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Near-infrared spectroscopy and machine learning to detect olive oil type: a systematic review

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ABSTRACT

The present study evaluates the effectiveness of visible/near-infrared spectroscopy (VIS/NIR) combined with machine learning in olive oil type detection. A search strategy based on the population, intervention, comparison, and outcome (PICO) framework was employed to formulate specific equations used in Scopus, ScienceDirect, and PubMed databases. After applying exclusion criteria, 53 studies were included in the review following preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The reviewed studies demonstrate that VIS/NIR spectroscopy coupled with machine learning allows rapid and accurate identification of different types of olive oil, highlighting the detection of fatty acids, polyphenols, and other vital compounds. However, variability in samples and processing conditions present significant challenges. Although the results are promising, further research is required to fully validate the efficacy and feasibility of this technology in industrial settings. This review provides a comprehensive overview of the advances, challenges, and opportunities in this field, highlighting the need to optimize machine learning models and standardize analysis procedures for practical application in the food industry.

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1. INTRODUCTION

The analysis of olive oil is crucial due to its importance in the food industry and its impact on public health. Thus, visible/near-infrared spectroscopy (VIS/NIR) and machine learning have emerged as promising tools for detecting the type of olive oil. Previous research has extensively explored this area, demonstrating that VIS/NIR spectroscopy combined with machine learning algorithms can offer a rapid, efficient, and non-destructive method to analyze olive oil's chemical and physical characteristics [1]–[4]. However, it is crucial to recognize that these promises are still in the research and development phase. Although studies have shown encouraging results so far, there is still work to be done to fully validate the effectiveness and feasibility of this technology in the real world.

Studies have addressed the identification of fatty acids, polyphenols, and other compounds present in olive oil using advanced spectroscopic techniques [5]–[8]. These techniques have the potential to offer a deeper understanding of the chemical composition of olive oil, which could lead to significant improvements in its quality, authenticity, and nutritional value. This would allow the different types of olive oil to be identified. However, despite the possibilities of these techniques, they are still being researched and developed. More studies are needed to validate its effectiveness in various olive oil samples.

Furthermore, it is crucial to address technical and methodological challenges, such as standardization of analysis procedures and accurate interpretation of spectroscopic data. The integration of VIS/NIR spectroscopy with machine learning techniques raises fundamental questions, such as its impact on the accuracy of olive oil type detection and its feasibility in industrial environments [9]–[12]. So, more research is needed to answer the following question: How does visible/near-infrared (VIS/NIR) spectroscopy combined with machine learning help in the accuracy of olive oil type detection? For example, although current studies suggest that these hybrid methods can achieve high accuracy rates in identifying various oil types, including distinguishing between extra virgin, virgin, and refined oils, further research is still needed to understand this technology's limitations and restrictions fully. Furthermore, the application of these systems presents additional challenges. Optimizing machine learning models, reducing spectroscopy equipment costs, and adapting systems to variable processing conditions are critical aspects that must be addressed.

VIS/NIR spectroscopy combined with machine learning has proven to be a powerful tool in identifying and characterizing different types of olive oil. Recent studies have shown its effectiveness in identifying fatty acids, polyphenols, and other key compounds that determine the quality and authenticity of olive oil [5], [6]. However, sample variability and processing conditions represent significant challenges that remain to be addressed. This systematic review will use A search strategy based on the population, intervention, comparison, and outcome (PICO) question. A comprehensive search of relevant scientific databases will be conducted to identify studies evaluating the effectiveness of VIS/NIR spectroscopy and machine learning in olive oil type detection. The selected studies will be critically evaluated to extract relevant data and synthesize the findings. The research aims to validate the effectiveness of combined VIS/NIR spectroscopy and machine learning techniques in real food industry environments. In addition, the aim is to develop and optimize machine learning models that can be implemented efficiently and profitably in the detection and classification of olive oils.

To date, several studies have been identified that demonstrate the promise of these technologies in accurately identifying different types of olive oil. Early results indicate that the combination of VIS/NIR spectroscopy and machine learning can significantly improve the accuracy and speed of olive oil analysis. However, more research is needed to overcome current limitations and validate these methods under a broader range of conditions. operational. Therefore, a comprehensive systematic review must address these issues and explore the most recent studies in the field.

This review will contribute to the advancement of scientific knowledge in olive oil type detection and will provide invaluable guidance to the food industry and public health professionals [13]–[16]. The promise of this review lies in its ability to condense the latest findings, identify emerging trends and patterns, and highlight areas for future research. This would allow the development of more solid and effective solutions in the detection and classification of olive oils, thus improving the authenticity of the products. Furthermore, the conclusions of this review could be very valuable for the food industry, as they could help implement more effective and reliable systems for classifying olive oils. This, in turn, would help to strengthen consumer confidence and ensure the integrity of products in the market.

Furthermore, this review is expected to address the professional competence of systems analysis, critically evaluating existing olive oil detection systems and proposing practical improvements based on the implementation of VIS/NIR spectroscopy and machine learning [17]–[20]. These improvements may involve specific suggestions for equipment selection, algorithm optimization, process standardization, and integration of emerging technologies. These improvements could revolutionize how olive oil types are detected and classified, thus increasing the effectiveness and efficiency of detection systems. This systematic review aims to give a comprehensive view of the advances, challenges, and opportunities for detecting olive oil type using VIS/NIR spectroscopy and machine learning to drive future research and practical applications [21]–[25]. This global perspective will enable an up-to-date understanding of these technologies in the food industry and encourage future research and practical applications that benefit industry and consumers.

2. METHOD

A clear search strategy based on the PICO question was used to conduct this systematic review, from which four research questions and a PICO table were generated. The PICO chart is a structure used to formulate research questions, which includes Population (P), Intervention (I), Comparison (C), and Outcome (O) [26]. Specific keywords were defined, such as “olive oil,” “visible/near-infrared spectroscopy,” “machine learning,” “authentication,” and “adulteration,” from which two search equations were obtained for three databases: Scopus, ScienceDirect, and PubMed.

2.1. Research questions

The combination of visible/near-infrared (Vis/NIR) spectroscopy with machine learning has aroused notable interest in the scientific community. The literature includes a wide range of studies that address the first applications of these technologies and the most recent developments [2], [27]. Recent research has highlighted how technological advances have improved the accuracy of these methods, underscoring the connection between technological progress and detection capacity. Therefore, organizing and synthesizing the information collected by creating tables in a systematic review is crucial. This procedure provides a clear overview of the existing literature and facilitates the comparison of results between different studies [28]. Furthermore, the clear and concise presentation of data in tables allows readers to quickly understand the breadth and variability of the included studies. Table 1 presents the PICO question and its components, and Table 2 details the keywords used in the PICO tool and its elements.

Table 1. PICO question and its components

PICO QUESTION
Question: How does visible/near infrared spectroscopy (VIS/NIR) combined with machine learning help in the accuracy of olive oil type detection?
COMPONENTS
RQ1: How has the accuracy in olive oil type detection been defined and measured using VIS/NIR spectroscopy and machine learning?
RQ2: What specific VIS/NIR spectroscopy techniques and machine learning algorithms have been used in the studies?
RQ3: What levels of precision and effectiveness have been obtained by the combined VIS/NIR and machine learning methods, and what are the reported limitations?
RQ4: How do the results obtain with the combination of VIS/NIR and machine learning compared to other olive oil type detection methods??

Table 2. PICO table

Strategy	Definition	Items	Keywords	Search Equation
P	Problem or Population	Deficiencia del análisis del tipo de aceite de oliva	"Olive Oil", "Type of Olive Oil"	("Olive Oil") AND ("Machine Learning" OR "Deep Learning" OR "VIS/NIR")
I	Intervention	Uso de VIS/NIR y machine learning	"VIS/NIR", "Machine Learning", "Deep Learning"	
C	Comparison	Métodos de evaluación del tipo de aceite de oliva tradicionales sin el uso de VIS/NIR o machine learning	"Detection of the Type of Olive Oil"	
O	Results	Eficiencia y precisión en la detección del tipo de aceite de oliva	"Olive Oil Type Detection", "Efficiency", "Precision"	

2.2. Search strategy

The search was carried out in three databases: Scopus, ScienceDirect, and PubMed, with the search equation ("olive oil") AND ("machine learning" OR "deep learning" OR "VIS/NIR") for the Sopus and ScienceDirect databases; and for PubMed the search equation was used: ("Olive Oil") AND ("Machine Learning" OR "deep learning" OR "neural networks" OR "artificial intelligence") AND ("Spectroscopy" OR "VIS/NIR" OR "Visible Near-Infrared Spectroscopy"), see Table 3. Also, studies that will analyze olive oil with VIS/NIR and machine learning were included [29]–[31], and records that dealt with other oils were excluded [32]–[34].

Table 3. Search on database

Database	Search Equation	Total
Scopus	("Olive Oil") AND ("Machine learning" OR "Deep Learning" OR "VIS/NIR")	154
ScienceDirect	("Olive Oil") AND ("Machine learning" OR "Deep Learning" OR "VIS/NIR")	1,146
PubMed	("Olive Oil") AND ("Machine Learning" OR "Deep Learning" OR "Neural Networks" OR "Artificial Intelligence") AND ("Spectroscopy" OR "VIS/NIR" OR "Visible Near-Infrared Spectroscopy")	32

Once the search was carried out in the three databases, 1,332 records were identified, and the inclusion and exclusion criteria were defined, where articles began to be excluded for duplicates, not meeting the required criteria, and containing exclusion criteria [35]. After excluding the articles, 53 records were included in the review, see Table 4. The article selection process followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) scheme, a standardized method for reporting systematic reviews, with all steps and results detailed and visualized in a flowchart, ensuring transparency and accuracy in the selection of literature, see Figure 1.

Table 4. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Studies analyzing olive oils, including extra virgin, virgin and refined	Studies that do not focus on olive oil
Research focused on the chemical characterization of olive oil	Data irrelevant to olive oil varieties
Using visible/near-infrared (VIS/NIR) spectroscopy for analysis	Studies that do not use VIS/NIR spectroscopy
Application of machine learning and deep learning algorithms in the detection of oil type	Research that does not apply machine learning or deep learning
Results that include improvements in the authenticity and quality of the oil	Results irrelevant or not applicable to the classification of olive oil
Original research articles and systematic reviews	Non-peer-reviewed articles or low-quality publications

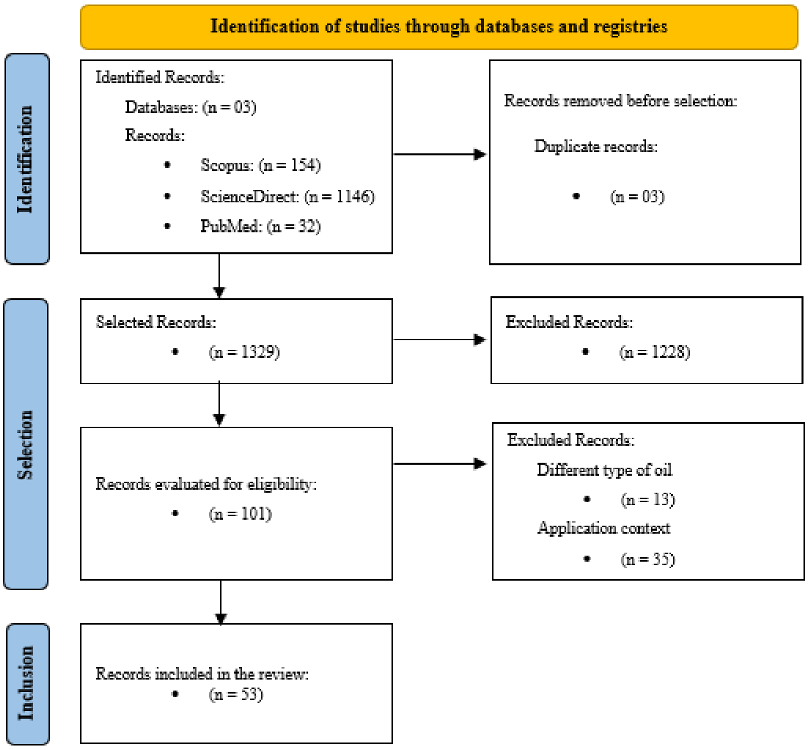

Figure 1. PRISMA flowchart

The combination of VIS/NIR spectroscopy and machine learning offers an accurate way to identify different types of olive oil, improving the accuracy of traditional methods [5], [7]. This approach effectively improves identification accuracy [8], [10]. Developing predictive machine learning models trained with spectroscopic data specific to different olive oils is essential to achieve this precision. Additionally, using VIS/NIR systems on production lines facilitates continuous, non-destructive analysis, allowing frequent testing without damaging samples. This non-destructive analysis method perfectly integrates into the production process, offering constant and efficient quality control. The ability to detect adulterations in olive oil is also significantly improved, ensuring product authenticity through machine learning algorithms that identify specific spectroscopic patterns of adulterations. The analysis process is automated by implementing automated systems with VIS/NIR and machine learning, reducing human intervention and associated errors.

Generating and maintaining a centralized database of olive oil spectra is essential to unify the results and guarantee consistency in the analyses [11], [17]. Furthermore, incorporating VIS/NIR analysis systems with real-time machine learning functionalities throughout the production process enables constant monitoring of the quality of the olive oil, allowing a rapid response to any problem detected. However, developing and maintaining these systems can involve high reagent costs and high labor demands. The benefits generated by such implementation are presented in Table 5.

Table 5. Benefits and implementation

Benefits	Implementation	Reference
Improved Accuracy	Develop predictive models with machine learning trained with spectroscopic data	[5]–[7], [29], [36]–[45], [46]–[49]
Fast and Non-Destructive Analysis	Integrate VIS/NIR systems into production lines to perform continuous and non-destructive analysis of olive oil	[8]–[10], [27], [31], [32], [50]–[59], [60], [61]
Adulteration Detection	Use trained machine learning algorithms to identify specific spectroscopic patterns of adulterations	[11]–[18], [20]–[23], [30], [61]–[65]

3. RESULTS AND DISCUSSION

In this section, a detailed analysis of previous research is carried out along with a bibliometric review, where the relationships between the terms visible/near-infrared spectroscopy (VIS/NIR) and machine learning are explored about the identification of the type of oil. Olive and the visual representation of the network overlap and density. In the second section, the scientific gap of the articles mentioned in this study is examined to develop an architectural model that facilitates the implementation of an algorithm to improve and optimize the detection of the type of olive oil.

3.1. Bibliometric analysis

Bibliometrics is a field that uses statistical and mathematical methods to examine scientific production. It also evaluates and examines the impact and evolution of research, detects trends in the evolution of science and technology, and measures the productivity of researchers and institutions. Bibliometric analysis is a valuable tool not only for scientists but also for science managers and policy makers, as it contributes to enriching the understanding of scientific research and its impact on society [66]–[68].

The network visualization in Figure 2 shows the connections and relationships between different research areas in using VIS/NIR spectroscopy and machine learning for olive oil type detection. This figure reveals how the concepts are interrelated, allowing us to identify networks of co-occurrence of terms and research structure in this field. Nodes represent specific research topics, while lines connect terms in multiple publications, highlighting collaborations and links between different topics. Network analysis is essential to understand how research is structured and which topics are central or peripheral. Larger and more connected nodes, such as "olive oil," "spectroscopy," and "machine learning," indicate areas of great relevance and connection within the field, suggesting that these topics are crucial for current and future research. According to the figure, the nodes are represented in 4 groups.

Group 1 (Red): Focused on key concepts like "extra virgin olive oil," "discriminant analysis," and "food analysis," this group highlights research dedicated to verifying the authenticity and quality of olive oil. Studies in this category often explore methods for detecting adulteration, classifying different oil grades, and ensuring compliance with food industry standards. Techniques such as chemical profiling and sensory evaluation are frequently used to assess purity and nutritional properties.

Group 2 (Green): Includes terms such as "machine learning," "convolutional neural networks," and "spectrum analysis," indicating a focus on applying artificial intelligence and spectral techniques in olive oil research. This group examines how computational models analyze spectral data to classify olive oils, improving quality control and authenticity verification. Machine learning enables more precise, automated assessments that enhance efficiency in the industry.

Group 3 (Purple): Centered on terms like "human," "adult," and "female," this group suggests research on the health effects of olive oil across different demographics. Studies may focus on its benefits for cardiovascular health, metabolism, or specific impacts on women's health. The inclusion of these terms indicates an interest in dietary patterns, disease prevention, and the role of olive oil in long-term well-being.

Group 4 (Blue): Contains keywords such as "infrared devices" and "chemometrics," reflecting an interest in advanced analytical techniques for olive oil evaluation. Research in this area explores the use of infrared spectroscopy and statistical modeling to assess the composition and quality of olive oil in a non-destructive, efficient manner. These technologies provide valuable insights for authentication and chemical characterization.

These advanced technologies have allowed researchers to develop precise and non-invasive methods for evaluating oil quality. Providing an alternative to traditional chemical analyses. Techniques like infrared spectroscopy and chemometrics enable faster and more efficient assessments while maintaining accuracy in detecting purity and authenticity [31], [32], [50].

The combination of VIS/NIR spectroscopy with machine learning algorithms, such as support vector machines (SVM), neural networks, and decision trees, has made it possible to analyze the spectral characteristics of olive oil samples. This approach is extremely effective in discriminating between extra virgin, virgin, and refined olive oils, achieving up to 98% accuracy in certain studies [29], [36]. Machine learning models have identified complex spectral patterns corresponding to various chemical compositions and oil purity levels [39], [45].

Adopting these methods has also simplified the evaluation of the chemical composition of olive oil, allowing the identification of specific compounds, such as fatty acids and polyphenols, which are key indicators of oil quality. This improves classification accuracy and provides relevant information for product authentication and quality control [50]–[55], representing a significant advance in food quality control. This innovative approach not only contributes to scientific knowledge but provides practical benefits for industry and consumers.

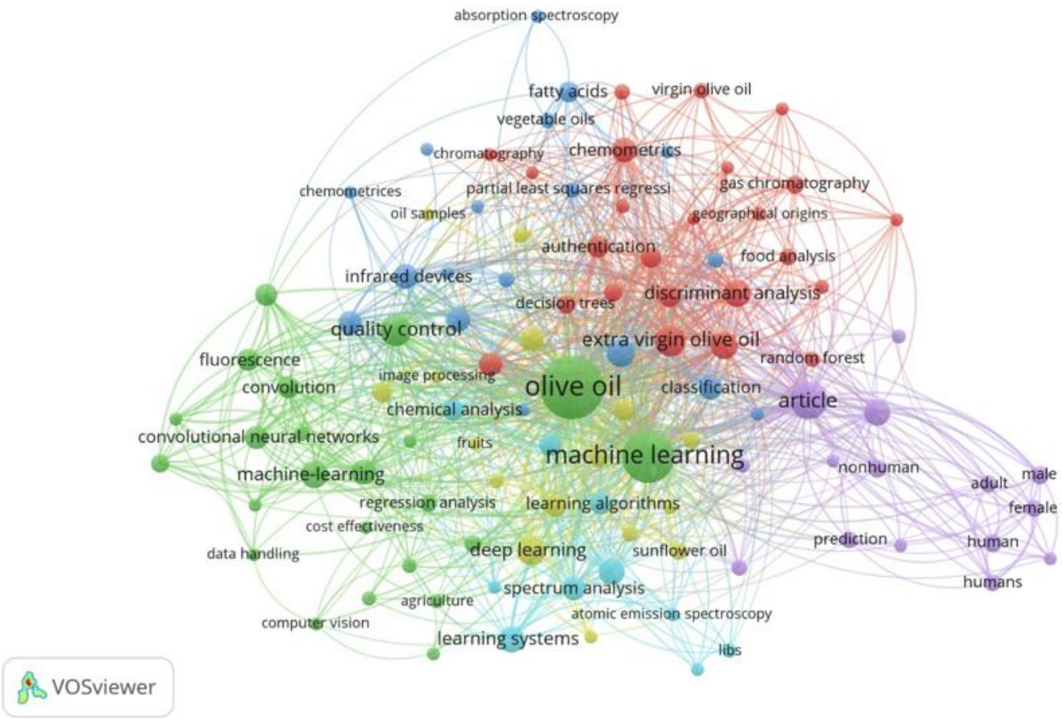

Figure 2. Olive oil study network visualization (VOSviewer)

3.2. Manuscript analysis

These advanced technologies have enabled researchers to develop precise and non-invasive techniques to evaluate oil quality, offering an alternative to conventional chemical methods [5], [7]. In the initial stage of the search, three scientific databases were used: Scopus, ScienceDirect, and PubMed. This exploration led to the initial identification of 1,332 records. Afterward, a purification process was carried out following the PRISMA methodology, which included eliminating duplicates and excluding documents irrelevant to the research. This thorough procedure resulted in a final selection of 53 relevant manuscripts for review, as Figure 1 of the article describes.

Phase 1 of this process was focused on the initial search of the records. Phase 2 involved removing duplicates, which reduced the number to 1,329 records. In Phase 3, these records were reviewed, and those that did not meet the inclusion criteria were excluded, leaving 101 documents for further evaluation. Finally, 48 articles that did not meet the requirements, such as the appropriate analysis of the oil type or the specific application of VIS/NIR spectroscopy and machine learning, were discarded, resulting in a final selection of 53 records, see Table 6.

Figure 3 presents a breakdown of the number of manuscripts for each of the databases used to provide a more detailed understanding of the distribution of these manuscripts. Scopus is the main source with 34 manuscripts, maintaining the highest number even after applying the corresponding filters. On the other hand, ScienceDirect contributed 15 relevant manuscripts, while PubMed contributed 4 manuscripts. Additionally, Figure 4 shows a line graph illustrating the annual distribution of manuscript publications, broken down by database and related indexes.

Here you can see the clearest image of how these manuscripts have been distributed over time, Figure 4 shows the number of documents per year of publication. This provides an evident perspective on the evolution of research in this field over the years. The figure highlights the periods of greatest research activity and facilitates the identification of patterns in the publication of studies on the quality of olive oil using advanced methodologies.

Table 6. Results obtained from the search

Database	Initial Search	Final Selection
Scopus	154	34
Science Direct	1,146	15
PubMed	32	4
Total	**1332**	**53**

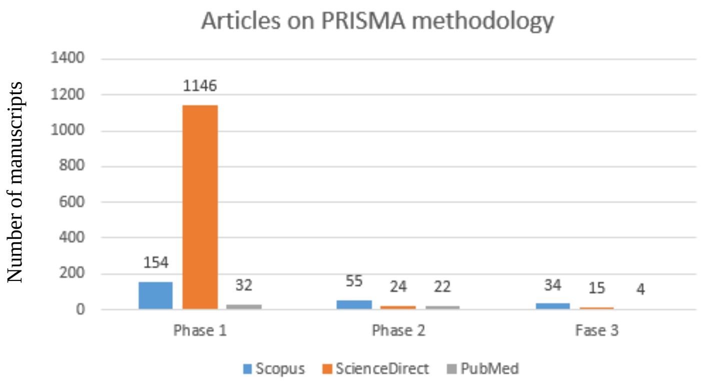

Figure 3. Number of documents in PRISMA methodology

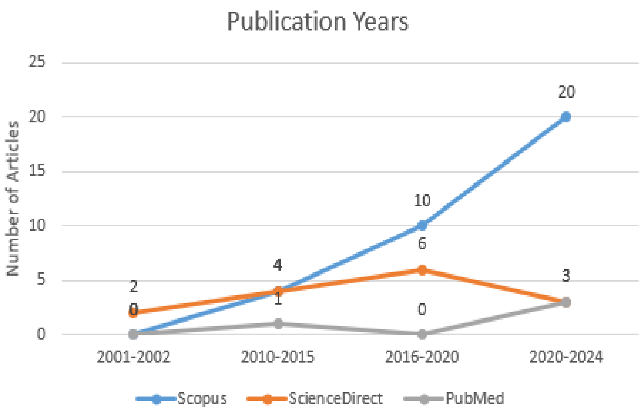

Figure 4. Number of documents per year of publication

3.3. Precision in the detection of the type of olive oil using VIS/NIR spectroscopy and machine learning

The accuracy of olive oil type identification using visible/near-infrared (VIS/NIR) spectroscopy and machine learning has been determined through its ability to classify different oil types correctly. This accuracy has been evaluated using standard metrics such as precision, sensitivity, and specificity. These metrics allow us to evaluate how effective predictive models are in classifying olive oils, surpassing traditional methods in terms of speed and accuracy.

Table 7 presents various studies that have implemented VIS/NIR spectroscopy techniques and machine learning algorithms to detect the type of olive oil. Among the spectroscopy techniques, reflectance and transmission spectroscopy stand out, as they are used to obtain detailed spectral data of olive oil [1]–[8].

Regarding machine learning algorithms, various methods have been used, including:

- Support vector machines (SVM): They are used for their ability to handle high-dimensional data and find the hyperplane that best separates the classes of olive oil. This method is particularly effective in distinguishing subtle differences in spectral data, ensuring accurate classification [9]–[18], [19], [20].
- Artificial neural networks (ANN): These models leverage multiple layers of processing to capture complex relationships between spectral variables and olive oil types. Their ability to learn patterns from large datasets makes them highly effective in predicting oil classifications with improved precision [21]–[25].
- Random forest: by combining multiple decision trees, these algorithms enhance accuracy and reduce overfitting, making them well-suited for classifying spectral data. Their robustness allows them to manage variability in olive oil samples and provide reliable classification results [26]–[30].
- K-nearest neighbors (K-NN): This proximity-based classification method is useful for identifying oil types based on similarities in VIS/NIR spectra. Its simplicity and efficiency make it a practical choice for quick and effective classification tasks [31]–[35].
- Linear discriminant analysis (LDA): This statistical approach is used to find the linear combination of features that best separates different classes of olive oil. It is widely applied for dimensionality reduction and improving classification performance in spectral analysis [36]–[40].

These machine learning techniques are complemented by preprocessing of the spectral data, such as normalization and baseline correction, improving predictive models' accuracy [21]–[25]. The evaluation metrics used, such as precision, sensitivity, and specificity, allow the effectiveness of these models to be measured [27]–[31]. Thanks to these techniques, high precision in olive oil classification has been achieved [32]–[41]. They have also demonstrated significant improvements in speed and accuracy compared to traditional methods [42]–[50].

Table 7. Techniques obtained

#	Techniques	Cantidad	Referencia
1	VIS/NIR reflectance and transmission spectroscopy	8	[1]–[8]
2	Machine learning algorithms like SVM	12	[9]–[18], [19], [20]
3	Data preprocessing: Normalization and baseline correction	6	[21]–[26]
4	Evaluation metrics: Accuracy, sensitivity, specificity	5	[27]–[31]
5	High precision in olive oil classification	10	[32]–[41]
6	Improvements in speed and accuracy compared to traditional methods	9	[42]–[50]
#	Total	50	

3.4. Precision levels and comparison of methods in the detection of the type of olive oil

Predictive models based on machine learning have demonstrated high precision and efficiency in detecting and classifying olive oil types using VIS/NIR techniques [10]–[17]. These models replicate complex and adaptive patterns, allowing for accurate product classification. However, certain limitations have been reported, such as sample variability and processing conditions, which may affect the accuracy and consistency of the results. The need for constant optimization and adjustments to the models is also an important barrier that must be overcome to improve the implementation of these methods.

The combination of VIS/NIR and machine learning techniques offers advantages compared to traditional olive oil-type detection methods. Analyses performed using VIS/NIR and machine learning are faster and non-destructive, significantly improving the efficiency of the detection process. Furthermore, quality control automation reduces human intervention and minimizes errors, allowing a rapid response to quality problems [25]–[28]. In comparison, traditional methods are typically slower and more destructive, which can limit their applicability in large-scale production environments [30]–[37]. The generation and curation of centralized databases also improve product traceability and authenticity, offering a more integrated and robust approach to olive oil quality control [40]–[44]; for more details, see Table 8.

Table 8. Number of technological approaches

#	Technological Approaches	Quantity	References
1	Predictive models with machine learning	4	[10]–[17]
2	Automation and optimization of quality control	4	[25]–[28]
3	Generation and conservation of centralized databases of olive oil spectra	7	[30]–[37]
4	Implementation of real-time analysis systems for rapid response to quality problems	7	[40]–[44]
#	Total	22	

4. CONCLUSION

The combination of visible/near-infrared spectroscopy (VIS/NIR) and machine learning techniques has been highlighted as an effective and efficient tool for detecting and classifying olive oil. The systematic review process addressed three main phases: initially, a comprehensive search of records was performed, resulting in 1329 documents. Subsequently, after the elimination of duplicates and review according to inclusion criteria, 101 articles were selected for further evaluation. Finally, after applying strict criteria, 53 records were included that met the specific requirements of oil type analysis and application of VIS/NIR spectroscopy together with machine learning.

According to the results, the distribution of these articles, Scopus stood out as the primary source with 34 articles, maintaining the highest number even after applying the relevant filters. ScienceDirect contributed 15 relevant articles, while PubMed contributed four more. These results evidence a growing interest and development in advanced analytical methods to improve the authenticity and traceability of olive oil, which are crucial aspects of quality assurance in the production chain.

The potential of rapid, non-destructive analysis using VIS/NIR spectroscopy, coupled with the predictive power of machine learning techniques, is truly transformative. This promising approach is set to revolutionize quality and safety standards in the olive oil industry. It optimizes quality control processes and equips us with practical tools to address emerging challenges in the authenticity and traceability of high-demand food products such as olive oil. This information should inspire us to study the future of olive oil analysis.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest regarding this research. No financial or institutional support was received that could have influenced the analysis, results, or conclusions presented in this study.

INFORMED CONSENT

Since this research is a systematic review of previously published studies, no direct interaction with human participants took place. Additionally, all reviewed studies explicitly state that informed consent was obtained from their respective participants.

ETHICAL APPROVAL

This study consists of a systematic review and does not involve collecting new data from human or animal subjects. All research included in this review adhered to ethical guidelines and was approved by the respective institutional ethics committees. The findings and conclusions presented in this work were derived from an objective and transparent analysis of existing literature.

DATA AVAILABILITY

As this study is based on a systematic review, no new data was generated or analyzed. The information supporting this research is derived from previously published studies, which are publicly available and cited accordingly. Readers can refer to the original sources, including DOIs and links, for further details on the methodologies and findings discussed in this work.

REFERENCES

[1] E. Borràs and others, "Prediction of olive oil sensory descriptors using instrumental data fusion and partial least squares (PLS) regression," *Talanta*, vol. 155, pp. 116–123, Aug. 2016, doi: 10.1016/J.TALANTA.2016.04.040.

[2] N. Abu-Khalaf and M. Hmidat, "Visible/Near Infrared (VIS/NIR) spectroscopy as an optical sensor for evaluating olive oil quality," *Comput Electron Agric*, vol. 173, 2020, doi: 10.1016/j.compag.2020.105445.

[3] X. Meng and others, "Rapid detection of adulteration of olive oil with soybean oil combined with chemometrics by Fourier transform infrared, visible-near-infrared and excitation-emission matrix fluorescence spectroscopy: A comparative study," *Food Chem*, vol. 405, p. 134828, Mar. 2023, doi: 10.1016/J.FOODCHEM.2022.134828.

[4] L. G. Dias, A. Fernandes, A. C. A. Veloso, A. A. S. C. Machado, J. A. Pereira, and A. M. Peres, "Single-cultivar extra virgin olive oil classification using a potentiometric electronic tongue," *Food Chem*, vol. 160, pp. 321–329, Oct. 2014, doi: 10.1016/J.FOODCHEM.2014.03.072.

[5] G. S. Folli and others, "Food analysis by portable NIR spectrometer," *Food Chemistry Advances*, vol. 1, p. 100074, Oct. 2022, doi: 10.1016/J.FOCHA.2022.100074.

[6] D. Zappi, C. Sadun, L. Gontrani, D. Dini, and M. L. Antonelli, "A new electrochemical sensor for extra-virgin olive oils classification," *Food Control*, vol. 109, p. 106903, Mar. 2020, doi: 10.1016/J.FOODCONT.2019.106903.

[7] A. Tay, R. K. Singh, S. S. Krishnan, and J. P. Gore, "Authentication of Olive Oil Adulterated with Vegetable Oils Using Fourier Transform Infrared Spectroscopy," *LWT - Food Science and Technology*, vol. 35, no. 1, pp. 99–103, Feb. 2002, doi: 10.1006/FSTL.2001.0864.

[8] T. Bhowmik, A. Chowdhury, and S. K. Das Mandal, "Deep Neural Network based Place and Manner of Articulation Detection and Classification for Bengali Continuous Speech," *Procedia Comput Sci*, vol. 125, pp. 895–901, Jan. 2018, doi: 10.1016/J.PROCS.2017.12.114.

[9] J. Schmidhuber, "Deep Learning in neural networks: An overview," *Neural Networks*, vol. 61, pp. 85–117, Jan. 2015, doi: 10.1016/j.neunet.2014.09.003.

[10] W. Liu, Z. Wang, X. Liu, N. Zeng, Y. Liu, and F. E. Alsaadi, "A survey of deep neural network architectures and their applications," *Neurocomputing*, vol. 234, pp. 11–26, Apr. 2017, doi: 10.1016/J.NEUCOM.2016.12.038.

[11] M. Meenu, Q. Cai, and B. Xu, "A critical review on analytical techniques to detect adulteration of extra virgin olive oil," *Trends Food Sci Technol*, vol. 91, pp. 391–408, Sep. 2019, doi: 10.1016/J.TIFS.2019.07.045.

[12] E. J. Rifna and others, "Advanced process analytical tools for identification of adulterants in edible oils – A review," *Food Chem*, vol. 369, p. 130898, Feb. 2022, doi: 10.1016/J.FOODCHEM.2021.130898.

[13] M. A. Faria, S. C. Cunha, A. G. Paice, and M. B. P. P. Oliveira, "Olive oil authenticity evaluation by chemical and biological methodologies," in *Olives and Olive Oil in Health and Disease Prevention*, 2010, pp. 101–107. doi: 10.1016/B978-0-12-374420-3.00012-7.

[14] M. K. Hazreen-Nita and others, "Olive oil by-products in aquafeeds: opportunities and challenges," *Aquac Rep*, vol. 22, p. 100998, Feb. 2022, doi: 10.1016/J.AQREP.2021.100998.

[15] E. Borràs and others, "Identification of olive oil sensory defects by multivariate analysis of mid infrared spectra," *Food Chem*, vol. 187, pp. 197–203, Nov. 2015, doi: 10.1016/J.FOODCHEM.2015.04.030.

[16] G. Aiello and D. Tosi, "An Artificial Intelligence-based Tool to Predict 'Unhealthy' Wine and Olive Oil," *J Agric Food Res*, p. 101179, Apr. 2024, doi: 10.1016/J.JAFR.2024.101179.

[17] M. Gavahian and others, "Health benefits of olive oil and its components: Impacts on gut microbiota antioxidant activities, and prevention of noncommunicable diseases," *Trends Food Sci Technol*, vol. 88, pp. 220–227, Jun. 2019, doi: 10.1016/J.TIFS.2019.03.008.

[18] A. Ruiz-Aracama, E. Goicoechea, and M. D. Guillén, "Direct study of minor extra-virgin olive oil components without any sample modification. 1H NMR multisupression experiment: A powerful tool," *Food Chem*, vol. 228, pp. 301–314, Aug. 2017, doi: 10.1016/J.FOODCHEM.2017.02.009.

[19] A. Castillo-Luna, C. A. Ledesma-Escobar, R. Gómez-Díaz, and F. Priego-Capote, "The secoiridoid profile of virgin olive oil conditions phenolic metabolism," *Food Chem*, vol. 395, p. 133585, Nov. 2022, doi: 10.1016/J.FOODCHEM.2022.133585.

[20] F. Hashempour-baltork and others, "Recent methods in detection of olive oil adulteration: State-of- the-Art," *J Agric Food Res*, vol. 16, p. 101123, Jun. 2024, doi: 10.1016/J.JAFR.2024.101123.

[21] I. A. Van Wetten, A. W. Van Herwaarden, R. Splinter, R. Boerrigter-Eenling, and S. M. Van Ruth, "Detection of sunflower oil in

extra virgin olive oil by fast differential scanning calorimetry," *Thermochim Acta*, vol. 603, pp. 237–243, Mar. 2015, doi: 10.1016/J.TCA.2014.11.030.

[22] T. C. Liang, H. S. Huang, and M. H. Chuang, "Study on fiber grating sensors for concentration measurement of cottonseed oil adulteration in pure olive oil," *Microelectron Eng*, vol. 148, pp. 21–24, Dec. 2015, doi: 10.1016/J.MEE.2015.08.003.

[23] N. Gutierrez, M. L. Rodríguez-Méndez, and J. A. De Saja, "Array of sensors based on lanthanide bisphtahlocyanine Langmuir–Blodgett films for the detection of olive oil aroma," *Sens Actuators B Chem*, vol. 77, no. 1–2, pp. 437–442, Jun. 2001, doi: 10.1016/S0925-4005(01)00752-3.

[24] R. Stella, J. N. Barisci, G. Serra, G. G. Wallace, and D. De Rossi, "Characterisation of olive oil by an electronic nose based on conducting polymer sensors," *Sens Actuators B Chem*, vol. 63, no. 1–2, pp. 1–9, Apr. 2000, doi: 10.1016/S0925-4005(99)00510-9.

[25] R. Garrido-Delgado, M. E. Muñoz-Pérez, and L. Arce, "Detection of adulteration in extra virgin olive oils by using UV-IMS and chemometric analysis," *Food Control*, vol. 85, pp. 292–299, Mar. 2018, doi: 10.1016/J.FOODCONT.2017.10.012.

[26] W. C. O. Araújo, A. F. G. Viera, and G. Varvakis, "Effectiveness of automated tools for developing search strategies in PubMed and Embase: constructing the PICO research question | Eficácia das ferramentas automatizadas para elaboração de estratégias de busca na PubMed e Embase: construindo a pergunta de," *Biblios*, vol. 86, pp. 114–135, 2023, doi: 10.5195/biblios.2023.1050.

[27] R. Reda and others, "Optimized variable selection and machine learning models for olive oil quality assessment using portable near infrared spectroscopy," *Spectrochim Acta A Mol Biomol Spectrosc*, vol. 303, 2023, doi: 10.1016/j.saa.2023.123213.

[28] A. C. Bethel, M. Rogers, and R. Abbott, "Use of a search summary table to improve systematic review search methods, results, and efficiency," *Journal of the Medical Library Association*, vol. 109, no. 1, pp. 97–106, 2021, doi: 10.5195/jmla.2021.809.

[29] S. Violino, C. Taiti, L. Ortenzi, E. Marone, F. Pallottino, and C. Costa, "A ready-to-use portable VIS–NIR spectroscopy device to assess superior EVOO quality," *European Food Research and Technology*, vol. 248, no. 4, pp. 1011–1019, 2022, doi: 10.1007/s00217-021-03941-5.

[30] Y. Yakar and K. Karadag, "Identifying olive oil fraud and adulteration using machine learning algorithms," *Quim Nova*, vol. 45, no. 10, pp. 1245–1250, 2022, doi: 10.21577/0100-4042.20170948.

[31] A. Arroyo-Cerezo, X. Yang, A. M. Jiménez-Carvelo, M. Pellegrino, A. F. Savino, and P. Berzaghi, "Assessment of extra virgin olive oil quality by miniaturized near infrared instruments in a rapid and non-destructive procedure," *Food Chem*, vol. 430, 2024, doi: 10.1016/j.foodchem.2023.137043.

[32] B. Giussani, A. T. Escalante-Quiceno, R. Boqué, and J. Riu, "Measurement strategies for the classification of edible oils using low-cost miniaturised portable nir instruments," *Foods*, vol. 10, no. 11, 2021, doi: 10.3390/foods10112856.

[33] A. M. Pérez-Calabuig, S. Pradana-López, A. Ramayo-Muñoz, J. C. Cancilla, and J. S. Torrecilla, "Deep quantification of a refined adulterant blended into pure avocado oil," *Food Chem*, vol. 404, 2023, doi: 10.1016/j.foodchem.2022.134474.

[34] V. Surya and A. Senthilselvi, "Identification of oil authenticity and adulteration using deep long short-term memory-based neural network with seagull optimization algorithm," *Neural Comput Appl*, vol. 34, no. 10, pp. 7611–7625, 2022, doi: 10.1007/s00521-021-06829-3.

[35] P. Veginadu, H. Calache, M. Gussy, A. Pandian, and M. Masood, "An overview of methodological approaches in systematic reviews," *J Evid Based Med*, vol. 15, no. 1, pp. 39–54, 2022, doi: 10.1111/jebm.12468.

[36] C.-H. Lu, B.-Q. Li, Q. Jing, D. Pei, and X.-Y. Huang, "A classification and identification model of extra virgin olive oil adulterated with other edible oils based on pigment compositions and support vector machine," *Food Chem*, vol. 420, 2023, doi: 10.1016/j.foodchem.2023.136161.

[37] S. Violino, C. Taiti, E. Marone, F. Pallottino, and C. Costa, "A statistical tool to determine the quality of extra virgin olive oil (EVOO)," *European Food Research and Technology*, vol. 248, no. 11, pp. 2825–2832, 2022, doi: 10.1007/s00217-022-04092-x.

[38] N. Gyftokostas, E. Nanou, D. Stefas, V. Kokkinos, C. Bouras, and S. Couris, "Classification of Greek olive oils from different regions by machine learning-aided laser-induced breakdown spectroscopy and absorption spectroscopy," *Molecules*, vol. 26, no. 5, 2021, doi: 10.3390/molecules26051241.

[39] V. Skiada, P. Katsaris, M. E. Kambouris, V. Gkisakis, and Y. Manoussopoulos, "Classification of olive cultivars by machine learning based on olive oil chemical composition," *Food Chem*, vol. 429, 2023, doi: 10.1016/j.foodchem.2023.136793.

[40] O. Gumus, E. Yasar, Z. P. Gumus, and H. Ertas, "Comparison of different classification algorithms to identify geographic origins of olive oils," *J Food Sci Technol*, vol. 57, no. 4, pp. 1535–1543, 2020, doi: 10.1007/s13197-019-04189-4.

[41] B. Vega-Márquez, I. Nepomuceno-Chamorro, N. Jurado-Campos, and C. Rubio-Escudero, "Deep Learning Techniques to Improve the Performance of Olive Oil Classification," *Front Chem*, vol. 7, 2020, doi: 10.3389/fchem.2019.00929.

[42] D. Stefas and others, "Discrimination of olive oils based on the olive cultivar origin by machine learning employing the fusion of emission and absorption spectroscopic data," *Food Control*, vol. 130, 2021, doi: 10.1016/j.foodcont.2021.108318.

[43] O. Gazeli, E. Bellou, D. Stefas, and S. Couris, "Laser-based classification of olive oils assisted by machine learning," *Food Chem*, vol. 302, 2020, doi: 10.1016/j.foodchem.2019.125329.

[44] E. Bellou, N. Gyftokostas, D. Stefas, O. Gazeli, and S. Couris, "Laser-induced breakdown spectroscopy assisted by machine learning for olive oils classification: The effect of the experimental parameters," *Spectrochim Acta Part B At Spectrosc*, vol. 163, 2020, doi: 10.1016/j.sab.2019.105746.

[45] M. Rashvand, G. Altieri, A. Matera, F. Genovese, and G. C. Di Renzo, "Potential of low frequency dielectric spectroscopy and machine learning methods for extra virgin olive oils discrimination based on the olive cultivar and ripening stage," *Journal of Food Measurement and Characterization*, vol. 17, no. 3, pp. 2917–2931, 2023, doi: 10.1007/s11694-023-01836-5.

[46] E. Ordukaya and B. Karlik, "Quality control of olive oils using machine learning and electronic nose," *J Food Qual*, vol. 2017, 2017, doi: 10.1155/2017/9272404.

[47] F. Venturini, S. Fluri, M. Mejari, M. Baumgartner, D. Piga, and U. Michelucci, "Shedding light on the ageing of extra virgin olive oil: Probing the impact of temperature with fluorescence spectroscopy and machine learning techniques," *LWT*, vol. 191, 2024, doi: 10.1016/j.lwt.2023.115679.

[48] S. Lohumi, S. Lee, H. Lee, and B.-K. Cho, "A review of vibrational spectroscopic techniques for the detection of food authenticity and adulteration," *Trends Food Sci Technol*, vol. 46, no. 1, pp. 85–98, 2015, doi: 10.1016/j.tifs.2015.08.003.

[49] F. Venturini, M. Sperti, U. Michelucci, A. Gucciardi, V. M. Martos, and M. A. Deriu, "Extraction of physicochemical properties from the fluorescence spectrum with 1D convolutional neural networks: Application to olive oil," *J Food Eng*, vol. 336, p. 111198, Jan. 2023, doi: 10.1016/J.JFOODENG.2022.111198.

[50] K. Kottaridi, M. Anna, D. Vasilis, R. Aimilia, and N. Vasileios, "A regression analysis method for the prediction of olive oil sensory attributes," *J Agric Food Res*, vol. 12, 2023, doi: 10.1016/j.jafr.2023.100555.

[51] R. Beghi, V. Giovenzana, R. Civelli, E. Cini, and R. Guidetti, "Characterisation of olive fruit for the milling process by using visible/near infrared spectroscopy," *Journal of Agricultural Engineering*, vol. 44, no. 2, pp. 56–61, 2013, doi:

10.4081/jae.2013.e8.
[52] C. G. Viejo and S. Fuentes, "Digital detection of olive oil rancidity levels and aroma profiles using near-infrared spectroscopy, a low-cost electronic nose and machine learning modelling," *Chemosensors*, vol. 10, no. 5, 2022, doi: 10.3390/chemosensors10050159.
[53] S. Grassi and others, "Near infrared spectroscopy as a green technology for the quality prediction of intact olives," *Foods*, vol. 10, no. 5, 2021, doi: 10.3390/foods10051042.
[54] N. Gyftokostas, D. Stefas, and S. Couris, "Olive oils classification via laser-induced breakdown spectroscopy," *Applied Sciences (Switzerland)*, vol. 10, no. 10, 2020, doi: 10.3390/app10103462.
[55] J. F. G. Martín, "Optical path length and wavelength selection using Vis/NIR spectroscopy for olive oil's free acidity determination," *Int J Food Sci Technol*, vol. 50, no. 6, pp. 1461–1467, 2015, doi: 10.1111/ijfs.12790.
[56] E. Valli and others, "Rapid and innovative instrumental approaches for quality and authenticity of olive oils," *European Journal of Lipid Science and Technology*, vol. 118, no. 11, pp. 1601–1619, 2016, doi: 10.1002/ejlt.201600065.
[57] M. I. Sánchez-Rodríguez, E. Sánchez-López, A. Marinas, J. M. Caridad, and F. J. Urbano, "Redundancy analysis to reduce the high-dimensional near-infrared spectral information to improve the authentication of olive oil," *J Chem Inf Model*, vol. 62, no. 19, pp. 4620–4628, 2022, doi: 10.1021/acs.jcim.2c00964.
[58] V. Giovenzana, R. Beghi, R. Romaniello, A. Tamborrino, R. Guidetti, and A. Leone, "Use of visible and near infrared spectroscopy with a view to on-line evaluation of oil content during olive processing," *Biosyst Eng*, vol. 172, pp. 102–109, 2018, doi: 10.1016/j.biosystemseng.2018.06.001.
[59] A. Casson, R. Beghi, V. Giovenzana, I. Fiorindo, A. Tugnolo, and R. Guidetti, "Visible near infrared spectroscopy as a green technology: An environmental impact comparative study on olive oil analyses," *Sustainability (Switzerland)*, vol. 11, no. 9, 2019, doi: 10.3390/su11092611.
[60] M. del M. Garrido-Cuevas, A.-M. Garrido-Varo, P. Oliveri, M.-T. Sánchez, and D. Pérez-Marín, "In-house validation of a visible and near infrared spectroscopy non-targeted method to support panel test of virgin olive oils," *Food Research International*, vol. 192, p. 114799, Sep. 2024, doi: 10.1016/j.foodres.2024.114799.
[61] L. Salguero-Chaparro and F. Peña-Rodríguez, "On-line versus off-line NIRS analysis of intact olives," *LWT - Food Science and Technology*, vol. 56, no. 2, pp. 363–369, May 2014, doi: 10.1016/J.LWT.2013.11.032.
[62] C. Scatigno and G. Festa, "FTIR coupled with machine learning to unveil spectroscopic benchmarks in the Italian EVOO," *Int J Food Sci Technol*, vol. 57, no. 7, pp. 4156–4162, 2022, doi: 10.1111/ijfs.15735.
[63] N. Gyftokostas, D. Stefas, V. Kokkinos, C. Bouras, and S. Couris, "Laser-induced breakdown spectroscopy coupled with machine learning as a tool for olive oil authenticity and geographic discrimination," *Sci Rep*, vol. 11, no. 1, 2021, doi: 10.1038/s41598-021-84941-z.
[64] R.-Y. Xian and others, "Quantitative analysis of deep-frying oil adulterated virgin olive oil using Vis-NIR spectroscopy with iPLS," *Guang Pu Xue Yu Guang Pu Fen Xi/Spectroscopy and Spectral Analysis*, vol. 36, no. 8, pp. 2462–2467, 2016, doi: 10.3964/j.issn.1000-0593(2016)08-2462-06.
[65] M. del M. Garrido-Cuevas, A.-M. Garrido-Varo, F. Marini, M.-T. Sánchez, and D. Pérez-Marín, "Enhancing virgin olive oil authentication with Bayesian probabilistic models and near infrared spectroscopy," *Journal of Food Engineering*, vol. 391, p. 112443, May 2025, doi: 10.1016/j.jfoodeng.2024.112443.
[66] J. Liang and others, "Global overview of anterior cruciate ligament reconstruction in children and adolescents over the past 20 years: a bibliometric analysis," *J Orthop Surg Res*, vol. 19, no. 1, 2024, doi: 10.1186/s13018-024-04829-2.
[67] S.-H. Zhao and others, "A bibliometric analysis of the spatial transcriptomics literature from 2006 to 2023," *Cell Mol Neurobiol*, vol. 44, no. 1, 2024, doi: 10.1007/s10571-024-01484-3.
[68] W. Yan, M. Li, and L. Zhang, "Bibliometric analysis on the structure and function of IL17," *Egyptian Rheumatology and Rehabilitation*, vol. 51, no. 1, 2024, doi: 10.1186/s43166-023-00236-3.

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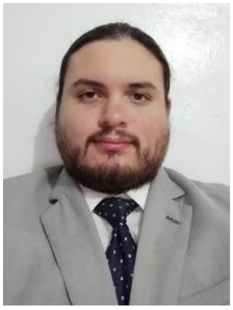

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