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Pattern analysis on *Aquilaria Malaccensis* using machine learning

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ABSTRACT

Aquilaria Malaccensis was found to generate agarwood. Because of its multiple benefits, agarwood essential oil, sometimes known as "black gold" is highly regarded universally. There is currently no accepted method for classifying various grades of agarwood essential oil. Due to the fact that the agarwood essential oil is assessed using a human sensory panel, the existing grading method is ineffective. Since different people may have different viewpoints on how to grade agarwood essential oil, it is not practical to apply the method universally. Several innovative methods for determining the classification of agarwood essential oil have been proposed and put into practise as a result of advanced technology. The study has constructed a pattern analysis on different grades of agarwood essential oil using 2D scatter plot. The results successfully indicate the scatter plots are scattered groupedly.

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1. INTRODUCTION

Agarwood is the fragrant resinous heartwood of Southeast Asian trees belong to the *Aquilaria malaccensis* (Thymelaeaceae) species [1]–[9]. The agarwood essential oil, or regarded as oudh oil, is extracted from agarwood trees. It is a non-timber forest product that is highly valued for its medicinal, aromatic, ceremonial, and other purposes, which vary according to culture and religion [1]–[6], [8], [10]–[14]. Due to its powerful scent, high resin content, and black colour, agarwood essential oil has risen its popularity among the modern consumers [1], [2], [4]–[6], [8]–[11], [13]–[22].

Some Asian countries, including Malaysia, Japan, and India, graded agarwood using two different methods. Malaysian researchers grade agarwood as kalambak and gaharu, whereas Japanese researchers grade agarwood as kanankoh and jinkoh for high and low quality grading, respectively. However, Indian researchers utilise the alphabet from A to D or the numbers from 1 to 4 based on the infection severity and colour [23]. Currently, the quality of agarwood essential oil is graded by a trained human sensory skilled with a variety of oil concentrations. The method yields varying outcomes depending on whether the testers have a keen feel for differentiating between oil grades. The traditional grading method does not confirm its purity or quality because it depends on the human's nose that cannot tolerate a large number of samples. This method is considered to be unreliable due to its rapid exhaustion, lack of consistency and lengthy procedure [8], [11], [24].

Due to market demand from China, Japan, India, Malaysia and the Middle East, *Aquilaria malaccensis* oil must have a global grading system and grade-based pricing. Grading system is essential for assorting materials as per their marketable grades, as well as for determining trade integrity and pricing decisions [1], [7], [9], [13], [14], [21], [25]. Agarwood essential oil quality grading can be determined by its chemical elements. This allows the classification of agarwood essential oil into different quality grades: low, medium low, upper low, medium high, high and upper high. The accurate findings can be examined using pattern analysis. Previous researcher has established four grades of agarwood essential oil by classifying it based on their chemical compounds [26]. They classify four grades as low, medium low, medium high and high by using a self-organizing map (SOM).

This study aims to identify the pattern analysis in analyzing the classification of agarwood essential oil chemical compounds based on its abundances from different grades; low, medium low, upper low, medium high, high and upper high. The data samples consist of eleven chemical compounds with 660 samples of agarwood essential oil. To conclude, this study is to evaluate and observe if the chemical compounds managed to classify the agarwood essential oil into different quality grades.

2. METHOD

2.1. Data preparation

The data classification of 660 samples of agarwood essential oil consists of different grades [11], [12]. The names of eleven chemical compounds are 10-epi-δ-eudesmol, δ-eudesmol, β-agarofuran, valerianol, β-dihydro agarofuran, δ-cadinene, α-guaiene, α-agarofuran, allo aromadendrene epoxide, ar-curcumene, and dihydrocollumellarin. Another paper from early step of research contain informations on the data gathering [24]–[26]. The chemical compounds of the samples are extracted by gas chromatography-mass spectrometry (GC-MS) using the standard operating procedure (SOP) of the Bio Aromatic Research Centre of Excellence (BARCE). The pattern analysis was conducted using MATLAB version R2021b.

2.2. Flowchart of experimental set-up

The flowchart of the study employing pattern analysis on agarwood essential oil is presented in Figure 1. The primary data has classified agarwood essential oil into four grades; low, medium low, high and upper high [26]. This study aims to classify agarwood essential oil into five grades; low, medium low, upper low, medium, and high and six grades; low, medium low, upper low, medium high, high, and upper high. The pattern analysis was done for evaluating and observe all the grades are grouped accordingly.

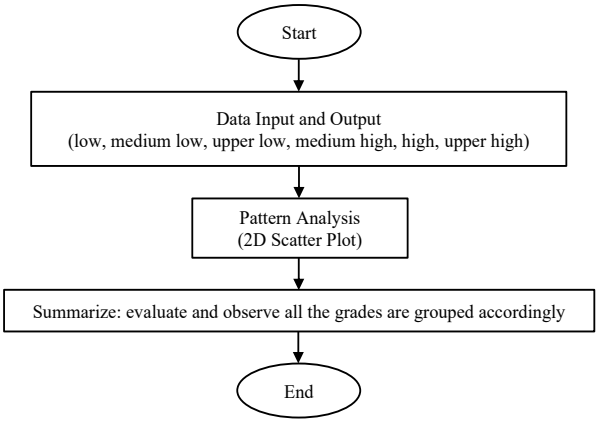

Figure 1. Flowchart of experimental set-up

3. RESULTS AND DISCUSSION

The pattern analysis of eleven chemical compounds of agarwood essential oil in different grades from 660 samples extracted using GC-MS analysis is discussed in this section. The pattern analysis was done using MATLAB software version 2021b. The pattern analysis evaluated eleven chemical compounds of agarwood essential oil to match with five and six different agarwood essential oil quality grades. The 2D graph was used for pattern analysis. The findings then will be use as a marker for modelling system of agarwood oil grades determination. Based on the different agarwood grades tabulate in the 2D graph discussed in section 3.1, it can be summarize that the high the value abundance of chemical compounds, the high the quality of oil.

3.1. Pattern analysis: 2D scatter plot

The pattern analysis of a 2D scatter plot has been generated to evaluate and observe the eleven chemical compounds: 10-epi-δ-eudesmol, δ-eudesmol, β-agarofuran, valerianol, β-dihydro agarofuran, δ-cadinene, α-guaiene, α-agarofuran, allo aromadendrene epoxide, ar-curcumene, and dihydrocollumellarin with respect to different grades; four, five and six of agarwood essential oil. Figure 2 displays a scatter plot in two dimensions of four grades from [26]. The scatter plot is scattered according to its groups; low, medium low, medium high and high.

A 2D scatter plot of five grades is shown in Figure 3 and the scatter plot is distributed based on its groups; low, medium low, upper low, medium high and high. For the low grade, the scatter plot is scattered from 0 to 0.35 on the x-axis, while on the y-axis, it is scattered from 0 to 0.30. For the medium low grade, the scatter plot is scattered from 0.20 to 0.85 on the x-axis and 0 on the y-axis. The upper low grade is scattered from 0.45 to 0.55 on the x-axis, while on the y-axis, it is scattered from 0 to 0.65. For the medium high grade, on the x-axis, it is scattered from 0.60 to 0.80, and on the y-axis, it is scattered from 0.50 to 0.60. The high grade is scattered from 0.65 to 1.0 on the x-axis, while on the y-axis, it is scattered from 0.60 to 1.0.

Figure 4 illustrates a 2D scatter plot of six grades, with the scatter plot divided into six groups; low, medium low, upper low, medium high, high, and upper high. The scatter plot exhibits distinct clusters. The scatter plot for the low grade is spread between 0 and 0.35 on the x-axis, and between 0 and 0.30 on the y-axis. The scatter plot for medium low grade is distributed from 0.20 to 0.85 on the x-axis and 0 on the y-axis. The upper low grade is ranged from 0.45 to 0.55 on the x-axis and from 0 to 0.65 on the y-axis. On the x-axis, the medium high grade is scattered between 0.60 and 0.80, and on the y-axis, it is scattered between 0.50 and 0.65. The high grade ranges from 0.65 to 0.90 on the x-axis and from 0.60 to 0.85 on the y-axis. The upper high grade scattered on the x-axis from 0.70 to 1.0 and on the y-axis from 0.80 to 1.0.

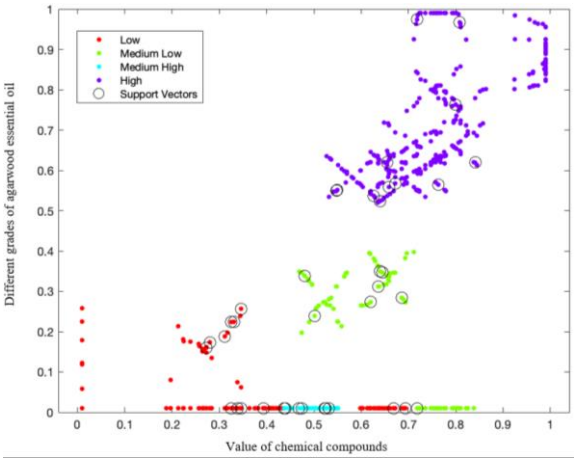

Figure 2. 2D scatter plot of four grades from [26]

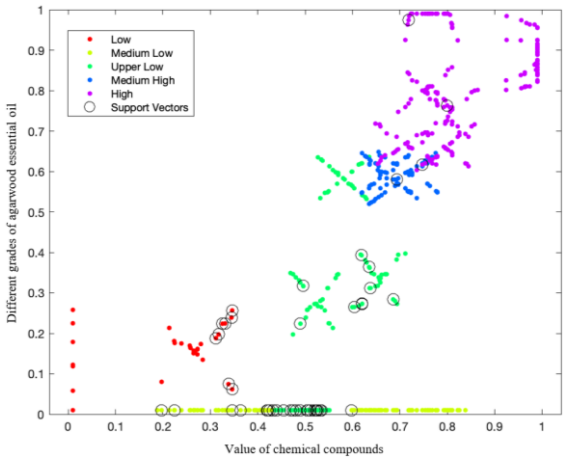

Figure 3. 2D scatter plot of five grades

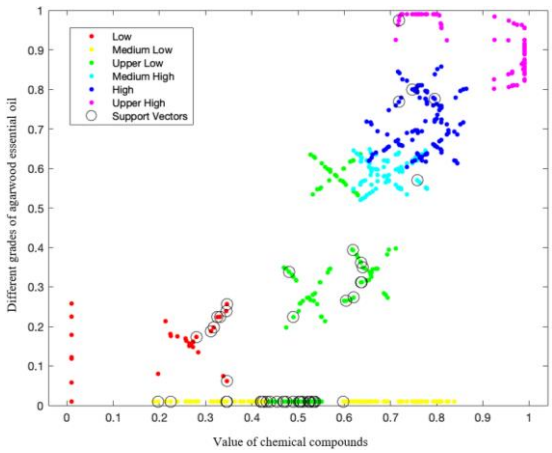

Figure 4. 2D scatter plot of six grades

4. CONCLUSION

This study successfully constructed a pattern analysis of agarwood essential oil. The pattern analysis method was utilized to visualize the categorisation data into different grades; low, medium low, upper low, medium high, high, and upper high. The classification was conducted using 2D scatter plot in MATLAB software version 2021b. All the scatter plots are scattered in a group. Both 2D plot for 5 grades and 6 grades shows that it is scattered around 0.65 to 1.0. The pattern of the plot also can be seen by naked eye where the color is grouped based on its different grades. There is a clear gap visible in the plot. The high grade and upper high illustrate a well-balanced distribution of value for the significant chemical compounds. It is proven that this clear gap advantageous for future modelling system. The research findings will be useful for future research, particularly in agarwood essential oil quality grading, its industry and research fields.

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