Increasing added-value of styrax resin through post-harvesting techniques improvement and essential oil based product innovation

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Abstract. Styrax resin is a major non-timber forest product from North Sumatra, Indonesia. However, thousands tons of raw resin are sent abroad, while various styrax oil-based products worth US millions dollars are imported annually. Limited harvesting and processing technology are some of root of causes the lack of styrax oil-based industry development in Indonesia. The objective of this paper was an overview of styrax forest management in North Sumatra, efforts to increase the added-value both quality and quantity of resin, and an alternative processing of raw material into a perfume innovation. Benzoin resin is produced by the injured inner epithelial bark of styrax tree. Therefore, tapping of bark is the best effort to harvest the resin. But, styrax forest management has been carried out traditionally, including harvesting techniques. One of scheme to increase added-value is resins processing into a perfume products with high economic value. The innovative products begin from extracting a solid styrax resin into pure essential oil. There are two methods used, namely (a) extraction with solvent, and (b) distillation method. The amount of yield of benzoin oil produced by solvent method is influenced by incense grade from 23.9 to 34.6% and higher than another method. But distillation method also produces high quality and quantity of hydrosol (side product) with a distinctive aroma. Combined with various essential oils from Indonesia's tropical forests, the styrax oil becomes a fixing agent for a signature perfume that formulated by considering the gradation of aroma in accordance with release of constituent essential oil particles. Processing resin into an essential oil increases the added-value of styrax resin. Innovation of styrax resin based products will explore the fragrance formulation of this commodities therefore reduce our country dependence on imported perfume and raw materials used for various personal cares.

1. Introduction
Forest resources management has been the main funding source for national development since the beginning of Indonesia independence. Including timber, forest management schemes that optimize community involvement with non-timber forest products as the main commodity have provided an alternative livelihoods and poverty alleviation. One of the NTFP that become as main communities livelihood in North Sumatra is tapping of styrax resin (benzoin or kemenyan). This commodity have been cultivated and become a major source of regional income in Tapanuli and surrounding areas since the beginning of civilization [1-3].
The benzoin tree (*Styrax sumatrana*) is managed in the form of a mixed forest or community’s garden. However, this endemic species has not been much increased in their added-value from raw material processing [4]. Thousands tons of raw resin are sent overseas while various derived incense products including medicines, perfumes, beauty and food ingredients with US millions of dollars are imported annually. The export volume of incense resin (including another resin) reaches 5,541 kg with a value of US $ 96,900. Otherwise, imports of derived styrrax essential oil mixed with various other essential oils reached a value of € 1.9 billion in form of perfume and cosmetic products in 2017 [5].

Low harvesting and processing technical skills are main problems the limited development of styrrax oil based industry in Indonesia. These conditions cause a low appreciation of this historic commodity. Furthermore, tree population decreases due to logging, conversion and productivity reduction. The remaining benzoin tree area of 22,005.81 ha in 2019, decreased significantly from 24,077.95 ha [6-8]. The forest area degradation was followed by productivity reduction from 6,060.89 tons/ha in 2008 to 4,620.54 tons/ha in 2012 [7].

Considering the cultivation history and the fact that styrrax resin has become main community livelihood in North Sumatra, the incense development with a broader spectrum is very prospective. However, styrrax forest management have not optimal, marked by lack of efforts to improve cultivation techniques, low harvesting technique and the low of added-value of processed products. One of scheme that increases the added-value is processing resins into various high economic value products. Not many people know if styrrax resins have a fragrant with soft aroma. For centuries, the fragrance was associated with the scent of burned incense while the utilization of styrrax oil to various high-value products was kept secret by the big producers. The benzoin fragrance formula have limited investigated so that diminished the appreciation for this resin. The development of premium products from incense oil is expected to be a solution for increasing this NTFP.

This paper provides an overview of the styrrax forest management in North Sumatra, efforts to increase the added-value of both the quality and quantity, and an alternative processing of incense raw material into a perfume innovation.

**2. Botany and Cultivation**

Incense toba tree (*Styrax sumatrana*) is found grow in the Lake Toba highlands region (900 to 1,400 masl), North Sumatra ([Figure 1]) [1,9]. Some incense producing centers are North Tapanuli, Humbang Hasundutan, Pakpak Bharat, and Toba Samosir district with a total area of around 21,119 ha [6]. Trees grow on a flat to hilly topography and various soil types of podsolic, andosol, latosol, regosol and associations, on fertile to infertile soils. This endemic flora requires high soil porosity but resistant to inundation, grows better in deep soil solum, soil pH between 5 to 7 with fairly high rainfall and spread evenly (climate types A and B) [1,10].

The styrrax tree grows to 60 to 100 cm diameter and 24 to 40 m height, straight stems with a slight branching, shallow grooved bark (3 to 7 mm) and burgundy bark color ([Figure 2]). The outer skin is cracked or notched smooth vertically, while inner skin is soft, brown to red, pink or purplish red with white sapwood. The leave is single form arranged in a spiral, elongated round shape (ellipse) with a rounded leaf base and pointed tip. Leaves are smooth, bottom surface rather shiny white to grey [11].

The tree matures sexually at 6 to 7 years old. Flowers have a compound structure, androgynous, arranged in a bunch or panicle (inflorescence) with 5 to 12 flowers. Flowering start in December to January, but fruiting is not synchronous. The best time for seed collection is in May, most of fruits are ripe physiologically (germination rate reaches 90%). Ripe fruits are round to slightly flattened, 2.0 to 3.8 cm in diameter. Covered with thick and hard flesh, there is a round-whitish brown seed, 13 to 20 mm in diameter. Each tree can produce 40 kg of fruit every year, and every 2 to 3 kg of fruit contains 1 kg of seeds. The number of seeds is 366 seeds/kg or 245 seeds/litre [11].
Figure 1. Natural distribution of Styrax population in Lake Toba region, North Sumatra

Fruits collection would be conducted when fruit falls naturally. Ripe seeds are characterized by slightly-blackish brown skin, otherwise immature seed coat is mostly white [11]. Seed extraction is carried out by knocking or hitting fruit peel, pinning with pliers or peeling by a knife. Therefore the seeds are air dried at room temperature. The sorting is conducted by soaking the seeds in water (absorption method). Non-viable seeds will float while good seeds will sink. The size of the seed does not affect the germination capacity, but the larger seed has a larger diameter of seedling stem [12].

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Figure 2. Morphology of branching and canopy (left), characteristic of resin (center), Morphology of leaves, flowering and fruiting (right)

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Moisture content of fresh fruit is average 45% (recalcitrant). Germination decrease when dried and stored at low temperatures. The seeds have after-ripening properties, in a period of 6 weeks, germination capacity increases to 90% compared to without a ripening treatment (40 to 50%) [12]. The seed germination is epigeal. The seed soaking for 3 days will accelerate the seed germination rate (88%). This treatment increases the water absorption (imbibition) of seeds, therefore the germination is faster and synchronous (germination start on the 29th day). The germination rate reached > 70% on the 45th day. The total germination time reaches 67 to 235 days [4] [12].

Styrax is a semi-tolerant tree species. Rejuvenation requires shade otherwise mature trees need full sunlight. Natural regeneration can be used to build styrax stands with several preconditions. The seedlings can grow well if there are sufficient gap (space) and a spacious forest floor to encourage seeds germination and seedlings growth. Up to poles stage, the regeneration is very sensitive to competition therefore thinning and clearing out weeds will encourage optimum growth to tree stage.

Considering the genetic traits superiority, planting from seedlings is advantage. Plant material should be prepared 10 to 12 months in the nursery previously. Seedling requirements are 40 to 80 cm height with a root diameter of 80 to 150 mm (minimum 18 months in nursery). The initial planting density is determined by site quality. In fertile sites, good drainage and low erosion risk, planting density reaches 1,100 seedlings/ha (planting distance 3 m x 3 m), whereas in moderate fertility sites, good drainage but prone to erosion, planting density reaches 1,600 seedlings/ha (2 m x 3 m). Otherwise, in infertile sites, poor drainage and high erosion, number of initial planting reaches 2,500 seedlings/ha (2 m x 2 m).

The plantation maintenances are generally carried out by weeding, replanting, fertilizing, thinning, and protecting plants from pests and diseases. These activities are carried out in the first, second and third year. Thinning of shading tree is applied gradually to open the canopy for sunlight. Due to high
initial density, two to three thinning can be conducted during the first 10 years to obtain an optimum stand density of 600-800 trees per ha.

3. Harvesting practices

Styrax resin is produced by the inner epithelium layer of injured bark [2]. Although in some cases, aqueous resin comes out naturally and hardens on the outer bark surface, the bark wounding (tapping) is the best practice to harvest the styrax resin. Tapping is carried out during flowering period when the barks are hollow from the wood. This stress condition disrupts the flowering and fruit formation consequently there are limited fruit in tapped trees.

Styrax forest management has been carried out traditionally, including harvesting techniques. Some simple tools are used include a guris (a bark cleaning tool), a tuhil (a tapping tool), a peeler-scraping, climbing ropes, baskets and plastic drying mats. Farmers use 2 pieces of wood with a rope along the 20 m (called polang) as a platform for climbing and standing or sitting when tapping the tree (Figure 3). There are two polang equipment types: standing polang and sitted polang. Sitted polang equipment is more productive than standing ones. This innovation tool saves time and energy because farmers do not suppose standing all the time when climbing. Therefore farmer ability to harvest increased from 6-8 trees initially to 8-12 trees in single day.

![Figure 3. The equipments for styrax resin harvesting](image)

The tapping process begins by cleaning the stems and removing mosses that grow on the trunk surface. Number of tapping holes (8 to 12 holes each tree) is made by puncturing the bark surface and making a space between bark and wood parts (cambium). This tapping wound has a 5 to 10 cm width. Furthermore, injured bark is closed again by knocking. The spaces that created in inner bark will be filled with resin during following 3-4 months. After the tapping hole is filled with hardened resin, harvesting is carried out by prying all resins including the bark pieces. This technique causes some sores in the form of sizable holes in the bark surface. Furthermore, harvested resins are air dried for two weeks until one month. Then dried resin sorted out according to size, color and cleanliness or impurities of resin, qualitatively. There is no technological application in this stage, chunks resins are sold by farmers.
Based on the grading set by local traders in some of producing centers in Tapanuli, there are six classes of incense resin quality namely Coarse Mata (Grade I), Fine Mata (II), Jurur (III), Tahir (IV), Babar (V) and Ash-flakes (VI) (Table 1). The two highest qualities (Coarse Mata and Fine Mata) are produced in first harvest period (main harvest), generally 3 months after tapping where applied. Second harvest conducted following month, the quality of resin tapped will decrease in to grade Tahir (III). One to two months later, the third harvest conducted, it would produce Jurur (IV) quality resin.

| 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| Small plates, coarse flakes | 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    |                              |                   |                            |                          |

These grading schemes are basically disadvantage to farmers. Recent investigation with Two Cluster Analysis shown that grading can be simplified into four classes [13], namely Grade I (Mata), Grade II (Jurur), Grade III (Tahir-Babar), and Grade IV (Ash - Flakes). The new proposed Grade I includes both current coarse Mata and fine Mata, regards the current grading basically differentiated according to size but recent investigation shown that their balsamic contents and purities were similar, relatively [14][15][16]. Furthermore, the new Grade III includes current grade Tahir and Babar resin, also only differing in size. The grading will be simpler and more profitable for farmers if the purification technology has been well mastered by farmers. This new qualification is also simpler and easier to apply at the farmer level compared to National Standards of Indonesia (Indonesian Industrial Standards (SII) No. 2044-87).

4. Product Innovation

4.1. Resin extraction

The styrax resin innovation starts by solid resin extraction into pure essential oil. There were two methods used, namely (a) extraction with solvents, and (b) distillation method. The first used a 95% alcohol solvent with a composition of 1:1 (1 kg resin with 1000 ml solvent). Furthermore to remove solvent, the solution was evaporated using a rotary evaporator.

The amount of oil yield is influenced by the grade of incense resin. Based on testing of color quality and purification, this extraction technique produces four quality classes of essential oils (EO) [13] namely:
a. EO grade I (produced from *Coarse* and *Fine Mata* resin) yield about 34.59% of balsamic acid content;
b. EO grade II (produced from Tahir resin) with a yield of about 30.94%;
c. EO grade III (produced from jurur and barbarian resins) with a yield about 26.88%;
d. EO grade IV (produced by ash and shale quality resin) with a yield of about 23.87%.

Furthermore, the second extraction method utilized a distillation tool. A chunk resin were steamed, evaporated and condensed to produce a yield 4-6% essential oil. Although it was lower than the solvent method, the steam distillation also produces high quality and quantity of hydrosol with a distinctive aroma. Different with the first, the second technique produced only one grade of quality incense oil.

4.2. Perfume innovation

Limited information described that styrax essential oil has a fragrant and soft aroma. Centuries, styrax resin is associated with the scent of burning incenses. The styrax resin fragrance formula have been limited investigated domestically, therefore the resin price were low appreciated.

This perfume is an innovative product that utilizes an advantage of styrax essential oil as a base-note for a signature perfume. Combined with a variety of essential oils from tropical forests include pines, eualypt, cananga, ouds, oranges, etc; the styrax oil became a fixing agent which formulated by considering the aroma gradation in accordance with the release of constituent essential oils particles.

As a signature perfume, absolutely different product compared to many perfumes item on the domestic market, styrax perfume is also free alcohol with a high essential oil concentration so that their exotic scent can last up to 16-24 hours. In addition to fragrance and refreshing, this perfume contains compounds that can calm the mind (aromatherapy and antidepressants), an effect that other perfumes do not have.

4.3. Added-value

As community forests managed, the incense resin trade-system has been carried out traditionally. For years the incense trade follows the following schemes:
a. The first pattern, this main scheme, farmers sell incense resin to small traders (local collectors).
   Furthermore, collectors sell the resin to large trader (whole trader), who are in the capital of the sub-district or district. Furthermore, whole traders send it outside the region or export abroad.
b. The second pattern, farmers sell resin directly to large (whole) traders. The whole traders send the resin outside the region or export abroad.

Generally, the resins have not been processed in these stages. The resins were traded according to the quality classes where described in Table 1, which classification and pricing were more determined by the trader. For years the incense resin price fluctuated unilaterally by whole traders. The following Table 2 illustrates the resin prices according to current resin grade at farmers and traders level in Lake Toba region.

| Grading         | Price at farmer- local trader (IDR) | Price at local seller – whole trader (IDR) | Margin Price (IDR) |
|-----------------|-------------------------------------|--------------------------------------------|-------------------|
| Grade I (Coarse Mata) | 250,000 – 290,000 | 300,000 – 350,000 | 50,000 – 60,000 |
| Grade II (Fine Mata)   | 180,000 – 220,000 | 230,000 – 280,000 | 50,000 – 60,000 |
| Grade III (Tahir)     | 150,000 – 170,000 | 175,000 – 200,000 | 25,000 – 30,000  |
| Grade IV (Jurur)      | 100,000 – 120,000 | 125,000 – 140,000 | 20,000 – 25,000  |
| Grade V (Barbar)      | 85,000 – 90,000  | 100,000 – 110,000 | 15,000 – 20,000  |
| Grade VI (Ash – flakes) | 50,000 – 75,000  | 60,000 – 80,000 | 5,000 – 10,000  |
The highest purchase price at collector (local) trader reaches IDR 250,000 to 290,000/kg for the highest quality (Grade I Course Mata) and the lowest is IDR 50,000 to 75,000 for the lowest (Grade VI ash - flakes). These incenses are sold to large (whole) traders. On this stage, the resins were sorted through sifting and repacking. The purchase price of highest quality (Coarse Mata) from local small traders set by whole traders at the price IDR 300,000 to 350,000/kg for. Furthermore whole traders sell the incenses outside the region at a price of IDR 400,000 to 450,000/kg for the highest quality. But, the highest quality is quite difficult to obtain, generally the resins concerned to trade are Grade II, III and IV.

Processing resin into an essential oil form can increase the added-value of styrax resin. When the resin has been processed into styrax oil, the selling price reaches IDR 5,000 to 7,000/ml or around IDR 5 to 7 million per liter. While the production costs and raw materials were calculated at IDR 1,000,000 to 1,500,000 per liter. In this case, the added-value of processing resin into high economic value of essential oil reaches four times or IDR 4,000,000 to 5,500,000 per liter. Furthermore this essential oil were processed into a base-note perfume. The innovation appreciates the price. Referring to styrax based perfumes (Styrax cuir) price at IDR 1,833,033 to 2,388,498 (volume of 30 ml) with a styrax essential oil concentration of 5 to 10%, the value of styrax oil if processed into a perfume raw material becomes IDR 60-80 million per liter. The targeted market prospect of development of styrax oil based products is to meet the demand for imported perfume products which reached US $ 401 million. The market segments are middle to upper society class who love the exotic and energetic scent; tourists visiting Lake Toba; aromatherapy oil collector; hospitality industry and tourism.

Impacts of the innovation include increasing the added-value of styrax resin so that the community's economy increases. Furthermore, the initiation of processing industry development in the country and around the location of raw material supply will increase the efficiency of production costs and driving the national competitiveness. These will also build the nation's pride on domestic innovations products.

5. Conclusions
Benzoic resin is produced by the injured inner epithelial bark of styrax tree. Therefore, tapping of bark is the best effort to harvest the resin. But, styrax forest management has been carried out traditionally, including the harvesting techniques. One of scheme to increase added-value is resins processing into a perfume products. The processing products begin from extracting a solid resin into pure essential oil. There are two methods used, namely (a) extraction with solvent, and (b) distillation method. The amount of yield of benzoin oil produced by solvent method is influenced by incense grade from 23.9 to 34.6% and higher than distillation method. But the second method also produces high quality and quantity of hydrosol as side product with a distinctive aroma. Combined with various essential oils, the styrax oil becomes a fixing agent for a signature perfume. Processing raw materials into an essential oil increases the added-value of styrax resin. Innovation of styrax resin based products will reduce our country dependence on imported perfume and raw materials used for various personal cares.

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