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SADRŽAJ:

The offer and quality of extra virgin olive oils in stores in the area of the Herzegovina-Neretva canton

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Abstract

This paper explores the significance of olives and extra virgin olive oil in nutrition, focusing on oil quality. The study aimed to analyse the quality of extra virgin olive oil available in the market of the Herzegovina-Neretva Canton (HNK) by analyzing three key chemical characteristics: free fatty acid (FFA) content, peroxide value and total polyphenol content. Six samples of extra virgin olive oil were analyzed. The results showed that sample no. 1 had the lowest free fatty acid (FFA) content (0.5%), indicating better quality than the other samples according to this parameter. In contrast, sample no. 3 (0.89%) and no. 5 (0.9%) had elevated FFA values, which reduced both the quality and shelf life of the oil. According to Regulation on Market Standards for Olive Oil (Official Gazette of BiH 81/12), samples no. 3 and no. 5 do not meet the criteria for extra virgin olive oil due to their higher free fatty acid content. The lowest peroxide value was observed in sample no. 1 (2.83 mmol O_2/kg), while the highest was in sample no. 2 (5.26 mmol O_2/kg). The acceptable limit for the peroxide value in extra virgin olive oils, according to the Regulation on Market Standards for Olive Oil (Official Gazette 81/12) and harmonised with EU Implementing Regulation (EU) 2022/2105, is ≤ 10 mmol O_2/kg. Regarding total polyphenols, sample no. 1 had the highest value (411.229 mg GAE/kg), while sample no. 5 had the lowest (159.278 mg GAE/kg). Polyphenols are crucial for the quality of olive oil, both organoleptically, and in terms of its nutritional and chemical properties. Statistical analysis (ANOVA test) revealed significant differences among the samples based on sensory evaluation, confirming that the quality of olive oil varies depending on the analyzed parameters. These findings highlight the need for stricter quality control of extra virgin olive oil in the HNK market, particularly concerning free fatty acid content and polyphenol levels.

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Key words: extra virgin olive oil, free fatty acids, polyphenols, peroxide value.

Introduction

Olive (*Olea europaea* L.) is one of the most significant plants in the Mediterranean region and is often regarded as the oldest cultivated plant species. The fruit of the olive tree is primarily used for the production of olive oil, which has become widely recognized as a symbol of a healthy diet and modern lifestyle. Numerous studies have demonstrated that olive oil positively influences human metabolism, and the health of the digestive system, blood vessels, arteries, liver, and bile ducts, while also contributing to increased life expectancy, particularly among the elderly population. Furthermore, it has been shown to support the growth and development of children (Žanetić et al., 2014). In addition to its health benefits, olive oil plays a significant role in the cosmetic industry, where it is used for maintaining skin health and beauty. Olive oil is obtained from the fruit of the olive tree, where natural biosynthetic processes within the olive contribute to the formation of oil droplets that accumulate during ripening. Extra virgin olive oil, in particular, is highly valued in the market today, making it one of the most sought-after and expensive food products. To justify its high price and demand, this oil must meet strict quality standards. Ensuring the high quality of extra virgin olive oil requires meticulous monitoring throughout all stages of production, including fruit ripening, harvesting, processing olives into oil , and proper oil storaging. Each of these stages significantly influences the development of both desirable and undesirable organoleptic properties of the oil, such as taste and aroma (Koprivnjak, 2006).
Due to its nutritionally balanced composition and distinctive aroma, olives and olive oil are considered fundamental components of the Mediterranean diet, the efficacy of which has been proven in the prevention of various diseases, maintenance of health, and promotion of longevity.

The Importance of Olive Oil for Human Health

Olive oil is a one of the most valuable source of fat in the human diet. Its nutritional significance is primarily attributed to its high content of monounsaturated fatty acids, particularly oleic acid, which exert significant biological and nutritional effects. Additionally, olive oil is rich in phenolic compounds, which act as potent antioxidants, enhancing its health benefits. Tocopherols, or vitamin E, present in the oil, also contribute to its stability and enhance its antioxidant properties. Numerous studies have confirmed the positive effects of extra virgin olive oil on cardiovascular health, particularly its ability to reduce blood pressure (Estruch et al., 2013; Schwingshackl et al., 2019; Sarapis et al., 2020). Research on animal models, particularly rats, has shown that phenolic compounds in extra virgin olive oil, such as tyrosol and hydroxytyrosol, significantly promote bone mass formation. The authors of these studies suggest that the consumption of olive oil may help prevent bone mass loss; however, further research is

needed to confirm these findings (Pejović et al., 2014). Moreover, olive oil has been shown to reduce the risk of certain types of cancer, particularly breast cancer

Garcia-Segovia et al. (2006) performed a study which was designed to assess the role of differential fatty acid intakes and olive oil consumption on breast cancer risk among women in the in the Canary Islands. The results of the study suggest that higher consumption of olive oil is associated with the lower risk of breast cancer

The anti-inflammatory properties of olive oil are attributed to oleic acid, which inhibits the synthesis of inflammatory mediators and other antioxidants such as oleocanthal. Notably, oleocanthal not only has anti-inflammatory effects but also exhibits analgesic properties. According to some studies, consuming 50 g of olive oil daily is equivalent to one-tenth of the recommended dose of analgesics for adults (Šarenić, 2018).

Free Fatty Acid Content

The content of free fatty acids (FFA) in olive oil, commonly called acidity, is a crucial indicator of oil quality. This parameter reflects various stages in the olive oil production process, including flowering, harvesting, processing, and storaging. It directly influences both the market value and the suitability of the oil for consumption. Oils derived from healthy olive fruits typically exhibit low free fatty acid content. In contrast, oils produced from damaged fruits-such as those affected by the olive fruit fly (*Bactrocera oleae*)-or fruits that have not been properly handled and stored for extended periods before processing, often show elevated FFA levels. The total fatty acid content in the oil is usually expressed as a percentage of oleic acid (Soldo, 2016).

Peroxide Value

The peroxide value is an indicator of the primary oxidation of olive oil, a process that leads to the formation of peroxides and hydroperoxides of fatty acids. Although these compounds do not have a distinct taste or odor, they can significantly affect the overall quality of the oil. The peroxide value is expressed as the amount of substance in the oil sample that oxidizes potassium iodide and is measured in millimoles of active oxygen per kilogram of oil (mmol O_2/kg) or in milliequivalents of active oxygen per kilogram of oil (mEq O_2/kg) (Mandić et al., 2020). The peroxide value provides valuable insight into oxidation processes, which can be either enzymatic or chemical. Since olive oil primarily contains unsaturated fatty acids with double bonds, the peroxide value is more likely to increase during processing, especially under high temperatures or improper storage conditions, such as exposure to air, light, and high temperatures. An increase in the peroxide value is often associated with a sensory defect commonly referred to as "rancidity" in olive oil (Dobra, 2017).

Total Polyphenol Content

Polyphenols are natural antioxidants that effectively protect olive oil from autoxidation, thereby contributing to its stability, preservation of quality, and extended shelf life. These phenolic compounds protect the unsaturated fatty acids within the triglycerides of olive oil from oxidation (Šindrak et al., 2007). In addition to their strong antioxidant properties, polyphenols also influence the organoleptic characteristics of the oil, such as its bitternes and pungency and play a significant role in the sensory evaluation of olive oil (Gorzynik-Debicka et al., 2018). Natural polyphenols are essential for human metabolism. Studies have shown that polyphenols reduce the incidence and/or slow the progression of cardiovascular diseases, neurodegenerative disorders and certain types of cancer. Their mechanism of action is primarily based on their antioxidant activity, which helps reduce the levels of reactive oxygen species in the body (Gorzynik-Debicka et al., 2018). Furthermore, polyphenols exhibit anti-atherogenic effects by binding to LDL particles and preventing their oxidation (Perona et al., 2006). Additionally, polyphenols possess anti-inflammatory, anti-allergic and anti-mutagenic properties. They are also capable of preventing DNA damage, potentially offering anticancer effects and inhibiting the expression of adhesion molecules (Gorzynik-Debicka et al., 2018).

Sensory Evaluation of Olive Oils

The organoleptic properties of olive oil, such as taste and aroma, are primarily influenced by the olive variety and its genetic predispositions. The effect of the variety (genotype) on these properties is most evident in enzymatic activity, which contributes to the formation of desirable volatile compounds, as well as in the content of phenolic compounds. These factors directly influence the taste and aroma characteristics of the oil, in addition to its resistance to oxidation (Klepo and Benčić, 2014). Sensory analysis is a crucial analytical procedure used to evaluate the taste and aroma properties of virgin olive oil and plays a key role in its market classification. This analysis is conducted by trained and experienced evaluators called panelists (Gauta, 2018).

Materials and Methods

The objective of this research is to analyze the supply and quality of olive oils available in stores within the Herzegovina-Neretva Canton (HNC). The study begins with a review of relevant literature to describe the biological characteristics of the olive tree and to analyze the nutritional and medicinal potential of olives and their products in the context of human health. Additionally, the peroxide value, free fatty acid content, and polyphenol content were determined for six samples of extra virgin olive oil available in stores in the HNC. The results were compared with the "Regulation on the Methods of Olive Oil Analysis" (Official Gazette of BiH 68/13) and the "Regulation on Market Standards for Olive Oil"

(Official Gazette 81/12). Sensory analysis of the six olive oil samples were conducted in order to evaluate their organoleptic properties. Finally, the results were compared with findings from similar studies conducted in Bosnia and Herzegovina and internationally.

The olive oil samples analyzed in this study were obtained from the local market. According to the lables, olive oils originated from the folowing countries: Spain, Croatia, Italy and France.The samples were collected in their original packaging, in 1-liter bottles, with identical expiration dates but from different producers and various regions of the European Union. Following the chemical analyses, a panel of trained evaluators, including individuals with no prior training, was formed to conduct the sensory analysis of the olive oils. This analysis took place in the laboratory of the Agromediterranean Faculty. The following samples were analyzed:

Sample 1: Zvijezda (Country of origin: Croatia);
Sample 2: Filippo Berio (Country of origin: France);
Sample 3: Blanqueta (Country of origin: Spain);
Sample 4: Trenton (Country of origin: Croatia);
Sample 5: Olitalia (Country of origin: Italy);
Sample 6: Basso (Country of origin: Italy);

Determination of Total Polyphenols

The total polyphenol content in the extracts of the olive oil samples was determined using a spectrophotometric method, based on the color reaction between phenolic compounds and the Folin-Ciocalteu reagent. The intensity of the resulting color was measured at a wavelength of 765 nm. The total polyphenol content was determined by comparing the absorbance of the sample with the calibration curve of the standard, and the results were expressed as milligrams of gallic acid per kilogram of sample (mg GAE/kg). The determination was performed in triplicate to ensure accuracy.

A methanol extract of each olive oil sample was prepared by mixing 1 g of olive oil with 10 mL of methanol, followed by vortexing for 2 minutes. The mixture was centrifuged at 4000 rpm for 10 minutes and the supernatant was used for further analysis

Preparation of Calibration Curve:

To prepare the calibration curve, 0.5 g of gallic acid was weighed, dissolved in 10 mL of 80 % methanol, and then diluted with distilled water to a total volume of 100 mL. Gallic acid solutions were prepared in concentrations of 50, 100, 150, 250, and 500 mg/L. Each solution was subjected to spectrophotometric measurement to generate the calibration curve.

Determination of Peroxide Value

The peroxide value is a measure of the amount of substances in the sample that oxidize potassium iodide, and it is expressed in millimoles of active oxygen per kilogram of oil (mmol O_2/kg) or milliequivalents of active oxygen per kilogram of oil (mEq O_2/kg). The peroxide value is determined according to the methods described in Regulation 68/13 and the Regulation on Market Standards for Olive Oil (Official Gazette 81/12). The acceptable limit for the peroxide value in extra virgin olive oils is ≤ 10 mmol O_2/kg.

Procedure:

A 250 mL Erlenmeyer flask with a ground-glass stopper was prepared. Approximately 5.00 g of the oil sample (m) was weighed into the flask (or the sample was weighed in a glass capsule and transferred quantitatively). A solvent mixture of chloroform and glacial acetic acid (2:3, v/v) was added (e.g., 10 mL chloroform + 15 mL acetic acid) and the sample was completely dissolved by swirling.
Then 1.0 mL of saturated potassium iodide (KI) solution was added. The flask was immediately stoppered, shaken vigorously for ~30 seconds, and kept in the dark for 5 minutes to allow iodine liberation.
After incubation, 75 mL of distilled water was added and the released iodine was titrated with standard sodium thiosulfate solution (e.g., 0.01 mol/L $Na_2S_2O_3$) with continuous shaking until the yellow color became pale.
At this point, 1–2 mL of freshly prepared starch solution (≈1%, w/v) was added as an indicator, producing a blue coloration. Titration was continued dropwise with sodium thiosulfate until the blue color disappeared and the solution became colorless. A blank determination was performed under the same conditions using all reagents but without the sample.

Calculation of Peroxide Value:

The peroxide value was calculated from equation 1,

$$PV = \frac{V \, x \, T \, x \, 1000}{2 \, x \, m} \qquad (1)$$

Where:

- V = volume of sodium thiosulfate (mL),
- T = molarity of the sodium thiosulfate solution,
- m = mass of the sample (g).

Determination of Free Fatty Acid Content

The content of free fatty acids in olive oil, also referred to as its acidity, is determined according to the methods outlined in Regulation 68/13 and the Regulation on Market Standards for Olive Oil, where the free fatty acid content in extra virgin olive oils should be ≤ 0.8%.

Titration Procedure:

For the titration procedure, 10 g of the olive oil sample was dissolved in 50 mL of a neutralized mixture of diethyl ether and ethanol in a 1:1 (V:V) ratio. The resulting solution was then titrated with sodium hydroxide (0.1 mol/L) using phenolphthalein as an indicator. The titration was performed until the first permanent color change of the indicator occurred, which must remain stable for at least 15 seconds.

Calculation of Free Fatty Acid Content:

The free fatty acid content (acidity) is expressed according from equation 2,

$$FFA = \frac{V \; x \; c \; x \; M}{10 \; x \; m} \qquad (2)$$

Where:
V = volume of sodium hydroxide used for titration (mL),
c = concentration of the standardized sodium hydroxide solution (mol/L),
M = molar mass of oleic acid (282 g/mol),
m = mass of the sample (g).

Sensory Analysis of Olive Oil

The sensory analysis of olive oils was carried out by a panel of 10 trained assessors, in accordance with the Regulation on Methods for Olive Oil Analysis (Official Gazette of BiH 68/13). The evaluation was performed under standardized tasting conditions, including controlled lighting and temperature, and using standardized blue tasting glasses in order to avoid visual bias during assessment.
A total of six olive oil samples were analyzed. The samples were coded and presented to the panelists in a randomized order. Sensory evaluation was conducted using the official evaluation sheet for the sensory assessment of virgin olive oils, which includes the assessment of olfactory–gustatory–tactile properties, gustatory–retronasal properties, and final olfactory–gustatory–tactile properties.

Olfactory–gustatory–tactile properties were evaluated with a maximum of 35 points, including fruity notes of olive (0–7), green notes (olive or grass; 0–2), fruitiness of other fruits (0–3), other positive attributes (0–3), and harmony, which increases when the attributes are well balanced (0–20).
Gustatory–retronasal properties were evaluated with a maximum of 45 points and included fruity notes of olive (0–10), green notes (0–2), sweetness (0–4), bitterness (0–3), pungency (0–3), other positive attributes (0–3), and harmony (0–20).
Final olfactory–gustatory–tactile properties were evaluated with a maximum of 20 points, including complexity (0–10), which increases with the intensity of aromas and flavors, and persistence (0–10).
Between samples, panelists rinsed their mouths with water to minimize carry-over effects and prevent sensory fatigue. The total sensory score for each sample was obtained by summing the scores of the individual groups of attributes, while the final values were expressed as the median of the panelists' scores, in accordance with the principles of sensory data processing.

Olfactory-taste-tactile properties – maximum score: 35 points
Taste-retro-nasal properties – maximum score: 45 points
Final taste-olfactory-tactile properties – maximum score: 20 points
Total score – maximum score: 100 points

Based on the sensory profile, fruitiness category classification of the olive oil samples (green or ripe) was also performed.

Statistical Analysis

Statistical analysis of the sensory evaluation data was performed using analysis of variance (ANOVA) to determine statistically significant differences between the olive oil samples and between the sensory attributes (aroma, taste and aftertaste harmony). A two-way ANOVA was applied at a 5% significance level. When a statistically significant effect was detected, the Tukey-Kramer post-hoc test was used to identify differences among the individual samples and sensory attributes. The results of the ANOVA test showed statistically significant differences both among the samples and among the sensory properties.

Results and discussion

This study analyzed the quality parameters of olive oils, including the content of free fatty acids (FFA), peroxide value, and total polyphenols. In this section, we will discuss the significance of the obtained results and their correlation with established quality standards.

Results of Free Fatty Acids (FFA) Content

The content of free fatty acids (FFA) is a crucial indicator of olive oil quality, as it reflects the degradation processes of the olive fruit, which are influenced by various factors. The most common causes of elevated FFA levels include mechanical damage and improper handling of the fruit.. An increase in FFA concentration is typically inversely related to the presence of other key components in olive oil, such as aromatic compounds, vitamins, and polyphenols. Consequently, higher FFA content can significantly reduce the nutritional and health benefits of olive oil (Klepo & Benčić, 2014). Table 1 presents the results of the FFA content in the analyzed olive oil samples, along with the values specified in Regulation 68/13. These results allow for a direct comparison between the obtained values and the regulatory standards, providing a basis for assessing the compliance of the analyzed olive oil samples with market standards for extra virgin olive oils.

Table 1. *Free Fatty Acid Content of Analyzed Oils and Values from Regulation 68/13*

Sample	Free Fatty Acids (FFA) Content (%) (as Oleic Acid)	Regulation 68/13
1	0.50	
2	0.68	
3	0.89	
4	0.71	≤0.8
5	0.90	
6	0.66	

The hydrolytic degradation of virgin olive oils is determined by the mass percentage of free fatty acids (FFA). This parameter serves as a standard market indicator for assessing the extent of hydrolytic deterioration (Koprivnjak, 2006). The classification criteria for free fatty acid content were compared with the standards defined in the Regulation on Market Standards for Olive Oil (Official Gazette 81/12) and the Implementing Regulation (EU) 2022/2105. In a study performed by Gauta (2018), nine olive oil samples from Croatia were analyzed and the FFA content ranged from 0.17% to 0.66%. Additionally, Dobra (2017) reported the average FFA values in the analyzed olive oil samples ranged from 0.21% to 0.55%. Mena et al. (2018) cited a range of FFA content from 0.18% to 0.8% in the analyzed olive oils. Research conducted by Carolina et al. (2020) on Spanish virgin olive oils, which focused on determining the total polyphenol content and metal concentrations, revealed that the FFA values were either lower or very close to 0.2 g oleic acid per 100 g of oil. This indicated that all analyzed samples met the criteria for extra virgin olive oil, except for one sample, which exceeded the maximum value of 0.8 g oleic acid per 100 g of oil despite being labeled as extra virgin. These findings align with the results of the present

study, where two of the samples exceeded the recommended FFA limits. In a study on the aromatization of virgin olive oil using seeds of *Pimpinella anisum* (Youssef et al., 2021), the FFA content in the control samples ranged from 0,03% to 1,46%. In the current study, the FFA content, expressed as a percentage of oleic acid, in the analyzed samples ranged from 0.5% to 0.9%. Sample 1 exhibited the lowest FFA value (0.5%), while Sample 5 had the highest (0.9%). Elevated levels of free fatty acids have a detrimental effect on the quality and shelf life of olive oil. According to Regulation on Market Standards for Olive Oil 81/12, Samples 3 and 5 should be classified as virgin olive oils due to their elevated FFA content.

Peroxide Value Results

The peroxide value is a critical indicator of oxidative deterioration in olive oil, expressed as the amount of active oxygen bound to one kilogram of oil (mmol O_2/kg). The maximum permissible peroxide value for virgin olive oil intended for human consumption, without any refining process, is set at 10 mmol O_2/kg (Klepo & Benčić, 2014). For high-quality, freshly produced oils, the peroxide value typically ranges from 1 to 3 mmol O_2/kg, indicating minimal oxidation and preserving the oil's quality (Koprivnjak, 2006).

Table 2. *Peroxide Value Results of Analyzed Olive Oils and Values from Regulation 68/13*

Sample	Peroxide Value (PV) in mmol O_2/kg	Regulation 68/13
1	2.83	
2	5.26	
3	4.75	
4	4.21	≤10
5	4.81	
6	3.85	

The peroxide value is a crucial indicator of oxidative degradation in olive oil, quantifying the amount of active oxygen bound to one kilogram of oil, expressed in millimoles (mmol O_2/kg). According to the guidelines, the maximum permissible peroxide value for virgin olive oil, without any refining, is 10 mmol O_2/kg (Klepo & Benčić, 2014). For freshly produced, high-quality oils, the peroxide value typically ranges from 1 to 3 mmol O_2/kg, reflecting minimal oxidative degradation (Koprivnjak, 2006). Gauta's study (2018) reported that, of the nine analyzed olive oil samples, the peroxide values were within the acceptable limits for extra virgin olive oil. Among these, five samples had a peroxide value below 3 mmol O_2/kg, while the highest recorded value was 5.7 mmol O_2/kg for sample 5. In contrast, Dobra (2017) analyzed five olive oil samples and found a broader range of peroxide values, ranging

from 4.9 mmol O_2/kg to 8.2 mmol O_2/kg, indicating a higher degree of oxidation in some of the samples. The study perofrmed by Youssef et al. (2021), which focused on the aromatization of virgin olive oil with *Pimpinella anisum* seeds, reported that the peroxide values in the control samples ranged from 0.51 mmol O_2/kg to 7 mmol O_2/kg, suggesting varying effects of the aromatization process on the oil's oxidative status. Similarly, Mena et al. (2018) observed a peroxide value range from 1.79 mmol O_2/kg to 4.69 mmol O_2/kg in their study, with results consistent with the findings of the current study. Shiling et al. (2022) conducted a comprehensive analysis of the chemical composition and health effects of edible vegetable oils using chemometric methods. In their study, the peroxide values of olive oils ranged from 0.06 mmol O_2/kg to 1,11 mmol O_2/kg, indicating high-quality oil compared to other samples evaluated. In the present study, the lowest peroxide value was observed in sample 1 (2.83 mmol O_2/kg), while the highest peroxide value was found in sample 2 (5.26 mmol O_2/kg). All samples analyzed in this study comply with the standards set by the Regulation on Methods of Analysis of Olive Oil (Official Gazette BiH 68/13) and the Regulation on Market Standards for Olive Oil (Official Gazette 81/12).

Results of Total Polyphenol Content

While the determination of polyphenol content is not classified as a primary quality indicator for olive oil, polyphenols are among the most significant groups of compounds that influence the overall quality of the oil. These compounds affect the organoleptic, chemical, and nutritional properties of olive oil. The unique combination of polyphenols in olive oil distinguishes it from other vegetable oils, contributing to both its distinctive flavor and its health benefits. The concentration of polyphenols in olive oil is influenced by several factors, including the degree of fruit maturity, olive variety, altitude, water supply, oil extraction methods, storage conditionsand any refining processes. Refined olive oils generally contain the lowest concentrations of polyphenols, as a significant portion of these compounds is removed during the refining process. In contrast, extra virgin and virgin olive oils typically retain the highest levels of polyphenols, which enhances their health-promoting properties and overall quality (Šindrak et al., 2007).

Table 3. *Total Polyphenol Content of Analyzed Olive Oils and Literature Value*

Sample	Total Polyphenols (mg/kg)	Literature Values (mg/kg)
1	411.229	150-300 (Orva J.H. et al., 2014.)
2	201.287	73-265 (Pellegrini et al., 2001.)
3	214.670	85.59 – 382.99 (Žanetić et al., 2014)
4	220.165	50- 500 (Espejo, 2005; Del Carlo et al., 2006)
5	159.278	178 – 591.8 (Ciafardini, et al., 2013; de la Torre-
6	178.519	Robles et al., 2014)

The total polyphenol content in olive oils, as reported in a study on the chemical composition and health effects of edible vegetable oils using chemometric analysis (Shiling et al., 2022), ranged from 7.40 to 62.96 mg/kg. Perona-Arquillué et al. (2003) found a higher polyphenol content of 631.3 mg/kg in olive oil, while Baccouri et al. (2008) reported that the polyphenol content in oils from wild olive varieties ranged from 182 to 430 mg/kg. Numerous studies have reported a wide range of total polyphenol content in extra virgin olive oils, typically from about 50 up to over 1000 mg/kg, depending on cultivar, ripening stage and processing conditions (Albdady, 2023; Arafat et al., 2016; López-Bascón et al., 2024; De Santis et al., 2022; Manai-Djebali et al., 2023). The polyphenol content in olive oil is influenced by several factors, with the olive variety being one of the most significant. However, the fruit ripeness is considered the most crucial factor affecting polyphenol levels (Škevin et al., 2003). Olive oils contain various phenolic compounds, which can exist either in their free form or bound with other compounds in complex structures. These compounds may degrade and break down into other components during the aging process of the oil. Similarly, Carolina et al. (2020) reported that the total polyphenol content in their analyzed samples ranged from 93 to 375 mg/kg, which aligns with previous findings. Based on the total polyphenol content observed in this study, it can be concluded that the results are consistent with the literature data, as shown in Table 3. Generally, the high-quality olive oils contain between 100 and 250 mg/kg of polyphenols (Saima et al., 2021).

Results of Sensory Analysis of Olive Oils

Virgin olive oils, after undergoing physico-chemical analysis, were subjected to sensory analysis. It is important to note that oils classified as extra virgin, following physicochemical analyses, must not exhibit any organoleptic defects (Median of defects=0) while their fruitiness must be higher than zero (Median of fruity >0).. In contrast, virgin olive oils may have minor organoleptic defects (Median of defects ≤3,5). . Additionally, the fruitiness of these oils must also remain above zero (Median of fruity >0). (Jiménez Herrera and Carpio Dueñas, 2008). The sensory analysis was conducted by 10 panelists, who assessed the olive oil samples across different properties, After completing the sensory analysis, the results were processed using statistical significance analysis (ANOVA). To determine statistical significance and correlations between the measured variables, the Tukey-Kramer test was conducted. The analysis revealed significant differences in the sensory properties between the evaluated olive oil samples.

Table 4 presents the scores from the sensory analysis of the olive oil samples. All assessors were provided with brief guidelines for evaluation before proceeding with the assessment. The results showed that Sample 1 received the highest score for all evaluated properties (smell, taste, and overall harmony), achieving the highest total score compared to the other samples. In contrast, Sample 4 received the lowest score across sensory properties. Additionally, the results indicate significant variation in the ratings of the oils across the different properties (smell, taste, overall harmony), suggesting notable

differences in the sensory properties of the analyzed samples. This variability reflects the unique characteristics of each olive oil, which may be influenced by several factors such as the olive variety, origin and production process.

***Table 4**. Results of Sensory Analysis Scores*

Samples	Aroma	Taste	Aftertaste harmony	Total score
1	245	306	159	710
2	169	240	114	523
3	237	287	130	654
4	134	143	79	356
5	225	279	132	636
6	215	257	126	598

Statistical Analysis of Sensory Analysis Results

A two-way analysis of variance (ANOVA) was conducted to assess the statistical significance of the differences in sensory properties and between the olive oil samples. The F-value obtained for the differences between the samples was 22.88, which was greater than the critical F-value (2.27), indicating a statistically significant difference between the samples. Similarly, the F-value for the differences in sensory attributes (such as smell, taste, and overall harmony) was 109.90, which exceeded the critical F-value (3.05). These results indicate a highly statistically significant difference in both the sensory properties and between the olive oil samples, as also confirmed in Table 5.

***Table 5.** Results of Statistical ANOVA Analysis at 5% Significance Level for Sensory Evaluation*

ANOVA 5%						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Samples	2641.983	5	528.3966667	22.88348705	2.45E-17	2.26996
Senses	5075.433	2	2537.716667	109.9019168	6.94E-31	3.051819
Interaction	340.8333	10	34.08333333	1.47606063	0.152589	1.889561
Within	3740.7	162	23.09074074			
Total	11798.95	179				

The Tukey-Kramer test was applied based on the data obtained from the sensory analysis to confirm the statistical significance in the measurements of olive oil samples and different sensory attributes. By

comparing all individual samples and sensory attributes (odor, taste, and overall harmony), a highly significant statistical difference was found between all analyzed parameters. The Tukey-Kramer test showed statistically significant differences only for the taste and aroma of sample 2 compared with samples 1 and 3, and for the odor of sample 4 compared with sample 5. No other significant differences were observed among the remaining samples. In 2010, during the Olive Oil Fair in Imola (Emilia-Romagna, Italy), Predieri et al. (2013) asked 133 consumers to evaluate four olive oil samples selected based on their sensory attributes related to quality. These samples were also evaluated by a trained panel, and the results were compared. Most consumers highlighted fruitiness, bitterness, and pungency as attributes of high-quality oils, which was in line with the evaluations of the trained panel. Additionally, 66% of consumers assigned higher ratings to samples with more bitterness and pungency, considering them of higher quality (Predieri, 2013). A similar study was conducted in Finland, where Recchia et al. (2012) asked 74 consumers to taste four different olive oils previously evaluated by a trained panel. The panel classified two of the oils as high-quality, with intense green fruitiness, bitterness, and pungency. Consumers were divided into three groups based on their knowledge of olive oil, and the authors expected a good correlation between the panel and the most dedicated group. However, all groups disagreed with the panel's classification, preferring less intense oils. The authors attributed these differences to the lack of sensory experience among the consumers. A high level of involvement with olive oil does not necessarily mean that the consumer has sufficient sensory experience to accurately assess its quality (Recchia et al., 2012). These studies indicate a similar trend in our research, where a low level of knowledge regarding the evaluation of extra virgin olive oil was also observed, possibly due to the lack of tradition in consuming olive oil in daily diets in our country. The sample of evaluators was small (10 evaluators), which limits the ability to generalize, but it was sufficient to conduct a comparative analysis of the sensory evaluations of the analyzed olive oil samples. Delgado et al. (2017) compared evaluations between a group of 23 olive oil experts and 110 American consumers on 22 olive oil samples. They found no correlation between the assessments of experts and American consumers. Experts classified sharper and more bitter samples as higher-quality oils, while American consumers preferred less intense samples. In some cases, consumers even preferred samples with sensory defects, such as rancidity, mustiness, cloudiness and winey acidity. Only in a few instances were the results correlated (Delgado et al., 2017). Similar patterns were observed in our research, where some evaluators gave higher scores to samples that were on the verge of a rancidity rather than to those with higher quality. However, ample 1 exhibited the best properties in the sensory analysis and received the highest overall score, as clearly seen in Table 4.

Conclusion

Extra virgin olive oil is highly valued for its balanced nutritional composition and characteristic aroma, making it an essential component of the Mediterranean diet and contributing to its recognized health benefits. This study assessed the availability and quality of extra virgin olive oils sold in the Herzegovina-Neretva Canton (HNK), leading to several key findings.

Sample 1 demonstrated the best overall quality, with the lowest free fatty acid content, the lowest peroxide value and the highest concentration of total polyphenols. Samples 3 and 5 exceeded the allowable limits for free fatty acids and should therefore be classified as virgin olive oils. All samples complied with regulatory requirements regarding peroxide value. Differences in polyphenol content among the oils were consistent with ranges reported in the literature.

Statistical analysis (ANOVA and Tukey-Kramer tests) confirmed significant differences among the samples in sensory attributes, with sample 1 receiving the highest sensory scores.

Overall, the results highlight noticeable variability in the quality of olive oils available on the local market. Increasing consumer awareness and sensory education may help prevent the mislabelling and misuse of the "extra virgin" designation and promote higher standards in olive oil quality.

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