588 evaluations closer to expert assessments than those in emerging or non-producer
589 countries. They uniquely appreciate bitterness and pungency as positive attributes (e.g.,
590 Caracciolo et al., 2020; Cavallo et al., 2019; Clicerì et al., 2021), even without
necessarily recognizing their connection to the polyphenols that contribute to EVOO's

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591 health benefits (e.g., Barbieri et al., 2015). Notably, consumers in producing countries
592 actively seek extra virgin olive oil (e.g., Ballco & Gracia, 2020a; Wilson et al., 2023),
593 valuing brand, PDO, and PGI certifications (Del Giudice et al., 2015) as they are able to
594 evaluate the relevance of those features more than less familiar consumers.

595 Consumers in countries categorized as medium or low familiarity exhibit similar
596 behavior, with a few exceptions. Both groups generally reject bitterness and pungency
597 (e.g., Cicerale et al., 2016; Delgado & Guinard, 2011). Consumers in medium
598 familiarity countries, however, differentiate themselves by using more EVOO, relying
599 on well-known brands, and prioritizing certifications compared to those in low
600 familiarity countries (e.g., Delgado et al., 2013).

601 The rejection of the intense flavors associated with polyphenols in EVOO by
602 consumers outside major producing regions presents a challenge in expanding its
603 consumption. This is particularly concerning, as bitterness and pungency are closely
604 linked to the health benefits of EVOO (e.g., Clicerì et al., 2021). The reluctance to
605 consume EVOO due to its bitter and pungent flavor is prevalent in countries with low to
606 medium familiarity, where consumers often prefer sweet flavors and ripe olives.
607 Neophobia, or the fear of new foods, may play a significant role in introducing EVOO
608 to these markets, as demonstrated by a study conducted by Jaeger et al. (2017) on food
609 preferences in New Zealand. They discovered that neophobia significantly influenced
610 both food intake frequency and product preferences.

611 Several attributes, including size (e.g., Corbeto-Fabón et al., 2018;), packaging
612 (e.g., Chrysochou et al., 2021), and the association between price and quality (e.g.,
613 Bernabéu et al., 2020), do not differ based on familiarity. Among intrinsic attributes,
614 fruitiness consistently emerges as a highly valued characteristic, valued by both experts
615 and consumers regardless of their country of residence (e.g., Di Vita et al., 2021;

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616 Erraach & Sayadi, 2020; Peršurić, 2020). Interestingly, some attributes that do not
617 differentiate consumers may help overcome limitations, particularly those related to the
618 rejection of pungent and bitter flavors (e.g., Cavallo & Piqueras-Fiszman, 2017).
619 Consumers value organic production (e.g., Vlontzos & Duquenne, 2014), are aware of
620 the health benefits of regular EVOO consumption (e.g., Chrysochou et al., 2021;
621 Fakhreddine et al., 2023), and are highly sensitive to label information. A key strategy
622 would be to inform consumers about the connection between the bitter and pungent
623 flavors (due to polyphenols) and the health benefits of EVOO consumption. Several
624 studies suggest that providing appropriate label information can mitigate the negative
625 impact of these unpleasant factors on consumer perception. Vecchio et al. (2019), for
626 example, found that informing consumers about EVOO's health properties positively
627 influenced their acceptance of bitterness.

628 However, the findings of this review suggest that messaging should be tailored
629 to varying levels of familiarity. In producing regions, emphasizing the health claim that
630 'polyphenols in olive oil contribute to the protection of blood lipids against oxidative
631 stress' on the label could enhance EVOO promotion, as even health-conscious
632 consumers may not be aware of its bioactive components or specific health benefits
633 (Barbieri et al., 2015). Additionally, providing more information about EVOO's health
634 benefits is crucial in countries with lower familiarity, as this can improve consumers'
635 understanding and positively influence purchasing decisions (Salazar-Ordóñez et al.,
636 2018a, 2018b). The success of promotional campaigns leveraging consumer
637 ethnocentrism is demonstrated by the growth of the EVOO market in Chile, where
638 occasional consumption has reached 71% (Romo-Muñoz et al., 2018).

639 By implementing the strategies such as the ones outlined above and
640 considering the benefits of EVOO consumption, we can gain a deeper understanding of

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641 the factors that influence consumer acceptance of bitter and pungent flavors. This
642 knowledge will facilitate the promotion of EVOO as a nutraceutical food in countries
643 with medium or low familiarity. The interaction between familiarity and consumer
644 appreciation of these flavors suggests that encouraging regular EVOO consumption can
645 gradually shift perceptions towards a more positive view. This shift could help
646 overcome a significant barrier to expanding EVOO consumption among the general
647 public.

648 In summary, this systematic review concludes that consumer preferences for
649 EVOO are influenced not only by the product itself and its attributes but also by the
650 level of consumer familiarity. Attributes related to production (e.g., origin, traceability,
651 cold extraction, type of oil, olive variety), trade (e.g., packaging, labelling, price, brand),
652 and certifications (e.g., PDO, PGI, Organic) often hold more significance than intrinsic
653 attributes, especially for consumers with medium to low familiarity. For these
654 consumers, label information is crucial and should be tailored to the specific
655 characteristics of the target market, particularly in terms of familiarity with the product.
656

657 *9. Implications for Olive Oil Stakeholders*

658 The findings of this systematic review offer valuable insights for olive oil stakeholders,
659 including producers, sellers, marketers, and policymakers. The interaction between
660 familiarity and flavor perception provides guidance on promoting widespread EVOO
661 consumption globally. While using country or region as a proxy for familiarity has
662 limitations, it offers a practical advantage.

663 This review demonstrates that region can effectively predict familiarity and
664 identify key factors for targeted promotion campaigns. Understanding the role of
665 familiarity in consumer preferences can guide marketing strategies. In regions with low

666 familiarity, campaigns should focus on educating consumers about EVOO's health
667 benefits, emphasizing its polyphenol content and connecting these benefits to its
668 distinctive flavors. Leveraging ethnocentrism, as demonstrated in Chile, can be a
669 powerful strategy to overcome neophobia and expand market presence in new regions.

670 For producers and sellers, tailoring product offerings to regional preferences,
671 such as emphasizing mild flavors in markets where consumers prefer sweet tastes, can
672 enhance market acceptance. Certification and labelling that highlight EVOO's health
673 benefits can influence consumer choice, especially in health-conscious segments.
674 Government policies supporting education and awareness campaigns around the health
675 benefits of EVOO can facilitate its acceptance as a functional food, contributing to
676 public health outcomes.

677

678 *10. Limitations and Future Research Directions*

679 While this review provides valuable insights, it has limitations. The assumption
680 that familiarity with EVOO closely correlates with living in a producer country or
681 region, while practical, overlooks variations within regions or among consumer
682 demographics. Using producing country as a proxy for familiarity confounds origin and
683 ethnocentrism. While this does not undermine the overall conclusions, future research
684 should measure familiarity directly, perhaps by assessing knowledge and experience
685 with EVOO across diverse locations, isolating familiarity from ethnocentrism.

686 Another limitation is the variability in how studies define and measure key
687 attributes. The studies included cover a broad range of thematic areas, leading to diverse
688 methodologies. We extracted comparable information while retaining other relevant
689 details. Standardizing definitions and methodologies in future research could lead to
690 more consistent results.

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691 Future research should explore the impact of targeted promotional strategies on
692 overcoming neophobia and other barriers to EVOO consumption in non-traditional
693 markets. Longitudinal studies could offer valuable insights into how consumer
694 perceptions and preferences evolve over time with increased exposure and education.
695 Examining the role of digital and social media in shaping consumer awareness and
696 acceptance of EVOO could reveal new opportunities for stakeholder engagement and
697 marketing effectiveness. Finally, conducting studies that compare evaluations between
698 experts and consumers with varying levels of familiarity will help identify and address
699 discrepancies between these groups, aiding in isolating the key factors needed to
700 effectively promote EVOO consumption in both traditional and non-traditional markets.
701

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

703 During the preparation of this work the authors used Gemini IA, Google, in order to
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707

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713

714 Conflict of Interest and Authorship Conformation Form

715

716 Please check the following as appropriate:

717

- 718 ✓ All authors have participated in (a) conception and design, or analysis and
719 interpretation of the data; (b) drafting the article or revising it critically for
720 important intellectual content; and (c) approval of the final version.
- 721 ✓ This manuscript has not been submitted to, nor is under review at, another
722 journal or other publishing venue.
- 723 ✓ The authors have no affiliation with any organization with a direct or
724 indirect financial interest in the subject matter discussed in the manuscript

725

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726 **Nomenclature**

727 EVOO: Extra Virgin Olive Oil

728 IOC: International Olive Council.

729 LDL: Low-Density Lipoprotein

730 OO: Olive Oil

731 PDO: Protected Designation of Origin

732 PGI: Protected Geographical Indications

733 PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

734 UNESCO: United Nations Educational, Scientific and Cultural Organization

735 UK: United Kingdom

736 USA: United States of America

737 WOS: Web of Science

738 WTP: Willing To Pay

739

740

741

742

view

743 **References**

744 In the references section, the 129 selected articles are presented first in a section
745 titled “Main References”. These articles are numbered for easy reference in the
746 complementary information, which includes a table of abstracts and analysis of biases
747 ([https://data.mendeley.com/preview/ftsx8cfnmf?a=ebee2bb5-589c-40ed-a87c-](https://data.mendeley.com/preview/ftsx8cfnmf?a=ebee2bb5-589c-40ed-a87c-a81f56d760ec)
748 [a81f56d760ec](https://data.mendeley.com/preview/ftsx8cfnmf?a=ebee2bb5-589c-40ed-a87c-a81f56d760ec)).

749 The “Complementary references” section lists guidelines, manuals, and other
750 articles that were consulted to define, justify, or expand on explanations or topic, but
751 were not included in the systematic review.

752

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1315 **Table 1**1316 *Search, Selection and Screening Process*

Cradle of information	Web of Science and Scopus database						
Bibliographic search	<p>Keywords used in the general search: "Consumer Preferences and Olive Oil." We used "olive oil" in the search since many publications use this term generally, often referring specifically to Extra Virgin Olive Oil. Terms were used in English because most relevant scientific literature is in this language, though publications in other languages were also included in the review. The review period spanned from January 2010 to December 2024 (the last 14 years). These dates were chosen to include a significant number of publications while maintaining sample homogeneity, as consumer perceptions of olive oil have been changing rapidly since the Mediterranean diet was declared an Intangible Cultural Heritage of Humanity during the fifth meeting of the UNESCO Intergovernmental Committee in Nairobi (Kenya) on November 16, 2010 (Trichopoulou, 2021; UNESCO, 2010, ITH/10/5.COM/CONF.202/6 – page 52).</p>						
Inclusion criteria	<p>Papers with a scientific methodology and/or published in scientific journals, book chapters, meta-analysis, systematic or narrative reviews. Articles were included that addressed the preferences of OO consumers from the perspective of their intrinsic and extrinsic attributes. Research involving the following criteria was included in the review:</p> <ul style="list-style-type: none"> • Consumer: Decision-making, choices, behavior, acceptance, satisfaction, habits and hedonic ratings. • Sensory: Profile, analysis, mapping, choice experiment, comparison between experts and consumers • Psychographic and sociodemographic variables, subjective norms, loyalty. • Traceability, Olive variety, Cold extraction, Type of oil • Degree of knowledge of the product or familiarity • Quality: Perception, parameters, dimensions and attribute • Health: Claim, properties, or attribute (Healthy), polyphenol content. • Preferences toward PDO (Protected Designation of Origin), PGI (Protected Geographical Indications), Country of Origin Labelling, Organic Production, and sustainability labels (Fair trade and European Union organic farming or Euro-leaf). • Labelling and Packing • Purchasing, buying intentions, WTP (Willing To Pay), Willing To Buy, OO demand 						
	<table border="1"> <thead> <tr> <th>Screening</th> <th>Exclusion criteria</th> </tr> </thead> <tbody> <tr> <td></td> <td>Irrelevant Food Focus: Publications that mention olive oil (OO) or consumer preferences but primarily focus on studying other types of food.</td> </tr> <tr> <td>Selection of studies</td> <td> <p>Reading of summaries</p> <p>Non-Scientific Publications: Articles that are not scientific publications, including non-peer-reviewed sources, opinion pieces, or popular media.</p> <p>Out-of-Scope Time Period: Publications that fall outside the review period of January 2010 to December 2024.</p> </td> </tr> </tbody> </table>	Screening	Exclusion criteria		Irrelevant Food Focus: Publications that mention olive oil (OO) or consumer preferences but primarily focus on studying other types of food.	Selection of studies	<p>Reading of summaries</p> <p>Non-Scientific Publications: Articles that are not scientific publications, including non-peer-reviewed sources, opinion pieces, or popular media.</p> <p>Out-of-Scope Time Period: Publications that fall outside the review period of January 2010 to December 2024.</p>
Screening	Exclusion criteria						
	Irrelevant Food Focus: Publications that mention olive oil (OO) or consumer preferences but primarily focus on studying other types of food.						
Selection of studies	<p>Reading of summaries</p> <p>Non-Scientific Publications: Articles that are not scientific publications, including non-peer-reviewed sources, opinion pieces, or popular media.</p> <p>Out-of-Scope Time Period: Publications that fall outside the review period of January 2010 to December 2024.</p>						

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Publications that did not specifically explore consumer preferences, but rather touched on related topics that are relevant to the olive oil industry: labelling fraud, relevance of the region of origin in general, table olives, chemical components of OO, other types of oil, olive-pomace oil, masking OO defects, joint design of consumer and company labelling, targeting EVOO tourism as a strategy to promote consumption, EVOO policies or consumer persuasion, olive industry, producers and importers.

Reading the article

The bias table of the selected publications was prepared following the Cochrane 2019 RoB-2 Risk of Bias-2 Scale (Cochrane Methods, 2019). The procedure carried out in this revision is registered in OSF (<https://doi.org/10.17605/OSF.IO/NKWJZ>).

1317

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1318 **Table 2**1319 *Intrinsic and Extrinsic Attributes of the OO evaluated in this Review*

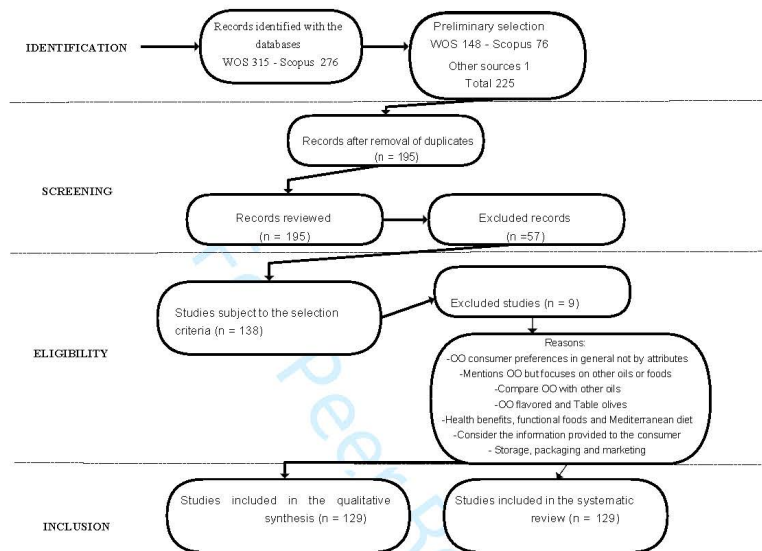
	INTRINSIC	EXTRINSIC
1320		
1321	Color	Size
1322	Flavor	Type of oil
	Bitter	Brand
1323	Pungent	Packaging
	Fruitiness	Origin and Certifications
1324	Smell	Price
	Viscosity	Label information
1325	Transparency	

For Peer Review

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1326 **Figure 1**

1327 *PRISMA Flowchart Followed in this Review*

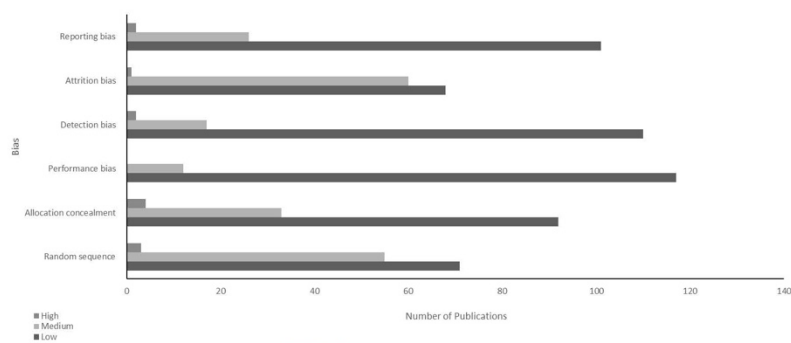


1328

1329 *Note.* The figure illustrates the process for the selection of the studies taken into account

1330 in the systematic review following the PRISMA 2020 protocol (Page, et al., 2021a;

1331 Page et al., 2021b).

1332 **Figure 2**1333 *Bias of the Selected Publications*

1334

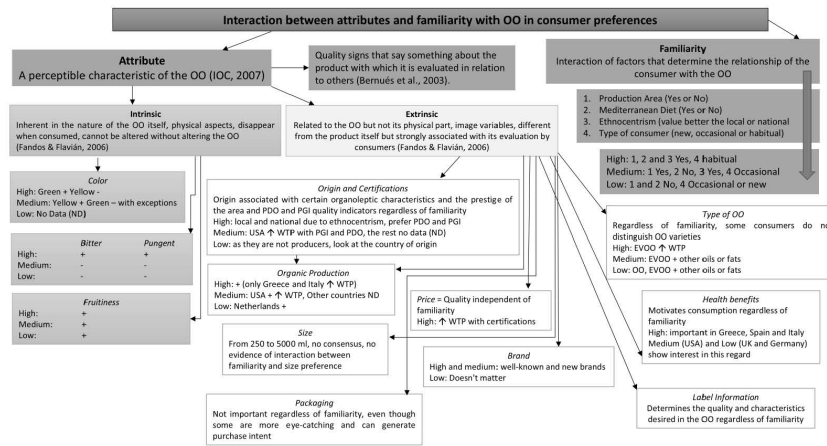
1335 *Note.* The analysis of biases is carried out by Following RoB-2 Risk of Bias-2 Scale –

1336 (Cochrane Methods, 2019).

1337

1338 **Figure 3**

1339 *Conclusions about the Interaction Between Familiarity and Attributes Evaluation*



1340

**4. Specific Goal 2. Dynamics of Sensory and
Decision-Making Processes in EVOO
Tasting conducted by a Consumers Panel**

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Food Quality and Preference
Dynamics of Sensory and Decision-Making Processes in the Evaluation of Extra Virgin Olive Oil by a Consumer Tasting Panel
 --Manuscript Draft--

Manuscript Number:	FQAP-D-24-01529
Article Type:	Research Paper
Keywords:	Double Dissociation Additive Test; Extra Virgin Olive Oil; Induced Expectations; Sensory and Decision Processes; Signal Detection Theory; Tasting Panel
Corresponding Author:	Juan Manuel M. Rosas University of Jaén SPAIN
First Author:	Sonia Milena Arbeláez-Mejía
Order of Authors:	Sonia Milena Arbeláez-Mejía Juan Manuel M. Rosas, PhD Manuel Miguel Ramos-Álvarez, PhD
Abstract:	This study aimed to assess whether a Signal Detection Theory-based approach could separately evaluate sensory and decision-making processes in untrained consumers replicating expert olive oil tasting conditions. In Experiment 1a, participants compared four unique non-commercial extra virgin olive oils (EVOOs) as "signals" against a commercial EVOO as "noise." Sensitivity (Grier's A' index) varied with oil attributes, while decision bias (Donaldson B'D index) stayed neutral. Experiment 1b used a Double Dissociation Additive Test, manipulating sensory variables (green vs. ripe oils) and decision bias (adjusting Signal-Noise base rates). Expectations influenced evaluations of ripe oils only, revealing an interaction between sensory and decision-making processes. Despite differing preferences for defect-free EVOOs, participants' willingness to pay did not vary. These findings highlight the value of methods that distinguish sensory from decision-making processes in tasting studies.
Suggested Reviewers:	Alessandra Bendini alessandra.bendini@unibo.it Specialist in EVOO sensory analysis and consumer acceptance Amanda Neris Dos Santos amandaneriss@gmail.com Specialist in EVOO sensory analysis and the use of consumer panels Jean-Xabier Guinard jxguinard@ucdavis.edu Specialist in using sensory and instrumental analysis in food assessment

Cover Letter

Editor of Food Quality and Preference

Dear Editor,

Enclosed is the manuscript entitled “Dynamics of Sensory and Decision-Making Processes in the Evaluation of Extra Virgin Olive Oil by a Consumer Tasting Panel,” for your consideration for publication in *Food Quality and Preference*.

The manuscript presents a study investigating the interaction between sensory and decision-making processes in evaluating extra virgin olive oil (EVOO) using a Signal Detection Theory-based methodology. A consumer tasting panel, modeled on expert tasting conditions, was employed. The study found that participants’ sensitivity varied depending on the oil’s attributes, while induced expectations influenced decision bias only for ripe oils. This highlights an interaction between sensory and decision-making processes during tasting evaluations. Additionally, the study revealed that participants' preferences for distinct EVOOs with zero defects did not correspond to differences in their willingness to pay for them.

I hope you and the reviewers will find this manuscript to be of interest to the journal's readership. I look forward to your feedback and send my best regards.

Sincerely,

Juan M. Rosas

jmrosas@ujaen.es

University of Jaén

Highlights

Highlights

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- This study investigates the interaction between sensory and decision-making processes in evaluating extra virgin olive oil by using a Signal Detection Theory-based methodology with a consumer tasting panel modeled on expert tasting conditions.
- Participants' sensitivity varied with oil attributes, while decision criteria remained neutral (Exp. 1a).
- Induced expectations impacted decision bias only for ripe oils, revealing an interaction between sensory and decision-making processes in tasting evaluations (Exp. 1b).
- Participants differential preferences for distinct EVOOs with zero defects did not translate into differences in their willingness to pay for them (Exp. 1a and 1b).
- The study underscores the need for methodologies that isolate sensory and decision processes to avoid biases in tasting evaluations.

Manuscript File

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1 SHORT TITLE: EVOO SENSORY AND DECISION-MAKING PROCESSES

2

3 **Dynamics of Sensory and Decision-Making Processes in the Evaluation of Extra**
4 **Virgin Olive Oil by a Consumer Tasting Panel**

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EVOO SENSORY AND DECISION-MAKING PROCESSES 2

21 **Authors' Note**

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31 commercial extra virgin olive oils used in this study.

32
33 **Declaration of Generative AI and AI-Assisted Technologies in the Writing**

34 **Process:** During the preparation of this work, the authors used ChatGPT to enhance
35 readability and language. The authors reviewed and edited the content as needed and
36 take full responsibility for the final published version of the article.

37
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42

EVOO SENSORY AND DECISION-MAKING PROCESSES 3

43 **Abstract**

1
2 44 This study aimed to assess whether a Signal Detection Theory-based approach could
3
4 45 separately evaluate sensory and decision-making processes in untrained consumers
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6 46 replicating expert tasting conditions. In Experiment 1a, participants compared four
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8 47 unique non-commercial extra virgin olive oils (EVOOs) as "signals" against a
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10 48 commercial EVOO as "noise." Sensitivity (Grier's A' index) varied with oil attributes,
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12 49 while decision bias (Donaldson B'D index) stayed neutral. Experiment 1b used a Double
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14 50 Dissociation Additive Test, manipulating sensory variables (green vs. ripe oils) and
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16 51 decision bias (adjusting Signal-Noise base rates). Expectations influenced evaluations
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18 52 of ripe oils only, revealing an interaction between sensory and decision-making
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20 53 processes. Despite differing preferences for defect-free EVOOs, participants'
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22 54 willingness to pay did not vary. These findings highlight the value of methods that
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24 55 distinguish sensory from decision-making processes in tasting studies.
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33 57 **Key-words:** Double Dissociation Additive Test; Extra Virgin Olive Oil; Induced
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35 58 Expectations; Sensory and Decision Processes; Signal Detection Theory; Tasting Panel;
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EVOO SENSORY AND DECISION-MAKING PROCESSES 4

60 **Highlights**

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- 61 • This study investigates the interaction between sensory and decision-making
 - 62 processes in evaluating extra virgin olive oil by using a Signal Detection
 - 63 Theory-based methodology with a consumer tasting panel modeled on expert
 - 64 tasting conditions.
 - 65 • Participants' sensitivity varied with oil attributes, while decision criteria
 - 66 remained neutral (Exp. 1a).
 - 67 • Induced expectations impacted decision bias only for ripe oils, revealing an
 - 68 interaction between sensory and decision-making processes in tasting
 - 69 evaluations (Exp. 1b).
 - 70 • Participants differential preferences for distinct EVOOs with zero defects did not
 - 71 translate into differences in their willingness to pay for them (Exp. 1a and 1b).
 - 72 • The study underscores the need for methodologies that isolate sensory and
 - 73 decision processes to avoid biases in tasting evaluations.
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EVOO SENSORY AND DECISION-MAKING PROCESSES 5

84 **Dynamics of Sensory and Decision-Making Processes in the Evaluation of Extra**
85 **Virgin Olive Oil by a Consumer Tasting Panel**

86

87 **1. Introduction**

88 Functional foods are defined as foods that provide health benefits beyond basic
89 nutrition, contributing positively to health by reducing the risk of disease or enhancing
90 overall well-being. The European Commission (2010) recommends consumption of
91 functional foods by the general public due to these additional health benefits. These
92 foods include a variety of products that have been enhanced with added nutrients or
93 bioactive compounds or that inherently possess properties beneficial to health, as is the
94 case with Extra-Virgin Olive Oil (EVOO). Numerous studies have demonstrated the
95 health benefits associated with EVOO consumption (Flynn et al., 2023; Martínez-
96 Gonzalez et al., 2022; Wildman 2020).

97 The widespread consumption of EVOO faces the challenge of its acceptance by
98 the general public. This is because the beneficial properties of EVOO are linked to the
99 polyphenols present in its bitter and spicy characteristics (Cicerale et al., 2016; Delgado
100 & Guinard, 2011). While experts tend to perceive these attributes favorably, consumers
101 often find them unpleasant, unless they live in a production area and are familiar with
102 the EVOO culture (Cavallo et al., 2018; Delgado & Guinard, 2011; Valli et al., 2014;
103 see review in Arbeláez-Mejía et al., 2024).

104 Overcoming the reluctance of consumers to use EVOO outside of producing areas
105 is a crucial challenge that needs to be addressed to unlock its health benefits for the
106 general public. To tackle this challenge, we need to go beyond consumers' sensory
107 perceptions and understand the underlying biases that influence their evaluations. These
108 biases are shaped by consumers' beliefs, motivations, and expectations, which in turn

EVOO SENSORY AND DECISION-MAKING PROCESSES 6

109 affect their consuming decisions. By identifying these biases, we can better understand
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110 the barriers that prevent consumers from accepting EVOO as a functional food. This
111 knowledge can help bridge the current gap between expert and consumer evaluations,
112 ultimately promoting the adoption of EVOO as a healthy choice. The primary goal of
113 this study was to develop a methodology that can effectively dissociate consumers’
114 sensory perceptions from the decision-making processes when evaluating the factors
115 that influence their perception of EVOO quality.

116 The protocols that should be followed in the field of EVOO’s sensory evaluation
117 are defined by the International Olive Council (e.g., IOC, 2023). These protocols
118 involve a sensory analysis that evaluates the organoleptic properties of EVOO, i.e., its
119 physical characteristics (taste, smell, texture, color, etc.) as well as its positive attributes
120 (fruity, bitter and spicy, etc.) and its defects (stunted, metallic, rancid, tassels, vinegary,
121 etc.). Sensory evaluation, conducted by tasters’ panels, allows for classifying olive oil
122 as lampante, olive, virgin or extra virgin (IOC, 2018, 2023). To ensure the quality of
123 the evaluation, the selection of tasters involves a meticulous process to determine their
124 initial sensitivity thresholds to key oil attributes, followed by a well-defined training
125 program that is based on classical psychophysics related to establishing absolute and
126 differential thresholds (IOC, 2023). The absolute threshold is that at which a given
127 stimulus is detected 50% of the time, while the differential threshold is that at which a
128 difference between stimuli is detected 75% of the time. These techniques have been
129 shown to be useful for establishing and training sensory processes, but they do not allow
130 to detect and take into account the potential biases of the tasters that may influence their
131 evaluations (e.g., Ramos-Álvarez et al., 2013).

132 Expert panels are heavily trained to avoid biased judgments. However, this is not
133 the case for inexperienced tasters participating in the evaluation of consumer

EVOO SENSORY AND DECISION-MAKING PROCESSES 7

134 preferences (Dos Santos et al., 2023). As participants' biases may determine their
135 consumption and decision-making processes, evaluations conducted with untrained
136 participants need to incorporate psychophysical models that include the role of the
137 decision-making process in the sensorial evaluation of EVOO (e.g., Martín-Guerrero et
138 al., 2014).

139 Signal Detection Theory (SDT) provides a model that differentiates the sensory
140 and decision processes, allowing for a separate evaluation of taster sensitivity, decision-
141 making, and response bias (e.g., Hautus et al., 2021; McNicol, 2005). SDT uses two
142 types of detection assays: Signal (the target stimulus), and Noise (identical to the signal
143 in all but the specific features of interest in the evaluation). Participants have to detect
144 whether the signal is present or absent in a given trial. There are four possible outcomes
145 of the combination between the participant's response and the presence or absence of the
146 signal: Hit (Signal present, response Yes), Miss (Signal present, response No), False
147 Alarm (Signal absent, response Yes), and Correct rejection (Signal absent, response
148 No). By combining these options, different sensory and decision indices can be
149 computed, which independently characterize participants' sensory performance and
150 decision process. Typically, sensory processes are manipulated by varying the intensity
151 of the signal, while decision criteria are manipulated by adjusting instructions,
152 expectations, or the proportion of signal-to-noise trials, which leads observers to adopt
153 either lenient or conservative response strategies (e.g., Green & Swets, 1966; Hautus et
154 al., 2021; McNicol, 1972).

155 SDT-based procedures have been successfully applied to the study of tasting
156 processes in untrained consumers. Increases in stimulus concentration correlated with
157 improvements in detection, in both, basic flavors (Martín-Guerrero et al., 2015) and
158 olive oil detection (Paredes-Olay et al., 2010). Moreno-Fernández et al. (2012) found

EVOO SENSORY AND DECISION-MAKING PROCESSES 8

159 that gradually increasing the concentration of EVOO in a paraffin dilution facilitated
160 difficult discriminations. Progressive training led participants to show a conservative
161 bias that did not appear when training was conducted with a difficult discrimination
162 from the start. Most important for the present discussion, this bias would have gone
163 unnoticed if the study would have been conducted under the premises of classic
164 psychophysics used in the IOC protocols (IOC, 2023). Related studies using basic
165 flavors found that lenient versus conservative response criteria could be manipulated via
166 a payoff matrix (Martín-Guerrero et al., 2016) and induced expectations (manipulating
167 signal-noise base rates; Ramos-Álvarez et al., 2024), regardless of the magnitude of the
168 stimulus (i.e., salt concentration).

169 Ramos-Álvarez et al. (2013) took a step further by developing the Double
170 Dissociation Additive Test (DDAT), an experimental methodology that allows to
171 evaluate the independence or interaction of sensory and decision processes in a given
172 tasting situation. In this experimental methodology, at least one factor from each
173 process is manipulated in a multifactorial design, allowing for evaluating whether
174 changes in sensory performance affect decision criteria and vice versa. The use of
175 DDAT allowed Ramos-Álvarez et al. (2013) to ensure that modifications of olive oil
176 concentration in untrained consumers only affected the sensory process, while
177 manipulation of the instructions only affected decision processes. These authors found
178 that the combination of DDAT with parametric indices of sensitivity A' and bias $B'D$
179 were, both conceptually and methodologically, the most suitable approach for ensuring
180 an independent evaluation of the sensory and decision processes in the context of olive
181 oil tasting (see also Martín-Guerrero et al., 2016; Ramos-Álvarez et al., 2024).

182 The aforementioned studies were conducted either with basic flavors (Martín-
183 Guerrero et al., 2015, 2016; Ramos-Álvarez et al., 2024) or by detecting the presence or

EVOO SENSORY AND DECISION-MAKING PROCESSES 9

184 absence of oil in other oils, such as sunflower oils or alimentary paraffin (Moreno-
1 185 Fernández et al., 2012; Paredes-Olay et al., 2010). While the use of basic flavors does
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5 186 not compromise the methodological scope of those studies, the potential applicability of
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7 187 SDT to the assessment of natural EVOO, which is inherently more complex in
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9 188 composition, remains to be explored. Therefore, the main goal of this study was to
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11 189 investigate whether the SDT based methodology developed by Ramos-Álvarez and his
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13 190 colleagues would allow to independently assess the sensory and decision processes of
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15 191 untrained consumers when the difference between signal and noise is not based on the
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17 192 presence or the absence of the oil, but on the relative subtle attributes of natural oils.
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19 193 This approach would allow to outline a framework for adapting SDT based evaluation
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21 194 methodologies such as the DDAT to the evaluation of oils based on attributes.
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26 195 To achieve this goal in a situation akin to the one used with expert tasters, a panel
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28 196 of regular consumers of EVOO was established (e.g., Dos Santos et al., 2023). Creating
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30 197 a panel of tasters that participates in all the experiments allows for using a repeated-
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32 198 measures experimental design within and across experiments, enhancing internal
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34 199 validity by controlling for individual differences, thereby increasing the design's
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36 200 statistical power. The study involved two experiments in which participants evaluated
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38 201 different EVOOs of the Picual variety with distinct flavor characteristics that were
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40 202 provided by a local mill against a commercial EVOO provided by a local supermarket.
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44 203 In Experiment 1a, four different types of EVOO were used as signals, against a
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46 204 commercial EVOO that was used as noise, so that the manipulation was expected to
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48 205 affect the sensory index A' keeping the bias index $B'D$ neutral. Applying the Double
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50 206 Dissociation Additive Test in Experiment 1b, the use of two EVOOs (green and ripe)
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53 207 was expected to elicit sensory differences, while the manipulation of the relative
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EVOO SENSORY AND DECISION-MAKING PROCESSES 10

208 number of samples of the target oil with respect to the oil playing the role of noise was
209 expected to affect the bias index B^*D without interacting with the sensory manipulation.

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211 **2. General Methodology**

212 **2.1. Participants**

213 Sixteen participants (nine women and seven men) were recruited to create a
214 panel of tasters integrated by regular consumers of EVOO without previous tasting
215 training. They were highly familiar with EVOO consumption and culture, given their
216 residency in the province of Jaén, where olive cultivation is a pervasive activity,
217 influencing nearly every aspect of daily life (Parras-Rosa et al., 2021; García et al.,
218 2010).

219 Following the protocols established by the IOC, the final panel consisted of
220 the eight consumers (three women and five men) who demonstrated the greatest
221 sensitivity in detecting the characteristic features of extra virgin olive oil. The mean age
222 of the participants was 39 years old (ranging from 27 to 60 years old). Five participants
223 had a professional qualification, one had a university degree, and two were PhD
224 holders. They reported consuming caffeinated beverages around once a day. Two
225 participants were regular smokers. Participants were required to refrain from smoking,
226 eating, or ingesting caffeinated beverages for at least half an hour before starting the
227 experimental sessions. The same individuals participated in both experiments (1a, 1b).
228 They volunteered to participate in the experiments without receiving any compensation
229 for their participation.

230 The sample was selected by convenience by the research team, due to the
231 specific characteristics of the study and the availability of subjects to participate in the
232 consumer panel. G*Power (version 3.1.9.7) was used to compute the power analysis for

EVOO SENSORY AND DECISION-MAKING PROCESSES 11

1 233 the selected sample size (Faul et al., 2009). Selecting a sample of 8 participants, the
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3 234 repeated measures factorial design used in Experiment 1b, a significance level of 0.05
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5 235 and a power of 0.95, a large effect size ($f = 1.09$) is expected to be detected.
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10 237 **2.2. Materials and apparatus**

11 238 *Stimuli*

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14 239 *Signal EVOO*: Picual variety olive oils from Agrícola de Bailén Virgen de
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16 240 Zocueca SCA, a company based in Bailén, Spain, were used as signal stimuli in this
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18 241 study. The company provided EVOO that were cold pressed with olives harvested at
19
20 242 stages of maturity produced by conventional, Agriculture of Integrated Production
21
22 243 (AIP) or mixed. This resulted in samples with distinct organoleptic characteristics. Two
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24 244 liters of each oil were stored in plastic containers and coded with a letter—A, B, C, and
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26 245 D for the oils used in Experiment 1a, and G (green) and R (ripe) for the two oils used in
27
28 246 Experiment 1b. The EVOO samples provided by the olive mill were subjected to a
29
30 247 qualitative analysis based on the judgement of expert tasters. A variant of Cleveland
31
32 248 dot-plot graph was used to compare the EVOOs sensory profiles according to the tasting
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34 249 attributes given the advantages that presents for displaying frequency distributions when
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36 250 compared to spider plots (see Cleveland, 1993; and Kosslyn, 2006). The used variant is
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38 251 based on a graphic template (theme_ipsum) that emphasizes simple shapes and
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40 252 condensed typography, with solid default kerning pairs and geometric numbers to
41
42 253 facilitate comparability between points connected on the same horizontal. To evaluate
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44 254 the separation between the different EVOOs used as stimuli, the Euclidean distance
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46 255 between the different EVOOs was calculated in relation to the dot-plot graphs,
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48 256 combining all the attributes in a global index, that allowed to perform a multivariate
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50 257 ordering of the different stimuli based on these Euclidean distances (for the organoleptic
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EVOO SENSORY AND DECISION-MAKING PROCESSES 12

1 258 characteristics of the oils used in each experiment, refer to the Methods sections of
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3 259 Experiments 1a and 1b.)
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5 260 *Noise EVOO*: A standard quality commercial EVOO from Agriculture of
6
7 261 Integrated Production (AIP), from olives of the Hojiblanca and Arbequina varieties
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9 262 (coupage), Hacendado EVOO – black cap, 3-liter carafe, Oleo Estepa, SCA, Pol Ind
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11 263 Sierra del Sur, Estepa, Sevilla, Spain, was used as noise in both experiments. Noise
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13 264 evaluation, as provided by the producer, reported an EVOO with zero defects, 3.6
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15 265 bitterness, 3.5 spiciness, and 5.5 fruitiness.
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19 267 *Tasting laboratory*
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22 268 The experiments were conducted in the psychology laboratory of the University
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25 269 of Jaén. This laboratory is equipped with 10 tasting stations. The laboratory has been
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27 270 adapted to the tasting tasks in accordance with the guidelines of the IOC: Tasting
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29 271 glasses and watch glasses Following IOC/T.20/Doc. no. 5, Rev. 2, 2020. "Glass for Oil
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31 272 Tasting". Test Room following IOC/T.20/Doc. no. 6, Rev. 1, 2007. "Guide for the
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33 273 Installation of a Test Room".
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35 274 The tasting booths are separate spaces where the participant can develop the task
36
37 275 without any interference. Each tasting booth included a computer, a screen, a mouse, a
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39 276 desk and a chair (workstation), as well as the sheet coaster for holding glasses where the
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41 277 participants left the samples after tasting them, and an industrial heater (which uses
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43 278 distilled water that guarantees the thermal maintenance of up to 24 samples, between 28
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45 279 + 2 °C), water and apple—for cleaning the palate between samples— (see Fig.1 in
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47 280 Ramos-Álvarez et al., 2013).
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51 282 *LearnOlive Software*
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EVOO SENSORY AND DECISION-MAKING PROCESSES 13

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283 The experiments were implemented using the LearnOlive software, developed in
284 Visual Basic (see Ramos-Álvarez et al., 2013). The software was designed to facilitate
285 the sensorial evaluation by consumers or expert tasters, in accordance with the standards
286 set forth by the IOC (2023). The software guides the participant throughout the
287 procedure: 1) Informed consent; 2) Sociodemographic and data of interest, such as
288 frequency of cigarette smoking and exciting drinks; 3) Explanation of the characteristics
289 of the procedure and electronic signature of the informed consent; 4) Questionnaire on
290 preferences and consumption patterns of EVOO; 5) General instructions to familiarize
291 with the workstation and the elements to be used; 6) “Turn-Smell-Taste-Clean” tasting
292 procedure; 7) Visual guidance of the steps to be followed in each block (location of the
293 reference sample and test, placing it on the glass plate and cleaning the palate); 8)
294 Recording of the responses; 9) Feedback; 10) Sensorial and economic evaluation; and
295 11) Reminder of the instructions and the next block.

296 The use of LearnOlive, guides the taster through the “Turn-Smell-Taste-Clean”
297 step-by-step process, providing performance feedback without researcher intervention.
298 The software is available for interested researchers upon request.

299

300 2.3. Procedure

301 This study was conducted in accordance with the ethical principles outlined in the
302 Declaration of Helsinki. Ethical approval was obtained from Ethical Committee of the
303 University of Jaén. All participants provided informed consent prior to their
304 involvement in the study, and they were informed of their right to withdraw at any time
305 without penalty. Participants’ data were kept confidential, and only aggregate data were
306 reported to ensure anonymity. The completion of the socio-demographic data forms and

EVOO SENSORY AND DECISION-MAKING PROCESSES 14

1 307 the informed consent were requested only in Experiment 1a. Except where noted later,
2
3 308 the procedure in Experiments 1a and 1b was identical to that described in this section.

4
5 309 The preparation of the samples was carried out one hour before participants
6
7 310 arrival, putting 10 ml of oil in the blue tasting glasses, which were covered with their
8
9 311 respective watch glass and positioned in the heaters according to the counterbalanced
10
11 312 order of samples provided by the program that ensures that all conditions are presented
12
13
14 313 in every possible order and combination. The program also provides a random
15
16 314 assignment of the experimental conditions to each tasting booth.

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18
19 315 The order of presentation of the signal and noise samples was counterbalanced,
20
21 316 in accordance with an extended Latin square design to achieve the objective of
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23 317 distributing the conditions in such a way that each one appears in each ordinal position
24
25 318 with equal frequency and to neutralize order effects. A basic 4×4 ensures that each
26
27 319 condition (1, 2, 3, 4) appears once in each position (1st, 2nd, 3rd, 4th). In the case of an 8-
28
29 320 participants study, the Latin square is repeated twice, ensuring that subjects 1 and 5, 2
30
31 321 and 6, 3 and 7, and 4 and 8 will have the same sequences. In experiment 1a conditions
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33 322 1, 2, 3 and 4 correspond to the 4 EVOOs used as signal (A, B, C, and D).

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38 323 In experiment 1b to the complete crossover of two types of EVOO (Ripe versus
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40 324 Green) with two signal/noise rates inducing two types of expectations (Lenient versus
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42 325 Conservative) conditions were as follows: Ripe & Lenient; Ripe & Conservative;
43
44 326 Green & Lenient; and Green & Conservative. This procedure ensured that the samples
45
46 327 reached the required temperature between 27 and 29 degrees Celsius at the time of
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48 328 tasting (IOC, 2018). In addition, a glass of water and apple chunks were available for
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50 329 cleaning the palate between trials.

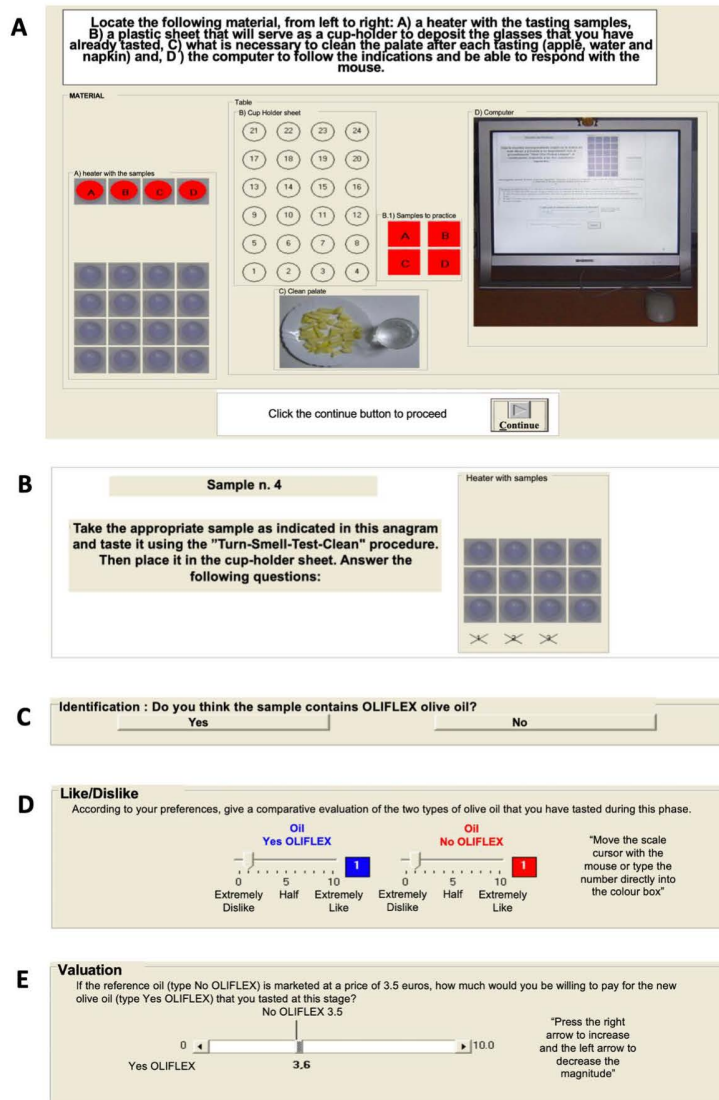
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58 331 *Tasting task*

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EVOO SENSORY AND DECISION-MAKING PROCESSES 15

1 332 The oils used as signal were named with the fictitious brand name Oliflex.
2
3 333 Participants task was to detect the presence of Oliflex in the sample. After each trial, the
4
5 334 program provided feedback to participants, letting them know whether their answer was
6
7 335 correct (“GOOD. Right choice”) or incorrect (“BAD. Wrong choice”).
8
9
10 336 The top panel of Figure 1 (Fig. 1A) presents an example of the initial screen in
11
12 337 which participants are requested to locate all the elements that they will be using during
13
14 338 the task within the workstation. Participants received the following instructions
15
16 339 regarding the tasting process:
17
18
19 340 “To conduct the tasting, follow this simple four-step procedure: Turn-Smell-
20
21 341 Taste-Clean. Take the glass, cover it with the watch glass, tilt it, and give it a full
22
23 342 turn to wet the inside as thoroughly as possible. Remove the watch glass and
24
25 343 smell the contents of the glass, taking slow, deep inhalations. Next, take a small
26
27 344 sip of the sample, ensuring the oil is distributed throughout the oral cavity—
28
29 345 from the front of the mouth and tongue to the sides, back, palate, and throat.
30
31 346 After tasting each sample, eat a piece of apple and drink some water to cleanse
32
33 347 your palate. Place the glass and watch glass on the coaster to indicate that the
34
35 348 sample has been tasted.”
36
37 349 Details of the procedure and its validation can be found at Paredes-Olay et al.,
38
39 350 (2010). Once participants confirmed they had no doubts about the procedure, they
40
41 351 received the following instructions:
42
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44 352 “In Jaén, a high-quality extra virgin olive oil called OLIFLEX has been
45
46 353 selected to study consumer acceptance. In this phase of the study, we
47
48 354 are interested in determining whether this olive oil has a distinctive
49
50 355 taste, and your participation is essential. The goal is to quantify how
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52 356 well you can differentiate OLIFLEX from other olive oils.
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EVOO SENSORY AND DECISION-MAKING PROCESSES 16

357 **Figure 1**358 *Example of the Instructions received by participants*

359 *Note.* A) Screen prompting participants to identify all elements of the workstation. B)
360 Screen displaying tasting instructions for a given trial. C) The window guiding sensory
361 evaluation responses. D) Window guiding preference selection and, E) economic
362 evaluation responses.
363

EVOO SENSORY AND DECISION-MAKING PROCESSES 17

1 364 Please take the glass marked with red at the bottom of the warmer;
2
3 365 it contains a sample of the OLIFLEX variety. Taste it using the tasting
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5 366 method you practiced earlier (Turn-Smell-Taste-Clean), focusing on its
6
7 367 properties to distinguish it clearly. Once you have tasted the Oliflex
8
9 368 olive oil, place it on the red glass holder on the table and press the
10
11 369 "continue" button."

12
13
14 370 Figure 1B presents an example of a given trial in which the participant receives
15
16 371 the indication about the sample that needs to take and taste from the coaster. The task
17
18 372 involved different blocks of trials in which participants had to taste different oils. At the
19
20 373 outset of each block, the tasters were instructed to taste the Oliflex. Once they do so,
21
22 374 they had to taste four samples. After tasting each sample the tasters must indicate with a
23
24 375 simple "yes" or "no" whether the oil they have just tasted is Oliflex Figure 1C shows
25
26 376 the area of the screen dedicated to the identification/discrimination response to the
27
28 377 stimulus presented in the current trial. Once the sensory identification has been carried
29
30 378 out, a new screen is used to capture the response related to the preferences for the
31
32 379 EVOOs tasted (Figure 1D), as well as the economic valuation of the EVOOs. (Figure
33
34 380 1E).

381 382 **2.4. Dependent Variables and Statistical Analysis**

383 *Dependent Variables*

384 Psychophysical indices were estimated to measure sensory and decision
385 processes. The participant's response can be classified as a "hit" (indicating a positive
386 response in a trial with Oliflex EVOO), a "correct rejection" (a negative answer in a
387 trial with noise), a "failure in detection" or "miss" (a negative response in a trial with
388 Oliflex EVOO), or a "false alarm" (an affirmative answer in a noise sample).

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EVOO SENSORY AND DECISION-MAKING PROCESSES 18

389 Performance is deducted from the calculation of the hit and false alarm rates (Green &
 390 Swets 1966; Hautus et al., 2021; Swets, 1996; see also Martín-Guerrero, 2014). Tasting
 391 tasks use few trials to avoid saturating participants' senses, making fulfilment of SDT
 392 parametric indexes (d' and c) assumptions unlikely (Wickens, 2002). Thus, a
 393 nonparametric alternative was chosen, that being less restrictive with respect to the
 394 assumptions (Macmillan, 1993). A' index for the sensory process (computationally
 395 developed by Grier, 1971), and the B'_D index developed by Donaldson (1992) for the
 396 decision process, comparing them with those traditionally favored in psychophysical
 397 research (see Ramos-Álvarez et al., 2013). For each of the test blocks, the hit (H) and
 398 false alarm (FA) rate was used for the computation of the A' and B'_D index according to
 399 the formulae:

$$\left\{ \begin{array}{l} \text{Grier } A' = 0.5 + \left[\text{sign}(H - FA) \cdot \frac{(H - FA)^2 + |H - FA|}{4 \cdot \text{Max}(H, FA) - 4H \cdot FA} \right] \\ \text{Donaldson } B'_D = \frac{(1 - H) \cdot (1 - FA) - H \cdot FA}{(1 - H) \cdot (1 - FA) + H \cdot FA} \end{array} \right\}$$

400

401

402 The use of few trials increases the likelihood of observing extreme rates. Thus, a
 403 log-linear correction strategy was used by adding a constant amount, .50, to all
 404 frequencies before calculating the rates (Brown and White, 2005).

405 The lower panel of Figure 1 (Fig. 1C) shows the exact instructions provided to
 406 participants regarding the preference-related indices. Specifically, it shows how the
 407 difference in preference for the target EVOO (Signal) compared to the reference EVOO
 408 (Noise) was calculated, and how much participants were Willing To Pay (WTP) for the
 409 Signal oil relative to the economic reference value of the Noise oil.

410 *Statistical Analyses*

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EVOO SENSORY AND DECISION-MAKING PROCESSES 19

1 411 The results of both experiments were represented graphically using box plots.
2
3 412 Each psychophysical index— A' for the sensory process and $B'D$ for the Decision
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5 413 process, as well as preference-related measures, Differential Preference and WTP—was
6
7 414 subjected to a repeated measures ANOVA. In Experiment 1a, only the type of EVOO
8
9 415 was manipulated and thus the ANOVA was for a one-way design. In Experiment 1b,
10
11 416 both the type of EVOO and the induced signal/noise rates were simultaneously
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13 417 manipulated according to the Double Dissociation Additive Test, so that the ANOVA
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15 418 corresponded to a two-way design. Although sequential effects were explicitly
16
17 419 controlled for by counterbalancing, the ANOVA was based on the mixed effects model
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19 420 approach to minimize the error term by explicitly adding the sequential effect in the
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21 421 linear equation, together with the fluctuations of the participants (Faraway, 2016). In
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23 422 particular, the optimal approach for analyzing the data of the present research was to
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25 423 specify a maximum random effects structure for each dependent variable, including
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27 424 random intercepts by-order, as well as random slopes by-subjects for each of the within-
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29 425 subjects variables -Expectation and EVOO type- (see Barr et al., 2013 for the
30
31 426 specification of terms in mixed analysis). In addition, the model includes EVOO, and
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33 427 Expectation as fixed effects, as well as the interaction between them.
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35 428 For the highest order design, the four stimuli conditions were arranged in a 2
36
37 429 EVOO (Green, Ripe) \times 2 Signal/Noise rate (Low, High) design to analyze the
38
39 430 independent effect of the EVOO or Signal/Noise rate condition compared to the
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41 431 combined effect (or interaction) between the two manipulations. In all analyses, we first
42
43 432 tested for interactions. If there was a significant interaction, we tested for simple effects
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45 433 of EVOO on each individual Signal/Noise rate condition for the sensory index, and in
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47 434 the opposite direction for the decisional index. In the case of the one-way experiment,
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49 435 the detailed statistical analysis of variables with more than two levels (e.g., 4 types of
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EVOO SENSORY AND DECISION-MAKING PROCESSES 20

1 436 EVOO) was addressed by a orthogonal planned analysis using Holm's method, a
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3 437 family-wise error rate correction to control type I error for multiple t-tests (see *p.adjust*
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5 438 command on R software). Since the oils were planned around the axis of green-ripe
6
7 439 differences (i.e., some of the oils were expected to be similar to each other, as they were
8
9 440 different from others), the detailed analysis of the sensory differences between the oils
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11 441 was established by planned orthogonal contrasts, in order to gain efficiency,
12
13 442 informativeness, and simplicity (see Furr & Rosenthal, 2003).
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16 443 The inferential analyses from the ANOVA perspective were complemented by
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18 444 a Bayes Factor and Effect size analysis. In particular, the Bayesian analysis aimed to
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20 445 validate the null results, i.e., to assess the level of support for the null hypothesis
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22 446 between the anecdotal and strong poles (according to Jeffreys and Raftery criteria, see
23
24 447 Wetzels et al., 2011). Effect size estimates are added to facilitate power estimates or
25
26 448 meta-analysis studies. A standardized estimate of effect size was included in all
27
28 449 analyses: generalized η^2 (η^2 from now on) for omnibus ANOVAs, and Cohen's *d* for
29
30 450 pairwise contrasts.
31
32 451 A more detailed level of analysis was included in order to better understand
33
34 452 the procedural dynamics. As reference values could be defined for all dependent
35
36 453 variables, one-sample tests were included for each experimental condition against the
37
38 454 appropriate reference value. Thus, one-sample t-test on chance performance, value 0.5,
39
40 455 on the sensory index A'. One-sample t-test on the neutral criterion, value zero, in the
41
42 456 case of the Donaldson index B'D. One-sample test on the null value in terms of the
43
44 457 differential preference between signal and noise. Finally, as the task provided an anchor
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46 458 value for the price of the reference EVOO, set at 3.5 Euros (the prevailing market value
47
48 459 for a liter of EVOO at the time the investigation was carried out), a one-sample t-test
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50 460 was also performed on the WTP for the signal oil against this reference value.
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EVOO SENSORY AND DECISION-MAKING PROCESSES 21

1 461 All analyses were performed in R 4.4.0 (R Core Team, 2024) using the
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3 462 {data.table}, {ggplot2}, {rtf}, {stringr}, {fmsb}, {emmeans}, {MASS}, {GSignTest},
4
5 463 {lme4}, {lmerTest}, {pbkrtest}, {BayesFactor}, and {pwrss} libraries. Statistical
6
7 464 significance was set at $p \leq .05$. Raw data files from participants in this study are
8
9 465 available at the following link:
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11 466 [https://data.mendeley.com/preview/8gnjtjb8hh?a=2ebe7e65-9146-455a-9615-](https://data.mendeley.com/preview/8gnjtjb8hh?a=2ebe7e65-9146-455a-9615-690827eb32b2)
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13 467 [690827eb32b2](https://data.mendeley.com/preview/8gnjtjb8hh?a=2ebe7e65-9146-455a-9615-690827eb32b2)
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19 469 *Control for extraneous Variables*
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22 470 In this study, the sociodemographic variables considered were age, level of
23
24 471 education, and gender. Variables related to the taster's lifestyle and illnesses were also
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26 472 considered as extraneous variables, as these variables may influence the results or
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28 473 reduce the perception of attributes as we can see: previous tasting experience, the
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30 474 presence of a physical impairment of the sense of taste or smell at the time (e.g. allergy,
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32 475 cold, flu, etc.) and as a persistent condition (e.g. asthma), cigarette consumption (30
33
34 476 minutes before the experiment and daily), and the consumption of stimulant drinks such
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36 477 as coffee or energy drinks (30 minutes before the experiment and daily). These variables
37
38 478 were recorded for the purpose of defining the characteristics of the sample (panel of
39
40 479 novice tasters), verifying compliance with the pre-experiment indications (no smoking
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42 480 or consumption of stimulant drinks 30 minutes before the experiment), determining
43
44 481 possible interactions between physical alterations (e.g., asthma, flu) and the sensory
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46 482 performance of the tasters, and controlling for aspects that could interfere with the
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48 483 results. These variables were not deemed relevant and are therefore they were not
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50 484 included in the statistical analysis presented in the results.
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486 3. Experiment 1a

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3 487 The combination of Signal Detection Theory and the Double Dissociation
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5 488 Additive Test applied to the sensorial evaluation of flavors comprise a methodology that
6
7 489 allows to reliably discern between the contribution to performance of sensory and
8
9 490 decision processes to the tasting tasks (e.g., Martín-Guerrero et al., 2014; Ramos-
10
11 491 Álvarez et al., 2013, 2024). However, previous studies have used either basic flavors
12
13 492 (Martín-Guerrero et al., 2015, 2016; Ramos-Álvarez et al., 2024) or mixtures of EVOO
14
15 493 (signal) diluted in sunflower oil (Paredes-Olay et al., 2010) and/or food paraffin (noise)
16
17 494 as the signal (Moreno-Fernández et al., 2012; Ramos- Álvarez et al., 2013). That is, the
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19 495 task of participants in those studies was to detect whether the flavor or the EVOO was
20
21 496 present in the mixture, a relatively simple task compared with the task of discerning
22
23 497 among the different features of complex natural olive oils that is regularly conducted by
24
25 498 expert tasters. To overcome this limitation, the goal of Experiment 1a was to develop
26
27 499 and test a procedure for evaluating the attributes of natural EVOO by a tasting panel of
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29 500 consumers using the SDT based methodology that would allow to independently
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31 501 evaluate sensory and decision processes.
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503 3.1. Stimuli

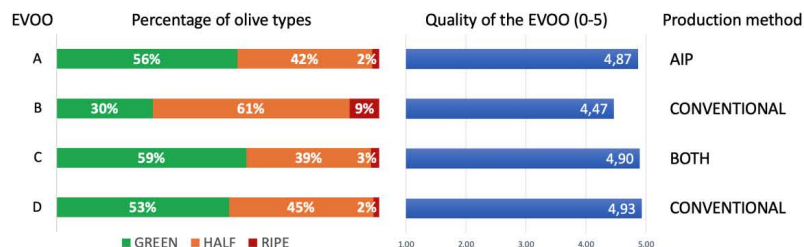
41
42
43 504 The four olive oils selected as signals for Experiment 1a exhibited varied
44
45 505 degrees of green, mixed, or ripe characteristics. The left section of Figure 2 illustrates
46
47 506 the results of a multispectral camera evaluation of the fruit, which enables the
48
49 507 determination of the percentage of green, ripe, and mixed fruit in each of the oils (A, B,
50
51 508 C, and D). The general assessment of the oils made by a panel of experts is presented at
52
53 509 the right section of Figure 2 in the form of a quality rating on a scale of 0 to 5, with 0
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55 510 indicating the lowest quality and 5 indicating the highest level of quality.
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511 The production method is referenced in terms of conventional agriculture,
512 integrated production (AIP), and a mixture between the two previous methods. A, C,
513 and D oils are similar with respect to both, the proportion of green, half and ripe olives
514 used in the mixture, and with respect to the quality evaluated by experts. Those three
515 oils can be considered as green EVOO and the different methods of production did not
516 seem to significantly affect to the quality of the product, as evaluated by the experts.
517 EVOO labelled as B is the one that shows the greater proportion of intermediate and
518 ripe fruits in its composition, being considered as the one with the lowest quality in the
519 experts' evaluation. Thus, B EVOO is of the ripe type, and more similar to the one used
520 as noise in these experiments of a type usually sold at large scale in the supermarkets,
521 which are elaborated with ripe fruit that provides a higher oil yield though it partially
522 sacrifices quality.

523

524 **Figure 2**525 *Composition and quality of the four olive oils from local mill used in Experiment 1a*

526

527 *Note.* The left section illustrates the percentage composition of green, ripe, and
528 intermediate fruit in each of the four olive oils provided by the local mill. The center
529 section presents the quality evaluation of these oils as assessed by the test panel. AIP
530 refers to the Agriculture of Integrated Production method.

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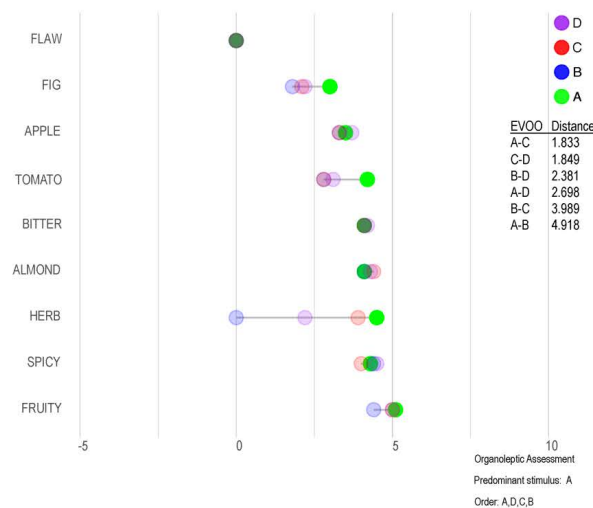
532 Figure 3 shows the results of the sensorial evaluation conducted by experts of
533 the four stimuli used as signals in Experiment 1a. All oils (A, B, C and D) showed

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534 similar values in terms of positive attributes (fruity, spicy and bitter). They differed in
 535 terms of herb (B, D), tomato (A) and fig (A). The Euclidian distance between oils
 536 confirms that EVOO B is the one that differed the most from the other three. Oils A and
 537 D also differed, as A had the highest herb flavor while D had the lowest. All the oils
 538 were evaluated with zero flaws. Compared to the EVOO used as noise (see general
 539 methodology), oils A, C, and D had a similar fruitiness value, while oil B had a slightly
 540 lower value. In terms of spiciness and bitterness, the noise oil showed a slightly lower
 541 value than all other oils (A, B, C and D).

Figure 3

544 *Sensorial Assessment of the Selected Olive Oils of Experiment 1a*



545
 546 *Note.* The figure shows the expert panel's evaluation results for the four oils (A, B, C, D)
 547 used in Experiment 1a. It includes the attributes identified in each oil, their corresponding
 548 values, and the Euclidean distance between the olive oils.

550 3.2. Experimental Design and Hypotheses

EVOO SENSORY AND DECISION-MAKING PROCESSES 25

1 551 In Experiment 1a, a one-way design was used. The factor was operationalized
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3 552 with four different types of EVOO, and repeated measures were taken from each
4
5 553 participant. As the number of natural EVOO samples (signal) and commercial EVOO
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7 554 samples (noise) within each block was kept identical (two samples of each) the expected
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9 555 decision criteria was neutral. The manipulation of the types of EVOO was expected to
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11 556 selectively affecting the sensory index A' and not the decision-making index $B'D$ (see,
12
13 557 for instance, Ramos-Álvarez et al., 2013) Finally, as the oils used as signal were of
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15 558 higher quality than the commercial oil, it was expected that participants would show a
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17 559 higher preference and willingness to pay (WTP) for them.
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561 **3.3. Procedure**

562 The procedure was identical to the one described in the general methodology
563 except for what follows. Participants received four blocks of 4 tasting trials each, two
564 with the oil playing the role of signal, and two with the commercial oil. A different oil
565 (A, B, C, and D) was used as signal in each block of trials, with the order
566 counterbalanced across participants as described in the general methodology.

567

568 **3. 4. Results and Discussion Experiment 1a**569 *Sensory and Decision-Making Processes*

570 Figure 4 shows the sensory index A' (left) and the bias index $B'D$ (right)
571 obtained when participants confronted the task of detecting the signal (Oliflex) and the
572 noise across blocks of tasting trials, were each EVOO (A, B, C, or D) served as the
573 signal. The mean values for Grier A' sensitivity index varied significantly based on the
574 type of EVOO [$F(3, 20.54) = 4.57, p = .0132$, with medium effect size, $\eta^2 = 0.40$, and
575 anecdotal evidence in favor of the alternative hypothesis, $BF = 1.059$, Fig.4A].

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EVOO SENSORY AND DECISION-MAKING PROCESSES 26

1 576 Orthogonal planned contrasts with Holm correction revealed no significant differences
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3 577 between the detection of oils A and B [$t(24.02) = 0.42$, very small Effect Size, $d =$
4
5 578 0.169 , $p > .999$], or between oils C and D [$t(24.02) = 0.21$, $p > .999$; in both analyzes
6
7 579 the effect size was of very low magnitude, d between 0.1 and 0.17]. However, detection
8
9 580 of oils C and D was significantly better than detection of oils A and B [$t(24.02) = 3.41$,
10
11 581 $p = .0069$, with large effect size, $d = 1.945$].

12
13 582 When Oliflex comprised oils A or B, participants' detection did not differ
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15 583 significantly from chance [differences from 0.5 for EVOO A: $t(7) = 0.70$; $p = .2520$;
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17 584 EVOO B: $t(7) = 0.17$; $p = .4334$]. In contrast, performance was significantly better than
18
19 585 chance when Oliflex consisted of oils C or D [differences from 0.5 for EVOO C: $t(7) =$
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21 586 4.25 ; $p = .0019$; and EVOO D: $t(7) = 3.26$; $p = .0069$]. Bayesian analysis supported
22
23 587 these findings. For oils A and B, the evidence favored the null hypothesis, albeit weakly
24
25 588 (BF between 0.3 and 0.4). In contrast, for oils C and D, the evidence strongly supported
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27 589 the alternative hypothesis (BF between 5 and 14).

28
29 590 The right section of Figure 4 (Fig.4B) displays the Donaldson B'_D index, which
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31 591 was used to evaluate the decision-making process in each signal-noise combination
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33 592 during Experiment 1a. As anticipated, participants generally exhibited a neutral decision
34
35 593 criterion when assessing the different oils. The only potential exception was oil B, for
36
37 594 which the median suggested a slight tendency toward a lenient criterion. However, the
38
39 595 ANOVA indicated no significant differences in the decision criterion across the four
40
41 596 EVOOs [$F(3.00, 24.00) = 1.04$, $p = .3911$]. The treatment effect's magnitude was
42
43 597 weak, $\eta^2 = 0.12$, and the Bayesian Factor, 0.011 , provided strong evidence in favor of
44
45 598 the null hypothesis.

46
47 599 Furthermore, the criterion values did not significantly differ from zero (neutral)
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49 600 for any of the oils [differences from zero for EVOO A: $t(7) = 1.53$, $p = .0852$; EVOO

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EVOO SENSORY AND DECISION-MAKING PROCESSES 27

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601 B: $t(7) = -0.90, p = .7998$; EVOO C: $t(7) = -0.24, p = .5905$; and EVOO D: $t(7) =$
602 $0.81, p = .2223$]. Bayesian analysis of the $B'D$ index supported these findings, showing
603 mostly weak evidence in favor of the null hypothesis, with BF values ranging between
604 0.3 and 0.80.

605 In summary, participants detected the differences between oils C and D and the
606 noise, but they did not perceive the differences between oils A and B and the oil used as
607 noise. The lack of distinction between oil B and the commercial oil is not surprising, as
608 both are made predominantly from intermediate-ripe fruits, making their differences
609 likely too subtle for untrained consumers to detect. However, this was not the case for
610 oil A, which shared a similar proportion of green, intermediate, and ripe fruits with oils
611 C and D. Furthermore, expert evaluations of the most relevant attributes—fruitiness,
612 bitterness, and spiciness—showed no differences among these oils.

613 The key distinction among oils A, C, and D lies in their production methods:
614 oils C and D are produced conventionally, whereas oil A is exclusively produced using
615 the AIP method. It seems unlikely that the production method would yield attributes
616 more easily distinguishable by untrained consumers than by experts, raising questions
617 about the relevance of this unexpected result. This is especially significant given the
618 weak evidence supporting the null hypothesis when comparing oils A and B.

619 Regarding the results of the decision criterion, the experiment's design did not
620 incorporate any variables expected to influence this measure. As anticipated,
621 participants exhibited a mostly neutral decision criterion in their responses.

622 The combined results of sensitivity and decision criterion indices suggest that
623 SDT can be successfully applied to the sensory evaluation of natural oils. Moreover, the
624 strategy employed to select and prepare consumers for participating in the tasting panel

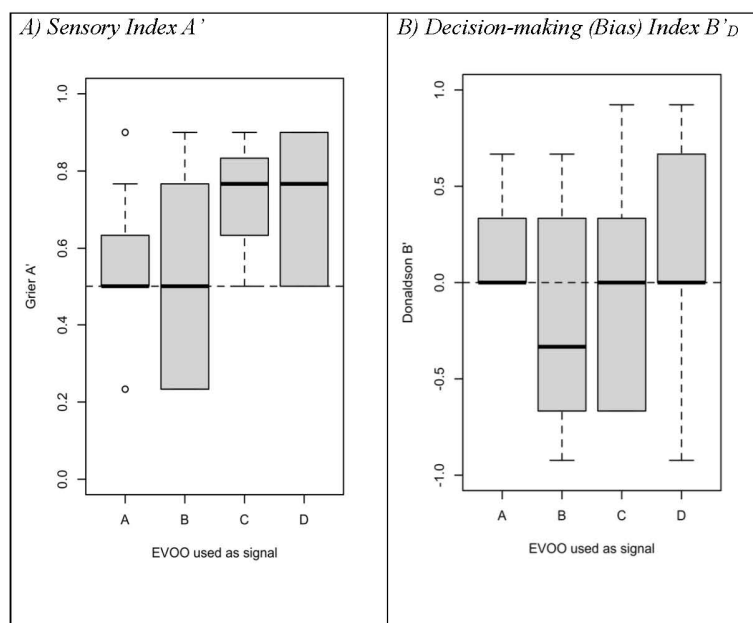
EVOO SENSORY AND DECISION-MAKING PROCESSES 28

625 proved effective and robust, offering a methodology that can be reliably applied in
 626 subsequent studies.

627

628 **Figure 4**

629 *Procedural indices of Experiment 1a*



630 *Note.* The Boxplots display the upper and lower quartiles of the data within the boxes,
 631 while the whiskers represent the minimum and maximum values outside the quartiles.
 632 The horizontal line inside each box indicates the median. The dashed line represents the
 633 value of chance in the sensory index (Panel A, left) and the value of a neutral criterion
 634 for the decision index (Panel B, right).

635

636

637 *Differential Preference and Economic Valuation (WTP)*

638 The left section of Figure 5 (Fig. 5A) illustrates participants' differential

639 preferences for each EVOO used as a signal compared to the standard quality EVOO

640 used as noise, with the reference value for a null difference represented by a dashed

641 line. While there appears to be a preference for some of the signal EVOOs, the ANOVA

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EVOO SENSORY AND DECISION-MAKING PROCESSES 29

1 642 revealed no significant differences among them [$F < 1$], providing extreme/strong
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3 643 support for the null hypothesis (BF of 0.007). However, differential preferences for
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5 644 some oils did significantly differ from zero. Specifically, participants showed a
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7 645 statistically significant preference for oils B and C compared to zero, while no
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9 646 significant differences were found for oils A and D relative to the noise [preference for
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11 647 EVOO A versus noise: $t(7) = 0.67, p = .2612, BF = 0.405$ (anecdotal/weak evidence for
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13 648 the null hypothesis); EVOO B versus noise: $t(7) = 4.02, p = .0025, BF = 11.243$
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15 649 (strong/positive evidence for the alternative hypothesis); EVOO C versus noise: $t(7) =$
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17 650 $1.90, p = .0497, BF = 1.148$ (anecdotal/weak evidence for the alternative hypothesis);
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19 651 and EVOO D versus noise: $t(7) = 1.23, p = .1294, BF = 0.601$ (anecdotal/weak
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21 652 evidence for the null hypothesis)].

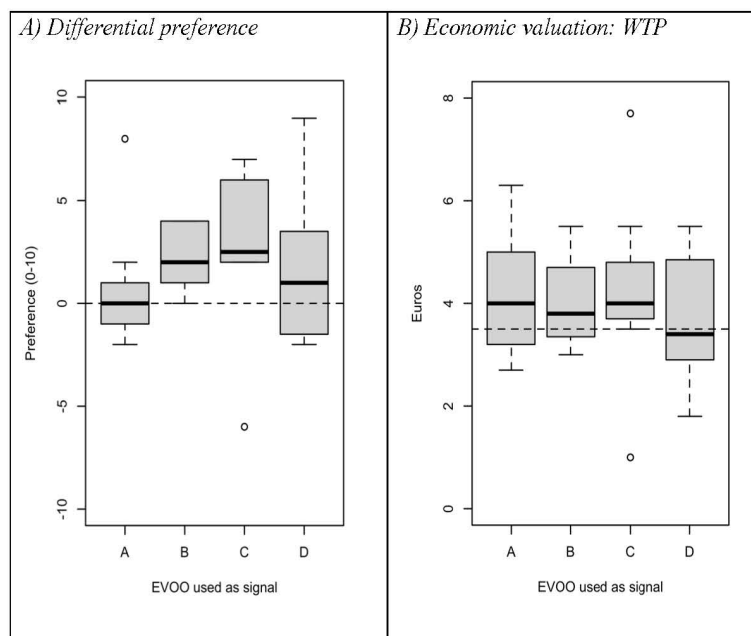
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26 653 The right section of Figure 5 (Fig.5B) shows the amount of money in euros
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28 654 participants were Willing To Pay (WTP) for each EVOO used as signal compared to the
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30 655 noise EVOO, represented with a dashed line in the figure. The ANOVA revealed no
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32 656 significant differences among the EVOOs used as signal [$F < 1$], providing a weak size
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34 657 effect, $\eta^2 = 0.06$, as well as anecdotal/weak evidence in support of the null hypothesis
35
36 658 BF of 0.997. Furthermore, the WTP values for none of the four EVOOS significantly
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38 659 differed from the appraised value of the reference EVOO, set at €3.5 [EVOO A: $t(7) =$
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40 660 $1.55, p = .0823$; EVOO B: $t(7) = 1.61, p = .0754$; EVOO C: $t(7) = 1.07, p = .1601$; and
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42 661 for EVOO D: $t(7) = 0.44, p = .3368$]. The prevailing Bayesian analysis of WTP
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44 662 provided further support for the null hypothesis, though the evidence was
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46 663 anecdotal/weak (BF between 0.36 and 0.86).

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49 664 Participants' ability to detect the differences between oils led them to prefer only
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51 665 EVOOs B and C over the commercial EVOO used as noise. Notably, oil B was the least
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53 666 distinguishable from the noise, as it contained the highest proportion of
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EVOO SENSORY AND DECISION-MAKING PROCESSES 30

667 intermediate/ripe fruit—a characteristic it shares with commercial EVOOs, such as the
 668 one used as noise. In contrast, the preference for EVOO C is less surprising, as experts
 669 have evaluated it as a high-quality oil. However, participants did not exhibit a clear
 670 willingness to pay more for oils that experts identified as superior quality (C and D),
 671 neither for those that they seem to prefer a little more (A and B).

672

673 **Figure 5**674 *Preference Indices of Experiment 1a*

675 *Note.* A) Differential preference for each of the four target EVOOs compared to the
 676 reference commercial EVOO. The dashed line represents the value for a null difference.
 677 B) Economic valuation, in Euros, of each of the four target EVOOs compared to the price
 678 set for the reference EVOO (3.5 Euros, represented by the dashed line), indicating
 679 participants' Willingness To Pay (WTP) for the target EVOOs.

680

681 This outcome is unsurprising, as all five oils used in this study were classified by

682 experts as having zero defects, meaning their differences may be too subtle to

683 significantly influence WTP among regular consumers when based solely on taste. This

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EVOO SENSORY AND DECISION-MAKING PROCESSES 31

1 684 finding aligns with growing evidence emphasizing the significant role of extrinsic
2
3 685 attributes, such as certifications and packaging, in shaping consumers' purchasing
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5 686 decisions for EVOO (see Arbeláez-Mejía et al., 2024, for a review)—a factor that may
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7 687 be particularly determinant when comparing EVOOs with zero defects.
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12 689 **4. Experiment 1b**
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14 Experiment 1a demonstrated the effectiveness of the SDT-based methodology
15
16 691 for evaluating natural olive oils with a panel of regular consumers. The results showed
17
18 692 that the distinct types of natural oils used did not influence the decision criterion,
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20 693 indicating that participants emitted their judgments based solely in the sensory process
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22 694 independent of external motivational factors.
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25 Building on this, Experiment 1b explored whether sensory and decision
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27 695 processes operate independently or interact when variables influencing both are
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29 696 simultaneously manipulated in the context of olive oil tasting within a panel of regular
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31 697 consumers. This approach allowed for a deeper examination of the interplay between
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33 698 sensory perception and decision-making within a controlled tasting panel setting.
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38 Previous research from our laboratory successfully employed the Double
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40 700
41 701 Dissociation Additivity Test methodology to demonstrate the independency of sensory
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43 702 and decision processes in various contexts, such as tasting basic flavors (e.g., Martín-
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45 703 Guerrero et al., 2014; see also Ramos-Álvarez et al., 2024), and detecting the presence
46
47 704 of olive oil in a paraffine mixture (Ramos-Álvarez et al., 2013). As outlined above, in
48
49 705 the DDAT formal model of additivity-convergent dissociation, one factor from each
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51 706 process is manipulated in a multifactorial design. This approach enables the
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53 707 simultaneous evaluation of how changes in the sensory performance might influence
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55 708 decision criteria and vice versa. In other words, the DDAT facilitates testing whether
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EVOO SENSORY AND DECISION-MAKING PROCESSES 32

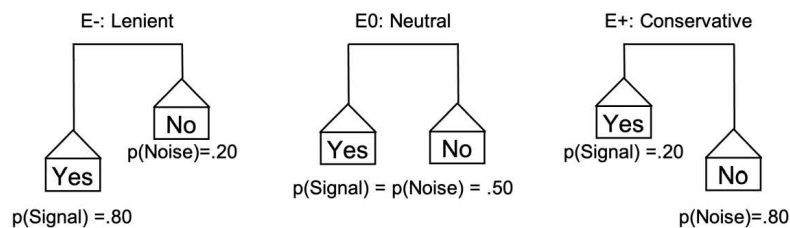
1 709 the two factors interact, are independent, or exhibit an additive effect when both are
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3 710 manipulated concurrently (see Kirk, 1995).
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5 711 In Experiment 1b tasters' perceptual sensitivity was manipulated by selecting
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7 712 two organoleptically distinguishable EVOOs, labeled as Green and Ripe, which differ in
8
9 713 their sensory profiles primarily in terms of bitterness and pungency. The difference in
10
11 714 bitterness and pungency was chosen as a focus because these flavors are often perceived
12
13 715 as unpleasant by consumers outside production areas, posing challenges to the
14
15 716 promotion and widespread consumption of EVOO (see review in Arbeláez-Mejía et al.,
16
17 717 2024).
18
19 718 The green attribute of EVOO, associated with fresh grassy notes, is linked to
20
21 719 specific volatile compounds such as (Z)-3-hexen-1-ol methyl ether and (E)-2-hexenal
22
23 720 (Ríos-Reina et al., 2022; Aparicio & Morales, 1998). These compounds emerge as
24
25 721 olives ripen, contributing to the oil's aromatic profile. Additionally, the bitterness and
26
27 722 astringency of EVOO from green olives are influenced by secoiridoids and aglucone
28
29 723 polyphenols—specifically tyrosol, hydroxytyrosol, and oleuropein. These compounds,
30
31 724 characterized catechol group phenolic molecules, contribute not only to the distinctive
32
33 725 bitter-astringent flavor but also to its strong antioxidant properties. These antioxidants
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35 726 provide protective benefits against conditions such as atherosclerosis, cardiovascular
36
37 727 disease, and certain cancers (e.g., Bendini et al, 2007; Campestre et al., 2017;
38
39 728 Lesschaeve & Noble, 2005).
40
41 729 We aimed to manipulate the decision-making process by adjusting the signal-to-
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43 730 noise ratio. Figure 6 illustrates how varying signal-to-noise ratios influence participants'
44
45 731 expectations. In the central scenario, where the probabilities of signal and noise are
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47 732 equal (0.5-0.5), participants are expected to adopt a neutral decision criterion. The left
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49 733 panel represents a scenario with a higher signal-to-noise probability (0.8-0.2), which is
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EVOO SENSORY AND DECISION-MAKING PROCESSES 33

734 predicted to induced a lenient decision criterion. Conversely, the right panel illustrates a
 735 scenario with a lower signal-to-noise probability (0.2-0.8), expected to result in a
 736 conservative decision criterion.

737 These predictions align with Signal Detection Theory models, which suggest
 738 that participants adjust their decision criteria based on the perceived signal-to-noise
 739 ratio (e.g., Macmillan & Creelman, 2005; Swets, 1996; Wickens, 2002; see also Ramos-
 740 Álvarez et al., 2024). This manipulation enables the evaluation of how decision-making
 741 processes are influenced under varying conditions of expectation and uncertainty.

742

Figure 6744 *Illustration of the programming of induced expectations*

745

746 *Note.* Different probabilities of the signal $-p(\text{Signal})-$ and noise $-p(\text{Noise})-$ were used
 747 to program two types of extreme and opposing expectations ($E-$): Lenient ($E-$) and
 748 Conservative ($E+$). These expectations are represented on the left ($E-$) and right ($E+$) of
 749 neutral reference condition ($E0$) which corresponds to equal probabilities of signal and
 750 noise.

751

4.1. Experimental Design and Hypotheses

752 The design of Experiment 1b utilized the two extreme probabilities to induce
 753 either lenient or conservative expectations, crossing them with two distinct types of
 754 EVOO (Green and Ripe). Specifically, Experiment 1b implemented a repeated-
 755 measures, within-subject factorial design with two factors, each having two levels: 1)
 756 EVOO type (Green versus Ripe) and 2) induced expectations (Lenient versus
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EVOO SENSORY AND DECISION-MAKING PROCESSES 34

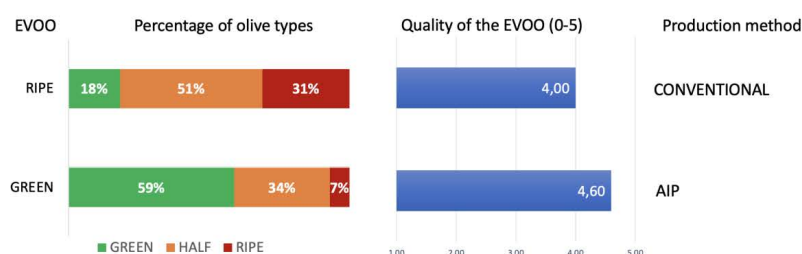
1 758 Conservative) determined by signal-to-noise probabilities (low versus high). This
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3 759 resulted in four factorial conditions: 1) Ripe-Lenient; 2) Ripe-Conservative; 3) Green-
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5 760 Lenient; and 4) Green-Conservative.
6
7 761 This design allowed for a comprehensive analysis of the interaction between
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9 762 sensory and decision-making processes in EVOO tasting situations comparable to
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11 763 expert panels, providing insights into whether these processes operate independently or
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13 764 interactively under different tasting conditions.
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15 765 Building on the work of Ramos-Álvarez et al. (2024), who investigated basic
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17 766 flavors, it was hypothesized that manipulating the two types of EVOO would influence
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19 767 the sensitivity index (A') without altering the decision criteria ($B'D$). In contrast,
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21 768 increasing the signal probability relative to noise was expected to induce participants to
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23 769 adopt a lenient strategy, leading to increase in false alarms (i.e., identifying the signal
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25 770 when not present), without affecting the sensitivity index. Conversely, decreasing the
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27 771 signal probability was anticipated to encourage a more conservative strategy, resulting
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29 772 in fewer hits (identifying the signal when present), again without influencing the
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31 773 sensitivity index.
32
33 774 Finally, Green EVOO was anticipated to be preferred over the commercial
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35 775 EVOO based on experts' evaluations. No differences were expected between the Ripe
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37 776 EVOO and the noise, as commercial EVOO is typically derived from ripe olives.
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39 777 Furthermore, consistent with the findings of Experiment 1a, it was not expected that
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41 778 these differences in preference would translate into differences in Willingness to Pay
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43 779 (WTP).
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56 **4.2. Stimuli**
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EVOO SENSORY AND DECISION-MAKING PROCESSES 35

782 Two EVOOs, Green and Ripe, were used as signals in Experiment 1b. As
 783 illustrated in Figures 7 and 8, these two EVOO varieties exhibit distinct characteristics
 784 both, from in composition and in the quality ascribed to them by the experts. The
 785 percentage of green fruit is higher in the Green EVOO than in the Ripe EVOO, and
 786 experts evaluate the Green EVOO as being of superior quality compared to the ripe
 787 EVOO (see Figure 7).

788

789 **Figure 7**790 *Composition and quality of the two olive oils used as signals in Experiment 1b*

791

792 *Note.* The left section illustrates the percentage composition of green, ripe, and
 793 intermediate fruit in each of the Ripe and Green olive oils provided by the local mill. The
 794 center section presents the quality evaluation of these oils as assessed by the test panel.
 795 AIP refers to the Agriculture of Integrated Production method.

796

797 The sensorial evaluation of the two olive oils used as signals in Experiment 1b is
 798 presented in Figure 8 in the form of a dot plot. Green EVOO achieves the highest
 799 organoleptic ratings across nearly all attributes, and demonstrated slightly superior fruit
 800 quality. A comparison of the sensorial evaluation provided by the producer, Oleo
 801 Estepa, for the EVOO used as noise with the oils used in Experiment 1b as signals
 802 reveals that the noise EVOO exhibits a higher value in terms of fruitiness. Regarding
 803 bitterness and spiciness attributes, the noise EVOO's values are closer to those of the

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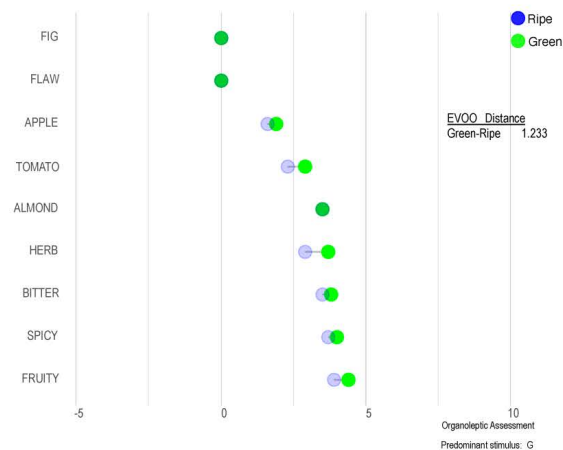
EVOO SENSORY AND DECISION-MAKING PROCESSES 36

804 Ripe EVOO than to the Green EVOO (for details, see section dedicated to the stimuli
 805 description in the General Methodology).

806

807 **Figure 8**

808 *Sensorial Assessment of the two olive oils used as Signals in Experiment 1b*



809

810 *Note.* The figure shows the results of the expert panel's evaluation of the oils (Green and
 811 Ripe) used in Experiment 1b. This evaluation includes the identified attributes and their
 812 corresponding values, as well as the Euclidean distance between them.

813

814

815 4.3. Procedure

816 The procedure adhered the general methodology, with the following

817 modifications. Participants completed four blocks of five tasting trials each. Two oils

818 (green and ripe) were used, with each serving as the signal in two blocks. The noise

819 condition was consistent with Experiment 1a. To induce extreme expectations, four out

820 of five trials in each block featured one type of EVOO (signal or noise), while the

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EVOO SENSORY AND DECISION-MAKING PROCESSES 37

1 821 remaining trial featured the opposite type, creating signal-to-noise ratios of 0.8 and 0.2

2 (see left and right sections of Figure 6).

3 823

4 **824 4. 4. Results and Discussion of Experiment 1b**

5 *825 Sensory and Decision-Making Processes*

6 Figure 9 presents the results of sensory (left) and decision (right) indexes for

7 each of the four conditions of Experiment 1b as box plots. The boxes indicate the

8 interquartile range, while the lines show the minimum and maximum values. The

9 horizontal line within each box represents the median.

10 830 Figure 9A (left) shows a significant difference in sensory sensitivity (Grier A')

11 based on the specific type of EVOO used [$F(1.00, 9.73) = 5.29, p = .0449$, with

12 moderate effect size, $\eta^2 = 0.35$, and moderate evidence in favor of the alternative

13 hypothesis, $BF = 3.927$], with no significant effects found for expectation or the

14 interaction between expectation and sensory manipulations [both $F < 1$, very low effect

15 size, η^2 less than or equal to 0.02, and evidence in favor of the null hypothesis, albeit

16 anecdotal, BF between 0.36 and 0.36]. Given these results, the main focus will be on the

17 main effect of oil type, independent of induced expectation. The sensory index for green

18 oil was higher than that for ripe oil, (see figure 9A). The sensory performance for ripe

19 oil did not significantly differ from the chance level of 0.5 [mean of 0.49 points, $t(15) =$

20 $-0.21, p = .5821$]. Conversely, sensory performance for green olive oil exceeds this

21 chance level [mean of 0.65 points, $t(15) = 3.44, p = .0018$]. Bayesian analysis

22 supported this pattern: the evidence was moderate/positive for the null hypothesis in

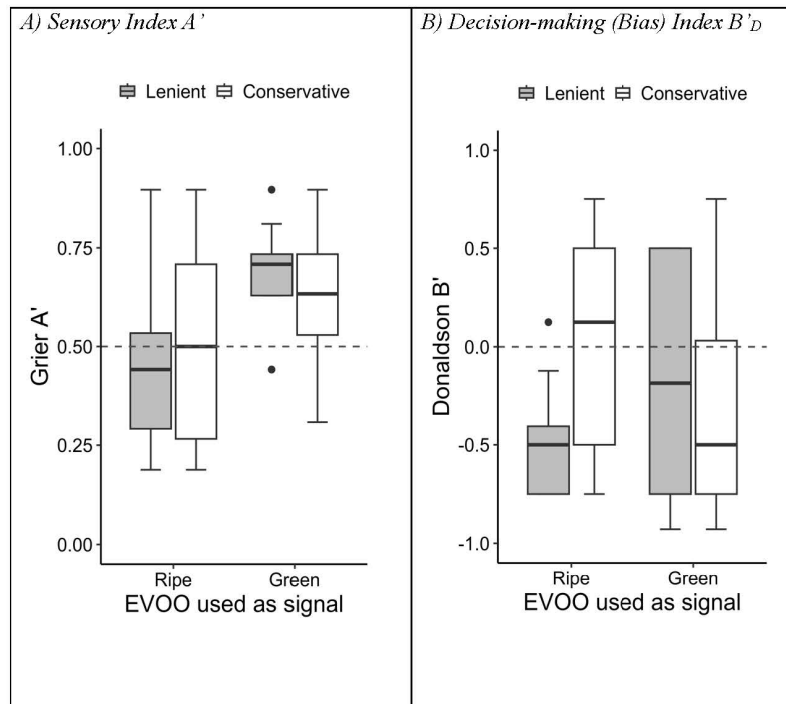
23 ripe oils conditions ($BF = 0.261$) and strong/positive for the alternative hypothesis in

24 green oil conditions ($BF = 12.665$).

25 845

EVOO SENSORY AND DECISION-MAKING PROCESSES 38

846 **Figure 9**
 847 *Procedural indices of Experiment 1b*



848 *Note.* The Boxplots boxes illustrate the distribution of data with boxes representing the
 849 upper and lower quartiles and whiskers extending to the minimum and maximum values
 850 outside the quartiles. The horizontal line within each box indicates the median. The
 851 factorial conditions from left to right are: Ripe-Lenient; Ripe-Conservative; Green-
 852 Lenient; and Green-Lenient. The dashed line represents the value of chance for the
 853 sensory index (panel A, left) and the neutral criterion for the decision index (panel B,
 854 right).

856 Figure 9B (right) presents the results for the decision index (Donaldson B'_D).
 857 Contrary to predictions, the influence of induced expectations varied between the Ripe
 858 and Green oils. The ANOVA showed a significant interaction between EVOO type and
 859 Expectation on the B'_D index [$F(1.00, 6.96) = 9.68, p = .0172$, with a moderate effect
 860 size, $\eta^2 = 0.58$, and anecdotal evidence supporting the alternative hypothesis, $BF =$
 861 1.539].

EVOO SENSORY AND DECISION-MAKING PROCESSES 39

1 862 Pos hoc contrasts with Holm's correction were performed to examine the simple
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3 863 effects of the Expectations variable for each type of EVOO. This analysis revealed
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5 864 significant differences only for Ripe EVOO [$t(14.661) = 3.09, p = .0076$] while the
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7 865 effect was not significant for Green EVOO [$t(14.661) = -0.77, p = .4516$]. Both effect
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9 866 size and Bayesian analysis supported this pattern. For Ripe EVOO, the effect size was
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11 867 medium, $d = 0.747$, and the Bayes factor favored the alternative hypothesis with
12
13 868 moderate/positive evidence ($BF = 5.552$). For Green EVOO, the effect size was small, d
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15 869 $= -0.187$, and the Bayes factor was anecdotal/weak in favor of the null hypothesis ($BF =$
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17 870 0.377).

21 871 For Ripe EVOO, the response criterion followed the expected pattern, with a
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23 872 negative value for the Ripe Lenient condition and a positive value for the Ripe
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25 873 Conservative condition (see figure 9B). The absolute difference between these two
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27 874 levels was not significant [$t(7) = 0.210, p = .8398$], indicating that the pattern was
28
29 875 symmetrical.

34 876 For Green EVOO, both expectation conditions resulted in statistically neutral
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36 877 criterion values: the difference for Green-Lenient from 0 was not significant [$t(7) = -$
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38 878 $0.73, p = .7554$], nor was the difference from Green- Conservative from 0 [$t(7) = -1.32,$
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40 879 $p = .8863$]. Bayesian analysis for Green EVOO showed BF values favoring the null
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42 880 hypothesis (BF between 0.40 and 0.65) indicating anecdotal/weak evidence against an
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44 881 effect.

48 882 In summary, the prediction for sensory performance was fully supported, as
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50 883 differences in sensitivity were observed between Green and Ripe EVOO's, independent
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52 884 of the induced expectations. However, prediction regarding the effect of induced
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54 885 expectations was only partially supported. It held true for Ripe EVOO but not for Green
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56 886 EVOO. Specifically, significant differences were found in the Grier Sensitivity measure
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EVOO SENSORY AND DECISION-MAKING PROCESSES 40

1 887 (A') according to EVOO type (Green versus Ripe), regardless of the expectation
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3 888 condition. In contrast, the Donaldson Decision index (B'D) showed a significant
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5 889 interaction between EVOO type and expectations, indicating that expectations
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7 890 influenced the decision-making process only for Ripe EVOO, not for Green EVOO.

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11 892 *Differential Preference and Economic Valuation (WTP)*

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14 893 Figure 10 displays a comparison of the four conditions (Ripe-Lenient, Ripe-
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16 894 Conservative, Green-Lenient, and Green-Conservative) in terms of overall preference
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18 895 and willingness to pay relative to the reference EVOO used as noise. Left panel of
19
20 896 Figure 10A indicates that participants generally preferred the target EVOO across
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22 897 conditions. However, the ANOVA revealed no significant main effects for EVOO type
23
24 898 [$F(1.00, 9.21) = 1.59, p = .2380$] or Expectations [$F < 1$], nor an interaction between
25
26 899 them [$F < 1$]. A small size effect prevailed (η^2 between 0.01 and 0.15), and Bayesian
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28 900 analysis provided anecdotal/weak evidence support for the null hypothesis (BF between
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30 901 0.4 and 0.6).

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36 902 Despite this, statistical analysis showed significant deviations from the null
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38 903 value in certain conditions: the Ripe-Lenient condition [$t(7) = 2.16, p = .0338$] and the
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40 904 Green-Lenient condition [$t(7) = 2.15, p = .0341$]. Other conditions were not significant,
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42 905 but they approached significance: the Ripe-Conservative [$t(7) = 1.76, p = .0609$] and
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44 906 Green-Conservative [$t(7) = 1.87, p = .0515$]. Bayesian analysis suggested evidence
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46 907 supporting the alternative hypothesis, though it was still considered anecdotal/weak (BF
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48 908 $> \approx 1$).

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53 909 Figure 10B (right) shows the results for willingness to pay (WTP). The analysis
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55 910 revealed no significant differences among the four experimental conditions (Ripe-
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57 911 Lenient, Ripe-Conservative, Green-Lenient, Green-Conservative) regarding WTP. The

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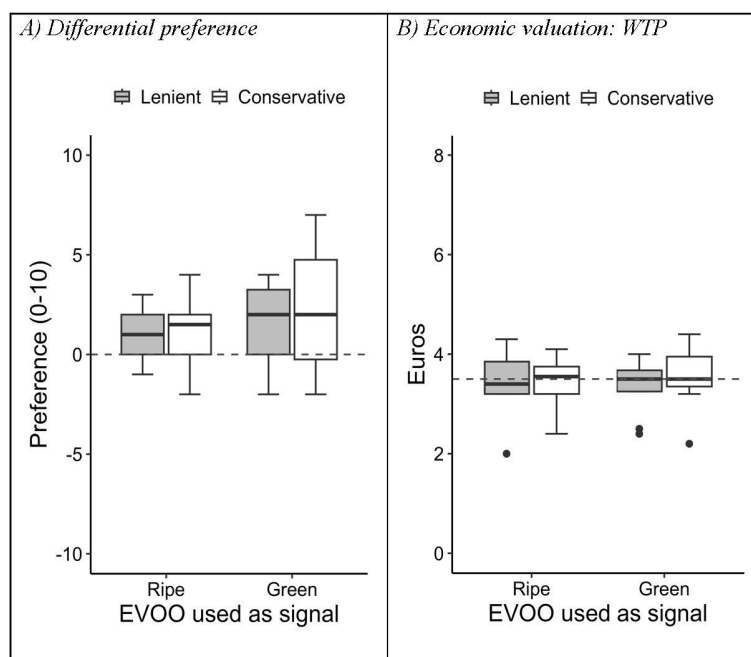
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912 ANOVA did not show significant main effects for EVOO type, Expectations, or
 913 interaction between them [$F < 1$ for all three analyses], with very small effect sizes (η^2
 914 less than or equal to 0.01) and anecdotal/weak evidence in favor of the null hypothesis
 915 (BF between 0.38 and 0.44).

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917 **Figure 10**

918 *Preference Indices of Experiment 1b*



919 Note: A) Displays the differential preference for each of the four experimental conditions
 920 compared to the reference, commercial EVOO. The factorial conditions are, from left to
 921 right: Ripe-Lenient; Ripe-Conservative; Green-Lenient; and Green-Conservative. The
 922 dashed line represents the null difference value. B) Shows the economic valuation in
 923 Euros for each of the four conditions compared to the set price of the reference EVOO
 924 (€3.5 Euros, dashed line) or the WTP for target EVOOs.

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927 The estimated WTP in all conditions did not differ from the reference value of

928 €3.5 (Ripe-Lenient: $t(7) = -0.36, p = .6337$; Ripe-Conservative: $t(7) = -0.38, p = .6439$;

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929 Green-Lenient: $t(7) = -0.65, p = .7329$; and Green- Conservative: $t(7) = 0.11, p =$

930 $.4593$). The Bayesian analysis of WTP consistently favored of the null hypothesis,

931 although the evidence was considered anecdotal/weak (BF between 0.35 and 0.40).

932 In summary, the overall results of the preference indices indicate that, while the

933 differences between the green and ripe conditions did not reach statistical significance,

934 participants showed a general trend to prefer the green EVOO. Consistent with

935 Experiment 1a, participants demonstrated an ability to differentiate between oils and

936 tended to align their preferences with the quality assessments provided by the expert

937 panel –see also Dos Santos et al. (2023). However, this preference did not translate into

938 differences in willingness to pay (WTP). These findings suggest that, although

939 untrained participants can detect quality differences in defect-free oils, their purchasing

940 decisions may be more influenced by external attributes than by taste-based quality

941 differences (see Arbeláez-Mejía et al., 2024, for a review).

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943 **5. General Discussion**

944 The primary objective of this study was to determine whether the Signal

945 Detection Theory-based methodology developed by Ramos-Álvarez et al. (2013) could

946 independently evaluate sensory and decision-making processes in the context of olive

947 oil tasting. Unlike prior research, which relied on simpler stimuli such as the presence

948 or absence of oil in a paraffin mixture or basic flavors (e.g., Martín-Guerrero et al.,

949 2014, 2015; Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010; Ramos-Álvarez

950 et al., 2013, 2024), this study required the differentiation of natural oils based on their

951 subtle and complex attributes. To address this goal, the study was conducted within a

952 tasting panel that simulated the judgment conditions of expert tasters while involving

953 untrained consumers (see Dos Santos et al., 2023).

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1 954 Experiment 1a aimed to test a methodology to disentangle sensory and
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3 955 decision-making processes in the evaluation of natural olive oil attributes by a tasting
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5 956 panel of regular consumers. The primary goal was to evaluate the utility of SDT in
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7 957 distinguishing sensory input and decision-making influences in these evaluations. To
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9 958 achieve this, we assembled a consumer-focused tasting panel that emulated the
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11 959 conditions of an International Olive Council (IOC)-standardized panel but adapted it for
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13 960 non-expert tasters.
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16 961 In Experiment 1a, sensitivity (measure by Grier's A' index) was manipulated
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18 962 by comparing four distinct non-commercial EVOOs, each with unique characteristics
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20 963 acting as "signals," against a commercial EVOO serving as "noise." The four EVOOs
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22 964 varied in the percentage of green, semi-ripe, and ripe olives used in their blends and in
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24 965 quality, as evaluated by an expert panel. Oils A, C, and D shared a similar composition,
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26 966 with 39–45% green olives, while oil B had a higher proportion of semi-ripe and ripe
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28 967 olives (61% and 9%, respectively), making it more similar to the commercial EVOO
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30 968 used as the noise in these experiments. All the oils, including the noise, were free of
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32 969 defects, meaning that differentiation among them relied solely on variations in the
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34 970 combination of their positive attributes. This design ensured that any detected
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36 971 differences in sensory evaluations were attributable to the oils' unique positive
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38 972 characteristics rather than the presence of defects. Participants successfully identified
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40 973 differences between oils C and D and the noise but failed to distinguish oils A and B
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42 974 from the noise. Furthermore, since Experiment 1a was designed without incorporating
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44 975 factors expected to affect the decision criterion (Donaldson B'D), it was anticipated that
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46 976 participants would adopt a neutral criterion. This expectation was validated by the
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48 977 results.
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EVOO SENSORY AND DECISION-MAKING PROCESSES 44

1 978 The lack of differentiation for oil B to its similarity to the commercial EVOO
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3 979 (noise) in terms of ripe olives composition, as corroborated by the sensorial evaluation
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5 980 provided by the producer. However, the case of oil A presents an exception. While oils
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7 981 B and D both employed conventional production methods, oil A exclusively used AIP,
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9 982 and oil C employed a mixed of conventional and AIP methods. Sensitivity results could
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11 983 suggest that the AIP method may result in oils, such as oil A, being evaluated by
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13 984 consumers as more similar to standard quality commercial oils (noise). Although this
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15 985 possibility cannot be fully dismissed without further research, it would require untrained
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17 986 consumers to detect differences that expert tasters overlook—a scenario that appears
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19 987 unlikely.
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24 988 A discrepancy emerges when comparing the sensory profiles and expert
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26 989 assessments with the consumer panel results for oils A and B. Despite being
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28 990 indistinguishable from the noise by consumers, oils A and B have the largest Euclidean
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30 991 distance (4.91) between them. Sensory profiles indicate similarity in bitterness and
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32 992 spiciness but notable differences in fruitiness, where oil A is closer to the noise than oil
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34 993 B. Both oils exhibit a ripe fruitiness, a trait highly valued by consumers (e.g., Roselli et
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36 994 al., 2018), which may cause the noise to stand out more and create an approximation in
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38 995 perception between oils A and the noise.
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43 996 Ultimately, the results of Experiment 1a affirm the effectiveness of using SDT
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45 997 to evaluate sensory and decision-making processes simultaneously in the tasting of
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47 998 natural EVOOs by regular consumers. By extending this methodology to assess natural
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49 999 oils based on nuance attribute differences rather than the binary presence or absence of
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51 1000 specific components (cf. Ramos-Álvarez et al., 2013, 2024), the study successfully
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53 1001 isolates sensitivity effects from decision-making biases. This advancement addresses a
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55 1002 critical limitation of traditional tasting methods, which often fail to detect potential
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EVOO SENSORY AND DECISION-MAKING PROCESSES 45

1003 biases in tasting contexts (see IOC, 2023). It is important to emphasize that this
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3 1004 limitation does not impact the work of professional tasting panels, which undergo
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5 1005 rigorous training to mitigate bias in their judgments. However, when assessing
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7 1006 untrained consumers, a methodology capable to disentangling sensory and decision-
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9 1007 making processes is crucial. Traditional tasting methods based on classical
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11 1008 psychophysics may overlook biases inherent in the judgments of untrained participants,
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13 1009 making the application of SDT-based methodologies particularly valuable in such
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15 1010 contexts.
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19 1011 Once the suitability of SDT-based tasting methodology for evaluating the
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21 1012 attributes of natural oils was established, Experiment 1b sought to examine the
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23 1013 independence or interaction of sensory and decision-making processes in the tasting
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25 1014 context. This was achieved by simultaneously manipulating variables expected to
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27 1015 differentially impact each process, following the logic of the Double Dissociation
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29 1016 Additive Test (Ramos-Álvarez et al., 2013). Prior research in our laboratory has shown
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31 1017 that those processes appear independent in simple detection tasks, such as identifying
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33 1018 the presence or absence of olive oil in a paraffin dilution (e.g., Paredes-Olay et al.,
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35 1019 2010; Ramos-Álvarez et al., 2013) or salt dissolved in water (Martín-Guerrero et al.,
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37 1020 2015, 2016; Ramos-Álvarez et al., 2024). However, Moreno-Fernández et al. (2012)
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39 1021 found that an easy-to-hard training sequence, theorized to impact only the sensory
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41 1022 index, also influenced the decision index, suggesting the relationship between sensory
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43 1023 and decision-making processes requires further investigation.
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47 1024 Experiment 1b found that sensory discrimination (Grier's A' index) was
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49 1025 influenced by the ripeness manipulation. Participants found it easier to discriminate
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51 1026 green oil from the noise compared to ripe EVOO, which aligns with expectations, as
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1027 commercial oils are typically extracted from ripe olives. This was corroborated by the
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3 1028 sensorial evaluation provided by the producer.
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5 1029 However, manipulations aiming at influencing the decision criterion measured
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7 1030 through Donaldson $B'D$ index (induced expectations) interacted with oil ripeness.
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9 1031 Evaluations involving ripe oil were significantly influenced by induced expectations,
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11 1032 while evaluations of green oil demonstrated a neutral decision index, unaffected by
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13 1033 expectation manipulations. This indicates that when oils were more distinguishable
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15 1034 (e.g., green EVOOs compared to noise), participants exhibited a bias toward an
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17 1035 assumed equal signal-to-noise distribution. That is, their decision criterion operates as if
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19 1036 there were no signal-to-noise mismatch. In reality, this leads to the adoption of a sub-
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21 1037 optimal criterion from an SDT perspective. The optimal criterion would involve biasing
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23 1038 responses toward the dominant stimulus (e.g., responding "Yes" when the signal
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25 1039 dominates or "No" when the noise dominates). However, this suboptimal adjustment
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27 1040 occurs only when discriminability is higher, which was selectively observed for the
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29 1041 green EVOO.
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31 1042 The findings demonstrate that when tasting tasks involve natural EVOOs,
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33 1043 sensory and decision-making processes are not independent but interact. This
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35 1044 interaction mirrors results from Bang and Rahnev (2017), who explored how stimulus
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37 1045 expectations influence perceptual decision-making. Their study showed that post-
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39 1046 stimulus cues, more than pre-stimulus cues, primarily affect decision criteria,
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41 1047 highlighting that expectations have a stronger influence on decision-making processes
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43 1048 than on sensory discrimination. Similarly, Ramos-Álvarez et al. (2024) found that
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45 1049 feedback absence diminished sensitivity performance and reversed conservative-lenient
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47 1050 biases induced by base rate manipulations. These findings collectively emphasize the
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1051 need for methods that disentangle sensitivity from decision-making processes in tasting
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3 1052 tasks.
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5 1053 The results of Experiment 1b suggest that sensitivity findings obtained through
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7 1054 traditional psychophysical methods could be confounded by decision biases, and vice
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9 1055 versa. Consequently, failing to jointly evaluate sensory and decision-making processes
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11 1056 may lead to erroneous conclusions that remain undetected. The SDT-based
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13 1057 methodology addresses this limitation, offering a more robust framework for
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15 1058 investigating perceptual and decision-making mechanisms in tasting tasks, especially
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17 1059 when evaluating complex and subtle natural attributes like those of EVOOs.
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19 1060 Finally, the results of Experiments 1a and 1b reveal a dissonance between
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21 1061 expressed preferences and the ability to detect differences between signal and noise.
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23 1062 While novice tasters could distinguish subtle differences in oil quality between EVOOs
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25 1063 (signal) and the commercial oil (noise), they did not value these differences. This lack
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27 1064 of appreciation for nuanced quality variations was evident in their unwillingness to pay
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29 1065 more for oils selected by experts as of higher-quality, even when consumers show a
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31 1066 preference for them. This outcome may stem from the study's focus on sensory
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33 1067 analysis, emphasizing intrinsic attributes of EVOO, such as taste, while excluding
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35 1068 extrinsic attributes like packaging, labeling, branding, and certifications. Consumers are
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37 1069 often more familiar with and influenced by these extrinsic factors when making
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39 1070 purchasing decisions in real-life scenarios (see review by Arbeláez-Mejía et al., 2024).
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41 1071 Hence, promoting high-quality EVOO and justifying its premium price may require
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43 1072 emphasizing these extrinsic elements to resonate more effectively with consumer
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45 1073 preferences.
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47 1074 A potential limitation in generalizing these findings to broader populations of
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49 1075 novice tasters is the study's participant recruitment. Participants were exclusively from
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1076 Jaén, Spain, the world's largest olive oil-producing region. Although they were
1077 unfamiliar with formal tasting procedures and lacked sensory analysis training, their
1078 cultural familiarity with EVOO—integral to their daily routine—may have influenced
1079 their preferences and perceptions. As highlighted by Arbeláez-Mejía et al. (2024),
1080 consumer preferences for EVOO attributes, such as bitterness and pungency, vary
1081 significantly between those from production regions and non-production regions. While
1082 these qualities are prized by experts and consumers in production areas, they are often
1083 rejected by individuals unfamiliar with EVOO culture. To improve generalizability,
1084 future research should include participants from non-production regions who are less
1085 accustomed to EVOO consumption.

1086 Despite this limitation, the study's primary conclusion remains robust: the
1087 application of SDT- and DDAT-based methodologies effectively separates sensory and
1088 decision-making contributions, providing reliable insights into consumer behavior.
1089 These methodologies address critical gaps in traditional tasting methods by accounting
1090 for potential decision biases, thereby offering a nuanced approach to understanding
1091 consumer evaluations of EVOO.

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Declaration of Interest Statement

Declaration of interests

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.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Author Statement

Author Statement for Submission to Food Quality and Preference

As the corresponding author of this submission to *Food Quality and Preference*, I confirm that the work presented is original and has not been published elsewhere. The research complies with ethical standards, ensuring that all data were collected, analyzed, and reported with integrity and transparency.

The study aims to contribute to the broader understanding of sensory evaluation, aligning with the journal's mission to advance knowledge in food quality, sensory preferences, and their implications for consumer behavior and industry practices.

All authors have actively contributed to the study's design, execution, and manuscript preparation. We declare no conflicts of interest and confirm that the findings are an accurate representation of the research conducted. Any funding sources have been appropriately acknowledged.

Juan M. Rosas

Ethical Statement

Ethical Statement

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from Ethical Committee of the University of Jaén. All participants provided informed consent prior to their involvement in the study, and they were informed of their right to withdraw at any time without penalty. Participants' data were kept confidential, and only aggregate data were reported to ensure anonymity.

***5. Specific Goal 3 Differences in Sensitivity
and Biases of Extra Virgin Olive Oil Sensory
Evaluation between Experts and Regular
Consumers***

SHORT TITLE: EVOO EVALUATION BY CONSUMERS AND EXPERTS

Differences Between Familiar Consumers and Experts in Olive Oil Sensory

Evaluation: A Matter of Degree, Not Quality

EVOO EVALUATION BY CONSUMERS AND EXPERTS 2

Abstract

Studies on EVOO (Extra Virgin Olive Oil) tasting have focused primarily on sensory performance, overlooking the influence of subjective aspects that could bias evaluations. This study employs signal detection theory (SDT) and the Double Dissociation Additive Test (DDAT) to compare experts and consumers, exploring the interaction between sensory and decision-making processes in EVOO analysis. A three-factor design was used, manipulating expertise (consumers vs. experts), EVOO type (green vs. ripe), and expectation (high vs. low signal EVOO). Expert and consumer panels exhibited similar behavior, both preferring green oil over ripe oil, although experts showed higher sensitivity and a greater willingness to pay for green oil. These findings underscore the potential role of familiarity in the discrepancies between expert and consumer evaluations reported in the literature.

Key-words: Experts' panel, Sensory analysis, Signal detection theory (SDT), Olive oil, Regular consumers

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**Differences Between Familiar Consumers and Experts in Olive Oil Sensory
Evaluation: A Matter of Degree, Not Quality****Introduction**

Regular consumption of extra virgin olive oil (EVOO) has shown to have a beneficial impact in human health (e.g. Flynn et al., 2023; Martínez- González., et al 2022; Medeiros & Hampton, 2020). The benefits of EVOO consumption are associated to the phenological and volatile compounds that give EVOO its characteristic bitter, spicy, and astringent flavor (e.g., Cicerale et al., 2016; Delgado & Guinard, 2011). Those attributes are considered positive by the International Olive Council (IOC) guidelines (IOC, 2007a, 2024a, 2024b), and there are highly valued by experts. However, they are negatively valued by consumers challenging promotion of general consumption of EVOO as a functional food outside the producing areas (e.g., Cavallo et al., 2018; Delgado & Guinard, 2011; Rébufa et al. al., 2021; Valli et al., 2014).

Comparisons between experts and consumers are based on the level of expertise, usually focusing on the sensory performance, following the IOC guidelines (2024a) which are based on classical Psychophysics and Threshold theory (see Allan & Siegel, 2002). A significant limitation in these studies is that they focus on sensory performance, overlooking subjective aspects that can introduce bias into their evaluations (see Ramos-Álvarez et al., 2013). While there are no doubts that classical Psychophysics is a useful tool to conduct EVOO sensory evaluation, it is not without shortcomings. Classical Psychophysics leaves aside subjective aspects that may influence judgments, such as tasters' motivation, beliefs and attitudes (Lawless & Heymann, 2010). Subjective factors are likely to have little relevance in highly trained experts, but that will not be the case when the tasting is conducted with untrained consumers.

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Signal Detection Theory (SDT) allows for the control of subjective factors in sensory analysis by separating two processes: the sensory process (how the stimulus is perceived) and the decision process (how the judge responds to the stimulus) (e.g., Hautus et al., 2021). Various studies in our laboratory have successfully applied SDT to tasting, evaluating both the sensitivity of the taster and their biases, providing a more complete understanding of the tasting process (Martín-Guerrero et al., 2014, 2015, 2016; Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010; Ramos-Álvarez et al., 2025). Ramos-Álvarez et al. (2013) proposes dissociating the sensitivity and decision processes by applying the Double Dissociation Additive Test (DDAT) in an experimental task with EVOO. Using DDAT, it is possible to evaluate the independence of sensory and decision-making indexes within a multifactorial design in which one factor from each process is manipulated. As a result, manipulations of the sensory did not affect the decision-making and vice versa (see also Martín-Guerrero et al., 2016; Ramos-Álvarez et al., 2025). This methodological approach allows for obtaining independent measures of sensory and decision-making processes that are independent, a result that is consistent with the perception studies (e.g., Howe et al., 1993; Huang & Ferreira, 2020; Swets, 1996; Wright et al., 2009).

Arbeláez-Mejía et al. (2025b) extended those results demonstrating the applicability of SDT based procedures to the sensory evaluation of the attributes of natural EVOO, as opposed to evaluating the presence or absence of salt (Martín-Guerrero et al., 2015, 2016; Ramos-Álvarez et al., 2025) or EVOO in dilution (Martín-Guerrero et al., 2014, 2015; Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010; Ramos-Álvarez et al., 2013). The study applied the DDAT, simultaneously manipulating variables expected to impact sensitivity (green vs. ripe oils) and bias (conservative vs. lenient induced expectations) to explore the independence or

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interaction of these two processes. Induced expectations were produced by adjustments of Signal/Noise base rates (Swets et al., 1961)—1/5 (Conservative) vs. 4/5 (Lenient)—. Contrary to what it was expected, induced expectations influenced only the evaluations involving ripe oil, with no effects observed when evaluating green oil, suggesting a possible interaction between sensory and decision-making processes in EVOO tasting when evaluating ripe oils against commercial oils. These findings highlight the importance of methodologies that separate sensory and decision-making processes in tasting contexts, particularly when working with consumers. The theoretical independence of sensory and decision processes that SDT assumes (Wright et al., 2009) may not be such within an actual tasting situation.

To our knowledge, the joint study of sensory and decision processes in the context of EVOO tasting has been conducted exclusively with novice tasters, while studies with experts had only considered the sensory process without evaluating the biases (Cavallo et al., 2018; Dos Santos et al., 2023; Fernandes et al., 2018; Rébufa et al., 2021). To our knowledge, the interaction between sensory and decision processes has been reported in only one study within the context of EVOO tasting (Arbeláez-Mejía et al., 2025b), raising questions about whether this interaction can be replicated in regular consumers and generalized to experts. Thus, the goal of this study was to compare regular EVOO consumers and experts' evaluations in a situation that allows for dissociating sensory and decision processes by applying the STD and DDAT methods that have been proved to be useful in the literature.

Counting with regular consumers as participants, and using the method of sample selection and training recommended by the IOC (2024a) was a key feature of the study that allows to shape the main hypothesis. First, a recent review conducted by Arbeláez-Mejía et al. (2025a) found that appreciation for bitter and spicy flavors tends

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to increase with familiarity operationalized as whether consumers live in a producing vs. non-producing country. As a result, regular consumers' evaluations appear more similar to those of experts. Second, Dos Santos et al., (2023) evaluated the role of familiarity with EVOO tasting in an experimental study in which they recruited two groups of consumers (novice tasters). Group T received basic training: following the IOC (2024b) and ISO 8586 guidelines, while group C remained untrained. They found that training (group T) improved both, sensory detection and hedonic evaluation of EVOO, and that differences between groups were subsequently attenuated when the evaluation was conducted after group C received basic training on EVOO tasting. Thus, we expected that differences between expert and regular consumer panels would be circumscribed to the level of sensitivity.

An additional goal of this study was to evaluate whether the unusual interaction between sensitivity and decision processes in the context of olive oil tasting holds beyond the study of Arbeláez-Mejía et al. (2025b) when conducting a double replication in regular consumer and expert Italian panels with different EVOO.

Experimental Design and Hypotheses

The design was based on the Signal Detection Theory (SDT) and the additive convergent dissociation model which allows for a dissociation between the sensory process and the decision-making process. The experimental manipulation involved Expertise (Consumers vs. Experts) as a between-subject factor, and EVOO (Green vs. Ripe) and Induced expectation—Lenient (75% Signal–25% Noise) vs. Conservative (25% Signal–75% Noise)—as a within-subject factors. Accordingly, the four factorial conditions were designated: 1) Green-Lenient; 2) Green-Conservative; 3) Ripe-Lenient; and 4) Ripe- Conservative.

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The type of EVOO (Green or Ripe) was predicted to primarily influence sensory sensitivity. Building on the review by Arbeláez-Mejía (2025a) regarding the role of familiarity in consumer evaluations, and findings by Dos Santos et al. (2023) demonstrating that basic EVOO tasting training enables novice consumers to approach expert evaluations, this study anticipated that differences between experts and familiar consumers would be limited to sensitivity levels rather than evaluation quality. These differences were expected to be smaller than those typically reported in the literature (Cavallo et al., 2018; Delgado & Guinard, 2011, 2012; Dos Santos et al., 2023; Fernandes et al., 2018; Rébuba et al., 2021).

Regarding the independence or interaction between sensory and decision processes, the hypotheses remained open. Based on Arbeláez-Mejía et al. (2025b), an interaction between these processes might occur in regular consumers. However, previous research on perception (e.g., Howe et al., 1993; Huang & Ferreira, 2020; Swets, 1996; Wright et al., 2009) and tasting evaluations involving basic flavors (Ramos-Álvarez et al., 2025) or the detection of olive oil in dilutions (Ramos-Álvarez et al., 2013) suggests that sensory and decision processes are generally independent. It is possible that the interaction or independence of these processes could depend on the level of expertise. Thus, this study aimed to assess the generality of the interaction between sensory and decision processes reported by Arbeláez-Mejía et al. (2025b) by comparing Italian consumer and expert panels evaluating different EVOOs.

Methodology*Participants:*

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Participants, comprising both consumers and experts, were required to refrain from smoking, eating, or consuming any stimulant substances for a minimum of 30 minutes prior to the commencement of the experiment.

Consumers: Sixteen participants (nine men and seven women) were recruited to form a panel of regular EVOO consumers with no prior tasting training. The participants, residents of Emilia Romagna (Bologna-Italy), followed a Mediterranean diet and were familiar with olive oil culture. In accordance with IOC (2024a) protocols, the final panel included the eight consumers (two women and six men) who demonstrated the highest sensitive to the EVOO characteristics. The selected consumers had an average age of 25 years, with 75% male and 25% female. regarding education levels, 37.5% held PhDs, 25% were professionals, 25% held master's degree, and 12.5% had professional training. Additionally, 50% of the panel were smokers, consuming an average of 8.5 cigarettes per day, and the group average consumption of coffee was two cups per day.

Expert' tasters: They were members of the professional committee of DISTAL (Department of Agrifood Sciences and Technologies) at the University of Bologna, recognized by the Italian Ministry of Agricultural, Food and Forestry Policies. The expert panel consisted of nine individuals, eight of whom were included in the comparison with the consumer cohort. The experts had an average age of 41 years and included an equal number of men and women (four each). Regarding education levels, 50% held PhDs, and 50% were professionals. None of the experts reported smoking, and their coffee consumption averaged two cups per day.

Due to the study's specific requirements and participant availability, the sample was recruited through convenience sampling. G*Power (version 3.1.9.7) was used to calculate the required sample size (Faul et al., 2009). With a sample of 16 participants

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(8 Consumers and 8 Experts), a significance level of 0.05, and a power of 0.95, we anticipate detecting a large effect size ($f=1.09$).

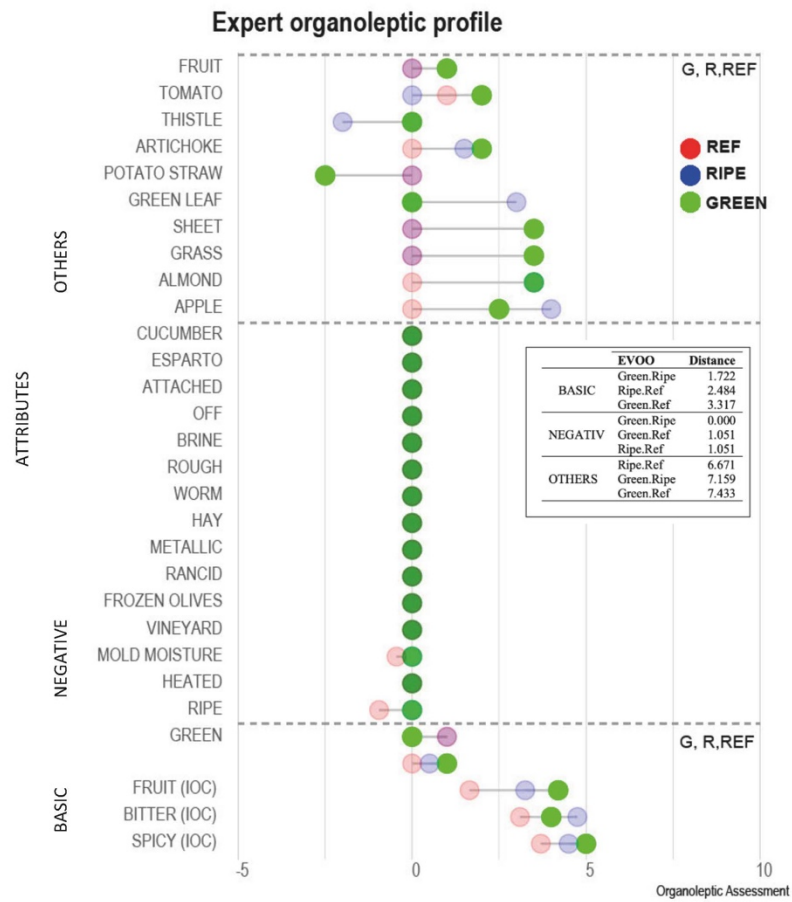
Materials and apparatus*Stimuli*

The two EVOOs used as a signal were selected according to the information on the label, Olitalia “Verdenso” is an unfiltered green fruity oil (Green). Coop Origine, is a ripe fruity oil (Ripe). The signal used in each block of trials was identified with the fictitious brand “Oliflex.” An EVOO Monini Clásico, one of the best-selling oils on the Italian market, was used as noise.

The three oils (Green, Ripe and Noise) were evaluated by the panel of experts after the experiment concluded. Following the IOC (2024b) guidelines, the evaluations averaged positive attributes, defects and olfactory nuances for each oil using the official “Profile Sheet for Virgin Olive Oil”. A variant of the Cleveland dot-plot graph, developed with the graphic template *theme_ipsum*, was used to visualize the sensory profiles. This design employed simple shapes, optimized typography, and geometrically arranged numbers, enabling coherent interpretation across points on the same horizontal line. Euclidean distances between the oils were calculated to create a global index for assessing their separation based on expert judgments, further analyzed through multivariate ordination using R code. While spider graphs are commonly used to compare sensory profiles (Lawless & Heymann, 2010), Cleveland plots were used as a more effective alternative for interpreting these profiles (see Arbeláez-Mejía et al., 2025b).

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Figure 1
Organoleptic Assessment of the olive oils of experiment



Note. The figure shows the results of the evaluation carried out by the panel of experts on the oil used as noise (REF) and the two olive oils used as signal (Green and Ripe). This evaluation included the attributes (basic, negative and others) identified in the oils and their respective values, as well as the Euclidean distance between them.

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Figure 1 provides an illustration of the distinct sensory profiles exhibited by the selected oils. Expert organoleptic evaluation ranked the green oil highest ratings all primary categories: fruity (4.3), spicy (4.7), and bitter (4.1). The ripe oil scored lower in fruitiness (3) and spiciness (4) but had a slightly higher bitterness (4.3). The noise sample displayed low fruitiness (2.1), a moderate bitterness rating (3.7), and a pungency profile closer to ripe than green. Quality grading identified the green oil as superior, followed by the ripe oil and, lastly, the noise oil, which shared similarities with the ripe oil.

The green oil's intensity and complexity surpassed the ripe oil in most attributes, though the ripe oil exhibited greater intensity in specific characteristics like bitterness, apple, tomato and green leaf. Despite these nuances, experts perceived the green as higher in quality. Euclidean distance analysis supported this hierarchy, showing greater separation between the green oil and the other two. Adding additional attributes further distinguished the green oil as the most unique, while the ripe and noise oils remained more similar.

Tasting laboratory

The experiment was conducted at the University of Bologna in the sensory analysis laboratory of the Bologna and Cesena sites. This space follows the guidelines of the IOC "Guide for the Installation of a Test Room" (IOC, 2007b).

The tasting sessions were conducted individually, following the experimental setup outlined by Ramos-Álvarez et al. (2013). The tasting station was equipped with a desk, chair, a control PC, and 5 heaters that could accommodate 4 samples at the time to maintain the samples at 28 ± 2 °C (IOC, 2024b), and coasters. A numbered sheet guided

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participants in placing the glasses during each trial. To cleanse their palates, participants had access to water and apple.

The experiment utilized the *LearnOlive* software, developed in Visual Basic (see Ramos-Alvarez et al., 2013) to facilitate and standardize the sensory evaluation process. Designed to align with IOC guidelines (2024a), the software provided step-by-step instructions in Italian (participants' native language) throughout the experimental session, offering both task guidance and feedback. It also helped researchers manage sample distribution in the heaters for each participant using a counterbalanced sequence.

LearnOlive ensured uniformity in task execution by minimizing experimenter intervention, a critical feature for working with unexperienced tasters. The program followed a structured workflow that included: 1) Sociodemographic data collection and participant profiling; 2) explanation of the experiment and electronic consent signing; 3) General instructions for familiarization with the workstation and tools; 4) tasting procedure guidance using the "Turn-Smell-Taste-Clean" approach including palate cleansing reminders; 5) A visual guide for block-by-block steps; 6) Response recording during tasting; 7) Feedback during tests; 8) Organoleptic and economic evaluations, including participants' willingness to pay (WTP) and hedonic assessments of oil tasted; and 9) Instructions for the subsequent block of the experiment.

For further details regarding the distribution of the tasting laboratory cubicles, and the software displays please refer to the figure presented in Ramos-Álvarez et al. (2013). A copy of the specific instructions in Italian may be found as the supplementary material in the following link:

<https://data.mendeley.com/preview/9pbh9n7hdm?a=8f0a84b0-5911-4813-9658-f446123c3cbb>

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Procedure

The study was reviewed and approved by the Department of Agricultural and Food Sciences (DISTAL) at Alma Mater Studiorum – University of Bologna and conducted in accordance with the ethical principles of the Declaration of Helsinki. Each participant who agreed to participate in the study provided informed consent electronically. Participants were informed of their right to withdraw from the study at any time without penalty.

Samples were prepared 30 minutes prior to each participant's arrival, whether expert or novice. A 10 ml portion of EVOO was poured into standard tasting glasses (IOC, 2020), covered with watch glasses, and placed in heaters to maintain optimal temperature. Apples and water were provided for palate cleansing between trials. The setup included 20 standard tasting glasses with corresponding watch glasses and heaters to ensure consistent thermal integrity.

Upon arrival, participants were assigned a subject code and given an explanation of the tasting task, including the elements to be used. Instructions and the general procedure were outlined, emphasizing that the *LearnOlive* program would provide step-by-step guidance. The experiment began with the collection of sociodemographic data and the signing of informed consent. Participants were then guided through the whole process by the *LearnOlive* program, ensuring standardized execution without intervention from the research team.

The program provided the following Instructions: "The next steps will guide you through: A) the instruments you will use, B) the general tasting procedure, C) how to respond using the computer, and D) the general guidelines for the task. Locate the following materials: heaters with tasting samples, a laminated sheet to hold used

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glasses, palate-cleaning items (apple, water, napkin), and a computer for instructions and responses.”

Participants were informed that the study aimed to examine basic sensory mechanisms common to all individuals in tasting situations. The task involved sampling olive oils and answering questions about their attributes. The tasting procedure was detailed as a four-step sequence: “Swirl-Smell-Taste-Clean.” This process was carefully explained and demonstrated by the experimenter to ensure clarity, particularly for consumers less familiar with such tasks. Experts, already acquainted with the process, required less guidance. Additionally, the program reminded participants of the tasting procedure at the end of each block to reinforce compliance.

The experiment consisted of four blocks, each with four samples, lasting 45–60 minutes per session. Signal-to-noise base rates were manipulated to induce expectations: $\frac{1}{4}$ (conservative) versus $\frac{3}{4}$ (lenient). Counterbalanced sequences were created using a Latin square design, ensuring equal frequency of conditions across ordinal positions and minimizing order effects (for details, see Arbeláez-Mejía et al., 2025b).

At the start of the experiment, participants were given the following instructions (in Italian): “We have selected a variety of high-quality extra virgin olive oil called OLIFLEX to study its acceptance by consumers. In this phase of the study, it is important to determine whether this olive oil has a distinctive flavor, and your collaboration is crucial. The objective is to quantify your ability to differentiate the OLIFLEX variety from other olive oils. The glass marked in red contains a specific sample of the OLIFLEX variety. Please take it now and taste it according to the tasting method previously indicated “Turn-Smell-Taste-Clean”. Focus on its properties to properly discriminate it.”

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At the beginning of each block, they were instructed to degust Oliflex, followed by the tasting of four additional samples. After tasting each sample 1) the tasters must indicate with a simple “yes” or “no” whether the oil they have just tasted is Oliflex, and 2) they must also quantify their confidence in their answer on a scale of 0 to 10, with 0 indicating no confidence, 5 indicating intermediate confidence, and 10 indicating maximum confidence. After each trial, the *LearnOlive* program provided immediate feedback on participants' choices. For correct responses, the message “GOOD. Right choice” was displayed, while incorrect responses were met with “BAD. Wrong choice” At the end of each block, participants conducted an economic evaluation of the oils, distinguishing between “Oliflex” (Signal in that block) and No Oliflex (Noise), rating their willingness to pay and their acceptance on a hedonic scale ranging from maximum dislike (0) to maximum liking (10).

Dependent Variables and Statistical Analysis

Psychophysical indices were used to assess both the sensory and decision-making processes of tasters. Following SDT, hit rates (H – probability of answering yes in a signal trial) and false alarm rates (FA – probability of answering yes in a noise trial) were calculated (Green & Swets, 1966; Hautus et al., 2021; Martín-Guerrero, 2015). Due to the limited number of trials to prevent sensory saturation, non-parametric indices (A' for sensory sensitivity and $B'D$ for decision processes) were used instead of traditional ones (d and c), as they are less restrictive and provide a more robust evaluation. To address potential extreme values in these indices, a log-linear correction was applied by adding a constant value (0.50) to all frequencies before calculation (Brown and White, 2005).

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Preference indices were evaluated by comparing the target olive oil (Oliflex or Signal) with the reference olive oil (Noise) and assessing participants' willingness to pay for Oliflex relative to the reference olive oil.

Box plots were employed to visualize and compare data distributions across conditions, highlighting central tendencies and potential outliers. For sensory performance (A' index), a score of 0.5 represents random performance. In decision-making (B'D index), a midpoint value of 0 indicates a neutral stance, with negative values suggesting leniency and positive values reflecting a more conservative bias. Reference points included a null difference (0) for differential preference and 5.6 euros for WTP.

A mixed-effects ANOVA model was used to minimize error by incorporating the sequential effect and participant-level data into the linear equation (Faraway, 2016). The analysis employed a maximal random effects structure for each dependent variable, including random intercepts for order and random slopes for within-subject factors, (Expectation and EVOO type), as recommended by Barr et al. (2013). Fixed effects included EVOO type, Expectation, and Expertise, along with their first- and second-order interactions. This approach ensured robust handling of within-subject variability and interaction effects.

A 2^3 , 2 Expertise (Experts vs Consumers) x 2 EVOO Type (green vs ripe) x 2 Expectations (Signal-to-noise ratio: low vs high) factorial analysis was employed. This approach enabled the evaluation of the main effects of EVOO Type, and signal-to-noise ratio, as well as the interaction, with results differentiated by evaluator expertise. The analysis prioritized testing interactions over the simple effects. Where significant interactions were identified, simple effects were examined using Holm's method to control the family-wise error rate in post-hoc contrasts.

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The analyses combined traditional ANOVA with Bayesian inference and effect size estimation. Bayesian methods were used to assess evidence for the null hypothesis following Jeffreys and Raftery criteria (Wetzels et al., 2011). Bayesian factors were interpreted on a scale ranging from anecdotal to strong evidence for or against the null hypothesis. Generalized η^2 for omnibus ANOVAs and Cohen's d was used for pairwise contrasts.

To enhance interpretability, reference values were established for all dependent variables, allowing one-sample tests for each experimental condition: Sensory index A' was compared against a reference value of 0.5 (indicating random performance), Donaldson index B'_D was compared against a neutral criterion value of zero (indicating no bias), Differential preference between signal and noise was tested against the null hypothesis, and WTP was compared to the market reference price for EVOO of 5.6 euros per liter.

The analyses were conducted using R 4.4.0 (R Core Team, 2024) with the following packages: {data.table}, {ggplot2}, {rtf}, {stringr}, {fmsb}, {emmeans}, {MASS}, {gSignTest}, {lme4}, {lmerTest}, {pbkrtest}, {BayesFactor}, and {pwrss}. The threshold for statistical significance was set at $p \leq .05$. The unprocessed data files from individuals who participated in this study can be accessed in the following link:

<https://data.mendeley.com/preview/9pbh9n7hdm?a=8f0a84b0-5911-4813-9658-f446123c3cbb>

Results

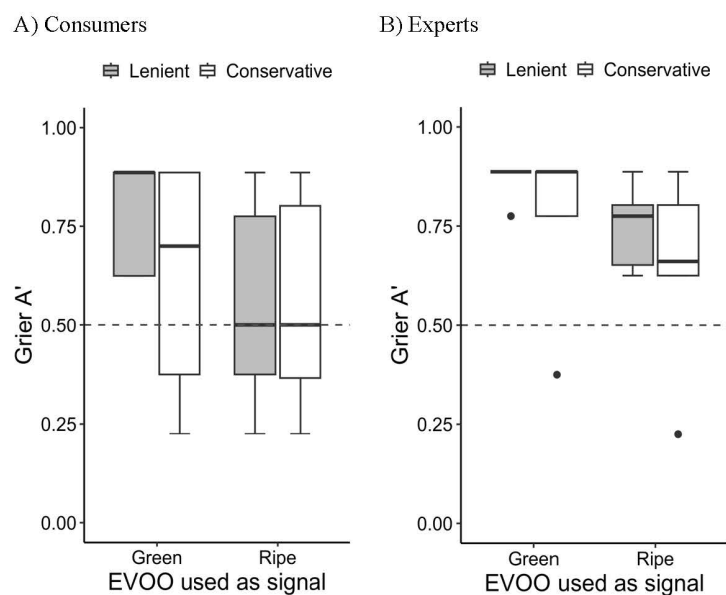
Figure 2 displays the Grier Sensitivity index (A') for consumers (Fig. 2A) and Experts (Fig. 2B) across the four experimental conditions. Each box plot illustrated the data distribution, with quartiles represented by the box, minimum and maximum values by the whiskers, and the median as the horizontal line within each

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box. The graph reveals that sensitivity was higher for green EVOO compared to Ripe EVOO across both expertise levels (Fig.2A and 2B), and expectation conditions (hatched vs unfilled boxes). These observations were supported by the results of a three-way ANOVA.

Figure 2

A' Sensitivity Index comparatively for consumers and experts



Note. Non parametric Signal Detection Theory Sensory Index for (A) Consumers and (B) Experts. The boxplots display the upper and lower quartiles of the data within the boxes, while the whiskers (extending lines) represent the minimum and maximum values outside these quartiles. The horizontal line inside the box shows the median. The dashed line in represents the level of chance performance in the sensory index. Factorial conditions: 1) Green-Lenient; 2) Green-Conservative; 3) Ripe-Lenient; and 4) Ripe- Conservative.

Only the main effects of expert level and EVOO type were found to be statistically significant [Expertise: $F(1.00, 16.35) = 6.57, p = .0206$, with moderate

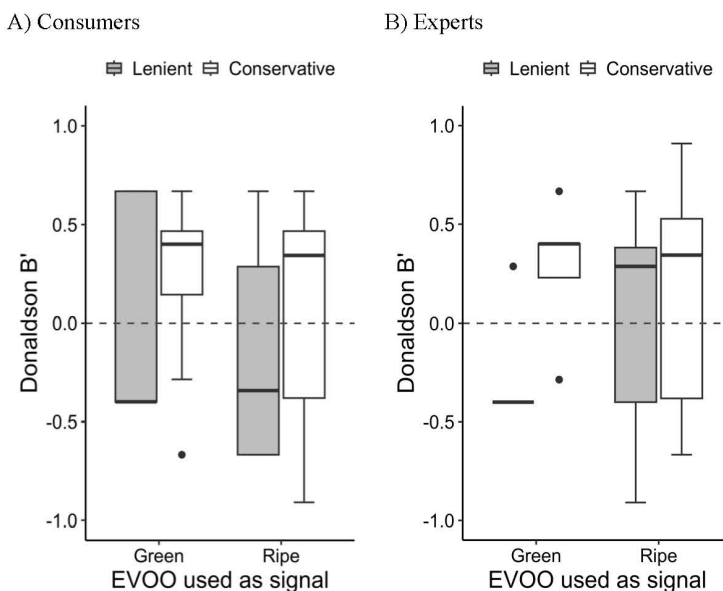
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effect size, $\eta^2 = 0.29$, and anecdotal evidence supporting the alternative hypothesis, $BF = 1.446$; EVOO: $F(1.00, 17.28) = 9.63, p = .0064$, with moderate effect size, $\eta^2 = 0.36$, and strong evidence supporting the alternative hypothesis, $BF = 13.228$]. In contrast, the effect of the type of expectation induced was not significant [$F(1.00, 30.37) = 3.32, p = .0781$], nor was the interaction of this variable with the type of stimulus oil [$F(1.00, 33.48) = 0.97, p = .3314$]. None of the remaining interactions with type of expertise were statistically significant, either first or second order [EVOO-Expertise interaction: $F < 1$; Expectation-Expertise: $F < 1$; EVOO-Expectation-Expertise: $F(1.00, 33.48) = 1.10, p = .3028$]. For all of these null effects, the effect sizes were small ($\eta^2 \leq 0.10$) and the Bayesian analysis provided anecdotal evidence supporting the null hypothesis ($BF = 0.34$ to 0.80).

The mean sensitivity values for each group further supported the findings. Experts demonstrated higher mean sensitivity (0.772) compared to consumers (0.633), and green EVOO elicited higher sensitivity (0.769) than ripe EVOO (0.636). In all 4 cases, the mean was significantly above 0.5 , the chance sensory performance [Ripe EVOO: $t(31) = 3.40, p < .0001$; Green EVOO: $t(31) = 8.07, p < .0001$; Expert: $t(31) = 3.08, p = .0022$; Consumer: $t(31) = 9.62, p < .0001$]. Consistently, BF pointed in the same direction in all 4 tests, supporting the alternative hypothesis with a moderate and even extreme magnitude [$BF > 9$].

In conclusion, the finding underscore the significant impact of in both expertise level and EVOO type on sensory sensitivity. Experts consistently demonstrated higher sensitivity, highlighting the critical role of training and experience in the accurate evaluation of EVOO sensory attributes. These results affirm the value of expertise in distinguishing the nuanced characteristics of different EVOO types, particularly between green and ripe oils.

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Figure 3*B'_D Decision-making (Bias) Index comparatively for Consumers and Experts*

Note. Non parametric Signal Detection Theory Criterion B'_D Donaldson Index for (A) Consumers and (B) Experts. Factorial conditions: 1) Green-Lenient; 2) Green-Conservative; 3) Ripe-Lenient; and 4) Ripe-Conservative. The dashed line indicates the neutral criterion for the decision index, values above a conservative criterion and below lenient. See Note of Figure 3 for statistical details of box plot.

Figure 3 displays the Donaldson B'_D Criterion Index for consumers (Fig. 3A) and Experts (Fig. 3B) across the four experimental conditions. The analysis of the Donaldson B'_D Criterion Index reveals that only the type of induced expectation significantly affected decision-making criteria [$F(1.00, 16.00) = 5.45, p = .0329, \eta^2 = 0.25, BF = 3.132$]. Other main effects, such as expertise level (experts vs. novices) and EVOO Type (green vs. ripe), were not statistically significant [$F < 1, \eta^2 < 0.1$, and moderate evidence supporting the null hypothesis, BF between .25 and .33]. Similarly,

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none of the first- or second-order interactions showed significance [EVOO-Expectation: $F(1.00, 16.04) = 1.30, p = .2708$; EVOO-Expertise: $F(1.00, 16.00) = 1.28, p = .2751$; Expectation-Expertise: $F < 1$; EVOO-Expectation-Expertise: $F(1.00, 16.04) = 1.50, p = .2376$], with small effect sizes ($\eta^2 \leq 0.09$) and anecdotal evidence supporting the null hypothesis (BF = 0.36 to 0.63).

The response criterion varied with expectancy manipulation. In the lenient condition, the B'_D index was negative (-0.109), indicating a liberal tendency to identify differences (Signal vs. Noise). In the Strict Condition, the index was positive (0.181), reflecting a conservative tendency to report fewer differences. The difference between the absolute values of the B'_D index of the two levels of induced expectancy was not statistically significant [$t(31) = -0.61, p = .5485$; with small effect size, $d = -0.10$, and moderate/positive support for the null hypothesis, BF = 0.224], aligning with the SDT prediction of symmetrical response criteria.

The induced expectations through signal and noise probability behaved as predicted by SDT (Ramos-Álvarez et al., 2013; Sternberg, 1998). These expectations showed no significant interaction with expertise or EVOO type, indicating consistency across participant groups (experts vs. novices) and EVOO types (green vs. ripe). This consistency is evident in Figure 3, where the effects of expectations are comparable between experts and consumers (Fig. 3A vs. Fig. 3B), and between EVOO types (left vs. right boxes in both panels).

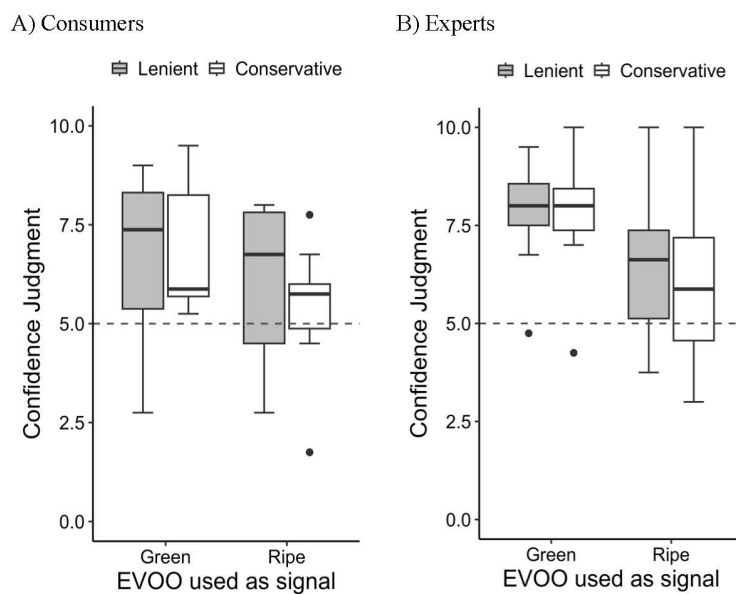
Figure 4 illustrates the confidence judgments made by participants, showing higher confidence for green EVOO compared to ripe EVOO. The results of the 3-way ANOVA indicate that EVOO type was the only significant factor affecting confidence judgments [EVOO: $F(1.00, 15.70) = 14.77, p = .0015, \eta^2 = 0.25, BF = 181.607$], with extreme evidence supporting the alternative hypothesis. The remaining effects

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(Expectation, Expertise, and interactions) were not statistically significant. Specifically, Expertise [$F(1.00, 16.03) = 1.17, p = .2947$], Expectation [$F < 1$], and all interactions (EVOO-Expectation, EVOO-Expertise, Expectation-Expertise, EVOO-Expectation-Expertise) showed small effect sizes ($\eta^2 \leq 0.07$) and anecdotal evidence favoring the null hypothesis (BF between 0.34 and 0.64).

Figure 4

Confidence ratings for Consumers and Experts



Note. The graph illustrates the confidence judgment value on a scale ranging from 0 to 10, where 0 indicates a null judgment, 5 denotes an intermediate judgment, and 10 signifies a high judgment. See Note of Figure 3 for statistical details of box plot.

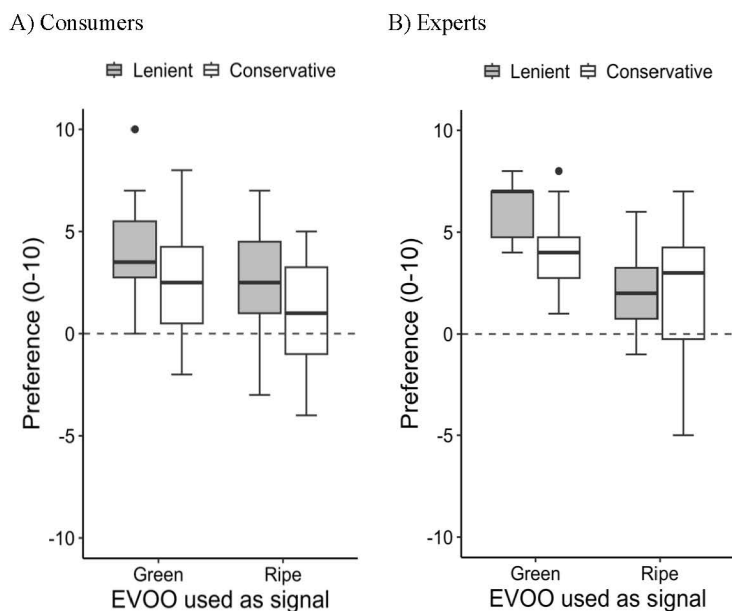
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In terms of confidence levels, participants showed significantly higher confidence for green EVOO (mean = 7.25) compared to ripe EVOO (mean = 5.99). Further analysis comparing these confidence levels with an intermediate value of 5 revealed that both EVOO types were rated significantly higher than 5: for ripe EVOO [$t(31) = 2.79$, $p = .0044$, $BF = 4.865$] and for green EVOO [$t(31) = 7.14$, $p < .0001$, $BF = 284887.232$], with strong evidence in favor of the alternative hypothesis for both cases.

Figure 5 shows the differential preference for the EVOOs used as a signal, highlighting possible differences based on the EVOO type (green vs. ripe) and expectations (lenient vs. conservative), with no modulation observed by expertise (compare left and right graphs). The 3-way ANOVA confirmed these observations. Only the effects of EVOO type and expectations were statistically significant [EVOO: $F(1.00, 16.00) = 11.96$, $p = .0032$, $\eta^2 = 0.43$, and extreme/strong support for the alternative hypothesis, $BF = 101.439$; Expectation: $F(1.00, 29.40) = 7.31$, $p = .0113$, with small effect size, $\eta^2 = 0.20$, and anecdotal/weak support for the alternative Hypothesis, $BF = 1.392$]. The expertise variable did not significantly affect differential preference [$F(1.00, 16.01) = 1.31$, $p = .2700$], nor were any of the first- or second-order interactions significant [$F < 1$], with small effect sizes ($\eta^2 \leq 0.05$) and BF providing anecdotal evidence in favor of the null hypothesis (0.32 to 0.54).

Differential preference was significantly higher for green EVOO (mean = 4.25) than for ripe EVOO (mean = 1.81), though statistical analysis showed significant deviations from the null value in both conditions: Green EVOO [$t(31) = 8.40$, $p < .0001$], and Ripe EVOO [$t(31) = 3.21$, $p = .0016$], with Bayesian analysis showing strong evidence for the alternative hypothesis, ($BF > 12$).

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Figure 5*Differential Preference for the EVOO Target Compared to the Reference*

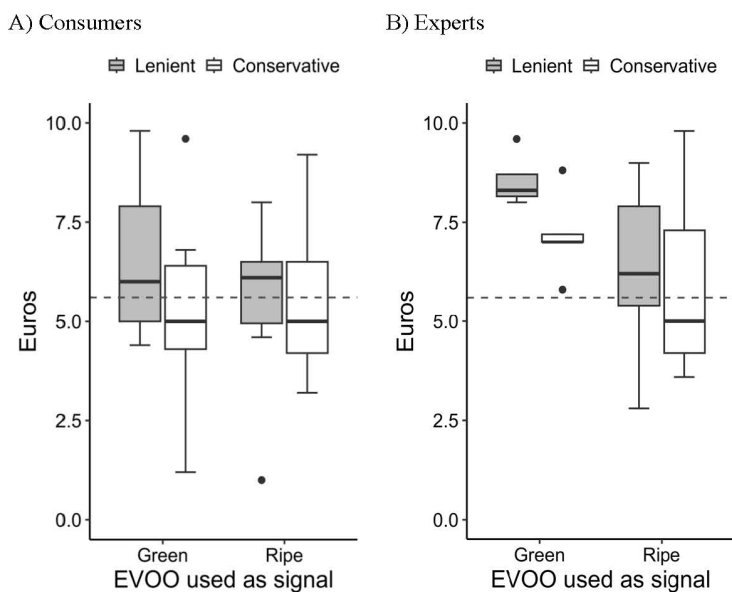
Note. Differential preference for each of the 4 conditions (Signal or Oliflex) compared to the reference, commercial, EVOO (Noise). Factorial conditions: 1) Green-Lenient; 2) Green-Conservative; 3) Ripe-Lenient; and 4) Ripe-Conservative. The dashed line indicates the null difference value. See Note of Figure 3 for statistical details of box plot.

Additionally, differential preference was higher in the lenient condition (mean = 3.72) compared to the conservative condition (mean = 2.34), reflecting the differences in the probability of signal vs. noise presentation (0.75 vs. 0.25, respectively).

Significant deviations from the null value were observed in both conditions: Lenient condition [$t(31) = 6.90, p < .0001$], and Conservative condition [$t(31) = 3.96, p = .0002$] with Bayesian analysis indicating very strong to extreme evidence for the alternative hypothesis, ($BF > 72$).

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Figure 6

Economic Valuation: WTP

Note. Economic valuation, in Euros, of each of the 4 conditions compared to the price set for the reference (Noise) EVOO (5.6 Euros, dashed line) or Willing To Pay (WTP) for target EVOOs. Factorial conditions: 1) Green-Lenient; 2) Green-Conservative; 3) Ripe-Lenient; and 4) Ripe- Conservative. See Note of Figure 3 for statistical details of box plot.

Figure 6 presents the results of the WTP analysis, illustrating potential differences based on EVOO type (green vs. ripe) and expertise (experts vs. consumers). The 3-way ANOVA showed a significant main effect of EVOO type [$F(1.00, 16.00) = 5.95, p = .0268$, with medium effect size, $\eta^2 = 0.27$, and strong evidence for the alternative hypothesis, $BF = 10.72$] and Expectation [$F(1.00, 16.01) = 6.92, p = .0182$, with medium effect size, $\eta^2 = 0.30$, and anecdotal evidence for null hypothesis, $BF = 0.715$]. The main effect of Expertise was not significant [$F(1.00, 16.10) = 3.61, p = .0754$, with small effect size, $\eta^2 = 0.18$, and anecdotal evidence for alternative

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hypothesis, $BF = 1.046$]. The interaction between EVOO type and expertise was significant [EVOO-Expertise: $F(1.00, 16.00) = 4.85, p = .0427$, with small effect size, $\eta^2 = 0.23$, with moderate evidence for alternative hypothesis, $BF = 5.344$]. No other interactions were significant [EVOO-Expectations interaction: $F(1.00, 16.01) = 2.14, p = .1626$; Expectations-Expertise: $F < 1$; EVOO-Expectations-Expertise: $F < 1$], with all remaining interactions showing small effect sizes ($\eta^2 < 0.12$), and the Bayesian evidence favoring the null hypothesis ($BF = 0.35$ to 0.43).

A simple effects analysis exploring the significant interaction between EVOO type and Expertise showed a significant difference in WTP between green and ripe EVOO only for experts [$t(18.241) = -0.16, p = .8768$, very small effect size, $d = -0.054$, and moderate evidence for the null hypothesis, $BF = 0.27$]. No significant difference was observed for consumers [$t(18.241) = -3.07, p = .0065$, large effect size, $d = -1.051$, and moderate evidence for the alternative hypothesis, $BF = 7.57$].

WTP was statistically above the reference price of €5.6 for both expectation conditions [Conservative: $t(31) = 2.53, p = .0084$; Lenient: $t(31) = 4.33, p = .0001$] and for Experts' WTP for both EVOOs [Green EVOO: $t(15) = 4.96, p = .0001$; Ripe EVOO: $t(15) = 1.98, p = .0335$]. However, no significant difference was found for consumers' WTP [Ripe EVOO: $t(15) = 1.32, p = .1037$; Green EVOO: $t(15) = 1.70, p = .0548$]. Bayesian evidence was stronger for the alternative hypothesis where WTP exceeded €5.6 (Lenient condition: $BF = 181.926$; Green EVOO for experts: $BF = 178.842$), and anecdotal for negative effects (consumers' WTP for Ripe and Green EVOO conditions, $BF = 0.532$ and 0.832).

Discussion

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This study sought to compare the evaluations of regular EVOO consumers and experts, employing methods that disentangle sensory and decision-making indices, namely STD and DDAT. By replicating previous research by Arbeláez-Mejía et al. (2025b) with panels of Italian experts and regular consumers evaluating different EVOOs, we explored whether the interaction between sensitivity and decision processes persists under these conditions.

Our findings revealed no significant interaction between sensory and decision-making processes, reaffirming the utility of DDAT for isolating these factors. Sensitivity was shown to selectively affect the measure A' , while expectations influenced B'_D without significant interactions. Notably, expertise exerted a direct effect on sensitivity, enhancing it compared to consumers. However, expertise did not significantly impact the decision-making index B'_D , suggesting that the interaction previously observed may be more related to the learning process of individuals across experiments rather than their level of expertise or familiarity with the product.

Sensitivity was higher for Green EVOO than for Ripe EVOO, likely due to the distinct sensory profile of green oil. Experts exhibited greater sensitivity compared to consumers, as expected due to their extensive training. However, the difference was smaller than anticipated, indicating that novice tasters' high familiarity with EVOO contributed to reducing this gap. This supports the hypothesis that familiarity or training can bridge the difference between experts and consumers, as suggested by prior studies (Arbeláez-Mejía et al., 2025a; Dos Santos et al., 2023).

The response criterion B'_D displayed expected patterns: Negative in the lenient condition, indicating a liberal tendency to identify signal-noise differences; and positive in the strict condition, reflecting a conservative tendency to report fewer differences.

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Preferences for EVOOs were influenced by signal-to-noise manipulations and sensory profiles, with Green EVOO preferred over Ripe EVOO due to its distinct sensory characteristics. Similarly, a differential willingness to pay (WTP) was observed, with experts showing a statistically significant increase in WTP for high-quality oils, unlike consumers. This aligns with previous findings that experts' training enables them to identify and value quality attributes more effectively (Cicia et al., 2013; Bongartz & Oberg, 2011; Delgado & Guinard, 2012).

Confidence judgments highlighted the influence of EVOO type on participant responses, with both Green and Ripe oils surpassing the neutral confidence threshold, albeit with Green EVOO eliciting higher confidence. Differences between experts and consumers in confidence judgments, although initially apparent, did not achieve statistical significance upon thorough examination.

Socio-demographic differences between experts and consumers, including age, education level, and smoking habits, may have contributed to the observed results. Experts, with higher average age, advanced education, and non-smoking habits, were better positioned to demonstrate superior sensory performance and decision-making. These factors, combined with training, underscore the significant role of expertise in shaping EVOO evaluations (Cicia et al., 2013; Bongartz & Oberg, 2011; Delgado & Guinard, 2012; Rébua et al., 2021).

Beyond sensory evaluations, discrepancies between experts and consumers extend to attributes deemed important during purchase decisions (see review in Arbelaez et al., 2025a). While experts prioritize intrinsic attributes like bitterness and pungency, consumers are more influenced by extrinsic factors such as origin and certifications (Dekhili et al., 2011). Familiarity with EVOO consumption enables some novice tasters to identify high-quality oils, yet it does not necessarily translate into

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higher WTP, reinforcing the idea that the promotion of olive oil consumption, even in regular consumers should be particularly focused in extrinsic attributes of the oil, such as the information that appears in the label, the packaging etc.

Overall, our findings emphasize the potential to bridge the gap between experts and consumers through targeted information and education on EVOO's sensory, health, and nutraceutical properties. Familiarity with EVOO consumption appears to mitigate differences, suggesting future studies could explore the application of these methodologies in non-producing countries to enhance recognition of EVOO as a functional food. These efforts could transform consumer perceptions and preferences, aligning them more closely with expert evaluations.

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6. General discussion

Extra virgin olive oil (EVOO) offers numerous health benefits, making its promotion highly relevant. It reduces the risk of cardiovascular disease (14%) and mortality (18%) (Guasch-Ferré et al., 2022), type 2 diabetes (Schwingshackl et al., 2023), and several types of cancer (Markellos et al., 2022). EVOO also improves cognitive function, prevents Alzheimer's disease (Valls-Pedret et al., 2015), strengthens bone health (García-Gavilán et al., 2018), and helps manage weight and body mass index (Zamora et al., 2020). Furthermore, it shows potential as a treatment for rheumatic diseases and cancer (Gonzalez-Rodriguez et al., 2023). Additional benefits include improving intestinal microbiota, glycemic control, and lowering LDL cholesterol. Its rich content of polyphenols and oleocanthal also aids in preventing age-related diseases (Millman et al., 2021; Flynn et al., 2023).

Despite the numerous health benefits associated with EVOO consumption, promoting its use as a functional food faces a significant challenge. Attributes such as bitterness and pungency, which are linked to the volatile compounds and phenols responsible for many of EVOO's beneficial effects, are often disliked by the general public. To address this challenge, the overarching objective of this doctoral thesis was to elucidate the factors that influence consumer preferences and decision-making processes regarding EVOO.

This general objective was approached through three specific goals, which form the core structure of the dissertation. The first specific goal was to characterize consumer perceptions of EVOO consumption as a function of their familiarity with EVOO culture. This aspect focused on understanding how cultural and geographical factors shape consumers' appreciation of the sensory attributes of EVOO. The second goal was to evaluate the potential role of consumer panels in the sensory analysis of EVOO. This involved utilizing methodological tools to analyze the dynamics of sensory and decision-making processes. The third specific goal was to compare expert and consumer perceptions within the same experimental setting. This comparison aimed to determine whether the differences between experts and regular consumers are a matter of degree

(quantitative differences) or represent fundamentally different perceptions (qualitative differences).

The general discussion of this dissertation is organized around these three specific goals. These are the objectives that led to the three studies that make up this thesis (sections 3, 4, and 5). The document concludes with a comprehensive overview of the main insights generated by this research and potential applications of the findings in promoting EVOO consumption and enhancing public health outcomes.

6.1. The role of familiarity in EVOO perception

The first specific goal of this dissertation was to evaluate whether consumer perception and evaluation of EVOO's sensory attributes are influenced by consumers' familiarity with olive oil culture. A key challenge in addressing this goal is the limited reporting of familiarity in most studies on consumer perception of EVOO. To overcome this issue, a systematic review was conducted, using country of residence as a proxy to assess the relationship between familiarity and consumer preferences. The underlying hypothesis suggests that consumers from EVOO-producing regions are more likely to exhibit a higher tolerance for and preference toward bitterness and pungency, attributes often linked to EVOO, due to their greater familiarity and exposure, compared to consumers in non-producing regions.

The findings indicated that the country of residence serves as a valid proxy for familiarity in evaluating consumer preferences. For instance, sensory attributes such as bitterness and pungency, often rejected in non-producing countries, are favorably perceived in producing regions. The review also identified EVOO as the globally preferred type of olive oil, with origin and certifications (e.g., PGI and organic labels) standing out as critical attributes. These certifications are perceived as indicators of superior quality, particularly for locally or nationally produced products, reflecting a tendency toward ethnocentrism. Furthermore, specific organoleptic characteristics were strongly associated with oils from traditional producing regions

This systematic review offers a comprehensive framework for understanding consumer preferences on a global scale. It provides actionable insights for the olive oil sector by highlighting critical factors, such as origin and certifications, that significantly influence consumer decisions. These findings serve as a foundation for designing targeted campaigns to promote EVOO consumption while emphasizing its substantial potential to improve public health.

6.2. Dynamics of sensory and decision-making processes in EVOO tasting conducted by a consumers panel

The second goal of this dissertation is to assess the validity of Signal Detection Theory (SDT) and the Double Dissociation Additive Test (DDAT) as tools for independently analyzing the sensory and decision-making processes of untrained consumers. This was achieved by differentiating signal from noise based on subtle attributes of natural oils rather than solely identifying the presence or absence of extra virgin olive oil (EVOO). The primary hypothesis posits that SDT-based evaluation methods, such as DDAT, can effectively determine whether sensory and decision-making processes function independently or interact when evaluating oils based on their sensory characteristics. This hypothesis was tested in two experimental studies, although the second one was also devoted to analyze the potential differences between consumers and experts in EVOO evaluation.

The first study included two experiments that were conducted with the same consumers' panel with the goal of assimilating the tasting conditions to the ones used when tasting studies are conducted by experts (see for example the IOC EVOO Tasting Standards, 2018). Experiment 1a used four non-commercial EVOOs as signals (A, B, C, and D), while the noise was a commercial EVOO. The goal was to evaluate participants' ability to distinguish subtle differences in sensory attributes among these oils. Results supported a neutral criterion in the decision-making process (Donaldson's B'_D index, 1992), as it was not manipulated experimentally. These findings validated the applicability of SDT to evaluate sensory and decision-making indices in parallel during tasting tasks with untrained consumers assessing natural EVOOs. This validation is particularly valuable when working with novice tasters.

Experiment 1b followed the logic of the DDAT to evaluate the independence or interaction between sensory and decision-making processes when natural EVOO were evaluated (Ramos-Alvarez et al., 2013). The sensory criterion was manipulated through the type of oil (green or mature), while the decision criterion was manipulated by inducing expectations via the probability of signal versus noise presentation (High/low likelihood of signal versus likelihood of noise). Results showed that the sensory index (Grier's A' , 1971) varied selectively depending on the type of oil, as would be expected from our previous work (Ramos-Alvarez et al., 2013). While participants could distinguish green oil from noise, they struggled to do so with mature oil, likely due to the sensory similarity between the mature oil and the noise.

In contrast, an interaction was observed in the decision-making index (Donaldson's B'_D , 1992), where induced expectations influenced evaluations of mature oil but not green oil. For the latter, the decision index remained neutral.

The findings of this study indicate an interconnection between sensory processes and decision-making mechanisms in evaluating natural EVOOs. These results align with Bang and Rahnev's (2017) research, which demonstrated that decision criteria are predominantly influenced by post-stimulus cues rather than pre-stimulus ones, emphasizing the stronger impact of expectations on decision-making compared to sensory discrimination. Similarly, Ramos-Álvarez et al. (2025) reported that the absence of feedback diminished sensitivity performance and mitigated conservative-lenient biases introduced by base rate manipulations.

However, when a similar manipulation was introduced in the second study, the interaction between sensory and decision processes disappeared, so that both processes were independently affected by manipulations that theoretically should affect one and not the other: green vs mature oil only affected the sensory index, while induced expectations only affected the decision-making index, confirming the theoretical predictions of SDT and prior literature highlighting the independence of these processes in perceptual studies (e.g., Howe et al., 1993; Huang & Ferreira, 2020; Swets, 1996; Wright et al., 2009) and research on EVOO tasting and basic flavors (e.g., Ramos-Álvarez et al., 2013, 2025).

A complementary result of these studies revealed a discrepancy between expressed preferences and Willingness To Pay (WTP) in the case of regular consumers. They detected subtle quality differences between signal and noise, expressing a preference for the signals used as EVOO over commercial EVOO (noise). However, they were not willing to pay more for the higher quality EVOOs, highlighting a divergence between sensory perception and economic decisions in regular consumers that was not observed in experts.

6.3. The perceptions of experts and consumers when they are evaluated within the same experimental setting

Building on the systematic review's findings about the reversal of negative evaluations of bitter and spicy attributes through familiarity and the study by dos Santos et al. (2023), which demonstrated that fundamental training in EVOO tasting can make consumer evaluations comparable to those of experts, the hypothesis of our Study 2 posited that disparities between experts and regular consumers are attributable to sensitivity rather than evaluation accuracy.

As expected, sensitivity was higher for green EVOO compared to ripe EVOO, likely due to the distinct sensory profile of both EVOOs. Experts demonstrated greater sensitivity than consumers, consistent with their advanced training. However, the narrower-than-expected gap suggests that novice tasters possessed a notable degree of familiarity, enhancing their sensitivity. This aligns with findings from the systematic review and dos Santos et al. (2023), indicating that familiarity or training can reduce the gap between experts and consumers.

The response criterion (B'_D index) exhibited a symmetrical bias, with lenient and conservative conditions producing negative and positive values, respectively, as expected. and this was true for experts and consumers alike. The lack of interaction between expectations and type of EVOO, as shown by the application of DDAT, demonstrates the independence between the corresponding sensory and decision-making processes, regardless of the level of expertise.

Similar results were found with respect to the confidence levels. Both experts and consumers exhibited confidence levels that significantly exceeded the neutral value of 5. While

green EVOO evaluations showed notably higher confidence, ripe EVOO evaluations demonstrated moderate confidence. Despite an initial appearance of significant differences between experts and consumers, further analysis revealed no further discrepancies in confidence levels.

Previous studies highlight a discrepancy between expert and consumer ratings, particularly regarding bitter and spicy attributes. Experts favor these characteristics, associating them with quality and health benefits derived from phenolic and volatile compounds (Cicerale et al., 2016; Delgado & Guinard, 2011). Consumers, however, tend to reject these attributes due to their association with naturally occurring toxic substances (Cavallo et al., 2018; Delgado & Guinard, 2011; Rébufa et al., 2021). Bitterness, while common in coffee, chocolate, and alcoholic beverages, is influenced by cultural factors (Cavallo et al., 2019; Delgado & Guinard, 2011). Experts prioritize intrinsic attributes such as bitterness, spiciness, and fruitiness, while consumers favor extrinsic attributes like origin and certifications (Dekhili et al., 2011). However, both groups positively value fruitiness (Cicerale et al., 2016; Delgado & Guinard, 2011, 2012; de Melo et al., 2021).

Choi et al. (2023) demonstrated that familiarization procedures stabilize decision criteria and enhance panel performance, making consumer evaluations comparable to those of experts. Similarly, dos Santos et al. (2023) highlighted the potential of basic sensory training to align consumer ratings with those of experts. However, unlike dos Santos et al. (2023), this study incorporated expert panels and revealed that familiarity plays a critical role in narrowing the gap between consumer and expert evaluations.

The findings suggest that differences between experts and consumers in sensory evaluations are primarily a matter of degree rather than quality. Familiarity and training can significantly bridge this gap, enhancing consumer appreciation of intrinsic attributes like bitterness and spiciness. These insights provide actionable implications for the EVOO industry, particularly in designing training programs and marketing strategies to promote EVOO as a high-quality product.

6.4. Final Insights and potential applications

This PhD dissertation includes a systematic review and two empirical studies, demonstrating that consumers' country of origin influences their familiarity with extra virgin olive oil (EVOO), which in turn shapes their preferences and perceptions of both intrinsic (taste, aroma, and color) and extrinsic attributes (e.g., label, brand, origin).

The systematic review provides a framework for promoting EVOO as a functional food, highlighting its health benefits and encouraging its broader consumption to positively impact public health. A key aspect of this analysis is understanding how consumer perceptions of EVOO attributes are influenced by their familiarity with the product. This familiarity affects both intrinsic attributes (such as flavor and aroma) and extrinsic attributes (like brand recognition and product packaging). Regardless of whether a country is an EVOO producer, this broader understanding of consumer preferences can be transferred to the olive oil sector to develop targeted campaigns that address the characteristics of specific populations. This approach will not only promote EVOO consumption in new markets but also provide insights that can change the perception of bitter and spicy attributes, which are associated with the health benefits of EVOO, thereby addressing the challenges reported in the literature (Cicerale et al., 2016; Delgado and Guinard, 2011).

Prior findings (Martin-Guerrero et al., 2014, 2015, Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010; Ramos-Álvarez et al., 2013) suggest that combining SDT and DDAT as methodological tools can effectively separate sensory performance from decision-making biases in EVOO sensory analysis. These tools were applied to basic flavours (e.g. salt) and also to EVOO, with converging results. In particular, in the work on the sensory evaluation of olive oil, the signal stimuli were a mixture of EVOO, sunflower oil and food paraffin; as the noise stimulus was equivalent but lacked EVOO (paraffin and sunflower oil mixture). In this dissertation, this methodology was extended to pure EVOOs (both signal and noise) and two experiments with regular consumers were conducted, simulating the characteristics of an expert

panel in accordance with IOC standards (2023). This empirical demonstration validates the methodology's ability to separate sensory performance from potential biases in evaluations, such as those related to subjective aspects like motivations, beliefs, and expectations, as highlighted by Schifferstein (1996).

The second empirical study built on this foundation, comparing experts and consumers to examine whether the discrepancies reported in the literature (e.g., Barbieri et al., 2015; Caracciolo et al., 2020; Cavallo et al., 2017, 2018, 2019; Delgado & Guinard, 2011, 2012; Delgado et al., 2013; Fernandes et al., 2018; Pagliuca & Scarpato, 2011; Predieri et al., 2013; Rébufa et al., 2021) can be minimized through increased familiarity with the product. This comparison is valuable because it allows us to differentiate the purely sensory process from biases in consumer responses, thanks to the validated methodology used in the first experimental study. The findings support our initial hypothesis, demonstrating that observed differences between experts and consumers are only due to sensory performance.

This dissertation contributes to the growing field of Sensory and Consumer Science, an interdisciplinary domain examining product perception through sensory faculties and how these experiences influence consumer behavior. This evolving field integrates sensory research methodologies with consumer-focused studies, employing diverse research approaches to understand the intricate relationship between sensory perceptions and consumer responses (Jaeger et al., 2025). Meiselman et al. (2022) provide a historical overview of the integration of sensory science with consumer research and technological advances, which now include a broader approach beyond taste alone. Key themes highlighted in their work include hedonism, discrimination testing, and the impact of social networks on consumer behavior. Among their findings, they emphasize consumer expectations—an important factor in sensory and consumer science. Research has classified expectations in terms of sensory descriptions, labels, health claims, and emotional connections to products, all of which are linked to consumer loyalty and behavior.

In addition, cross-cultural studies examining food-related attitudes (e.g., EVOO) show that extrinsic factors like price and labeling significantly influence food acceptance, as observed in the systematic review concerning origin and certification. These studies also call for conceptual models that integrate intrinsic and extrinsic factors influencing consumer behavior, aligning with the aims and findings of the review. The integration of SDT and DDAT methods offers a robust tool for understanding sensory processes, decision-making, and preference indices, which can be applied to both sensory science and consumer behavior studies.

Drake et al. (2022) consider sensory science's integration with neuroscience and psychology, utilizing psychophysics tests to assess consumer perception and preferences, with methods ranging from tests of discrimination to methods of a more qualitative nature, such as ethnography, to methods of measuring variables related to attitudes and preferences (e.g. surveys). Despite advancements in technology, traditional approaches remain essential for ensuring the reliability of results, as evidenced by the preference indices reported in our **Studies 1 and 2**, as well as findings from the systematic review on EVOO attributes and consumer preferences.

Additionally, areas such as neuromarketing, which aim to understand the processes behind consumer decision-making, could be conjugate with the methodology proposed throughout this this dissertation. These include the use of techniques like functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and eye tracking, which provide insights into the brain's reward system and consumer focus (Adhikari, 2023). These tools complement traditional sensory analysis by revealing emotional responses and attention metrics.

In a similar vein, the studies reviewed in the Signal Detection Theory (SDT) framework show relevance to the findings of this dissertation. For example, Pleskac et al. (2010) explain the Dynamic Signal Detection (DSD) model, which incorporates post-decisional evidence impacting confidence and is positively correlated with decision-making time. Their research suggests that judges exhibit reduced confidence under speed conditions, a finding that aligns with our **Study 2**, where confidence indices were recorded, demonstrating that both consumers and experts reported high confidence levels in their judgments.

Finally, Lee et al. (2024) utilized SDT and the "double-faced applicability" (DFA) test to enhance product optimization by examining consumer sensory perceptions. This methodology, based on two-step scoring and expectation profiles, stabilizes evaluation criteria, improves sample discrimination, and augments consumer satisfaction, which could also lead to complementary results to those obtained from our Double Dissociation Additive Test (DDAT).

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7. PhD Dissertation Highlights

- The level of olive oil production of the country of residence of the consumer can be used as a valid proxy of familiarity.
- Consumer's rejection of bitter and pungent flavours may be reversed by familiarity.
- Linking the bitter and pungent flavors to the health benefits of EVOO consumption will be a crucial strategy in overcoming the challenge of promoting its consumption in non-producer regions.
- Label information is crucial and should be tailored to the specific characteristics of the target market, especially regarding familiarity with the product.
- Participants' sensitivity varied with oil attributes, while decision criteria remained neutral in the absence of specific manipulations that induced biases.
- Although with some qualifications, induced expectations impacted decision bias while oil attributes impacted sensitivity, regardless of whether the study was conducted with experts or familiar consumers.
- Consumers differential preferences for distinct EVOOs with zero defects did not translate into differences in their willingness to pay for them.
- Experts demonstrated higher sensitivity and were more willing to pay for green EVOO compared to consumers.
- Both expert and consumer panels preferred green EVOO over ripe EVOO, with a clear distinction in sensitivity levels.
- The findings suggest that familiarity, influenced by expertise and expectations, plays a significant role in the discrepancies between expert and consumer evaluations.
- The dissertation highlights the importance of understanding how familiarity and subjective factors, such as expectations, influence the sensory evaluation of EVOO, bridging the gap between expert and consumer preferences.

8. Resumen extendido

La dieta mediterránea se ha convertido en un modelo nutricional saludable y con un impacto positivo en la salud lo que llevó a la UNESCO a considerarla parte del patrimonio intangible de la humanidad en noviembre de 2010 (Trichopoulou, 2021; UNESCO 2010).

Los estudios sobre Aceite de Oliva Virgen Extra (AOVE) muestran que este puede ser uno de los principales contribuyentes a las propiedades saludables de la dieta mediterránea. Su contenido en polifenoles genera efectos positivos en la salud (Flynn et al., 2023), con propiedades antiinflamatorias y antioxidantes (Francisco et al., 2019), cardioprotectoras (González et al., 2023) y beneficiosas para la prevención de trastornos oculares (Moyano et al., 2010). Además, previene el síndrome metabólico, el cáncer de mama y de próstata, contribuye a la prevención del daño hepático y podría proteger contra el deterioro cognitivo relacionado con la edad y la enfermedad de Alzheimer (Medeiros & Hampton, 2020), ya que puede atenuar la neurodegeneración causada por esta enfermedad (Tzekaki et al., 2021). Por lo expuesto anteriormente, ha sido considerado un alimento funcional (Quiles et al., 2006) o nutraceutico, término que hace referencia a las propiedades nutritivas y farmacéuticas de algunos alimentos (Casini et al., 2014; Medeiros & Hampton, 2020).

Los polifenoles, responsables de los atributos amargo y picante del AOVE, están asociados con sus beneficios para la salud (Cicerale et al., 2016; Delgado y Guinard, 2011). Sin embargo, existe una discrepancia entre expertos y consumidores respecto a estos atributos. Mientras que los expertos los valoran positivamente, los consumidores pueden mostrar rechazo hacia los mismos, asociándolos con sustancias tóxicas (Cavallo et al., 2018; Valli et al., 2014). Por lo tanto, estos atributos pueden representar un obstáculo para la promoción del consumo de AOVE como un alimento funcional.

Desde esta perspectiva, el hecho de que un alimento sea saludable no necesariamente implica que será aceptado por los consumidores (Casini et al., 2014). La familiaridad con el AOVE, entendida como el conocimiento adquirido a través de la experiencia con el producto, influye en las percepciones de los consumidores. Diversos estudios han señalado que la familiaridad puede cambiar según si se reside en una zona productora o no (Di Vita et al., 2020). Los consumidores de países mediterráneos tienden a basar sus decisiones en atributos intrínsecos (amargo, picante, olor y color) y sus valoraciones pueden ser similares a las de los expertos (Jiménez-Guerrero et al., 2012). En contraste, en países no productores, los consumidores basan sus decisiones más bien en atributos extrínsecos como la marca, certificaciones o la información proporcionada por la etiqueta (Delgado y Guinard, 2011), induciendo incluso a considerar positivos ciertos defectos del AOVE (Fernandes et al., 2018).

El primer objetivo específico de esta tesis doctoral fue comprobar si la idea general de que la percepción del AOVE cambia con la familiaridad tiene sustento científico más allá de lo apuntado por unos cuantos estudios. Dado que la familiaridad, o bien no se considera, o se considera de manera muy diferente en distintos estudios, se realizó una revisión sistemática con la hipótesis de trabajo de que el país donde se realiza el estudio podría utilizarse como proxy válido de familiaridad a la hora de clasificar las percepciones de consumidores sobre los atributos del AOVE. La revisión sistemática se realizó considerando publicaciones de los últimos 14 años (2010-2024) en las bases de datos Scopus y Web of Science (WOS). Se utilizó el término "Consumer Preferences AND Olive Oil" para obtener un panorama amplio, encontrándose 315 publicaciones en WOS y 276 en Scopus. Tras una selección preliminar, se incluyeron 225 trabajos en la fase de tamizaje, de los cuales, tras eliminar duplicados y aplicar criterios de inclusión y exclusión se analizaron 129 estudios cualitativa y cuantitativamente.

En cuanto a los aspectos metodológicos, utilizamos el protocolo PRISMA (Page, et al., 2021) y los sesgos se analizaron siguiendo RoB-2 Risk of Bias-2 Scale de Cochrane (Cochrane Methods, 2019). El protocolo detallado se registró en OSF (<https://doi.org/10.17605/OSF.IO/NKWJZ>). Debido a la variedad de metodologías utilizadas en los estudios seleccionados (experimentos de elección, sesiones de cata, encuestas, grupos focales y entrevistas), no fue posible realizar un metaanálisis. Se elaboró una tabla con información complementaria, la cual está disponible públicamente en <https://data.mendeley.com/datasets/ftsx8cfmfm/1>

Los resultados indican que las preferencias de los consumidores en relación al AOVE están moduladas por el país de residencia de los consumidores, con resultados diferenciados en función de que se trate de un país productor o no. Los atributos amargo y picante son valorados negativamente por los consumidores residentes en países con producción media y baja, pero aceptados en países productores. Además, el atributo más valorado es el origen de procedencia, pues se prefiere el AOVE de producción local al considerarlo de mayor calidad. En países no productores, las certificaciones DOP (Denominación de Origen Protegido) e IGP (Indicaciones Geográficas Protegidas) son determinantes para asociar ciertas características organolépticas al AOVE de determinadas regiones (Del Giudice et al., 2015).

Para promover el consumo de AOVE como alimento funcional es necesario proporcionar más información a los consumidores sobre los compuestos fenológicos asociados a los sabores del amargo y picante, así como sus propiedades para la salud. De esta manera, el conocimiento podría favorecer la familiaridad con el producto y su aceptación (Tuorila et al., 2014; Vecchio et al., 2019).

El segundo objetivo de esta tesis fue validar la Teoría de Detección de Señales (TDS) y el Test de Doble Disociación Aditiva (TDDA, Ramos-Álvarez et al., 2013) como

herramientas metodológicas para estudiar la dinámica del proceso sensorial y de toma de decisiones de consumidores noveles en la evaluación de aceites de oliva naturales, a través de test de discriminación entre señal y ruido a partir de atributos sutiles en lugar de la mera detección de la presencia o ausencia de AOVE, o de sabores básicos (véase p.e., Martín-Guerrero et al., 2014; Moreno-Fernández et al., 2012; Paredes-Olay et al., 2010; Ramos-Álvarez et al., 2013).

Se realizó una investigación experimental con ocho consumidores, formando un panel que emuló las condiciones de un panel de expertos según las directrices del Consejo Oleícola Internacional (IOC, 2024a, b). Con estos consumidores se llevaron a cabo dos experimentos (1a y 1b). En el Experimento 1a, como señal se utilizaron cuatro AOVES naturales (A, B, C y D), mientras que en el Experimento 1b se utilizó un AOVE verde y otro maduro, toda vez que se el ruido se definió a partir de un AOVE comercial. Se utilizó el programa informático *LearnOlive* para guiar el proceso de cata y recopilar los datos relevantes (véase Ramos-Álvarez et al., 2013).

En el Experimento 1a, donde únicamente se manipuló el tipo de AOVE, se encontró que los participantes distinguieron los aceites C y D del ruido, pero no lograron diferenciar los aceites A y B. El criterio de decisión se mantuvo neutro, como era de esperar, dado que no se incluyó manipulación alguna que lo afectara. Estos resultados permiten validar el uso de la TDS para evaluar los procesos sensoriales y de toma de decisiones en consumidores habituales participando en un panel de cata, ampliando el alcance de otros abordajes metodológicos previos, más clásicos y basados en una aproximación psicofísica más limitada (véase Martín-Guerrero et al., 2014).

En el Experimento 1b, se manipuló tanto el tipo de AOVE como las expectativas inducidas. Se observó que los consumidores diferenciaban el aceite verde del ruido, pero

no el maduro, posiblemente debido a la similitud del maduro con aceites comerciales. El criterio de decisión varió según la expectativa inducida, mostrando un criterio subóptimo cuando la discriminación era más clara. Se encontró una discrepancia entre la capacidad de detección sensorial y la disposición a pagar, lo que sugiere que los consumidores habituales valoran más atributos extrínsecos que sensoriales en su toma de decisiones de compra.

El tercer objetivo de la tesis fue comparar la valoración del AOVE entre consumidores y expertos para comprobar si las diferencias entre ambos eran una cuestión de grado o de calidad. Dicho objetivo fue de la mano de una investigación experimental basada en nuestra metodología de paneles de cata, uno conformado por 8 expertos y el otro por 8 consumidores habituales, ambos italianos, con el fin de evaluar si existían diferencias en sensibilidad y toma de decisiones. Se utilizó un diseño factorial $2 \times 2 \times 2$, considerando experiencia, tipo de AOVE y expectativas inducidas. Junto a las medidas psicofísicas habituales en nuestros trabajos, índices sensorial y decisorio, se midieron además los juicios de confianza en la detección, así como las valoraciones hedónicas y económicas.

Los resultados mostraron que el tipo de AOVE afecta selectivamente al índice sensorial A' (Grier, 1971) y las expectativas únicamente al índice de decisión $B'D$ (Donaldson, 1992), confirmando la validez del TDDA para analizar ambos procesos separadamente. Los expertos mostraron mayor sensibilidad que los consumidores, aunque la diferencia fue menor de lo esperado, sugiriendo que la familiaridad con el producto podría reducir la brecha sensorial. En función de las valoraciones, se confirma que el AOVE verde supera al maduro, influida por sus perfiles sensoriales más distintivos. En cuanto a los juicios de confianza, estos fueron elevados para ambos aceites, pero superiores en el caso del verde.

8.1. Conclusiones

Los principales resultados de la investigación realizada en esta tesis doctoral pueden resumirse en los puntos siguientes:

- El nivel de producción de aceite de oliva en el país de residencia del consumidor puede ser utilizado como un indicador válido de familiaridad.
- El rechazo de los consumidores hacia los sabores amargos y picantes se puede revertir con la familiaridad cultural del AOVE.
- Relacionar los sabores amargos y picantes con los beneficios para la salud del consumo de AOVE será una estrategia básica para superar el desafío de promover su consumo en regiones no productoras.
- La información en las etiquetas, un recurso importante, se adaptaría a las características específicas del mercado objetivo, especialmente en lo referente a la familiaridad con el producto.
- La sensibilidad de los participantes varía según los atributos del aceite de oliva, a la vez que permanecen neutrales los criterios de decisión en ausencia de manipulaciones específicas que indujeran sesgos.
- Aunque con ciertas matizaciones, las expectativas inducidas impactaron en el sesgo de decisión, mientras que los atributos del aceite afectaron la sensibilidad, independientemente de si el estudio se llevó a cabo con expertos o consumidores familiarizados con el AOVE.
- Las preferencias diferenciadas de los consumidores por AOVes distintos y sin defectos no se tradujeron en diferencias en su disposición a pagar por ellos.
- Los expertos demostraron una mayor sensibilidad y estuvieron más dispuestos a pagar por el AOVE verde en comparación a los consumidores.

- Tanto los paneles de expertos como los de consumidores prefirieron el AOVE verde frente al maduro, con una clara distinción en los niveles de sensibilidad.
- Los hallazgos sugieren que la familiaridad, influida por la experiencia y las expectativas, desempeña un papel significativo en la explicación de discrepancias entre las evaluaciones de expertos y consumidores.
- La tesis destaca la importancia de comprender cómo la familiaridad y los factores subjetivos, como las expectativas, influyen en la evaluación sensorial del AOVE, acortando la brecha entre las preferencias de expertos y consumidores.

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