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SENSORY CHARACTERISTICS OF VINEGAR: IMPACTS AND CHALLENGES IN SENSORY ANALYSIS

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ABSTRACT: Vinegar, an aqueous solution containing acetic acid and other compounds, presents challenges in sensory analysis due to its intense flavor. Its quality is influenced by the raw materials and fermentation processes. This study aims to conduct a systematic and integrative review of sensory evaluation and highlight the importance of this approach in the sensory characterization of vinegars over the years. A 27-year literature review was conducted, covering various databases, including Google Scholar, CAPES, Science Direct, and SciELO. The studies employed diverse methodologies, such as Flash Profile, Descriptive Analysis, 9-point hedonic scales, and detailed analyses of volatile compounds using techniques like gas chromatography-olfactometry. The works involved a limited number of tasters, reflecting the difficulty in recruiting participants. This characteristic can compromise the formation of a robust sensory panel, affecting the quality and accuracy of the evaluations. The research highlighted the sensory complexity of vinegars, influenced by the raw materials and production processes. Gender analysis revealed differences in emotional expression, emphasizing the importance of having tasters equally divided by gender. It is concluded that advancing the definition of protocols that ensure the safety and reliability of sensory analysis of vinegars is fundamental, contributing to a better understanding and appreciation of this complex product. Highlighting its functional claims may help attract voluntary tasters.

Keywords: acetic acid; aroma profiles; taste perception; quality assessment.

Características sensoriais do vinagre: impactos e desafios na análise sensorial

Resumo: : O vinagre, uma solução aquosa contendo ácido acético e outros compostos, apresenta desafios na análise sensorial devido à sua intensidade de sabor. Sua qualidade é influenciada pela matéria-prima e processos de fermentação. Este trabalho tem o objetivo de realizar uma revisão sistemática e integrativa, da avaliação sensorial e destacar a importância dessa abordagem na caracterização dos vinagres ao longo dos anos. Uma revisão bibliográfica de 27 anos foi conduzida, abrangendo diversas bases de dados. Os estudos empregam metodologias variadas, como Flash Profile, Análise Descritiva, escalas hedônicas de 9 pontos e análises detalhadas de compostos voláteis usando técnicas como cromatografia gasosa-olfatométrica. Os trabalhos envolveram um número limitado de provadores, refletindo a dificuldade em recrutar participantes. Essa característica pode comprometer a formação de um painel sensorial robusto, afetando a qualidade e a precisão das avaliações. A pesquisa destacou a complexidade sensorial dos vinagres, influenciada pela matéria-prima e pelos processos de produção. A análise por gênero revelou diferenças na expressão emocional, destacando a importância de se ter provadores divididos

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igualmente por gênero. Conclui-se que é fundamental avançar na definição de protocolos que garantam a segurança e a confiabilidade da análise sensorial de vinagres, contribuindo para um melhor entendimento e valorização desse produto complexo.

Palavras-chave: ácido acético; perfis de aroma; percepção de sabor; avaliação da qualidade.

1 INTRODUCTION

Vinegar is an aqueous solution containing acetic acid, as well as carbohydrates, alcohols, acids, volatile compounds, and amino acids. Its quality is influenced by the raw materials used, the acetification process, fermentation, and aging. This product results from alcoholic and acetic fermentation, with origins dating back to the dawn of humanity when fermentation was discovered. Historically, a wide variety of vinegars have used grapes as their main raw material (Miranda; Barana, 2023).

Positive correlations have been observed between vinegar consumption and blood pressure control, gastrointestinal regulation, antioxidant activity, elimination of free radicals, bactericidal action, and reduction of body weight in mice (Chen et al., 2017; Shishehbor; Mansoori; Shirani, 2017).

Vinegars can be produced from various raw materials, such as fruits, cereals, and honey, each imparting unique characteristics to the product (Miranda; Barana, 2023). However, the sensory characterization of this condiment faces a significant challenge: the difficulty in recruiting tasters. Due to the sensory intensity of acetic acid present in vinegar, many individuals are reluctant to participate in evaluations, which limits the formation of a robust sensory panel and, consequently, can compromise the accuracy and quality of the sensory analyses performed.

Tasters need to be prepared to evaluate not only the characteristic acidic taste but also a complex range of aromas that can vary significantly with the raw material used, fermentation method, and aging process. The penetrating nature of vinegar can hinder the perception of subtle nuances, such as fruity or floral notes, which are essential for detailed sensory evaluation. Additionally, achieving a balance between the acidic taste and other attributes like residual sweetness and the presence of volatile compounds requires skill and sensitivity from tasters for accurate and thorough evaluation (Rosa, 2015).

Therefore, this study aims to deepen the understanding of the importance of sensory analysis in vinegar. It will explore the challenges, focusing on flavor complexity and distinct sensory qualities. The objective is to provide insights that can not only optimize sensory evaluation methods but also emphasize the fundamental role of this type of research in characterizing vinegars sensorially, serving as a reflection for possible protocol development.

2 METHODOLOGY

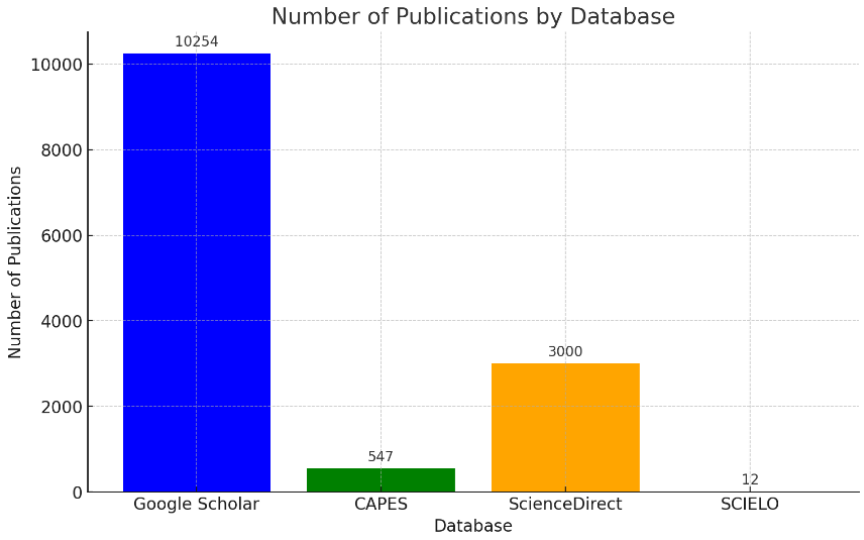
A systematic and integrative review was conducted through a qualitative literature review covering a period of 27 years, from 1997 to 2024. To collect relevant materials, the descriptor "vinegar sensory" was used as a search mechanism. The inclusion criteria required that the term "sensory" appear at least once in the title and/or body of the text. Additionally, to be considered in the research, articles needed to specifically address topics related to "vinegar aromatics," "vinegar sensory," and "sensory aspects of vinegar." Several databases were consulted to retrieve relevant scientific production, including Google Scholar, CAPES Portal of Journals (Coordination for the Improvement of Higher Education Personnel), ScienceDirect, and SciELO. To ensure the quality and relevance of the articles included in the review on sensory analysis of vinegars, rigorous exclusion criteria were established. Articles that did not specifically address the sensory analysis of vinegars, as well as those with inadequate or poorly described methodologies, were disregarded. Non-peer-reviewed publications, such as conference abstracts and unevaluated technical reports, as well as articles in low-impact journals or with low citation indices, were excluded. Studies prior to 1997 were disregarded unless essential for historical understanding of the field. Articles not available in accessible languages, such as English and Portuguese, and those whose full text was not accessible due to payment restrictions or lack of institutional access, were also excluded.

Articles that did not present significant results or did not substantially contribute to the knowledge in the area were excluded, as well as studies analyzing vinegars of very distinct or unrelated types, unless they offered relevant insights. Finally, articles with clear evidence of conflicts of interest that could compromise the objectivity of the results were discarded.

3 RESULTS AND DISCUSSION

In the context of discussions on the sensory analysis of vinegars, a detailed analysis of data from 1997 to 2024 reveals a significant increase in the number of publications, as illustrated in Figure 1. These data reflect the growing relevance and global interest in this beverage. Notably, from 2020 onwards, there has been a substantial rise in the number of studies dedicated to the topic. Between 2020 and 2024; 6,123 articles were published on Google Scholar, 323 on CAPES, 2,048 on ScienceDirect, and 7 on SciELO. This growth in the volume of publications suggests an intensified academic and scientific focus on the sensory analysis of vinegars, reflecting the increasing importance of this field of study.

Figure 1 – Number of Publications by Database from 1997 to 2024.



Source: The Author.

According to Miranda and Barana (2023), three main methods are known for vinegar production: the slow surface method, the fast method, and the submerged method. The slow method involves keeping wine in partially filled containers, allowing air contact to promote the growth of acetic bacteria. These bacteria use the fermented alcohol from the wine to produce the "vinegar mother," or α-cellulose. In contrast, the submerged method is accelerated by aeration during fermentation at a temperature of around 30°C, completing in 20 to 24 hours. Patented by *Heinrich Frings-Bonn* in the 1950s, this method requires submerging acetic bacteria in the fermented mixture and continuous oxygen supply to convert ethanol into acetic acid. Although efficient in productivity and time, it presents challenges such as high initial cost, need for specialized labor, constant maintenance, continuous aeration, and the requirement for filtration to remove vinegar turbidity.

The fast process, introduced in Germany by *Schüzenback* in 1832, also known as the German method or *Schüzenback Boerhave* method, uses a large surface exposed to air with addition of materials such as charcoal, sugarcane bagasse or corn, and wood to support acetic bacteria. This method, carried out in equipment called vinegar generators, is susceptible to infestation by insects like *Drosophila melanogaster* and excessive proliferation of polymer-producing bacteria, which can interfere with the circulation of the mixture inside the central cylinder where bacteria adhere.

The vinegar production methods play a crucial role in determining its distinct sensory characteristics. The choice of production method not only influences production efficiency and time but is

also critical in ensuring the desired sensory quality of the final vinegar. This underscores the importance of specific practices to meet consumers' expectations regarding taste and aroma (Marrufo-Curtido et al., 2015; Neves et al., 2021; Prisacaru et al., 2021; Spinosa et al., 2015).

The quality of a food can be assessed through various aspects, including its nutritional value, physicochemical parameters, microbiological aspects, and sensory properties. In the case of vinegar, its organoleptic characteristics are fundamental, especially considering its widespread use as a condiment. Sensory analysis is an essential tool for evaluating these characteristics through the senses. However, one of the main challenges when tasting vinegar is the penetrating sensation caused by acetic acid. Therefore, it is crucial to establish an appropriate sensory analysis method, involving a trained sensory panel (Tesfaye et al., 2002, 2009, 2010).

However, setting up a trained sensory panel for vinegar analysis presents several significant challenges. Firstly, the availability of panel members is a challenge, as it is necessary for all to be regular vinegar consumers and to be able to adjust their daily schedules to participate in evaluation sessions. Another obstacle is the high financial cost involved in forming and maintaining a sensory panel, which includes the resources necessary for training and tasting sessions.

Additionally, a small panel can have its activities compromised by the withdrawal or need for members to leave for personal or health reasons. The lack of a sufficient number of tasters can affect the continuity and quality of the evaluations. It is also important to highlight that a larger number of tasters is more statistically representative, providing more reliable and robust results. Therefore, all these difficulties combined make the process of setting up and maintaining a trained sensory panel complex and demanding.

Currently, there is a scarcity of scientific studies dedicated to the sensory analysis of vinegars, and so far, a standardized method or protocol for this evaluation has not been established. In contrast, for other products such as olive oil, a systematic approach has been developed and regulated for the evaluation of its sensory characteristics (Rosa, 2015).

Below, in Table 1, a bibliographic review of scientific studies exploring the sensory analysis of vinegars is presented.

Table 1 – Research on the sensory aspects of vinegars.

Publication Title	Year	Tasters/Methodology	References
Multivariate analysis of composition and sensory quality criteria of white vinegars	1997	57 tasters. Hedonic scale rated from 0 (extreme dislike) to 100 (extreme like)	(Gerbi et al., 1997)
Physicochemical, nutritional, and sensory characteristics of vinegars from different raw materials	2008	50 tasters, Discriminative Preference Ranking Test.	(Marques, 2008)
Targeting key aromatic substances on the typical aroma of Sherry vinegar	2008	8 tasters, Gas Chromatography-Olfactometry.	(Callejón et al., 2008)

Improvement of wine vinegar elaboration and quality analysis: Instrumental and human sensory evaluation	2009	Trained panelis, affective discriminant methods, such as triangle tests, paired comparison test, duo-trio test, A-not A test, two out of five and analytical descriptive methods.	(Tesfaye et al., 2009)
Chemical characterization of commercial sherry vinegar aroma by headspace solid-phase microextraction and gas chromatography-olfactometry	2011	Threshold Determination.Gas Chromatography Analysis. Aroma Extract Dilution Analysis (AEDA)	(Aceña et al., 2011)
Analysis of aroma compounds of commercial cider vinegars with different acidities using SPME/GC-MS, electronic nose, and sensory evaluation	2013	30 tasters.Eletronic nose analysis. 9 points hedonic scale .	(Jo et al., 2013)
Development of a Vinegar Tasting Panel - Sensory Characterization of Apple Vinegars	2015	Recruitment of candidates, selection, and training of assessors. 10 assessors on the panel. Principal Component Analysis	(Rosa, 2015)
Effect of vinegar on the perceived saltiness of naengmyeon and onmyeon soup systems	2015	41 tasters. An expanded version of Glms (Magnitude estimation and labeled magnitudescal) was used to rate the intensity of the attributes.ANOVA.	(Ko et al., 2015)
Novel vinegar-derived product enriched with dietary fiber: effect on polyphenolic profile, volatile composition and sensory analysis	2015	12 to 15 expert assessors. Discrimination test and descriptive profile. ANOVA	(Marrufo-Curtido et al., 2015)
A comparative study on aromatic profiles of strawberry vinegars obtained using different conditions in the production process	2016	Gas chromatography–olfactometry	(Ubeda et al., 2016)

Chemical and sensory characteristics of orange-based vinegar	2016	10 tasters. Structured nine-point scale.	(Cejudo-Bastante et al., 2016)
Consumer perception of balsamic vinegar: A cross-cultural study between Korea and Italy	2017	Quantitative descrip-tiveanalysis.Spectrum descriptive analysis method.	(Torri et al., 2017)
The flavor and taste of cereal Chinese vinegars	2017	20 tasters. Descriptive test.	(Giudici et al., 2017)
Establishment of the volatile signature of wine-based aromatic vinegars subjected to maceration	2018	GC-MS.HS-SPME.	(Perestrelo et al., 2018)
Chemical Properties, Antioxidant Activities and Sensory Evaluation of Berry Vinegar	2019	30 tasters. 9 points hedonic scale.	(Boonsupa, 2019)
Sensory and spectroscopic characterization of Argentinean wine and balsamic vinegars : A comparative study with European vinegars	2020	48 tasters. First triangular tests. Preference test.	(Ríos-Reina et al., 2020)
Characterization and Comparison of Aroma Profiles and Aroma-Active Compounds between Traditional and Modern Sichuan Vinegars by Molecular Sensory Science	2020	20 tasters.Descriptive Profile Analysis.	(Al-Dalali et al., 2020)
Vinegar from Anacardium othonianum Rizzini using submerged fermentation	2021	154 tasters. 9 points hedonic scale .	(Neves et al., 2021)
Sensory Analysis as a Simple and Low-Cost Tool to Evaluate and Valorize a New Product from Local Fruits in Rural Communities: The Case of Highly Aromatic Vinegar from Prickly Pear	2023	4 tasters. Flash profile technique.	(Es-Sbata et al., 2023)

Fruits			
Emo-sensory profile and chemical characterization of wine vinegars from the Douro and Rioja Demarcated Regions	2024	15 tasters.Quantitative Descriptive Analysis. Emo-sensory profile.	(Mota, 2024)

Source: The author.

The Table 1 provides a detailed review of scientific studies dedicated to the sensory analysis of vinegars. Each research employed specific methodologies to explore different sensory aspects of vinegars, including their aromatic characteristics, profile of volatile compounds, sensory preferences, and influences on taste perception. For instance, some studies used hedonic scales to assess overall and specific acceptance of attributes such as acidity and sweetness, while others adopted discriminative tests to distinguish between different types of vinegar or production methods. Additionally, advanced techniques such as gas chromatography-olfactometry were employed to identify compounds responsible for the distinctive aromas of vinegars. These varied approaches enabled researchers to gain detailed insights into how factors such as raw materials, fermentation processes, and aging affect the sensory characteristics of the products.

It is noteworthy that most studies involved a limited number of tasters, typically fewer than 60, which reflects the difficulty in recruiting participants due to the pungent sensory characteristic of acetic acid present in vinegar. This intensity of flavor can pose a significant obstacle to forming a robust and representative sensory panel, directly impacting the quality and accuracy of the sensory evaluations conducted.

Another aspect that deserves attention is the absence of a standard method for tasting vinegars in sensory analyses. Mota (2024) conducted a direct tasting, serving undiluted vinegar and salad, with a trained panel of 12 women and 3 men. Es-Sbata et al. (2023) served pure vinegar in an exclusively olfactory test with an untrained panel of tasters. Neves et al. (2021) served the vinegar as a condiment in a chopped tomato salad with added salt to an untrained panel. Meanwhile, Al-Dalali et al. (2020) conducted an olfactory test with 12 trained tasters.

Neves (2020) invited tasters for the sensory characterization of vinegars and, in his study, segmented the participants into two distinct groups. Group 1 was provided with information about the functional claims of the vinegar, while Group 2 did not have access to such information. The results indicated that Group 1, which was informed about the functional claims, gave higher ratings to the samples (ranging from 8 to 9) and showed a greater willingness to participate in the test.

Based on the analysis of keywords over the past 27 years, as reported in this bibliographic review, the following word cloud is displayed in Figure 2.

Figure 2 – Word Cloud.

Source: The Author. (Site: https://wordcloud.online/pt)

From this word cloud, it is possible to extract trends and research focuses on the field of sensory analysis and sensory characterization of vinegars. Firstly, the diversity of vinegars is notable, with many different types being studied, including orange vinegar (Cejudo-Bastante et al., 2016), cider vinegar(Rosa, 2015; Jo et al., 2013), fruit vinegar (Es-sbata et al., 2023), cereal vinegar (Giudici et al., 2017), wine vinegar (Mota, 2024; Gerbi et al., 1997), balsamics vinegar (Ríos-Reina et al., 2020), and Sichuan vinegar (Al-Dalali et al., 2020).

A significant focus lies in the identification and analysis of volatile compounds and polyphenols, which are essential for the flavor, aroma, and antioxidant properties of vinegars. There is a variety of methods used to characterize vinegars, including gas chromatography-olfactometry (GC-O) and sensory methods such as hedonic scales.

Fermentation and microbiology, often mediated by mixed cultures of *Lactobacillus plantarum*, *Saccharomyces cerevisiae*, and *Acetobacter*, are recurring themes, highlighting the importance of microbiological processes in vinegar production. Antioxidant activity and quality analysis are significant concerns, often linked to the presence of phenolic compounds and other nutrients. According to Pagliarino (2021), adopting a healthy diet rich in antioxidants can help prevent various diseases.

There is an interest in new products and innovations, as well as the challenge of sensory evaluations' complexity, which includes the intensity of acidic flavor, the need for a trained panel of tasters, and robust sensory analysis methods.

Several brands of white vinegar were evaluated by a panel of 57 assessors, and it was observed that diluting vinegar or neutralizing it with alkalis distorts the aromas and diminishes the differences between samples. For this reason, vinegars, according to the authors, should be tasted in their natural state (Gerbi et al., 1997).

In another study, Gas Chromatography-Olfactometry (GC-O) was applied to identify substances responsible for aromatic notes associated with selected descriptors of aged Jerez vinegar aroma. Odor detection frequency was conducted by a panel of two individuals who simultaneously performed a total of nine sniffs of the sample in duplicate, using the same operational conditions and the same chromatograph (Callejón et al., 2008).

Regarding Argentine vinegars, the sensory panel study revealed a preference for products that exhibit high complexity in aromatic nuances, achieved primarily through slow and meticulous production processes. The lack of strict regulation and control over vinegar production in Argentina has led to wide variability in the quality of products available in the market, despite being sold at similar prices. To promote higher quality Argentine vinegars and enhance the value of local production, it is suggested to implement new regulations addressing the type of acetification, production methods, and geographical origin of the products (Ríos-Reina et al., 2020).

To describe the aromatic profiles of vinegars, a descriptive profile analysis method was employed where twelve panelists were trained and asked to identify the aromatic composition of the samples. As a result, the following organoleptic descriptors were adopted by the evaluators: acidic, fruity, floral, almond-like, sweet, toasted, spicy, herbal, and woody notes. All organoleptic descriptions were referenced against standard compounds as follows: isobutyl acetate (fruity), phenylethyl alcohol (floral), γ-nonalactone (sweet), acetic acid (acid/rancid), trimethylpyrazine (toasted), tetramethylpyrazine (almond-like), 2-methoxyphenol (woody), 5-methylfuran-2-carbaldehyde (spicy), and (E)-3-(furan-2-yl)-2-methylprop-2-enal (herbal) (Al-Dalali et al., 2020).

According to Al-Dalali et al. (2020), Sichuan Chinese vinegar exhibited odors where most of the identified active aromatic compounds were aldehydes and acids. Aldehydes often contributed to sweet, floral, spicy, herbal, buttery, and coconut notes, which are considered significant odorants in vinegar. Ketones contributed to floral, buttery, and fruity notes, phenols to herbal, spicy, and woody notes, and acids to sour, acidic, and sweet notes.

The application of Quantitative Descriptive Analysis (QDA) and Comparative Preference Profile (FCP) in the sensory characterization of prickly pear vinegars allowed for defining similar aromatic profiles. FCP proved to be a promising methodology due to shorter session times and reduced sample demand compared to QDA, and future studies should further explore these influences and validate promising results using FCP with a larger panel (Es-Sbata et al., 2023).

A recent study aimed to create emo-sensory profiles for samples of white wine, red wine, balsamic, and Port vinegars. Initially, the samples were evaluated using Quantitative Descriptive Analysis (QDA) by a panel of trained tasters, followed by analysis of consumers' facial expressions with *Noldus FaceReader software*. The most frequently mentioned sensory attributes were "clarity" and "acidity," and tasting sheets were developed based on these frequencies to construct a sensory profile. Comparison with the analysis revealed that white wine vinegars, for example, shared similar profiles, whereas Port wine vinegars showed distinct sensory characteristics and were more similar among themselves. It was also observed that acidity significantly influenced the emotional response of the tasters, with a predominance of neutral emotion. This study also explored differences in emotional response between genders, with women showing higher negative emotional expressiveness, such as sadness, and men tending more towards neutrality or positive emotions (Mota, 2024).

Seventeen commercial Chinese vinegars were analyzed using an electronic nose containing nine thick-film gas sensors doped with nano-ZnO. The doping was performed with 5 and 10 wt% TiO_2, 5 and 10 wt% MnO_2, 1 wt% V_2O_5, 5 wt% Bi_2O_3, 0.6 and 2.4 wt% Ag, and 5 wt% W, respectively. Five artificial neural networks were applied to calculate the attributes and act as the panel in the sensory analysis. The identification accuracy of the vinegars reached 89.7%. Thus, the study aimed to develop a commercial electronic nose for vinegar quality control and to eliminate ambiguity in the fingerprints of certain vinegars, such as those of the same type (Zhang et al., 2008).

Therefore, assembling a diverse panel of tasters not only contributes to a more comprehensive and representative sensory analysis of vinegars but also takes into account cultural influences that can significantly affect sensory perceptions and consumption preferences. Additionally, functional claims help to encourage voluntary tasters to participate in sensory testing. The focus on sensory analysis of vinegars has significant impacts on the market, from improving product quality to developing new items. It ensures consistency, identifies sensory defects, and fosters innovation in product development to meet consumer preferences. It also differentiates brands and products, communicates quality and authenticity, and contributes to consumer satisfaction and loyalty. In international trade, sensory analysis helps adapt products to different markets and meet required sensory standards, facilitating export. Moreover, vinegars with superior sensory profiles can be valued and positioned as premium, attracting consumers

willing to pay more for a high-quality experience, as is the case with Balsamic vinegars.

4 CONCLUSION

This study provides insight into the impacts of sensory characteristics of vinegars, highlighting their complexity and diversity, which can be influenced by raw materials, fermentation methods, and aging processes. However, recruiting tasters remains a significant challenge due to the pungent taste of acetic acid, the main component of vinegar, which can compromise the quality of sensory analysis. Additionally, gender analysis reveals marked differences in emotional expression, with women tending to show more negative emotions such as sadness, while men exhibited greater neutrality or positive emotions. These findings underscore the urgent need to develop methodologies that ensure precise and unbiased sensory analysis, preserving the true characteristics of the sample. The search for methods to minimize the impact of acetic acid and facilitate the recruitment of tasters is crucial for advancing the sensory understanding and appreciation of vinegars. Furthermore, functional claims of vinegars may help attract voluntary tasters to participate in research in this area.

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