The grading classification for *Styrax sumatrana* resins based on physico chemical characteristics using two-step cluster analysis

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**Abstract.** Non timber forest management of styrax resin has become the main community livelihood in the Tapanuli region, North Sumatra, Indonesia. However, thousands of tons of incense resin produced have not been graded simply and inaccurately. The resin grading has been determined visually based on shape, size, and color. This is a disadvantage regarding the important value of this commodity is its chemical content. The objectives of the study were (a) to investigate the physico chemical properties of styrax resin based on current local grading, and (b) to develop a new grading classification of Sumatran incense (*Styrax sumatrana*) resin. A completely random design was carried out to determine the physico chemical properties of styrax from six incense grade traded. The results showed that the current quality grading affects the physico chemical properties of the resin. The first grade contains the best physico chemical properties, conversely the sixth is the lowest among others. Isolated cinnamic acid from various grades produces different levels of purity. The highest balsamic acid content and purity were derived from the highest quality incense (current local Grade I) while the lowest was contained by Grade VI. A two-step cluster analysis was performed to identify an accurate classification of resin grade according to both numerical and categorical attributes. Clustering algorithms with the two-step method worked efficiently and determined the optimal number of clusters, four grade incense profiles. The most important grade contains higher balsamic content and purity, lower impurities, ash content, melting point, and moisture content. Ash content and impurities were the most important predictor for differentiating each segment. The information obtained is expected to facilitate more accurate and honest resin quality grading application for farmers and traders.

1. Introduction

Non-timber forest management of styrax resin has become the main community livelihood in the Tapanuli region, North Sumatra, Indonesia [1]. However, thousands of tons of incense resin produced have not been graded simply and accurately [2,3]. The mechanism for determining prices was practically fluctuated and determined unilaterally by big buyers or whole traders [1].

The resin grading in local trading has been determined visually based on shape, size, and color. This is a disadvantage because the important value of this commodity is its chemical content. Several studies were examined the physico chemical characteristics of various incense resins grade, especially the application of significant difference tests for resin quality classification [4]. However, most of these algorithms work restricted to numerical data. Nevertheless, physico chemical resin data contains...
both numerical and categorical attributes. The two-step cluster is an SPSS method that solves this problem. Data clustering is a method applied to distinguish classes of objects with similar characteristics [5,6,7]. This accurate method is an advantage for determining the proper number of clusters, so that resin grading is simpler and more applicable.

The objectives of the study were (a) to investigate the physico chemical properties of styrax resin based on current local grading, and (b) to develop a new grading classification of Sumatran incense (Styrax sumatrana) resin using two-step cluster method. The information obtained is expected to facilitate farmers and traders for more accurate resin quality grading applications. Simple and accurate postharvest processing technology that can be applied by farmers and traders is expected to increase added value in initial processing of incense resin.

2. Materials and Methods

2.1. Materials

The main ingredient includes incense toba (Styrax sumatrana) resins that harvested in three periods in December 2019 to March 2020 from the community forest in Humbang Hasundutan District, North Sumatra, Indonesia. The analytical materials included some distilled water, xylene solvent, ethanol 96%, ethanol p.a., KOH-ethanol 0.5 N, MgSO₄, HCl, ether, NaHCO₃, chloroform, NaOH, oxalic acid, phenolphthalein indicator, and filter paper. While equipments applied include some glasses, analytical scales, erlenmeyer bottles, oven, thermometer, separating funnel, spiritus lamp, condenser and others.

2.2. Methods

2.2.1. Grading resin quality test

A completely random design and followed by Tukey HSD-test were carried out to determine both quality and quantity differences of styrax resin properties and the balsamic acid content of the six grading incense quality where traded in the local market. The resins with its bark were collected from tapping 20 incense trees for three harvest periods (first/main, second, and third). All resins were cleaned from impurities and sorted visually according to commonly traded grading (6 grading) and harvest periods. Visual observations made include resin color, size, and shape.

Some tests were applied to the physico chemical characteristics of each resin quality including water content, ash content, impurities, melting point, balsamic acid content, and purity. The analysis procedure is based on SNI 7940: 2013 and several previous related studies [4,8,9].

a. Moisture content, calculated by dissolving 5 grams of incense into a 300 mL erlenmeyer glass and added 100 to 150 mL xylene solvent. Then, erlenmeyer was connected to the Aufhauser equipment and heated until the contained water in resin came out completely. The moisture content was read on the scale on the Aufhauser device.

b. Ash content, analyzed by heating 3 grams resin into the kiln. The samples with porcelain containers were heated to a temperature ±625°C until the resin turns into ash form. Then, the sample and container was cooled and weighed to a constant weight. Ash content were calculated by:

\[
Ash\ content = \frac{(W1 - W) \times 100\%}{(W2 - W)}
\]

where:

W: weight of empty container (cup)
W1: weight of ashes with container
W2: weight of incense sample with container

(c. Level of impurities, investigated by dissolving 2 grams of incense into 100 mL erlenmeyer containing 25 mL of ethanol 90%. The solution was filtered with filter paper. Furthermore, the residue was washed with 90% warm ethanol and dried at 100°C for 6 hours to a constant weight. The level of impurities was calculated by the formula:
Level of impurities = \( \frac{W_1 - W_2}{W} \times 100\% \)  

where  
W: weight of incense sample  
W1: weight of filter paper and insoluble ingredients at 90% ethanol  
W2: weight of filter paper  

d. Melting point, tested by melting 30 grams of incense fine powder into a ring and fills up to the entire surface. After the molten resin cools, a ring containing hardened resin was placed on a ring holder and a steel ball were placed above the ring. Furthermore, the ring, steel ball, and thermometer were inserted into a glass cup filled with 800 mL water, followed by heating so that the resin softens and the steel ball slowly drops and touches the bottom of the device. The melting point was determined based on the temperature read on thermometer when the ball falls on the bottom of device.  

e. Cinnamic acid content, run based on SI 2044-1987. A total of 3 grams of incense powder was put into a closed erlenmeyer containing 50 mL KOH-ethanol 0.5 N and refluxed for one hour. Then, ethanol was evaporated to dry condition, and then residual evaporation was dissolved with 75 mL hot distilled water until it was homogeneous and cooled. After it cools down, the solution was added with 80 mL distilled water and 75 mL of MgSO\(_4\) 3% solution then stirred thoroughly and left for 10 minutes, and then it was filtered. The residue was washed with distilled water and 96% ethanol. Furthermore, the filtrate was collected and acidified with HCl 4 N, then extracted with ether 3 times. The ether phases were collected and extracted gradually with 40 mL and 20 mL of NaHCO\(_3\) solution 5%. The aquades phase was collected and washed with ether, while the ether phase is removed. Hereinafter, the aquades phase was acidified with HCl 4 N and then it was extracted gradually with 60, 40, and 20 mL of chloroform. The chloroform solution was collected in an erlenmeyer bottle and chloroform fraction was evaporated to dryness. The residue was added with hot water (heated) and filtered under hot conditions. Furthermore, the filter was cooled with ice. The resulting crystal was filtered and washed with cold water, then dried in an oven at ± 50°C for 3 hours. The results obtained are expressed as cinnamic acid crystal.  

\[ \text{Cinnamic acid content} = \frac{W_1}{W} \times 100\% \]  

where:  
W: weights of sample incense (grams);  
W1: dry weight of cinnamic acid crystal (grams)  

f. The purity of cinnamic acid, the test was carried out by dissolving 0.1 gram of cinnamic acid crystal into an erlenmeyer glass containing 20 mL of ethanol p.a. neutral. Then, sample was heated in oven at ± 50°C for one hour. Subsequently, the sample was cooled, followed by titration with NaOH 0.5 N solution standardized by oxalic acid 0.0318 N and phenolphthalein as an indicator. Color changes were observed from yellow to reddish orange. The purity was calculated by the formula  

\[ \text{The purity of cinnamic acid (\%)} = \frac{V \times N \times 14.2}{W} \times 100\% \]  

where:  
V: volume of NaOH used (mL)  
N: normality of NaOH (N)  
W: weight of sample crystal (mg)  
148.2 = BE of cinnamic acid (g/ek)  

2.2.2. Compilation of new quality classification  
A two-step cluster analysis was performed to identify an accurate classification of resin grade according to qualitative and quantitative parameters i.e. shapes, size, color, moisture content, ash content, impurity, melting point, and cinnamic acid content. Two-step cluster analysis was carried out using the SPSS statistical software package [5-7]. The process consisted of two major steps; the first
step, initial clustering of observations into small sub-clusters performed, and further on these sub-clusters treated as separate observations. The decision of whether the observation was joined in an already formed cluster or a new cluster shall be formed was made on the bases of distance criteria. The grouping of these new observations was applied by hierarchical cluster method. The second step was groping, where the sub-clusters were bases for analysis, and it was grouped into required number of clusters [5-7].

In this analysis there were one or more categorical variable, the log-likelihood distance measure was applied. The log-likelihood distance measure represents the distance based on probability. The distance between two clusters in relation to decrease of value of log-likelihood distance measure, when two clusters were joined in one. While calculating the log-likelihood distance measure, normal distribution for continuous variables, and multinomial for categorical variables were assumed. Also, the independence of variables and independence of observations were also assumed. The distance between clusters \( R \) and \( S \) were defined as

\[
d_{(R,S)} = \xi_R + \xi_S - \xi_{(R,S)}
\]

(5)

where:

\[
\xi_v = -N_v\left(\sum_{k=1}^{K^A} \frac{1}{2} \log(\hat{\sigma}_k^2 + \hat{\sigma}_v^2) + \sum_{k=1}^{K^B} E_{v-k}\right)
\]

\[
E_{v,k} = -\sum_{l=1}^{L_k} \left(\frac{N_{v,k,l}}{N_v} \log\left(\frac{N_{v,k,l}}{N_v}\right)\right)
\]

here \( K^A \) is a total number of continuous variables in analysis; \( K^B \) is a total number of categorical variables; \( R_k \) is interval or range of \( k \) continuous variable; \( N \) is a number of observations; \( N_k \) is a number of objects in \( k \) cluster; \( \hat{\sigma}_k^2 \) is estimated variance of \( k \) continuous variable; \( \hat{\sigma}_{vk} \) is estimated variance of \( k \) continuous variable in \( R \) cluster; \( N_{rkl} \) is number of objects in \( R \) cluster, where \( k \) categorical variable takes \( l \) category; \( d_{(R,S)} \) is distance between \( R \) and \( S \) clusters; \( (R,S) \) is index that represents cluster which is formed by joining of clusters \( R \) and \( S \) [5-7].

If the \( \hat{\sigma}_k^2 \) is ignored in equation, the distance between clusters \( R \) and \( S \) will be equal to the decreased value of log-likelihood distance measure when two clusters were joined. The expression \( \hat{\sigma}_k^2 \) given as a solution to rising problem, if \( \hat{\sigma}_k^2 = 0 \), by undefined values for natural logarithm were reached.

For automatic determination of clusters number, SPSS has developed the two-step procedure which is compatible with hierarchical cluster analysis. In the first step, the BIC or Bayes Information Criterion was calculated for each different cluster solution with different clusters number. In the second step, initial estimate was improved by finding the highest distance increase between two closest clusters during each stage in hierarchical clustering [5-7].

The statistics \( BIC \) for \( R \) clusters were defined as

\[
BIC_R = -2 \sum_{i=1}^{R} \xi_R + m_R \log(N)
\]

(6)

\[
m_R = R \left(2 K^A + \sum_{k=1}^{K} (L_k - 1)\right)
\]

(7)

where \( L_k \) is the number of groups in \( k \) categorical variable

3. Results and Discussion

3.1. Physico chemical properties

Styrax resin is produced by inner epithelium layers of injured bark, therefore bark tapping is the best practice to harvest this valuable resin [2]. Styrax forest management has been carried out traditionally, including the harvesting techniques. Some simple tools are used include a guris (a bark cleaning tool),
The tapping process begins by cleaning the stems and removing mosses that grow on the trunk. The number of tapping holes (8 to 12 holes each tree) were made by puncturing the bark surface and making a space between bark and woody parts (cambium). This tapping wound has a 5 to 10 cm in width. Therefore, the injured bark was closed again by knocking gently. The spaces created in the inner bark will be filled with resin during the following 3-4 months. After the tapping holes were filled with hardened resin, harvesting activities were carried out by prying all resins including the bark pieces. This technique causes some sores in form of sizable holes in bark surface.

Furthermore, harvested resins were air dried for two weeks until one month. Then resin sorted out according to size, color, and cleanliness or impurities of resin, qualitatively. There were no technological applications in this stage, chunks resins are sold by farmers. Based on the grading set by traders in Tapanuli region, there were six classes of incense resin quality namely Coarse Mata (Grade I), Fine Mata (Grade II), Tahir (Grade III), Jurur/jarir (Grade IV), Barbar (Grade V) and Ash flakes (Grade VI) (Table 1).

Table 1. Grading of styrax resin at farmer and local trader

| Grading        | Color            | Shapes          | Sizes                  | Remarks                  |
|----------------|------------------|-----------------|------------------------|--------------------------|
| Grade I        | White, pure white| Chunk, medium plates | width ≥ 3 cm, length ≥ 5 cm | First harvest, Main quality |
| (Coarse Mata)  |                   |                 |                        |                          |
| Grade II       | White - yellowish white | Small - medium plates | width 2-3 cm, length 3-5 cm | First harvest             |
| (Fine Mata)    |                   |                 |                        |                          |
| Grade III      | Light yellow to reddish brown | Medium to small plates | width ≤ 2 cm, length ≤ 3 cm | Second harvest, mixed with dirt |
| (Tahir)        |                   |                 |                        |                          |
| Grade IV       | Reddish yellow | Coarse flakes | Diameter 1-2 cm | Third harvest, mixed with dirt |
| (Jurur/jarir)  |                   |                 |                        |                          |
| Grade V        | Light reddish brown | flakes | Diameter < 1 cm | collected during bark cleansing |
| (Barbar)       |                   |                 |                        |                          |
| Grade VI       | Light reddish brown | Granules, flakes | Granules, fines | cleaning remnants |
| (Ash - flakes) |                   |                 |                        |                          |

The first quality is a large plate resin with 3 cm width, 5 cm length, and white or pure white color. The second class is a smaller white and yellowish white plate resin with 2-3 cm width and 3-5 cm length. These two highest grades were produced in the first harvest period (main harvest), generally 3 months after tapping were applied. Both of these were hardened resin between the inner bark and the woody part of the trunk (cambium).

Third grade is small light yellow to reddish-brown plates up to 2 cm wide and up to 3 cm long in. In this local grade trade, it called Tahir, produced by the second harvest conducted one to two months after the first (main) harvest. Tahir resins were produced by a hardened resin on the outside of the bark or around tapping holes.

The three lowest qualities are small pieces of resin. Grade IV is reddish yellow coarse flake resin that produced by the third harvest (intermediate harvest), while Grade V, light reddish-brown flake resin was produced by bark cleansing. This third harvest period was run one to two months later after the second harvest. The lowest one is ash quality (Grade VI), light reddish-brown fine flakes, or granules, resulting from cleansing barks or trunk. It contains a lot of impurities.

In local and regional trade, the first grade is highly desirable, but relatively more difficult to
obtain, so it is valued much higher. Based on tapping of 20 sample trees with the application of 8-12 tapping holes per tree, the average of resin productivity based on the local grading was obtained in the following Table 2.

**Table 2.** The resin productivity based on the local grading from tapping of 20 sample trees

| Grading     | Dried resin weight (grams) | Proportion (%) | Remarks            |
|-------------|----------------------------|---------------|--------------------|
|             | Mean | Std. Dev | Mean | Std. Dev |                  |
| I (Coarse Mata) | 233.1 | 40.9 | 15.6 | 1.4 | First harvest     |
| II (Fine Mata)  | 280.0 | 33.6 | 18.8 | 1.2 | First harvest     |
| III (Tahir)     | 322.4 | 29.6 | 21.8 | 1.5 | Second harvest    |
| IV (Jurur)      | 249.7 | 31.0 | 16.8 | 1.3 | Third harvest     |
| V (Barbar)      | 219.6 | 29.2 | 14.8 | 1.9 | Bark cleansing    |
| VI (Ash-flakes) | 180.3 | 29.9 | 12.1 | 1.6 | Cleaning remnants |
| **Total**       | 1,484.9 | 142.7 |      |      |                  |

Overall, resin productivity is 1,484.9 grams per tree. The highest proportion (21.8%) is Grade III (Tahir) with productivity about 222.4 grams per tree. The highest quality (Grade I Coarse Mata) produces about 233.1 grams (15.56%), while the second quality (Fine Mata) at 280.0 grams or 18.8%. If these two highest qualities were combined, it contributed 34.4% of total resin productivity.

**Table 3.** An overview of variance analysis of the parameters tested

|                    | Sum of Squares | df | Mean Square | F     | Sig.  |
|--------------------|----------------|----|-------------|-------|-------|
| Moisture content   |                |    |             |       |       |
| Between Groups     | 5.385          | 5  | 1.077       | 24.141| 0.000 |
| Within Groups      | 2.409          | 54 | 0.045       |       |       |
| Total              | 7.794          | 59 |             |       |       |
| Ash content        |                |    |             |       |       |
| Between Groups     | 18.008         | 5  | 3.602       | 726.407| 0.000 |
| Within Groups      | .268           | 54 | 0.005       |       |       |
| Total              | 18.276         | 59 |             |       |       |
| Impurities         |                |    |             |       |       |
| Between Groups     | 474.581        | 5  | 94.916      | 349.987| 0.000 |
| Within Groups      | 14.645         | 54 | 0.271       |       |       |
| Total              | 489.226        | 59 |             |       |       |
| Melting point      |                |    |             |       |       |
| Between Groups     | 3032.952       | 5  | 606.590     | 55.954| 0.000 |
| Within Groups      | 585.408        | 54 | 10.841      |       |       |
| Total              | 3618.360       | 59 |             |       |       |
| Balsamic acid      |                |    |             |       |       |
| Between Groups     | 999.824        | 5  | 199.965     | 51.029| 0.000 |
| Within Groups      | 211.609        | 54 | 3.919       |       |       |
| Total              | 1211.433       | 59 |             |       |       |
| Purity             |                |    |             |       |       |
| Between Groups     | 501.231        | 5  | 100.246     | 120.061| 0.000 |
| Within Groups      | 45.088         | 54 | 0.835       |       |       |
| Total              | 546.319        | 59 |             |       |       |

Furthermore, a complete randomized sampling was carried out to investigate the effect of quality differentiation on physico chemical properties. The parameters tested were water content, ash content, impurities, melting point, balsamic acid content, and purity. The design ran with 10 replications for each grading. An overview of the variance analysis of the parameters tested was described in Table 3.

The results of the analysis described that current quality grading affected the physico chemical properties of the resin. Based on the significant value of 0.000, the current classification of six resin qualities also influenced the moisture content, ash content, impurities, melting point, balsamic acid
content, and purities. An overview of results of analysis of physico chemical properties of incense resin was listed in Table 4.

Table 4. The physico chemical properties of incense resin based on current quality grading

| Grading | N  | Moisture content (%) | Ash content (%) | Impurities (%) | Melting point (°C) | Balsamic acid Content (%) | Purity (%) |
|---------|----|----------------------|----------------|----------------|-------------------|--------------------------|------------|
| I       | 10 | 2.26±0.16 a          | 0.07±0.02 a    | 3.31±0.34 a    | 57.45±1.21 a      | 35.06±1.35 a            | 96.53 a    |
| II      | 10 | 2.21±0.11 a          | 0.08±0.01 a    | 3.55±0.36 a    | 57.86±1.12 a      | 34.12±1.20 ab           | 96.18 a    |
| III     | 10 | 2.29±0.13 a          | 0.25±0.05 b    | 3.98±0.22 a    | 60.71±1.27 a      | 30.94±0.81 b            | 93.97 b    |
| IV      | 10 | 2.45±0.14 a          | 0.50±0.03 c    | 4.74±0.24 b    | 67.27±1.78 b      | 27.29±0.91 c            | 93.28 bc   |
| V       | 10 | 2.47±0.10 a          | 0.67±0.07 d    | 6.08±0.22 c    | 69.43±2.11 b      | 26.47±1.58 d            | 92.67 c    |
| VI      | 10 | 3.10±0.09 b          | 1.66±0.03 e    | 11.47±0.38 d   | 77.33±3.15 c      | 23.87±0.82 d            | 87.77 d    |

The mean difference is significant at the 0.05 level (Tukey HSD test)

Overall, first grade contains the best physico chemical properties, conversely the sixth grade is the lowest among others. This best quality (Grade I) resin has a balsamic acid content reaching 35.06%, the highest with purity 96.53%, resin impurities 3.31%, ash content 0.07% and 2.26% moisture content. The impurities and ash contents were the lowest among others.

Furthermore, the Tukey HSD-test showed that the physico chemical properties of Grade II were similar to Grade I. The balsamic acid content reached 34.12% with purity 96.18%, resin impurities 3.55%, ash and moisture content were 0.08% and 2.21%, respectively. These similarities were a consequence of difference between these two highest grades only in shape and size and visual sorting that carried-out. Similar results were also reported by previous study [4] where the similarity in physics-chemical properties includes Grade I, II, and III.

In a single variable of balsamic acid content, the Tukey HSD-test showed that there were four levels of content quality. Grade I and II have the same balsamic acid content relatively, followed by Grade III at the second, then Grade VI at the third level. The two lowest grades (V and VI) have the similar balsamic acid content relatively even though both ash content and impurities were different. Levels of isolated cinnamic acid from resins Grade I to VI were above 11%, indicating that all grades tested meet the minimum requirements for these compounds in incense resin.

Isolated-cinnamic acid from various grades produces different purity levels. The highest purity (96.53%) was derived from the highest quality incense (Grade I) while the lowest was contained by Grade VI (87.77%). Based on the Tukey HSD-test, there were four different purities levels. The first grade purity was similar to the second, relatively, while Grade III has a purity of about 93.97%, statistically as similar as Grade IV (93.28%). These purities were similar regarding their same origin as outer bark resins. However, the purity of grade IV is also similar to Grade V (92.67%), due to higher impurities content. Grade VI contains the lowest purity resin (87.77%). The cinnamic acid purity tends to decrease at an increasingly lower quality also reported [4].

Ash content, impurities level, and the melting point of Grade I and II were lower than others. This is due to higher cleanliness of both grades. The resin comes from parts between the inner skin and stem, so these protected resins were not affected by an unfavorable environment. Conversely, resins in grades III, IV, and V derived from hardened resin outside the barks at the second and third harvesting, consequences both higher impurities and ash content. These characters were caused by the melt hardened resin which also traps various other organic and inorganic materials on the surface of the trunk.

Except for Grade VI, the others have similar moisture content. Even though it was granules or fine flakes, contained water in lowest grade was higher due to the high impurities content. These impurities include wood chips or other materials that contain higher moisture content. The highest ash content was also demonstrated by grade VI. Ash content shows the amount of minerals in an ingredient. Organic materials will ignite and evaporate when heating, while inorganic materials will be left as ashes. High impurities in this quality cause high ash content.
Referring to National Standards (Indonesian Industrial Standards (SII) No. 2044-87 (Processed Form), Grades I, II and III meet the First Quality (Mutu I) requirements (balsamic acid content > 30), while Grade IV, V and VI classified as Second Quality (Mutu II) (balsamic acid content > 25%). The processed resins also meet the requirements of water content, ash content, and soft spots for each quality.

3.2. Clustering
Two-step cluster is an SPSS method that works with both numerical and categorical data. This method has an advantage in determining the number of proper clusters effectively. In this method, data clustering can form objects classification with similar characteristics.

The dataset that has been used for this study has been obtained from physico chemical analysis which was carried out in the previous stages of this study. The dataset has 420 records and the overview is presented in Table 5. This table contains information about the resin grade (visual classification), moisture content, ash content, impurities, melting point, balsamic acid content, and purity. Table 5 presents and overview of the data.

| Variables | Category |
|-----------|----------|
| X1 Grade  | Categorical data |
| X2 Moisture content (%) | Continuous data |
| X3 Ash content (%) | Continuous data |
| X4 Impurities (%) | Continuous data |
| X5 Melting point (°C) | Continuous data |
| X6 Balsamic acid content (%) | Continuous data |
| X7 Purity (%) | Continuous data |

The database contains one categorical variable and six continuous variables. Continuous variables were standardized by default. Considering this study used a mixture of data, only log-likelihood option for distance measure. In the first running, BIC was chosen to determine the number of clusters, though it may override this and specify a fixed number.

According to the SPSS algorithm, the optimal number of clusters is four, because the largest ratio of distances is for four clusters. The cluster distribution is shown in Table 6.

| Cluster | N | % of combined | % of total |
|---------|---|--------------|------------|
| 1       | 10| 16.7         | 16.7       |
| 2       | 10| 16.7         | 16.7       |
| 3       | 20| 33.3         | 33.3       |
| 4       | 20| 33.3         | 33.3       |
| Combined| 60| 100.0        | 100.0      |

The first and second clusters fill about 16.7% data, respectively. The important clusters are third and fourth clusters. Both are the largest cluster (33.3%, respectively). SPSS presents also the frequencies for each categorical variable. Table 7 shows the frequencies for the grade variable. The first and second clusters contain 100% Grade VI and III, respectively. Furthermore, the third cluster consists of 100% Grade IV and V. While the last cluster contains resins classified as Grade I and II.
The frequencies for grade variable

| Cluster | Grade I | Grade II | Grade III | Grade IV | Grade V | Grade VI |
|---------|---------|----------|-----------|----------|---------|----------|
|         | F %     | F %      | F %       | F %      | F %     | F %      |
| 1       | 0 0.0   | 0 0.0    | 0 0.0     | 0 0.0    | 10 100.0| 10 100.0 |
| 2       | 0 0.0   | 0 0.0    | 0 0.0     | 10 100.0 | 0 0.0   | 0 0.0    |
| 3       | 0 0.0   | 0 0.0    | 0 0.0     | 10 100.0 | 10 100.0| 0 0.0    |
| 4       | 10 100.0| 10 100.0 | 0 0.0     | 0 0.0    | 0 0.0   | 0 0.0    |

The determinant variables for the formation of clusters were shown in Figure 1. Both ash content and impurities are the most important predictor for differentiating each segment. While the moisture content variable is the lowest predictor. This is similar to the results of the Tukey HSD-test analysis that applied previously where moisture content does not have much effect on grading differentiation.

![Figure 1. Predictor importance](image)

A brief profile of each cluster with the characteristics differentiating each segment from the other groups as outlined below (Figure 2).

![Figure 2. Clustering and physico chemical properties description](image)

Briefly, a two-step cluster analysis with BIC identified four optimum clusters. The first cluster, which fills about 16.7% sampling data, contains resins with higher ash content (1.68%) and impurities (11.47%), but lower resin purity (87.77%). The melting point is about 77.33°C with lower balsamic acid content (23.97%) but higher moisture content (3.10%). The characteristics of these variables are represented by resins at the lowest current local Grade VI (Ash).
Furthermore, the second cluster covers about 6.7% observation data. This cluster contains resins with low to moderate of ash content (0.25%), low to moderate impurities level (3.97%), and moderate cinnamic acid purity (93.98%) with balsamic acid content (30.94%). The average melting point is about 60.71°C and moderate moisture content (2.29%). These properties are contained by the current local Grade III (Tahir).

The third cluster represents about 33.3% data which contains a moderate ash content resin (0.59%) and impurities (5.41%), respectively. This cluster also accommodates resins with low to moderate balsamic acid content (26.88%) with moderate purity (92.98%). The melting point is about 68.35°C with moisture content about 2.48%. The cluster is also represented by resins at the current local Grade IV (Jurur) and V (Barbar).

The most important cluster is the fourth. This is the largest cluster (33.3%) containing physicochemical properties resins with lowest ash content (0.08%) and impurities (3.43%), but highest balsamic acid content (34.59%) and purity (96.36%) respectively. The melting point is lower about 57.65°C as well as moisture content (2.24%). These properties are represented by both current local Grade I (Coarse Mata) and II (Fine Mata), resins with the highest economic value.

Furthermore, based on the four clusters identified above, the new classification of styrax resin grading was prepared as shown in Table 8. This new grading is simpler and more measurable compared to current local grading (6 classes) or SNI (5 grades).

Table 8. New classification of styrax resin grading

| Current grading       | Proposed new grading          |
|-----------------------|-------------------------------|
| I (Coarse Mata)       | Grade I: Pure white, yellowish white | Chunk, medium - small plates | 2.24 | 0.08 | 3.43 | 57.65 | 34.59 | 96.36 |
| II (Fine Mata)        | Grade II: Light yellow to reddish brown | Small plate, coarse flakes | 2.29 | 0.25 | 3.97 | 60.71 | 30.94 | 93.98 |
| III (Tahir)           | Grade III: Reddish yellow, light fine flakes | Coarse to reddish brown | 2.46 | 0.59 | 5.41 | 68.35 | 26.88 | 92.98 |
| IV (Jurur) V (Barbar) | Grade IV: Light reddish brown | Granules, flakes | 3.10 | 1.66 | 11.47 | 77.33 | 23.87 | 87.77 |

*Indonesian National Standard/Indonesian Industry Standards (SII) No. 2044-87

The proposed new grading consists of four grade resins. The new first grade represented by resins at the current local grade I (Coarse Mata) and II (Fine Mata). The highest grade contains high balsamic content and purities, but lower impurities and ash content (Table 8). The physical properties are indicated by a pure white to yellowish white color with a chunk, medium to small plate size.

The new second grade consists of resins at the current local Grade III (Tahir). This cluster contains moderate resin quality which indicated by low to moderate ash content and impurities, moderate balsamic acid content, and purity. The physical properties are indicated by a light yellow to reddish brown color with a small plate to coarse flake resin.

The third grade is a new cluster of resins which are classified in both current local Grade IV (Jurur) and V (Barbar). The physical properties are indicated by a coarse to fine flakes resin form with
reddish yellow, light reddish color. The grade represents a low to moderate balsamic acid content and purity, but moderate ash content resin and impurities (Table 8).

The lowest quality, fourth grade, contains resin with higher ash content and impurities, but lower balsamic acid content and purity. The physical properties resins at this grade are granules or flakes form with a light reddish brown color. These characteristics are represented by resins at the lowest current local Grade VI (Ash), the lowest economic value [10].

Compared to current local grading with six classes, the new classification with four grades will encourage farmers easier to sort resins visually. Furthermore, even compared to Indonesian National Standard (SNI) with five grades, a simpler and measurable grade application will promote a more honest and consistent resin quality classification, so that pricing becomes fairer for all parties [10].

4. Conclusion
The results of the analysis showed that the current quality grading affects the physico chemical properties of styrax resin. The first grade contains the best properties, conversely the sixth is the lowest among others. The highest balsamic acid content and purity were derived from the highest grade (Grade I) while the lowest was contained by Grade VI.

Clustering methods can be applied in both numerical and categorical attributes. Clustering algorithms with a two-step method can be easily used and determines four optimal clusters. The most important profile (Grade I) contains higher balsamic content and purity, lower impurities, ash content, melting point, and moisture content. Ash content and impurity variables are the most important predictor for segment differentiating. These simpler and measurable grades application will encourage a more honest and consistent resin quality classification.

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