Physical and mechanical properties of natural fiber from *Sansevieria trifasciata* and *Agave sisalana*

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Abstract. Sansevieria and sisal plants are ornamental plants that are very famous in Indonesia. Both are plants grow easily even though in the area with less water and sunlight. These plants have potential natural fibers that are used as raw material requirements for the fabric textile industry. The aims of this research were to determine physical and mechanical characteristics of sansevieria and sisal for fibers utilization. The mechanical decortication process was used for fiber extraction. The research method used was an experimental laboratory with a descriptive method. Parameters measured were length and diameter of fiber, color, fineness, moisture regain, tensile strength, and stretch strength. The results revealed that sansevieria and sisal fibers have diameter 103,60 μm and 182,50 μm; average length 68,40 cm and 81,60 cm; brightness level (L*) 67,62 and 66,42; yellowness (b*) 20,42 dan 23,80; fineness 6,30 tex and 19,70 tex; moisture regain 11,93 and 12,57 tensile strength per bundle 24,891.60 gf and 35,263.90 gf; stretch strength per bundle 20% and 22,90%. The physical and mechanical characterization showed that sisal fiber had better characteristics than sansevieria fiber. Fibers from these two plants have potential textile material characteristics, which are used as a needle.

1. Introduction
Sansevieria plant (*Sansevieria trifasciata Prain*) and sisal plants (*Agave sisalana Perrine*) are ornamental plants that are quite popular in Indonesia and can be easily found on roadsides, in parks, and in yards or planted in pots to decorate rooms [1]. They show the diversity of colors and shapes on the leaves. This sansevieria and sisal plant grows well in tropical and subtropical regions. Both are plants that are very easy to cultivate because they can grow in areas with little water and sunlight and without the need for much care given [2]. Sisal plants have started to be cultivated specifically as fiber-producing plants [3]. In Indonesia sisal plants have been developed in several areas, namely in East Java (Banyuwangi, Madura, Jember, Malang, Blitar, and Kediri), in Central Java (Magelang, Solo), Yogyakarta (Kulonprogo), in West Java (Pamanukan and Ciamis) and in North Sumatra (Pematang Siantar and Bilah) [4].

The use of these two plants that are often found is only as ornamental plants, but in fact, the two plants have other benefits that are still not widely known. This plant with advantages as pollutant adsorbents as well as fiber raw materials. The sansevieria plant has the ability to absorb pollutant gases (dangerous air gas) [5]. In addition, the leaves of this plant contain natural fibers that have the same characteristics as pineapple leaf fibers. These characteristics are not easily fragile, shiny, and long. Based on these advantages, this plant is potentially very used in industrial purposes. The fiber of sansevieria has begun to be developed in the field of the automotive industry as a reinforcing material...
in the manufacture of polyester composite materials [6]. Other uses of sansevieria fiber are used as raw material for making pulp (paper) [7]. Sisal plant fibers in Indonesia are widely used for rope needs, crafts such as footwear, brooms, brushes, burlap sacks, brushes [8]. The research of [9] made the fiber of sansevieria as a rope. The amount of utilization of natural fibers from both plants is because natural fibers have many advantages, namely the availability of quite abundant in nature, can be cultivated by humans (renewable), lighter loads, relatively cheap prices and most importantly are environmentally friendly.

The main chemical content that will determine the quality of the fiber is the content of cellulose and lignin. The higher the cellulose level, the better the quality of fiber and the higher the lignin will produce a stronger product because lignin will cause rigid structural properties [9]. The sansevieria plant and sisal plant contain high chemical components of cellulose and lignin [10]. Therefore, the sansevieria and sisal plants can be used as alternative natural fiber ingredients in industrial activities and a large number of engineering applications.

Natural fibers can be used as raw materials in fabric making. One of the widely used fabric-making techniques is weaving. So far the research related to the manufacture of woven fabrics from sansevieria and sisal fibers has not been done much. These study aims were to 1) analyze the yield value of dried fiber making, 2) to analyze the physical and mechanical characteristics of sansevieria and sisal fiber production without any chemical treatment.

2. Materials and methods
This research was conducted from November 2018 to June 2019. The process of making fibers to woven fabrics and testing the physical and mechanical characteristics of fibers and woven fabrics produced were carried out in several different locations. Fiber extraction is carried out in Alfiber a Small Pineapple Fiber Manufacturing Industry in Subang District, West Java. Testing of water content and color was carried out in the Postharvest and Process Technology Laboratory, Faculty of Agricultural Industrial Technology, Padjadjaran University, West Java. Testing of physical and mechanical characteristics was carried out at the Physics Laboratory, Bandung College of Textile Technology, West Java.

2.1. Materials
The materials used in this study were the leaves of the sansevieria and sisal plants and water for fiber washing. The tools used include calipers, analytical scales, decorticator machines, scissors, chromameters, ovens, saucers, desiccators, tensolab, Instron, and air permeability testing machines.

2.2 Methods

2.2.1 Raw material preparation
Harvesting or pruning the leaves of the sansevieria and sisal plants, then sorting and cleaning from the dirt carried away. Next, the leaves of the sansevieria and sisal are measured in length, width, and
thickness of the leaves, besides the initial weighing is done to be able to calculate the yield value of each process.

2.2.2. Fiber making
The leaves of the sansevieria were carried out using fiber using a decorticator machine. The decorticator machine is 80 cm long, 42 cm wide and 95 cm high, and uses a propulsion force of 7 PK. The fiber produced is then washed using clean water and carried out by using a tap to clean the remnants of waste or fiber binding substances that are still attached. Clean wet fibers are then dried using direct sunlight for about 3-5 days, depending on the weather. The decorticator machine is shown in figure 1. The flow diagram of the research is presented in figure 2.

![Flow diagram of the fiber making](image)

**Figure 2.** Flow diagram of the fiber making

2.2.3 Parameter testing
Some parameters measured starting from the preparation of the material to the fiber produced include:
1. Raw material characteristics (length, width, and thickness of leaves)
2. The yield of dry fibers
3. Water content [11]
4. Testing the physical properties of fiber
   a. Length and diameter of fiber (SNI 08-0590-1989) [12]
   b. Brightness [13]
   c. The fineness of fiber (SNI 08-1111-1989) [14]
   d. Moisture regain (SNI 8100: 2015) [15]
5. Testing the mechanical properties of fibers
   a. Tensile strength and stretch of fiber per bundle (SNI 08-1112-1989) [16]
   b. Tensile strength and stretch of fiber per strand (SNI 08-0618-1989)[17]

3. Results and discussions

3.1 Raw Material Characteristics
The leaves that have been cleaned and grouped are then measured for leaves dimensions. Sisal leaves have a longer in size, wider, and thicker than the sansevieria leaves. The length of the leaves of the sisal plant and the sansevieria used have met the requirements for fiber extraction using a decorticator machine. Appropriate leaves length criteria are needed. The length of the leaves that can be processed using a decorticator machine should at least 50 cm as a result, the leaves fibers are not swallowed or carried into the machine. The overall raw material characteristics are presented in table 1.

| Type of leaves | Parameters | (cm)         |
|---------------|------------|--------------|
| Sansevieria*  | length     | 77.18 ± 7.56 |
|               | width      |              |
|               | The edge   | 5.76 ± 0.75  |
|               | The middle | 6.33 ± 0.87  |
|               | The base   | 4.38 ± 1.08  |
|               | thickness  |              |
|               | The edge   | 3.68 ± 0.50  |
|               | The middle | 3.39 ± 0.52  |
|               | The base   | 2.99 ± 0.48  |
| Sisal         | length     | 89.03 ± 4.12 |
|               | width      |              |
|               | The edge   | 7.64 ± 1.37  |
|               | The middle | 14.85 ± 1.15 |
|               | The base   | 8.63 ± 1.76  |
|               | thickness  |              |
|               | The edge   | 4.27 ± 0.69  |
|               | The middle | 3.63 ± 1.05  |
|               | The base   | 3.01 ± 0.39  |

* Source: Napitupulu et.al, 2019 [29]

3.2 Fiber yield

3.2.1. Partial yield.
The partial yield was obtained from a series of dry fiber making processes which consist of several stages, namely fiber extraction, fiber washing, and fiber drying. Fiber extraction is done mechanically using a decorticator machine and the process is called decortication. The decortication process has the advantage of fast and easy fiber extraction process, besides that it does not use chemicals that can damage the environment. The results of calculating the average yield can be seen in table 2.
Table 2. Partial yield

| Type of leaves | The yield of fiber extraction (%) ± SD | The yield of fiber washing (%) ± SD | The yield of fiber drying (%) ± SD |
|----------------|--------------------------------------|-------------------------------------|----------------------------------|
| Sansevieria*   | 4.74 ± 1.06                          | 69.89 ± 1.48                        | 40.61 ± 1.25                     |
| Sisal          | 12.89 ± 2.10                         | 96.46 ± 4.62                        | 38.45 ± 4.30                     |

The largest fiber yield found in sisal plants was 12.89% compared to the Sansevieria of 4.74%. Both sisal and sansevieria have substantial yields compared to hemp plants which only range from 2.5-3% but are still lower compared to 30-40% cotton and 20% cotton [18]. The condition of the leaves of sisal plants and Sansevieria is used in a fresh and not in a dry state. Both sisal leaves and sansevieria are processed 1 day after harvest. This is known from the water content of the raw material. Water content data of raw materials can be seen in table 3.

Table 3. The moisture content of fresh leaves

| Type of leaves | Moisture content (%) wb ± SD |
|----------------|------------------------------|
| Sansevieria*   | 93.99 ± 0.20                |
| Sisal          | 81.18 ± 0.29                |

Based on table 3, it reported that the sansevieria water content is 93.99% and sisal is 81.18%. The high water content will make it easier when taking fiber or releasing leaf meat. The condition of the sansevieria and sisal used has gone through the sorting stage so that there are no damaged leaves.

Dirty wet fibers then pass to the washing stage. The washing process is carried out to reduce fiber binding agents [19]. Washing yields in both types of fiber both sansevieria and sisal are not 100%. This due to the washing and cleaning process of the two fibers. The washing process is carried out by scraping or cleaning the gum (fiber binding agent) which is still attached to the fiber using agape. In addition, cutting is done at the end of the fiber. Cutting is done at the end of the tangled fiber. In the washing process, the largest yield value found on sisal was 96.46% while the sansevieria was 69.89%.

Clean fibers then pass through the drying stage. Fiber drying is carried out in the sun drying method. Fiber drying takes between 3-5 days depending on the weather when drying. The drying of the two types of fiber is not 100% due to the evaporation of the water content in the fiber. The dried fiber produced can be seen in figure 3.

Figure 3. (a) dried sansevieria fiber (b) dried sisal fiber

The resulting partial yield value is influenced by the water content value. Water content measurement is carried out on wet fiber and dried fibers. The results of measurements of fiber water content can be seen in table 4.
The largest drying yield occurred in sansevieria wet fiber by 40.61%, while the drying yield of sisal wet fiber was 38.45%. This is because the water content of sisal wet fiber is 64.97% greater than the moisture content of sansevieria fiber, which is 62.04%. The higher the moisture content of wet fiber, the less dry fiber mass being produced. This is presumably because there is more mass evaporating in the form of water compared to the solid mass. The water content of dried fiber from sansevieria leaves was 10.79% and sisal dry fiber was 10.66%. Dried fiber water content is very important to know because it will affect the next process and also the shelf life of the fiber. Fiber that is too wet will be easily damaged or short shelf life, while fibers that are too dry will be easily brittle or damaged when the next process will be carried out. Water content and air humidity that is too low results in decreased fiber strength and easily broken fibers, which will affect the length of the fiber [20].

3.2.2. Total yield
The total yield in this study is the yield of the final product in the form of dried fiber. The total yield value is presented in table 5. These results exhibit that the largest total yield is found in sisal leaves of 4.79% compared to sansevieria leaves of 1.32%. Overall, the total yield to reach dried fiber is fairly low yield.

3.3. Physical and mechanical characteristics of dried fiber
The physical and mechanical characteristics of the fiber are very important characteristics to know. The physical and mechanical characteristics of the fiber will affect the fabric to be produced. Measurement of fiber physical characteristics includes fiber length, fiber diameter, color, fiber smoothness, and moisture regain. Measurement of mechanical characteristics includes tensile strength and elastic stretch and fiber strand, and the value of tenacity.

3.3.1 Length of fiber
Length is one of the important characteristics or properties of the fiber. Each fiber has a structure of shapes and sizes that vary depending on the nature of the fiber. The nature of the fiber in the textile industry is very important because the nature of the fiber determines the textile material produced. In addition, by knowing the nature of the fiber, it can determine the right processing. Fiber length is presented in Table 6.

Sisal fiber has a longer size compared to sansevieria fiber. This is because the length of the fiber produced depends on the length of the leaf or the raw material used. The longer the raw material used,
the longer the fiber being produced. The size of sisal leaves 89.03 cm is longer than that of the Sansevieria leaves of 77.18 cm. Leaves' length can be affected by plant age. Sisal fiber and sansevieria have a longer size compared to other natural fibers such as flax fiber 10.24 cm [21], as well as commercial fiber, 2.85 cm cotton fiber and 1.60 cm cotton fiber [18].

3.3.2 Colour of fiber
The colors in testing the characteristics of the fibers that need to be known consist of brightness (L*) and degrees of yellow (b*). In addition, there are values of a* and H. The color of the fiber is related to the aesthetic value of the fiber both of which will be given coloring or without impingement. The color of the fibers is presented in table 7.

| Type of fiber | L*± SD   | b*± SD   | a*± SD   | H ± SD   | Chromaticity     |
|---------------|----------|----------|----------|----------|-----------------|
| Sansevieria   | 67.62 ± 0.34 | 20.24 ± 0.41 | 0.89 ± 0.05 | 87.52 ±0.16 | Yellow Red      |
| Sisal         | 66.42 ± 0.23 | 23.80 ± 0.60 | -0.17 ± 0.18 | 90.41± 0.43  | Yellow          |

The results showed that the sansevieria fiber has a higher brightness value (L*) compared to sisal fiber. Sansevieria fiber has an L* value of 67.62 while sisal fiber has a value of L* of 66.42. This indicated that the sansevieria fiber visually appears whiter and brighter compared to sisal fiber.

Table 7 represented that the yellowish degree (b*) of sisal fiber is greater than the fiber of sansevieria. This demonstrated that sisal fibers visually appear more yellow than sansevieria fibers. The yellowish degree of these two types of fiber is greater than the yellowish degree of kapok fiber of 12.7 and cotton fiber 9.1 [18]. Accordingly, the brightness and yellow degrees of sansevieria fiber were visually whiter, brighter and shiny.

The a* value of both fibers shows a very small value. The a* value for sansevieria fiber is 0.89 and sisal fiber is -0.17. This was proven that sansevieria and sisal fibers do not have many red pigments and tend to be yellow.

The last parameter in color measurement is degree hue (H). Hue values are adjusted according to the color chromaticity range so that the colors of the fibers can be determined. Hue degree of the in-law leaf fiber is yellow-red, while for sisal fiber is yellow.

3.3.3 Fineness of fiber
Fineness is one of the important physical properties and needs to be observed. The fineness of the fiber is the relative size of the diameter expressed in terms of the weight of the unit length [22]. In this study, the value of smoothness is expressed in tex. The small tex value indicates the finer the fiber. The smaller the fineness of the fiber, the lighter the fiber will be. The fineness of the fibers is presented in table 8.

| Type of fiber | Fineness (tex) ± SD |
|---------------|---------------------|
| Sansevieria   | 6.30 ± 0.20         |
| Sisal         | 19.70 ± 0.40        |

Based on the average value of fineness in Table 8 it is known that the average smoothness of sansevieria is 6.3 tex and sisal at 19.7 tex. The fiber of sansevieria is finer than sisal fiber. This is because the weight of sisal fiber is greater than that of the sansevieria in the same length. Visually, sisal fiber has a larger size than the fiber of sansevieria. Fiber sansevieria and sisal have a value of fineness that is large enough when compared with the fineness of other natural fibers namely hemp fiber of 6 denier or equivalent to 0.67 tex [21].
3.3.4 Diameter of fiber
Fineness in textile fibers can indicate the size of the diameter of the fiber. This diameter is the result of the conversion of fineness then converted to diameter. Fiber diameter values are presented in Table 9.

| Type of fiber | Diameter (μm) ± SD |
|---------------|--------------------|
| Sansevieria * | 103.60 ± 0.00      |
| Sisal         | 182.50 ± 0.00      |

Based on Table 9 it can be seen that the average diameter of the fiber of the Sansevieria is 103.6 μm and Sisal is 182.5 μm. Sisal fiber has a larger diameter compared to Sansevieria fiber. This is proportional to the fineness of the fiber, which is a small fineness compared to the fiber of the sansevieria. The smaller the fiber diameter, the finer the fiber. This is because fineness is a ratio of length to the weight of fiber. According to [9] the diameter of sisal fiber is 100-300 μm. Meanwhile, according to [23], the diameter of the fiber of the sansevieria (*S. trifaciata*) extracted by water retting is 120 μm.

3.3.5 Moisture regain of fiber
Moisture regain is a characteristic index of the ability of water vapor absorption in the air (humidity), which also reflects the characteristics of the fiber structure. The moisture regains value is expressed in%. Almost all the fibers absorb water to a certain extent. Some types of fiber absorb more water vapor than other fibers. Fibers that absorb more water can be said to be hygroscopic [24]. The amount of moisture regain is very important in the textile industry because it deals with comfort (comfort) when used. Moisture regain values are presented in Table 10.

| Type of fiber | MR ± SD |
|---------------|---------|
| Sansevieria * | 11.93 ± 1.52 |
| Sisal         | 12.57 ± 0.19 |

Based on Table 10 it can be seen that the average value of moisture regain (MR) of the Sansevieria is 11.93% and Sisal is 12.57%. The mean value of sisal moisture regain is greater than that of Sansevieria fiber. Both of these fibers have greater moisture regain value than 8% cotton and 8.5% cotton [18], but the moisture regain the value of the Sansevieria fiber is smaller when compared to flax fiber which is 12% [21]. Sisal fiber has great moisture regain value. This shows that sisal fibers have the ability to absorb water faster than other natural fibers, but if the MR value of fiber is too high it may cause a shorter shelf life because the value of fiber moisture content will increase. The value of moisture regain is related to the value of fiber water content (MC). The higher the value of the water content, the MR value will increase as well. The value of moisture regain can be influenced by the morphology of the fiber. Fiber that has a structure or morphology that has many gaps in it or is called a lumen, then the possibility of fiber has high moisture regain value. This is because the lumen can act as a capillary along the fiber and can hold 27 times the weight of the fiber [26].

3.3.6 Tensile strength and stretch strength
Tensile strength and elongation are some of the fiber properties that are very important to know. The bundle tensile strength is the breaking strength or the ability of the fiber bundle to withstand breaking loads. In addition, tensile strength can be converted into specific stress or tenacity which is the tensile strength expressed in force per fiber fineness. Fiber stretch strength is the ability of the fiber to grow longer when there is a tensile load experienced by the fiber before breaking. Therefore, the term elongation is often stated in elongated when breaking up with units of %, which indicates the increase in length before breaking compared to the initial length. The value of tensile strength and elongation of bundling fibers is presented in Table 11.
Based on table 11 it can be seen that the average value of the tensile strength of sansevieria bundles is 24891.6 g and sisal fiber is 35263.9 g. The difference in the tensile strength value of the bundles of the two fibers is quite small. Aloe-in-law fiber and sisal fiber show high tensile strength values, this is due to the high cellulose content in the fiber. The cellulose content in fiber influences the characteristics of the fiber. The higher the cellulose content, the better the quality of the fiber [9]. The fiber of the sansevieria has high cellulose content up to 79% [7]. Sisal fiber contains 64–71% α-cellulose [3]. Sisal fiber has a greater tensile strength compared to in-law parents because of the rigid nature of sisal. This is influenced by the level of lignin in the fiber which causes the fiber to become hard and stiff. Lignin content in sisal fibers is 8% greater than in-fiber sansevieria 3% [10]. The tensile strength of sisal fiber is greater than that of sansevieria, but in contrast to the value of tenacity, the sansevieria fiber has a value of 33.17 g / tex which is greater than that of sisal fiber 30.92 g / tex. Tenacity is a textile parameter that is still related to the strength of a textile material. The smaller the size of the fiber but high strength, the fiber is said to have a high tenacity. This is in accordance with the size of the sansevieria is smaller than the sisal fiber but has a fairly high tensile strength like sisal fiber.

The elasticity of textile fibers is very useful, considering that there are so many tensile loads experienced by the fiber in the spinning, weaving and finishing processes. Based on table 11 it can be seen that the largest average value of bundle stretches was found in sisal fibers by 22.9% while the average value of stretching sansevieria bundles of fibers was 20%. The greater the elasticity of fiber, in a similar way, the better the fiber being produced as a fabric. This is because if the textile fiber has a small stretch, then even when there is a small tensile load the fiber will break easily so that it is not good to use it as a textile fiber for raw material for clothing.

The tensile strength of the fibrous strand is the same amount of strength as the load that the fiber can withstand until it breaks. The value of tensile strength really needs to be known because it will affect the product to be produced. The greater the strength of the fiber, the stronger the yarn and fabric produced. The fiber creep is the increase in fiber length during the test expressed in percent. The tensile strength and elongation strength values are presented in table 12.

### Table 11. Tensile strength and stretch strength per bundle and tenacity of fiber

| Type of fiber | Tensile strength (gf) | Stretch Strength(%) | Tenacity (g/tex) |
|--------------|-----------------------|---------------------|------------------|
| Sansevieria  | 24891.60 ± 5770.60    | 20.00 ± 1.80        | 33.17 ± 4.07     |
| Sisal        | 35263.90 ± 10583.70   | 22.90 ± 3.10        | 30.92 ± 4.61     |

Based on table 12 it is known that the average value of the tensile bonding strength of the sansevieria fiber is 364.25 gf and sisal fiber is 1264 gf. Sisal fiber has an average value of greater tensile strength compared to sansevieria fiber, but both of these fibers have greater tensile strength compared to 35.1 g hemp fiber [21]. The tensile strength value of the sansevieria fiber of the bride in this study was greater when compared with the study of [26] of 112 g with NaOH immersion treatment and 144 g with water immersion treatment without NaOH solution. This shows the process of taking fiber with a manual soaking process or water retting and the addition of a chemical NaOH solution can reduce the tensile strength value of the fiber. Chemical treatment of fiber can change the physical and chemical structure of the fiber surface [27].

Table 12 reported that the average value of sisal fiber elastic fibers is 11.50% compared to the average value of 7.50% sansevieria fiber fibers. According to the research of [28], the value of sisal fiber elasticity ranges from 5-14%. The average elongation value of both sansevieria and sisal fibers is...
high compared to the value of the cotton creep of 8% and cottonwood of 3.8% [18] and is greater than the value of flax fiber creep of 4.14% [21]. This shows that sisal leaf fiber and sansevieria have high elastic properties so that if it goes through the process or the next stage it will not break easily. If the allotment of fiber as yarn, the smaller the level of fiber creep will result in the low stretch of the fiber that will be produced.

4. Conclusion

In terms of chemical, physical, and mechanical characteristics, sisal fibers showed the best results for the fabric textile industry with a dry fiber moisture content value of 10.66%; fiber length of 81.60 cm; fiber diameter of 182.50 μm; brightness (L *) 66.42; yellow degree (b *) 23.80; value (a *) -0.17; Hue (H) value of 90.41; fineness 19.70 tex; moisture regain 12.57%; bundle tensile strength 35263.90 g; bundles stretching 22.90%; tenacity 30.92 g / tex; tensile strength of 1264.00 g; and stretched 11.50%.

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