

# Precise Classification of Five Grades *Aquilaria Malaccensis* Essential Oil: Multiclass Support Vector Machine Utilizing Pattern Graphical Representation on a Two-dimensional Graph

Anis Hazirah 'Izzati Hasnu Al-Hadi<sup>1</sup>, Noor Aida Syakira Ahmad Sabri<sup>1</sup>, Nurlaila Ismail<sup>1\*</sup>, Zakiah Mohd Yusoff<sup>1</sup>, Ali Abd Almisreb<sup>3</sup>, Saiful Nizam Tajuddin<sup>2</sup>, Mohd Nasir Taib<sup>1</sup>

<sup>1</sup> School of Electrical Engineering, College of Engineering,  
Universiti Teknologi MARA Shah Alam, 40450 Selangor, MALAYSIA

<sup>2</sup> Bioaromatic Research Centre,  
Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Gambang, Pahang, MALAYSIA

<sup>3</sup> Faculty of Engineering and Natural Sciences,  
International University of Sarajevo, 71000 Ilidža, BOSNIA-HERZEGOVINA

\*Corresponding Author: [nurlaila0583@uitm.edu.my](mailto:nurlaila0583@uitm.edu.my)

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## Abstract

A member of the *Thymelaeaceae* family, *Aquilaria Malaccensis* is a well-known tree species recognized for its aromatic resinous wood. In Indonesia and Malaysia, the tree is known by local names such "gaharu" and "karas". Its resinous wood is highly valued for its distinct scent and is commonly used in cultural, religious, and economic settings. The absence of a uniform grading system weakens market stability for agarwood essential oil. Creating a standardized grading system is vital to tackle these problems and maintain the stability the industry. This study aims to demonstrate the effectiveness of Multiclass Support Vector Machine (MSVM) strategies in evaluating agarwood essential oil. The MSVM is recognized as a highly successful classification tool. The MSVM was built using a Radial Basis Function (RBF) as the kernel function in MATLAB2021b. There are 660 data samples for each of the 11 chemical elements in the dataset. The agarwood essential oil is classified into a total of five grades. The research presented in this study demonstrates that the actual and predicted data for five grades do not differ in 5x5 confusion matrix, with the pattern graphical representation being dispersed according to its quality classification. The model attained 100% accuracy, sensitivity, specificity, and precision, as evidenced by a 5x5 confusion matrix in which actual and predicted data are aligned perfectly. The results validate that the MSVM model can consistently categorize the agarwood essential oil quality grades, hence establishing a reliable foundation for grading assessment in the industry.

## 1. Introduction

*Aquilaria Malaccensis* trees are famous for yielding resin-infused wood with a pleasant fragrance, often called Agarwood [1, 2]. In Malaysia, Agarwood is famously known as “Gaharu” [2]. Agarwood is highly valued as a non-timber forest resource because of its immense demand. It is valuable in traditional medicine, aids in the creation of scented items, and is an essential ingredient in religious and cultural rituals and celebrations in different countries and religions [1, 3]. Recently, several types of agarwood products and crafts have flooded the market, leading to a significant issue of counterfeit mixing [4]. Currently, the agarwood available in the market originates from various sources and requires physical processing before it can be utilized in medicine or any type of fragrances. Assessing the quality of agarwood based on its physical features is challenging, and distinguishing between different agarwood craftsmen is even more complex and challenging. Identifying the fraud in the market with a naked eye is nearly impossible, leading to high prevalence of fraud [4].

Yet, a globally acknowledged benchmark for agarwood essential oil is still being established [4-5]. Various countries use different techniques to assess the quality of agarwood essential oil [4, 6], with the current grading system largely based on consumer perception and preferences. Doubts may emerge since the grading process varies among countries that export agarwood essential oil [7]. The lack of a defined identification techniques allows for the possibility of manipulations and fraudulent acts, leading to the sale of low-quality oil at higher costs.

Most researchers in recent years have been using innovative techniques based on the chemical elements of agarwood essential oil [8-11]. This study purposes utilizing a MSVM using the standard template in MATLAB2021b as a smart grading approach for classification of agarwood essential oil. The emphasis is on five grades of agarwood essential oil – low, medium low, upper low, medium high and high. Evaluating the performance of MSVM involves analyzing the parameters such as accuracy, sensitivity, specificity, precision and utilizing a confusion matrix of 5x5.

## 2. Literature Work

Support Vector Machine (SVM) is a robust supervised learning technique utilized for classification and regression tasks [12-13]. It is highly efficient in high-dimensional spaces and is commonly applied in pattern recognition, picture classification, text classification, and bioinformatics. SVM operates by identifying the ideal hyperplane that effectively divides the data into distinct groups while maximizing the margin between them [14]. SVM has demonstrated efficacy in solving real binary classification issues. SVM has demonstrated superior efficiency compared to other supervised learning techniques [14-15]. A crucial stage in the process is training the SVM decision function, which entails finding a hyperplane that maximizes the distance or margin between the support vectors of the two classes [13, 15-16]. The hyperplane acts as the decision boundary that divides the classes in the feature space. SVM differs from classic classifiers like logistic regression by emphasizing the identification of an ideal hyperplane, leading to enhanced generalization performance and reduced classification errors, especially when dealing with limited input data [13-15].

By optimizing the margin between classes, SVM can effectively generalize from training data to unknown data, which is the fundamental idea underlying the algorithm. Support vectors, the data points nearest to the decision boundary, are essential in determining the margin [14, 17]. SVM may develop a strong decision function for reliably classifying fresh data points by effectively recognizing and utilizing these support vectors. SVM has the capability to obtain good classification performance by utilizing a tiny fraction of the original dataset. SVM is computationally and memory-efficient for large datasets since only a small number of support vectors are needed to establish the decision boundary [17-18].

SVM rely heavily on kernel functions to decide how to translate data points into higher-dimensional areas where a hyperplane can divide them. The selection of kernel function and its parameters has a substantial impact on the efficacy of SVM [14]. Conversely, the binary SVM can be expanded to accommodate the multiclass scenarios commonly found in remote sensing applications. To do this, the multiclass problem is usually broken down into a sequence of binary analyses that can be solved using a binary SVM with a multiclass technique like the One Versus All (OVA) strategy [19]. The technique of utilizing binary classification algorithms for multi-class classification is known as "One vs. All" [20-21]. It involves dividing the multi-class dataset into multiple binary classification tasks. For each binary classification task, a binary classifier is trained, and the model with the highest confidence is utilized for making predictions [20].

Once a categorization model has been built and tested, it is crucial to assess its efficacy in meeting the established goals. Assessing the model's performance is essential for determining its applicability for real-world applications. Commonly utilized key performance measurements for this purpose include sensitivity, specificity, precision, and accuracy [22]. Evaluation is essential as it determines the model's ability to generalize to unfamiliar data. It aids in detecting possible problems like overfitting or underfitting and offers guidance for enhancing and adjusting the model. Furthermore, assessing previously unexplored data helps to prevent bias in the model's performance caused by the training dataset.

The study conducted in [23] examined the classification of agarwood essential oil into low and high grades using the RBF kernel parameter. The generated model successfully met all performance measures for RBF. The performance measures include specificity (%), sensitivity (%), accuracy (%), precision (%), error test, and error rates. All the performance measurements achieved scores higher than 80%. It has been demonstrated that RBF has excellent performance in the classification of agarwood essential oil [23]. The previous study conducted in [22] conducted a comparative analysis of Multilayer Perceptron (MLP) and RBF in the classification of agarwood essential oil into low and high grades. According to the study, RBF had superior performance in categorizing agarwood essential oil compared to MLP [22].

### 3. Methodology

#### 3.1 Data Acquisition and Pre-Processing Analysis

A total of 660 data samples were obtained from the Forest Research Institute Malaysia (FRIM) [23] and analyzed at the Bio-Aromatic Research Centre of Excellence (BARCE) using gas chromatography-mass spectrometry (GC-MS) in accordance with a standard operating procedure [24]. Previous research studies [8] contains comprehensive details regarding the data acquisition procedure. The primary chemical elements that were identified are as follows: 10-epi- $\gamma$ -eudesmol,  $\alpha$ -agarofuran,  $\beta$ -agarofuran,  $\gamma$ -eudesmol, dihydrocollumellarin,  $\alpha$ -guaiene, allo aromadendrene epoxide, valerianol, ar-curcumene,  $\beta$ -dihydro agarofuran, and  $\gamma$ -cadinene.

The focus of the pre-processing analysis, which involved boxplot analysis, was to identify the most critical chemical elements that were associated with the four grades of agarwood essential oil that comprised the initial data set of the study. In [25], the pre-processing analysis's detailed results are examined. The most significant chemical elements were  $\alpha$ -agarofuran,  $\beta$ -agarofuran, and 10-epi- $\gamma$ -eudesmol, as per the results of [25]. Fig. 1. illustrates that these three elements were established as indicators for the classification of agarwood essential oil into five grades. Fig. 2 shows the summary of the agarwood essential oil samples from 4 grades to 5 grades.

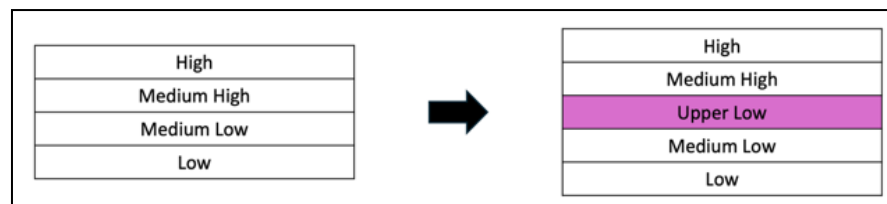


Fig. 1 Data extraction from four grades to five grades

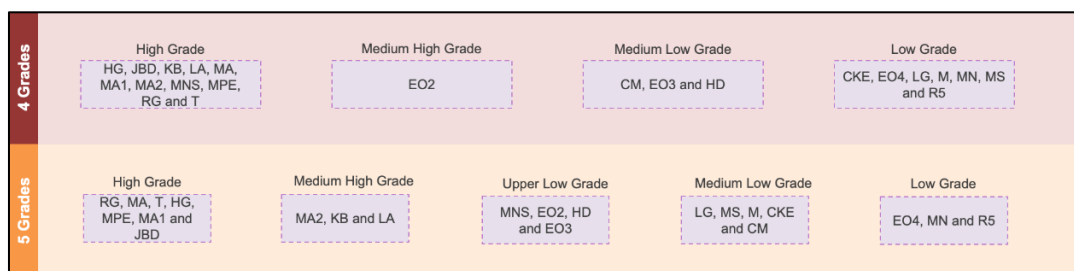


Fig. 2 The summary of the agarwood essential oil samples from 4 grades to 5 grades

#### 3.2 MSVM Model

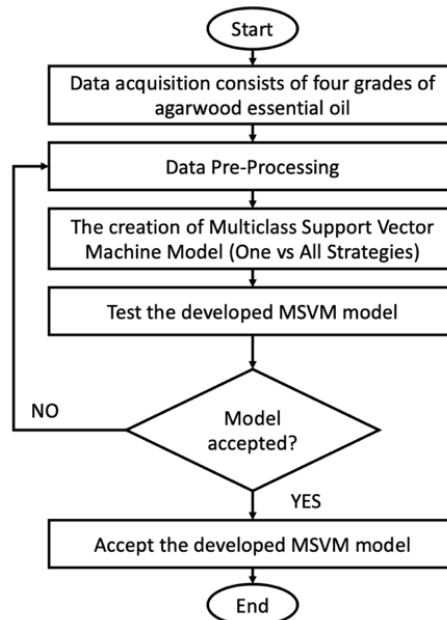
A self-organising map (SOM) was used in a prior study by [8] to classify the initial data samples of agarwood essential oil into four grades: low, medium low, medium, and high. By employing a multiclass support vector machine (MSVM) model to classify the agarwood essential oil into five grades—low, medium low, upper low, medium high, and high—the current study seeks to improve this classification. By include the "upper low" grade, the classification procedure becomes more precise and offers a more nuanced categorization.

A multiclass support vector machine model was created to categorize and assess the various grades for the purpose to do this. The study started by importing the input and output data into the MATLAB workspace, as shown in Fig. 3. The five predefined grades were represented in the output data, while the input data comprised 660 samples of agarwood essential oil. Pre-processing procedures for the data samples included normalization, randomization, and an 80:20 split of the data into training and testing sets.

The model applied SVM as the technique and classification as the type of analysis, using the Radial Basis Function (RBF) kernel as the parameter inside the standard template. A multiclass classification strategy based

on binary classifiers was used to provide robust categorization. In this machine learning job, the One Versus All (OVA) technique was chosen as the best approach for multiclass categorization. All 528 training samples were employed in the building of the SVM model, with the remaining 132 examples kept aside for testing and standard metrics evaluation of the model's performance.

This methodical approach not only made it easier to classify agarwood essential oil into the five different grades, but it also guaranteed the accuracy and dependability of the model, establishing a standard for further research and real-world uses in the classification of agarwood essential oils.



**Fig. 3** Flowchart of the study

### 3.3 Performance Measurement

The performance measurement of the MSVM classification model is done using a confusion matrix that includes accuracy, sensitivity, precision, and specificity. The confusion matrix chart depicts a 5x5 table representing five grades quality of agarwood essential oil: high, medium high, upper low, medium low, and low. Eq. 1 to 4 are the formulas for accuracy, sensitivity, specificity, and precision [26].

$$Accuracy = \frac{tp + tn_t}{tp + tn_t + fp_t + fn_t} \times 100 \quad (1)$$

$$Sensitivity = \frac{tp}{tp + fn_t} \times 100 \quad (2)$$

$$Specificity = \frac{tn_t}{tn_t + fp_t} \times 100 \quad (3)$$

$$Precision = \frac{tp}{tp + fp_t} \times 100 \quad (4)$$

## 4. Results and Discussion

This section discusses the pattern graphical representation and confusion matrix analysis of eleven chemical elements found in agarwood essential oil from 660 data samples extracted using GC-MS analysis. The study was conducted using MATLAB software version 2021b. The pattern graphical representation and confusion matrix to correspond with five different grades of agarwood essential oil quality. The 2D graph was utilized for pattern graphical representation. Subsection Pattern Graphical Representation and Confusion Matrix provide an intricate analysis of different grades of agarwood essential oil, with a specific emphasis on the distribution of chemical elements among these grades. The graphs presented in these sections visually illustrate the relationship between the concentration of different chemical elements and the overall potency of the agarwood essential oil. Subsection Pattern Graphical Representation shows the correlation between the concentration levels for significant chemical elements and the quality of agarwood essential oil. It has been noted that greater concentrations of elements are linked to better essential oil quality. This implies that the existence of these chemical elements is a sign of the sophistication and quality of the essential oil. It also provides more evidence to support the findings by

demonstrating a comparable pattern, where the arrangement and density of the chemical elements correspond to the varying levels of oil quality. The data points in both figures consistently show that essential oil of greater quality have a higher concentration of valuable chemical elements, thereby demonstrating a positive correlation. Both figures highlight the crucial significance of chemical element concentration in establishing the quality of agarwood essential oil. They visually demonstrate how these elements impact the grade and perceived worth of the essential oil.

#### 4.1 Pattern Graphical Representation

The pattern graphical representation had been done to analyze and see the eleven chemical elements – 10-epi- $\gamma$ -eudesmol,  $\alpha$ -agarofuran,  $\beta$ -agarofuran,  $\gamma$ -eudesmol, dihydrocollumellarin,  $\alpha$ -guaiene, allo aromadendrene epoxide, valerianol, ar-curcumene,  $\beta$ -dihydro agarofuran, and  $\gamma$ -cadinene. Fig. 4 displays the pattern graphical representation for five grades of agarwood essential oil. The scatter plot is clustered according to its grading classification – low, medium low, upper low, medium high and high. The low grade is clustered in red colour from 0 to 0.35 on the x-axis and 0 to 0.30 on y-axis. The scatter plot for medium low grade is in yellow colour ranges from 0.20 to 0.85 on the x-axis and 0 on the y-axis. The upper low grade is clustered in green colour from 0.45 to 0.55 on the x-axis and from 0 to 0.65 on the y-axis. The medium high grade clustered in blue colour ranges from 0.60 to 0.80 on the x-axis and from 0.50 to 0.60 on the y-axis. Finally, the high grade is clustered in purple colour ranges from 0.65 to 1.0 on the x-axis while on the y-axis, from 0.60 to 1.0. In conclusion, the pattern graph representation clearly shows the scatter plot clustered according to its grades.

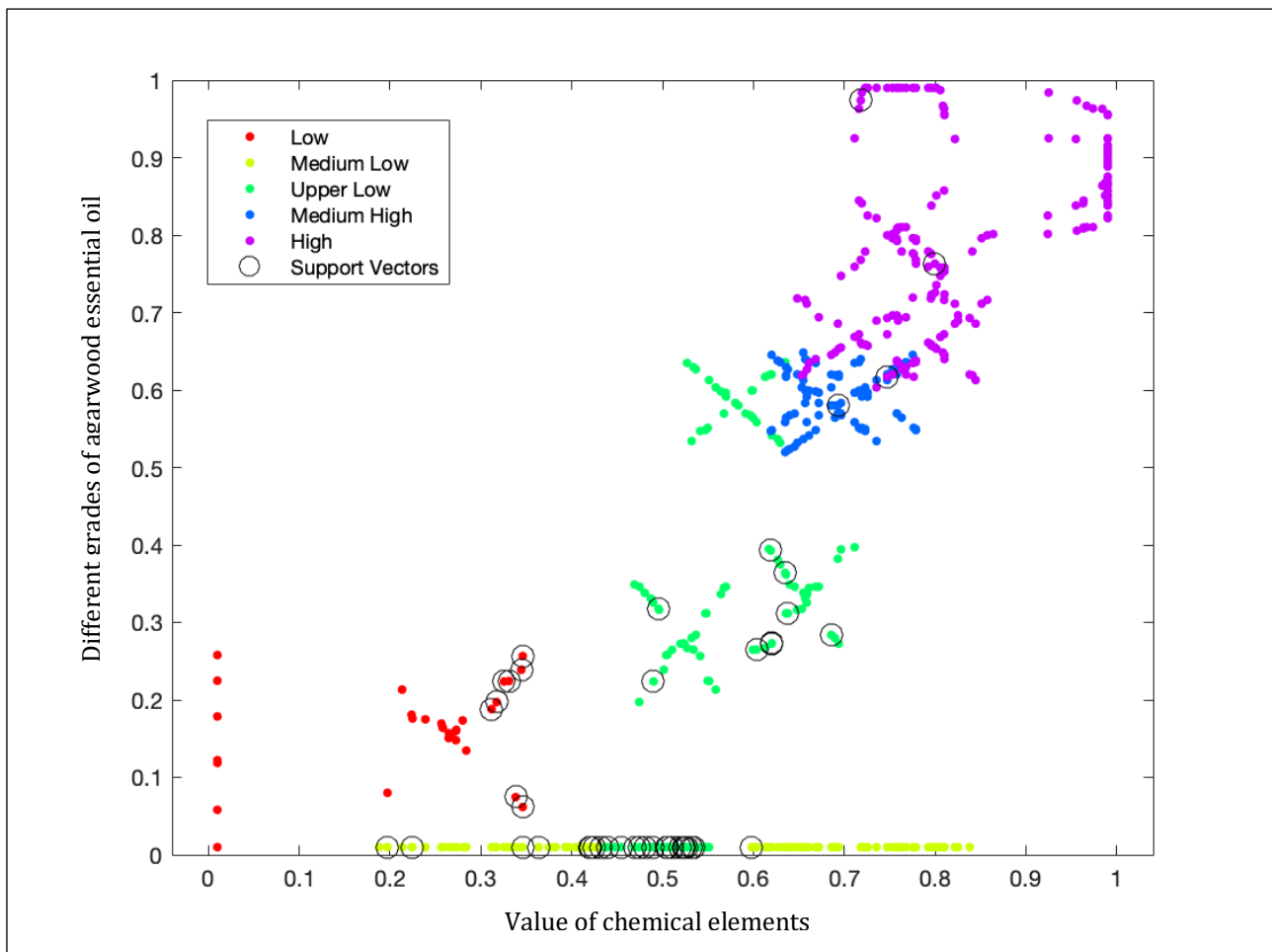


Fig. 4 Pattern graphical representation for five grades

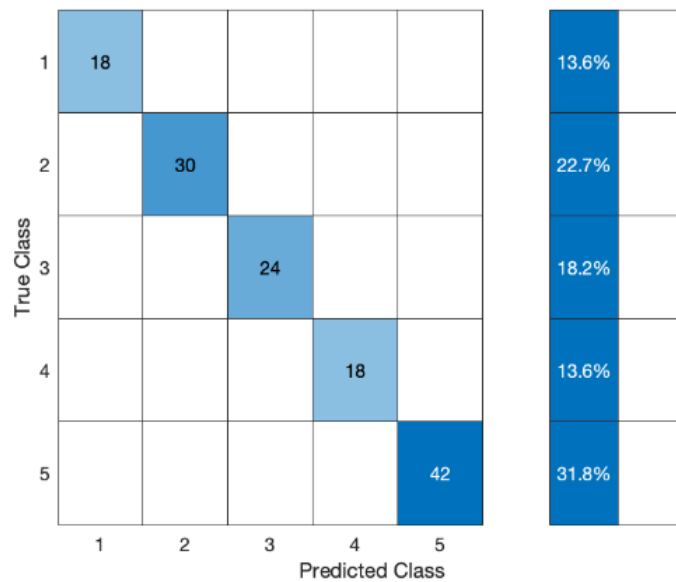
#### 4.2 Confusion Matrix

Fig. 5 illustrates the confusion matrix for the five grades. The initial data samples from four grades were utilized to construct the MSVM model, outlined in [8]. The distribution of testing data in the current study indicates that Class '1' (low grade) comprises 13.64% with 18 samples, Class '2' (medium-low grade) comprises 22.73% with 30 samples, Class '3' (upper low grade) comprises 18.18% with 24 samples, Class '4' (medium-high grade) includes 13.64% with 18 samples, and Class '5' (high grade) comprises 31.82% with 42 samples. It is important

to note that the confusion matrix in Fig. illustrates a flawless classification, with no discrepancies between the predicted and actual grades. This demonstrates the model’s ability to differentiate between the five quality grades.

In contrast to the findings of prior research, such as [8] , the classification accuracy was done by distinguishing up to four grades of agarwood essential oil only. The predictive performance of the model has been considerably improved by the increase in grading resolution and data specificity in the current study.

The quantity of samples for each purity grade of agarwood essential oil—low, medium low, upper low, medium high, and high—is summarized in Table 1. The dataset is composed of 660 samples, which are distributed as follows: There are 210 samples for high grade, 90 for medium high grade, 120 for upper low grade, 150 for medium low grade, and 90 for low grade. Table 2 illustrates that the present model's performance measurements, which include precision, specificity, sensitivity, and accuracy, all achieved a perfect score of 100%. This performance measurements emphasizing the significance of refining the grading criteria to enhance model accuracy and the efficacy of utilizing the identified essential chemical elements for classification.



**Fig. 5** Confusion matrix for five grades

**Table 1** Summary of number of samples for each of the five quality of agarwood essential oil

| Quality Classification | Number of Samples | Percentage |
|------------------------|-------------------|------------|
| High Grade             | 210               | 31.82%     |
| Medium High Grade      | 90                | 13.64%     |
| Upper Low Grade        | 120               | 18.18%     |
| Medium Low Grade       | 150               | 22.73%     |
| Low Grade              | 90                | 13.64%     |

**Table 2** Performance measurements for five grades

|             |      |
|-------------|------|
| Accuracy    | 100% |
| Sensitivity | 100% |
| Specificity | 100% |
| Precision   | 100% |

## 5. Conclusion

The MSVM classification model was created to classify agarwood essential oil into five distinct categories: low, medium low, upper low, medium high, and high. The study's findings serve as evidence that the classification task was successfully completed. The results prioritized a comprehensive analysis of the classification of agarwood essential oil categories before assessing the model's performance measurements. Scatter plots were employed to

visually represent the distribution of data points across various grades, thereby revealing distinct clustering tendencies. The data points from the same grade were closely clustered, resulting in distinct clusters for each grade. These clusters were easily identifiable by the different colors as displayed on the plots. This visual separation implies that the scatter plots effectively depict the differentiation between the classes, as the gaps between clusters indicate a distinct boundary between the various grades. This separation suggests that the classification model can effectively implement these distinct clusters to accurately classify samples into their respective classes.

The model's ability to differentiate between the five grades was assessed using a 5x5 confusion matrix in the classification approach. The confusion matrix offered a thorough analysis of the model's predictions in comparison to the actual grades, demonstrating a flawless alignment between the predicted and observed classifications. The model's performance was rigorously evaluated using key evaluation metrics, including accuracy, sensitivity, specificity, and precision, after the classification framework was established. During the assessment phase for the five grades, the model exhibited flawless classification with no discrepancies, achieving 100% across every measure of performance. This was a remarkable achievement.

The robustness of the MSVM model in administering multiple grades simultaneously is emphasized by its capacity to categorize agarwood essential oil into five different classes. The model's ability to reliably differentiate between different grades of agarwood essential oil was rigorously validated through the utilization of the confusion matrix and a comprehensive performance measurement. In addition to verify the classification model's reliability and robustness, this methodology offers valuable insights for future research and practical applications in the agarwood essential oil industry. The model's demonstrated precision and reliability render it a potent instrument for the advancement of the classification and quality control of agarwood essential oils, thereby establishing a solid foundation for future advancements in this field.

The standardized technique for classifying agarwood essential oil proposed in this study shows great potential for being widely adopted and implemented globally. The study includes thorough research and validation procedures to guarantee the reliability and accuracy of the classification system. The strength and reliability of the system inspire trust in future users regarding its ability to classify agarwood essential oil grades appropriately.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Ali Abd Almisreb, Mohd Nasir Taib; **data collection:** Saiful Nizam Tajuddin; **analysis and interpretation of results:** Anis Hazirah 'Izzati Hasnu Al-Hadi, Nurlaila Ismail, Zakiah Mohd Yusoff; **draft manuscript preparation:** Anis Hazirah 'Izzati Hasnu Al-Hadi, Noor Aida Syakira Ahmad Sabri. All authors reviewed the results and approved the final version of the manuscript.*

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