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Emosensory profile and chemical characterization of wine vinegars from the Douro and Rioja demarcated regions

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Abstract. Wine vinegar is valued for its tangy flavor and versatility. They serve as microbial inhibitors and acidifiers, and despite being low in calories and rich in antioxidants, their quality may diminish after opening. This study examines the physical-chemical, sensory, and emotional characteristics of 22 wine vinegar samples from the Douro Demarcated Region and La Rioja. Upon opening and after one year, degraded samples were analyzed for pH, total phenol content, antioxidant activity, acetic acid, and ethanol. Sensory profiles were obtained through QDA and CATPCA, while emotional responses were analyzed with FaceReader. Results showed increased pH in degraded samples, particularly red wine vinegar, without significant sensory impact. Decreases in acetic acid and total phenol content were not statistically significant, but antioxidant activity decreased significantly in all samples. Residual ethanol content increased substantially in white wine and balsamic vinegars. Catalase-positive microorganisms were found in red wine vinegar samples. Sensory analysis indicated that balsamic and red vinegars had diverse sensory characteristics, while white wine vinegars were noted for their appearance. Port wine vinegars lacked the expected sweet attributes. Acidity intensified negative emotions, particularly sadness, with females showing greater expressiveness. Overall, wine vinegar's intensity declines post-opening, evoking negative emotions when consumed out of context.

1. Introduction

Wine vinegar is an agricultural product renowned for its enduring role as a flavoring and preserving agent. It stems from the biological processes of alcoholic and acetic fermentation involving yeasts and acetic acid bacteria [1-3]. In the European Union, vinegars must meet standards of at least 6% total acidity and less than 1.5% residual alcohol to be marketed [3,4].

Despite its nutraceutical significance, particularly its antimicrobial properties, sealed vinegar lacks a definitive expiration date. However, upon opening, it can undergo biochemical changes such as darkening in color, precipitate formation, and loss of quality. These changes result from compounds' oxidative processes and the activity of acetobacter, yeasts, or molds that metabolize organic acids and residual ethanol, producing undesirable metabolites that compromise product quality [5,6].

Sensory analysis is a standard tool for evaluating the quality and authenticity of food and beverages. Quantitative descriptive analysis (QDA) is a test that allows for a detailed assessment of sensory attributes [7]. Emotional response is crucial in shaping consumer opinion, predominantly sensory evaluations. The quantification of emotions through facial micro-expressions has gained traction in consumer preference assessment, facilitated by tools like the Noldus FaceReader software, which captures and quantifies basic emotions from individuals exposed to stimuli over defined periods [8-10].

Therefore, this study aims to biochemically characterize 22 samples of wine vinegar from the Douro

Demarcated Region and La Rioja while developing an emo-sensory profile for them through the QDA test and Noldus FaceReader.

2. Materials and methods

2.1. Samples

Twenty-two non-commercial samples of white wine vinegar, red wine vinegar, balsamic vinegar, and Port wine vinegar from Douro (Cima Corgo and Douro Superior) and La Rioja (Rioja Alta) regions were selected and given a 3-digit identification. For biochemical degradation analysis, samples were stored in uncontrolled conditions, exposed to air and sunlight for one year, and labeled as "degraded samples."

2.2. Chemical analysis

Chemical parameters for characterizing the vinegar samples included pH, acetic acid, residual ethanol, total phenols, and antioxidant activity. Due to limited replicates, enzymatic kits quantified acetic acid (K-ACET 04/18, Megazyme) and ethanol (ab65343, BioVision). pH was measured with a potentiometer, total phenols with the Folin-Ciocalteu method, and antioxidant activity using ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)).

2.3. Microbiological analysis

After one year of exposure to uncontrolled conditions, wine vinegar samples were analyzed for microbiological degradation and microorganism growth. The samples were enriched in YPD medium with 2% ethanol and incubated at 25ºC for eight days. The cultures were then streaked on CARR medium and incubated at 25ºC for two weeks to observe colony growth. Aliquots from each plate were dissolved in saline and examined under a microscope. A catalase test was performed for microorganism differentiation.

2.4. Sensory analysis

The QDA panel consisted of 15 non-smoking faculty members (12 females, three males) aged 22-59 from the University of Trás-os-Montes and Alto Douro (UTAD). An open-response tasting sheet initially generated perceived attributes for three wine vinegar references. This was followed by six sensory analysis sessions, with panelists scoring sensory attributes on a 5-point scale, covering visual, olfactory, taste, and retronasal properties. All analyses were performed in an ISO 8589 (2007) laboratory. Samples were served in 21.5 cl, ISO 3591 (1977) tasting glasses (Figure 1).

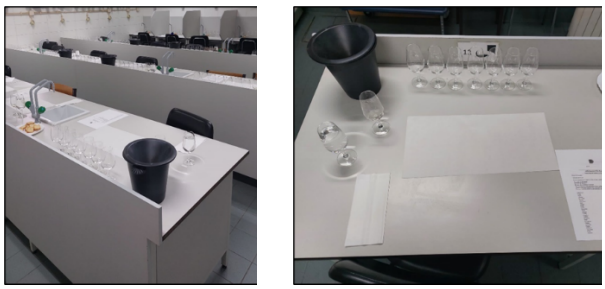

Figure 1. Sensory lab, glasses, and other materials used in the sensory QDA test.

2.5. Emotional response

Participants, recruited via digital platforms or personal contact with UTAD members, included 30 adults (12 men and 18 women, aged 18-64). They provided informed consent, ensuring General Data Protection Regulation compliance and data confidentiality during image capture. Emotional responses to six wine vinegar samples (two white, two red, two Port) were studied. Sessions took place in a university tasting room for over 30 minutes, with participants briefed on the study and tasting samples under optimal lighting, reduced noise, and good facial capture conditions (Figure 2)

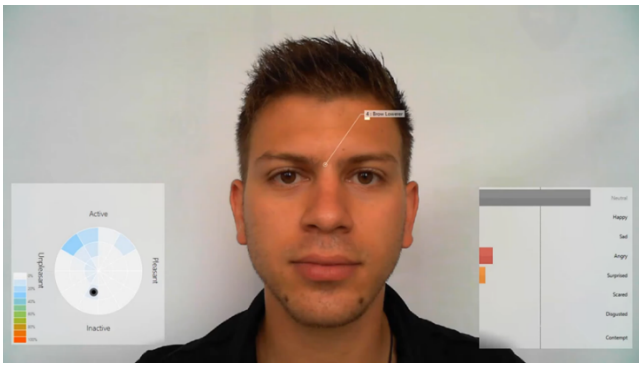

Figure 2. Capture conditions and primary display of FaceReader software performance.

2.6. Statistical Analysis

Descriptive statistics (mean and standard deviation) were computed for the variables. For QDA, descriptive statistics, frequency distributions, and radar charts were used to display sensory descriptors.

All analyses were performed using SPSS version 29 at a 5% significance level.

3. Results and discussion

3.1. Chemical Characterization of Wine Vinegar Samples

The wine vinegar samples had pH between 2.55-3.73, total phenols 0.19-1.86 mg/mL GAE, acetic acid 0.18%-10.70%, residual ethanol 0.19%-2.60%, and antioxidant activity 0.35-4.96 mM/mL trolox. Four samples (one Port, two Portuguese red, and one Spanish balsamic) had less

than 6% acetic acid, and one red (Douro Superior) and one Port (Cima Corgo) exceeded 1.5% residual ethanol.

Differences were found among the vinegar types: white wine vinegars exhibited substantial variations in antioxidant activity, acetic acid, residual ethanol, and pH, with notable decreases in antioxidant activity and acetic acid levels alongside an increase in ethanol content and pH; red wine vinegar samples showed significant differences primarily in pH and antioxidant activity, with a marked decrease in antioxidant activity and an increase in pH; balsamic vinegar samples demonstrated differences in antioxidant activity and ethanol content, characterized by a pronounced reduction in antioxidant activity and an increase in ethanol content, while samples of Port wine vinegar displayed a significant decrease in antioxidant activity compared to other vinegar types.

Antioxidant activity decreased in wine vinegar samples following exposure to uncontrolled conditions, affecting product stability. Changes in acetic acid levels were observed and influenced by acetic acid bacteria and ongoing ethanol conversion processes. Challenges in ethanol quantification using enzymatic kits were noted, potentially due to kit quality or procedural issues, highlighting the need for methodological refinement in future studies.

3.2. Microbiological characterization of wine vinegar samples

Microbial growth was observed on Petri dishes (YPD medium with 2% ethanol and incubated at 25°C for two weeks), confirming the presence of microorganisms in some vinegar samples (Figure 3). Catalase testing indicated the presence of catalase-positive microorganisms (Figure 4).

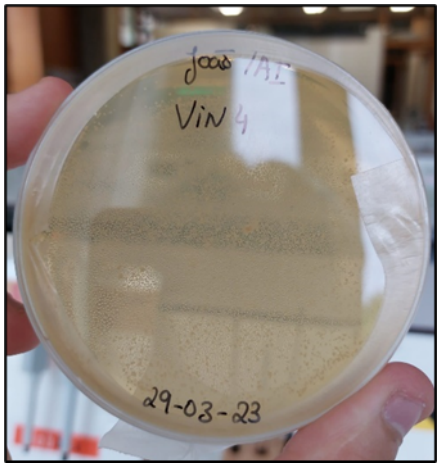

Figure 3. Photograph of beige punctiform colonies of acetic acid bacteria.

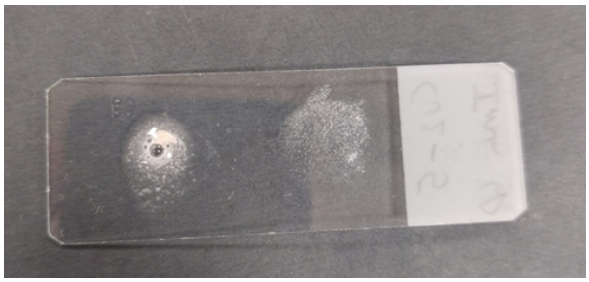

Figure 4. Photograph of the catalase test results performed on the beige punctiform colonies of acetic acid bacteria. Bubbles indicate a positive reaction.

3.3. Sensory characterization of wine vinegars

The sensory profiles of the vinegar samples revealed distinct characteristics: Spanish balsamic vinegar exhibited robust and persistent acidity and floral intensity compared to Portuguese Port wine vinegar, which featured sweeter, honeyed notes with hints of the ruby color and occasional alcohol nuances. Portuguese and Spanish white and red wine vinegar showcased varying attributes, including citrusy and fruity flavors, alongside bright, spicy, and woody elements, illustrating their unique sensory compositions. The sensory characterization of each type of wine vinegar is illustrated in Figures 5 to 8. Notably, sample WWV056 is Portuguese, and WWV876 is Spanish. Additionally, samples RWV612, RWV209, and RWV565 are Spanish, while the remaining are Portuguese.

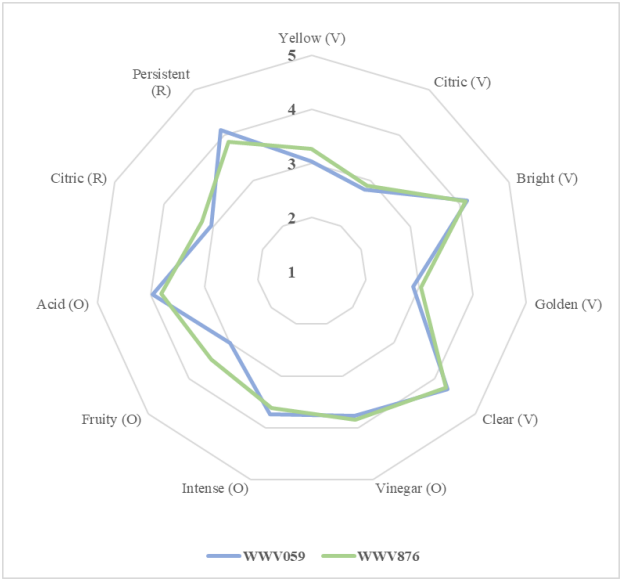

Figure 5. Sensory profile of white wine vinegar (WWV) samples. "V" stands for visual attribute, "O" for olfactory attribute, and "R" for retronasal attribute.

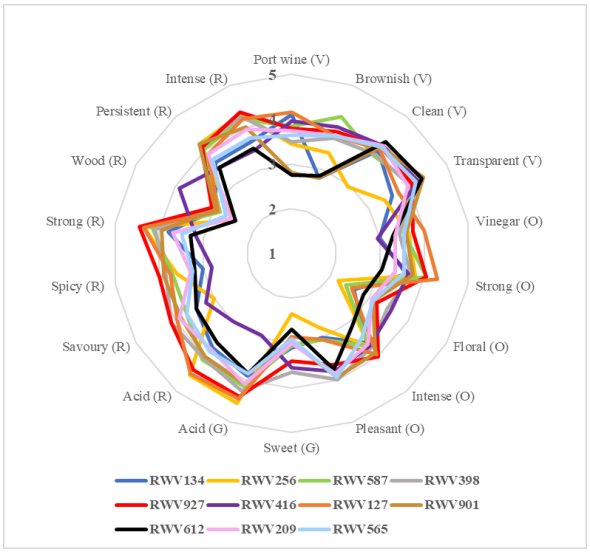

Figure 6. Sensory profile of red wine vinegar (RWV) samples. "V" stands for visual attribute, "O" for olfactory attribute, "G" for gustatory attribute, and "R" for retronasal attribute.

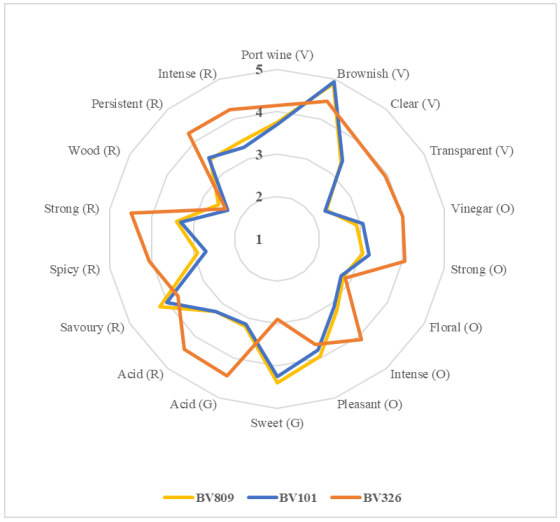

Figure 7. Sensory profile of balsamic vinegar (BV) samples. "V" stands for visual attribute, "O" for olfactory attribute, "G" for gustatory attribute, and "R" for retronasal attribute.

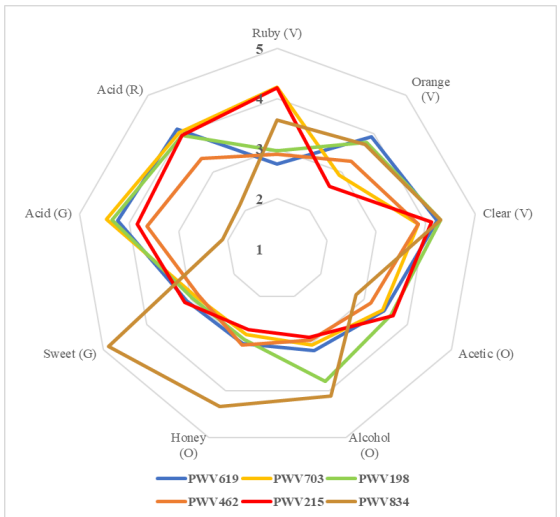

Figure 8. Sensory profile of Port vinegar (PWV) samples. "V" stands for visual attribute, "O" for olfactory attribute, "G" for gustatory attribute, and "R" for retronasal attribute.

3.4. Emotional characterization of wine vinegars

The predominant emotion observed during the wine vinegar tasting was neutral (Figure 9), characterized by calmness and balance, indicating an absence of intense emotional responses [11,12].

However, one Port wine vinegar sample, characterized by 9% acidity and low pH, disrupted this neutrality, leading to heightened feelings of sadness, the second most quantified emotion. Sadness is often associated with discouragement and melancholy [13,14].

Besides that, happiness emerged as the sole positive emotion linked to contentment and satisfaction [15], particularly towards the end of the tasting session. This suggests that happiness arose from enjoying richer taste profiles following initial acidity.

The study also emphasized familiarity's role in alleviating apprehension, drawing on prior experiences with vinegar's sensory attributes. Emotional responses leaned towards negativity during the tasting, mainly influenced by acidity. Notably, female participants showed more pronounced emotional responses than their male counterparts, especially toward feelings of sadness, as shown in Figures 10 and 11.

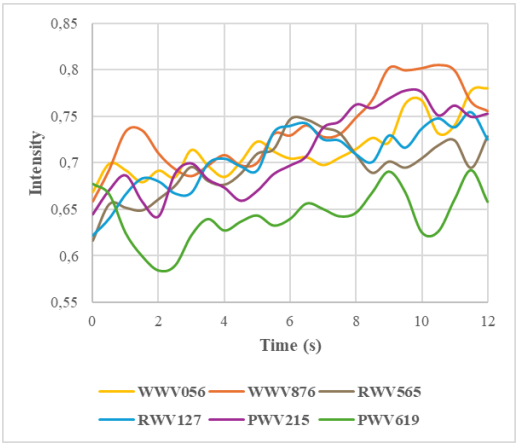

Figure 9. Variation in the intensity of the neutral emotion across each sample.

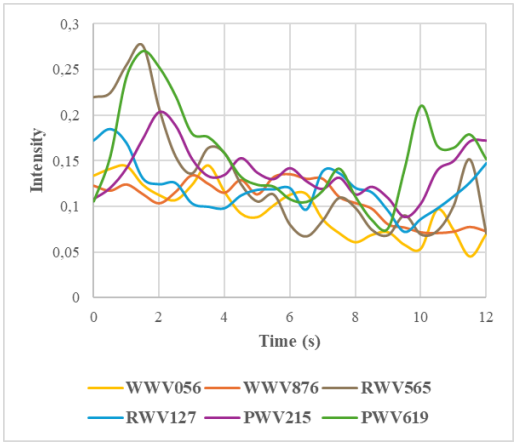

Figure 10. Variation in the intensity of the sad emotion across each sample for the female gender.

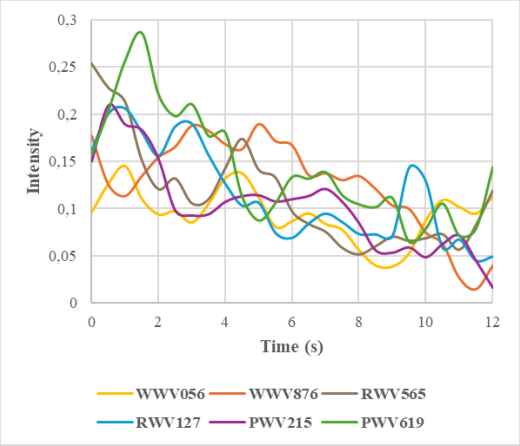

Figure 11. Variation in the intensity of the sad emotion across each sample for the male gender.

4. Conclusion

The study highlighted wine vinegar's natural acidity and potential health benefits, with antioxidant activity proving most sensitive to degradation after opening. Microbiological analysis identified catalase-positive microorganisms in red wine vinegar, warranting further genetic analysis. In the emotional-sensory study, white wine vinegars were visually characterized, red wine emphasized aromas and taste, balsamic focused on scent, and Port wine lacked distinct visual descriptors. Both genders predominantly experienced neutral and sad emotions, influenced by vinegar familiarity and acidity. These findings are essential for understanding wine vinegar's properties and challenges in maintaining quality post-opening, guiding both production practices and consumer preferences in the culinary and health sectors.

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