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Sisal Fiber Of Agave H11648 as A Potential Raw Material For Eco-Friendly Textile

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Abstract : Sisal (*Agave sisalana*) is one of the most interesting fiber plants. Sisal fiber has good quality due to its physical characteristics such as shiny yellowish white color, strong, saltwater resistant, and eco-friendly raw material. The sisal fiber is biodegradable. In addition, the plant has also an important rule in improving land productivity. It contains 63.78% of alpha cellulose, 94.35% of holocellulose, 20.91% of pentosan and 4.76% of lignin. Usually, sisal fiber is used for carpet, mat, rope, bag and other handicrafts. With some treatments, sisal fabric quality can be improved to produce good quality textile. H 11468, a hybrid of *A. amaniensis* Trel. and Nowell × *A. angustifolia* Haw x *A. amaniensis*, is one of the most popular *Agave* fiber plants in the world. In Indonesia, it has been grown in an area of 800 ha of West and East Nusa Tenggara provinces, with total production approximately 5.57-ton dry fiber/year in the fourth year of planting. The bundle strength of the fiber achieved 31.36 g/tex. The individual fiber has intermediate length : width ratio (184.35). Sisal fiber has tenacity 40-49 cN/tex, strain 2-3%, initial modulus 25-26 N/tex, and tensile strength 510-635 N/mm^2. The fiber can be used for clothing, domestic use, geotextile, and others coarser material.

Keywords: H 11468, Sisal fiber, textile, ecofriendly
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Introduction

As a commitment to the environment, using natural resources to replace non-biodegradable material become the best choice of some industries. Indonesia is the top 5 of textile producing countries. Fashion sector is raising very fast and requiring more textile materials. Natural fiber resources from animals as well as plants have more advantages because of their environment-friendly sources, biodegradable, and has specific characters. The sisal plants grown in arid and semi-arid could improve land productivity.

Plant fibers are grouped according to plant parts where the fiber comes from e.i. bast fiber, leaf fiber, and fruit fiber. Bast fiber comprises of kenaf (*Hibiscus* *cannabinus*), ramie (*Boehmeria nivea*), roselle (*Hibiscus sabdariffa*), jute (*C. olitorius* and *C. capsularis*), linum (*Linum usitatissimum*). Coir (*Cocos nucifera*), cotton (*Gossypium hirsutum*) and kapok (*Ceiba petandra*) are grouped as fruit or seed fiber. Leaf fiber covers Agave (*Agave sisalana* and *A. cantala*), abaca (*Musa textillis*), etc.

One of promising fiber plant that can be developed in Indonesia is agave. There are several agave species developed around the world, but only two species of Agave developed in Indonesia e.i. *A. sisalana* (sisal) and *A. cantala*. Agave fiber has been used for long time by Indonesian for ropes, bag, geotextile, handy-craft, fishing nets, etc (Santoso, 2009). Agave has good physical charactersas fiber, ie: the color is shiny white, strong, salt water resistant, recyclable, and eco-friendly.

In 2015, PT Sumbawa Agro Sisal introduced H 11648 from Guangdong, China, and then The Indonesian Sweetener and Fiber Crops Research Institute (Balittas) has released it in 2017. H 11468 is a hybrid of *A. amaniensis* Trel. and Nowell × *A. angustifolia* Haw x *A. amaniensis* from East Africa and has been spread around the world due to its excellent fibre and production.

Fiber from Dry Climate

West and East Nusa Tenggara Provinces have a dry climate and semi-arid region. Usually, Sumbawa farmers planted corn or secondary crops once a year during rainy season with low productivity due to water inadequacy. Dry seasonis not suitable for food crops because there is no water irrigation. However, sisal plant can grow well in these conditions where other plants hard to grow (Gintare, 2018) since sisal plant is a xerophytic perennial herb, monocarpic and robust plant. Sisal is a strong tropical plant that requires full sunlight and moderate relative humidity. The plant uses Crassulacean Acid Metabolism (CAM) pathway, where CO2 fixation is able to conduct at night and closed stomata during photosynthesize at the day to minimize transpiration. It makes sisal is able to survive at extreme heat and drought conditions. Therefore sisal widely developed in arid and semi-arid regions (Dahal et al., 2003). Sisal plant tends to grow better on limestone land that loaded with bases, especially Calcium(Dahal et al., 2003; Santoso, 2009). Furthermore, during cultivation process, sisal only requires little treatment (Santoso, 2009). Other advantages of planting sisal are their extensive roots of the plant could reduce soil erosion. Sisal could also used as a border to protect crop from predators since its leaf arrangement. During fiber process, leaf extraction produces organic waste for compost or organic matter to fertilize soil andfor biogas (Hulle et al., 2015) and natural fungicide.Xie et al. (2016) reported that *Lasiodiplodia theobromae* the cause of mulberry root rot could be controlled significantly (73.1%) by fresh leaf juice of H 11648.

According to Berger (1969) and Tohir (1967), in the past between 1950-60's agave plantation has been developed in East Java (Ijen dan Kelud volcano), Middle Java (Merapi volcano area), West Java (Pamanukan and Ciasem), and North Sumatera (Siantar and Bilah). Today, most of *A. cantala* grown on Madura Island, while *A. sisalana* developed in South Malang, Jember, and South Blitar (Santoso,

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2009). Since 2015, the new introduction hybrid of sisal, H 11648, has been developed in an area of 800 ha, mainly on Sumbawa Island, West Nusa Tenggara and some areas ofEast Nusa Tenggara. The hybrid is well adapted on Sumbawa Island, grows faster and produces higher yield than in China, therefore it could increase land productivity on Sumbawa Island (Setyo-Budi et al., 2017).

Agave H 11648: Plant and Fiber Characteristics

Plant Characters

Agave H 11648 (Hybrid 11648) is a hybrid plant from backcrossing of (*A. amaniensis* × *A. angustifolia*) × *A. amaniensis* (Dahal et al., 2003; Huang et al., 2019). The hybrid is widely planted in many countries. Agave H 11648 has lanceolate bluish-green leaves. The potential length of the leaves reached 120-150 cm and the potential width ranged from 11 to 15 cm. The plant has a dark brown spike at the tip of each leaf and without spines on the leaves margin. The leaves shrouded in a thin layer of wax.During its life cycle of 8 to 13 years, the plant produces 560-650 leaves. Each leaf has a maximum weight of 520 g with fiber content 4-5.3%. H 11648 produces 4.73 – 5.96ton dry fiber/year/ha depends on the environmental conditions, farming management, and age of the plant. The first harvest was carried out at 36 – 48 months after planting. On Sumbawa Island, H 11648 produces 5.57-ton dry fiber/year/ha in the fourth year of planting. The variety adapts to various environmental conditions. Nevertheless, H 11648 is susceptible to zebra diseasecaused by *Phytophthora* (Setyo-Budi et al., 2017). The life cycle is longer, the leaf and fiber production of Agave H 11648 are higher than *A. sisalana* (Dahal et al., 2003). Committe on Commodity Problems (2013) of FAO reported that *Agave sisalana* could produce 12.5 tonnes of dry fiber/hectare while H 11648 produced 17.6 tonnes of dry fiber/hectare in 8 year sisal life cycle in Tanzania.

Figure 1. Appearance of sisal H 11648 plant. Source : Setyo-Budi et al. (2017)

Figure 2. H 11648 fiber

Chemical Composition of Fiber

Main chemical components of plant fibers are cellulose, hemicellulose, and pectin with ratio are widely different between plant types and species (McDougall et al., in Brink et al., 2003). According to Magaton et al. (2015),in Brazil, fiber of Agave H 11648 has similar chemical composition to *Agave sisalana*. However, chemical composition of fiber of*A. sisalana* grown in Indonesia different to this grown in Brazil (Table 1).

Table 1. Chemical composition (%) of *A. sisalana* and H 11648 fibers

Agave	Celluloce/ Glucans	Pentosan/ Xylan	Holo-cellose	Lignin Klason	Extract-ives	Fiber origin	Reference
sisalana	63.78	20.91	94.35	4.76	0.18	Indonesia	(Jamil et al., 2018)
sisalana	61.40	13.80		10.70	2.43	Brazil	(Magaton et al., 2015)
H 11468	60.20	14.10		12.00	3.34	Brazil	

Morphology of Fiber

Morphological properties of the fiber will determine compatibility of fiber use. For textile material,the most important factor is the ratio of length and width of the individual fiber cell. For example, clothing requires length and width ratio more than 1000, which will be fulfilled by ramie, flax, and cotton fibers. while jute, kenaf, roselle, abaka, and sisal fibers are less than 1000 and considered as intermediate length: width ratio, thus they are usually used for coarse textile. The surface and the cell tips of sisal fiber are uniforms(Brink et al., 2003).

Table 2. Fiber morphology of H 11648

Parameters	Value
Length (mm)	2.43
Width (μm)	13.18
Length : width ratio	184.35

Source : Unpublished data

Physical Properties of Fiber

H 11648 fiber has a shiny yellowish white color. The fiber bundle strength reached 31.36 ± 1.85 g/tex (Setyo-Budi et al., 2017). There is a lack of information about the properties of H 11648 fiber. For sisal fiber physical properties, the tenacity reaches 40-49 cN/tex, strain 2-3%, initial modulus 25-26 N/tex (Hulle et al., 2015). According to Weindling in Brink et al. (2003) tensile strength of fiber strands and

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durability in leaf fiber group, sisal fiber are the second after abaca fiber and better than New Zealand flax and Mauritius hemp. Tensile strength of sisal achieves 510-635 N/mm^2 (Eichhorn et al. In Brink et al., 2003). However physical properties can be widely different within species even between fiber strands in the same plant. Moisture content, temperature, and test methods also affecthe value of physical properties (Brink et al., 2003). Moreover, Ekundayo and Adejuyigbe, (2019) explained that sisal fiber is biodegradable, does not trap dust and moisture, can be dyed, sound absorber, and fire resistant with natural borax treatment.

Sisal Fiber as A Textile Material

Before, plants fiber used as a raw material for textile, it passes through several steps including cultivation, harvestingleaves, fiber extraction, fiber hackling and weaving (Li et al., 2008). Sisal fiber is extracted from sisal leaves using a decorticator machine. The fibers are spinning into yarn or thread and then knitting or woven to get fabric. Clothing, domestic use, and coarser material such as burlap are included in fabrics (Brink et al., 2003). Meanwhile, FAO (2019) wrote that the main use of sisal fiber in textile is for buffing clothbecause sisal fiber has enough strength to polish steel without scratch it. Sisal fiber also used as geotextile in road constructions, reclamation of land and stabilization of slopes (Teresinha, 2017). Sisal yarn has a potential function as a flame retardant and the ability was increase up to 1.5 times aftermethylol dimethylphosphonopropionamide (MDPA) application (Shukla et al., 2017).

According to Methacanon et al. (2010) research, sisal fiber has good potential as raw material for woven limited life geotextiles (LLGs) for land strengthening. Dry sisal and roselle fiber have a significantly higher tensile strength than that of water hyacinth and reed fiber. Furthermore, the tensile strength and elongation of them are increased when the fibers are wet. The researchers also investigated the moisture absorption, thermal property, and durability of the fibers after accelerating weather exposed.

Figure 3. Fabrics made from sisal fiber (Manyam and Alapati, 2018)

Manyam and Alapati (2018)have successfully increased the flexibility of sisal fiber for better yarn spinning with an eco-friendly method. The yarn weaved to form

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a fabric. The sisal fiber treated with an enzyme to make it smoother, brighter, slightly more flexible, drapability, and suitability of the fabric.

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