The Extraction of Fibre from Sisal Plant Leaf and Study of Comfortable Chemical Properties for Apparel Use

J.Ethiraj^{1,2}, Muktar Kassim¹, Erit Salahadin¹

¹ Department of Chemistry, Arba Minch University, Ethiopia

² Department of Chemistry, C. Byre Gowda Institute of Technology, Kolar, India

Paper Status

Received : March. 2020

Accepted : April 2020

Published : May 2020

Abstract: In vision of recent worldwide environmental issues, scientists have begun to show interest in developing the full potential of natural fibers and their assorted uses. Historically most of the methods used for the extraction of the sisal fiber inclusively the natural retting and mechanical process is not efficient in the removal of fibre compounds. In this study is related to how the impurities are removed from the fiber for apparel use. The alkali treatment, acidic treatment and treatment with varying solution of sodium salts is performed. The extractions of fibre have two stages, preliminary stage and laboratory stage. Primarily attaining maturity, sisal leaves was harvested manually by cutting from the leaf base with a sharp specialized crescent like knife having long handle. The harvested the fibres were systematically washed with distilled water and dried in a vacuum oven pre-set at 80°C for 24 hours after which raw fibres were sampled. They were then treated with diethyl ether: petroleum ether: Ethanol (2:2:1), followed by ethanol. After the extraction process was completed, the length, diameter, moisture adsorption properties, physical shape, color, the visual appearance of fibre after treated with NaOH and some other physico-chemical properties of fibre will be evaluated.

Corresponding Author

Ethiraj J

Ethirajj96@gmail.com

Keywords: Apparel, Comfort, Extraction, Sisal, Bamboo Fabric

Citation: J.Ethiraj, Muktar Kassim, Erit Salahadin, *The Extraction of Fibre from Sisal Plant Leaf and Study of Comfortable Chemical Properties for Apparel Use, Research Journal of Textile and Leather, 1(1), 28-35, 2020*

1. INTRODUCTION

Textile Fibers are long strands of molecules inter-connected to form a linear, string-like structure. They can be natural, synthetic or sometimes semi-synthetic [1-2]. Natural fibers are bio-based fibers from vegetable and animal origin. Natural fibers are greatly elongated substances that can be spun into filaments, thread or rope [3]. This definition of natural fibers includes all natural cellulosic fibers, such as cotton, jute, sisal, flax, hemp, etc. and protein based fibers such as wool and silk. The United Nations declared 2009 to be the International year of natural fibers, with the central objective of promoting the use of natural fibers in current and novel applications,

which contributes to increased levels of income for fiber producers, processors and traders, while at the same time contributing to the increased use of environmentally friendly materials in those applications [4].

Sisal is a vegetable fiber extract from leaves of an Agave (Agave sisalana Perrine), a major tropical fiber used in agricultural and parceling twine of various kinds in addition to ropes, sacks, carpets, and upholstery. Agave is a genus that includes the common sisal (A.sisalana) and many other species such as Agave fourcroyodes (Henequen). The Agaves are indigenous to tropical and sub-tropical regions of Southern America, Mexico, Southern Coast of United States of America and the Caribbean Island. It was introduced to Tanzania by a German

agronomist in 1893 who imported bulbils from Florida, USA. From there, sisal spread to Kenya and other parts of East, Central and Southern Africa [5].

Sisal is also an excellent CDM (Clean Development Mechanism) crop for bioethanol as well as for afforestation over poor quality arid lands giving both permanent carbon credits of forestry for carbon sequestration [6]. In general sisal is not much infested by many disease and insect pest; and therefore, sisal plantation does not produce pesticide load to the environment. Besides, sisal plants reduce soil erosion through its extensive root system and contribute positively to watershed management. Sisal has several distinguishing characteristics which makes sisal a 'specialty crop' for conservation agriculture [6].

1.1 Fiber Extraction

Many research and developments are focused on composites with natural fibers as reinforcements. Natural fibers like hemp, jute, sisal, banana, bamboo, coir, etc., reinforced with polymer resins were investigated. Natural fibers especially plant fibers have attracted the researchers due to its low cost and biodegradability [7]. However, it has some disadvantages like poor bonding and high moisture absorption properties. Fibers have an appearance of hair-like strands. Fibers can be obtained from natural and synthetic forms. Natural fibers can be obtained from plants and animals [8].

Historically fiber is produced by using retting and mechanical process. Retting method is a traditional method to remove contaminations from the plant by biodegradation process comprising microbial sisal leaves which fiber from the pitch [9]. This process takes 15-21 days for a single cycle of extraction and degrades the quality of the fiber and under retting causes the removal of gummy materials such as pectin substances, and extraction of fiber becomes difficult [9].

Mechanical fiber extraction is small scale operations by using machines and is not effective in the elimination of cementing complexes such as mostly waxes, hemicelluloses, lignin and hydrocarbons in the between fibers [10].

As a pre-treatment step, distilled water is used to clean raw sisal plant leaves. Then after

drying the fiber is treated with diethyl ether: petroleum ether: Ethanol (2:2:1) followed by ethanol, to ensure the removal of all polar and nonpolar compounds which includes waxes and other extractives such that only macro molecules or polymers remain. Then alkali treatment is followed to improve quality of the fiber [11].

Alkali used in fiber extraction softens the lignocellulose material between fibers and splits structural links between lignin and cellulose, which pointers to improved surface area as well as a degree of polymerization and reduces the breaking strength of fibers [12].

Historically the fiber extracted by using traditional method which is not very clean and the process is found to be a very slow and tedious exercise. This study concerns on how to improve the structural and chemical properties of sisal fibers and remove impurities from the fiber by using chemicals. The use of alkalis, glacial acetic acid and sodium chloride solutions with the varying concentrations will improve the fibers surface smoothness by removing the gluing substances [13].

1.1.1 Retting Process

Retting process is the traditional method. It is biological degradation method comprising microbial putrefaction of sisal leaves which splits fiber from the pith. This process takes 7-21 days for a single cycle of extraction and lowers the quality of fiber [14].

1.1.2 Decortication Process

Mechanical extraction with the help of decortication (Raspador) machine is best suited for small scale operations at village level. It is a semi-automatic machine running either on diesel or electricity and can extract fiber from 12 sisal leaves per minute. In this process the leaves are feed through sets of fluted crushing rollers. The crushed leaves are held firmly at their centers and both ends are passed between pairs of metal drums on which blades are mounted on scrap away the pulp and the centers are scrapped in the same way. The fiber strands are washed and either air or artificially dried. In Indonesia and Africa the dried fiber is held against a revolving metal drum to remove the remaining of dry adhering pulp [14].

Table 1. Chemical composition of sisal fiber

S. No	Chemical components	% by weight
1.	Cellulose	55-65
2.	Hemi-cellulose	10-15
3.	Pectin	2-4
4.	Lignin	10-20
5.	Water soluble materials	1-4
6.	Fat and wax	10.15-10.3
7.	Ash	0.7-1.5

2. MATERIALS AND METHODS

Matured sisal leaves were collected near the stadium in Abaya campus manually by cutting from the leaf base with a sharp specialized crescent like knife having long handle. The leaves were 75-165 cm in length [15].

Figure 1. Sisal fibre

2.1 Fiber Separation

The fibers were separated by Retting method and mechanical method. In Retting process sisal leaves were taken and the outer cuticle of leaf was removed off in order to accelerate the removal of non cellulose components of the leaves. The leaves were also detached lengthwise, coiled, engrossed and drenched in water in a plastic sink for 7 days at atmospheric temperature, to putrefy and loosen the gum that impasses the fibres to the leaves, that is when it was easy to remove the fibres from the leaf biomass and when shiny greasy filtrate was easy to remove from the fibres. The fibres were then extracted by mechanical deformation that is the rounded side of the knife was used to fix off the gum or the linked parenchyma cells from the fibre. Then the fibres were hung in air to dry and arranged for pre-treatment [14-15].

In Mechanical method sisal leaves were taken and leaves are crushed and beaten by blunt metal on flat and smooth surface of wood, then after simple scrapping only fibers was removed. The other parts of the leaf are washed away by water and the fibres were

hung to dry and made ready for pre-treatment [16].

Figure 2. Retting process

Figure 3. Extracted sisal fibre

2.2 Pre-treatment

As a pre-treatment step, the fibers were thoroughly washed with distilled water and dried in a vacuum oven pre-set at approximate 80°C for 24 hours. The fibers were removed and taken for Pre-treatment. The fiber was treated with diethyl ether: Petroleum ether: Ethanol (2:2:1) followed by ethanol to ensure the removal of all polar and nonpolar compounds which includes waxes and other extractives such that only macro molecules or polymers remain. Then fibers were thoroughly washed with distilled water and dried in an oven at 50 °C for 1 hr. [16].

2.3 Treatment with Different Solutions

After pre-treatment the fiber was treated with glacial acetic acid, sodium chloride solution, sodium hydroxide and sodium carbonate solution of varying concentrations. Hence, proper drying is important the fibers was dried under shade to avoid bleaching by direct sunlight [17].

2.4 Treatment with Sodium Hydroxide Solutions

Accurately Two types of treatments are carried out with sodium hydroxide solution. Such as treatment at the boiling temperature and the second is treatment at the temperature of 90-95°C for 15, 30 and 60 minutes for varying concentrations. Such as 0.2 N, 0.4 N, 0.6 N, 0.8 N solutions of sodium hydroxide. On three different 1 g of fiber samples in 30 ml solution for 15, 30, 60 minutes separately. In order to carry out the treatment is prepared. Here Six types of treatments are carry out only with 0.2 N NaOH solution. The same is true for other three solutions. After each treatment the fibres were safely hung in air to dry and ready for evaluation [17].

2.5 Treatment with Sodium Carbonate

Here similar procedure of treatment with sodium hydroxide solution was repeated with different concentrations of sodium carbonate solution for treatment. And also treated sample was store the same way [17].

2.6 Treatment with Glacial Acetic Acid

Three different 100 mL beaker were taken and 10 ml of glacial acetic acid was added on each. Then 1 g of fiber samples was immersed in each for 15, 30 and 60 minute respectively. Then the treated fiber was dried in air and safely kept for evaluation [17].

2.7 Treatment with Sodium Chloride

About 10 mL solution of sodium chloride was prepared in three different beaker. Then 1 g of fiber samples was immersed in each for 15, 30 and 60 minute respectively [17].

2.8 Evaluation of Fiber

Fiber length, moisture content, visual and hand evaluation such as; color, texture, smoothness, flexibility, physical shape and the burning characteristics of the fiber like other known cellulosic fibers was tested [18].

2.9 Fiber Length

The fiber length was determined by using mechanical method i.e. the fiber was measured in direct scale.

2.10 Moisture Content of the Fiber

Moisture content of the fiber was determined by difference in weight. The fiber weighed

before and after tested in oven. In order to determine the moisture content single sample should be put in the oven for 45 minutes.

2.11 Visual and Hand Evaluation

In visual and hand evaluation of Agave sisalana fibers the observation of fiber shape, color, and surface appearance are visually evaluated.

2.12 Burning Test

The fiber is brought near the flame and its flammability was tested.

3. RESULT AND DISCUSSION

The feasibility preliminary experiments of Agave sisalana fibre extraction confirmed that conventional or natural retting and mechanical technique have been the two comparative eco-friendly, low cost and environment friendly strategies that can be used to extract the fiber. These two approaches were chosen to be used for fibre extraction in the study. The identification confirmation properties, bodily structure and material performance properties of Agave sisalana fibre that was once extracted through the two approaches had been evaluated.

Fiber is very soft after each treatment before dryness and treatment for more than 30 minute lead to dryness both on boiling and heating at the temperature of 90-95°C with solutions. Color, smoothness and softness of the fiber depend on the length of the time. 15 minutes treatment no cause more color and appearance change and above 30 minute treatment is pale yellow. There is some color and appearance difference between boiling and 90-95°C temperature treatment with solutions. Boiling for 60 minutes causing burning. To sum up fiber heated 90-95 °C for 30 minute is pleasant to touch and smooth than others. The fibres were swollen and became smooth by the treatment of sodium hydroxide.

In this treatment the fibres became stiff and harder. There was no significant change on fibre length. The appearance of the treated fiber for most of the treatment is bumpy and the residue is adsorbed to the surface of the fibers. Here also 15 minutes treatment no cause

Table 2. Treatment of fiber with varying concentrations of sodium hydroxide solution.

NaOH	Treatment time (min)	Pictures	
		(90-95°C)	Boiling
0.2 N	15
	30		
	60		
0.4 N	15
	30		
	60		
0.6 N	15
	30		
	60		
0.8N	15
	30		
	60		

Table 3. Treatment of fiber with varying concentrations of Na_2CO_3

Na_2CO_3	Treatment time (min)	Pictures	
		(90-95 °C)	Boiling
0.2 N	15
	30		
	60		
0.4 N	15
	30		
	60		
0.6 N	15
	30		
	60		
0.8 N	15
	30		
	60		

Table 4. Treatment of fiber with glacial acetic acid and sodium chloride

Time for treatment (minute)	Glacial acetic acid (10 mL)	Sodium chloride (10 mL)
15
30		
60		

3.1 Length Measurement:

Fiber length was measured and the observation from the length is summarized in the following table.

Table 5. Length measurement

Leaves	Maximum length in cm	Average length in cm
Big leaves:	165	247.9556
Small leaves:	75	69.12

This indicates that the tip of leaf is very sharp and pointed.

3.2 Moisture Content of the Fiber

Moisture content the fiber treated with 0.2 N concentrations of sodium hydroxide solution, which is treated at the temperature of 90-95°C is determined by using moisture content testing oven and tabulated as follows:

Table 6. Moisture content of the fiber

Concentrations of solutions	Time treatment (min)	Moisture content
0.2 N	15	0.08
	30	0.13
	60	0.20

This result shows increment of moisture content of the treated fiber as time of treatment increases. This shows that sodium hydroxide improves the quality by removing the gumming substances from the fiber but sodium ion form ligand with the fiber.

3.3 Visual and Hand Evaluation

Visual inspection of the fibre for appearance and hand was performed first to consider the physical homes of sisal fibre.

The statements of the colour, shape, floor texture, flexibility and size of the fibre have been visually evaluated.

3.4 Color of the Fibre

The color of the uncooked untreated sisal fiber is white and the color of dealt with the fibre degrees from off-white to yellow relying upon the processing method used for fibre cure and the processing time. The retted fibre used to be darkened and discolored with a naturally searching mild brown colour. Treatment with Sodium carbonate develops the mild brown to rust shade (table 5).

3.5 Texture of the Fibre

The dry sisal fiber is stiff, harsh, coarse and hard-surfaced; the usual characteristic of dry leaf fibres however they are flexible, smooth and slippery solely when wet. The fibre feels strong and durable. It has a natural appear and the textured appearance when it is dry, the property that gives it a unique quality.

3.6 Physical Structure of the Fiber

The fibre is long, spherical and usually taper to a point, having one facet thicker, mainly from the lower facet of the leaf.'

3.7 Burning Test

When the fiber sample was once added close to the flame, it burnt brightly. In the flame the fiber persevered burning readily with a yellow-bright flame and persisted burning even after removal of flame. The scent of burning sisal fiber is like burning paper. Sisal fiber turns into very fragile when exposed to excessive temperature higher 100°C. The burning behavior of Agave Americana fibers is comparable to that of other natural cellulosic fibers.

4. CONCLUSION

The Agave sisalana fibres were extracted from the plant using dew retting process and the characteristics were studied. Based in the investigation it is concluded that the extracted Agave sisalana fibres are having the desirable properties for the application of textiles. The extracted fibre is having good moisture regain and sufficient fibre length. The smoothness, bulkiness and appearance of the fibres are improved by treating it with sodium hydroxide. The treatment of Agave sisalana fibres with sodium carbonate makes the fibres stiff and

hard. The treatment of Agave sisalana fibres with glacial acetic and sodium chloride makes fibre more brittle. Based on visual and hand evaluation it is concluded that colour, shape, surface texture, flexibility and length of the fibres are with the desirable properties state.

5. REFERENCES

- [1]. Nayak, L., Mishra, S.P. (2016). Prospect of Bamboo as a Renewable Textile Fiber, Historical Overview, Labeling, Controversies and Regulation. *Fash Text*, Vol.3 (2).
doi: 10.1186/s40691-015-0054-5
- [2]. Avinash, P. Manian., Thomas Bechtold. Handbook of Properties of Textile and Technical Fibres. (2nd ed.), 2018.
- [3]. Vilane, V.S., Thwala, J.M., Ndlovu, T., Zwane, P.E., Masarirambi, M.T. (2017). The Bio-processing of Fibres from Agave Sisalana and Agave Americana. *Research Application Summary*, pp.393-399.
- [4]. Furqan, A., Heung, S.C., Myung, K.P., (2014). A Review: Natural Fiber Composites Selection in View of Mechanical, Light Weight, and Economic Properties. *Macromolecular Materials and Engineering* 300 (1) 10-24.
doi: 10.1002/mame.201400089
- [5]. Mousumi, D., Mukeshwar, P., Rohit Sharma, G., Thakur, S., Pushpa Lal. (2010). Biotechnological Intervention of Agave Sisalana: A Unique Fiber Yielding Plant with Medicinal Property. *Journal of Medicinal Plants Research*, 4(3) 177-187.
- [6]. Sitangshu, S., Jha, A.K. (2017). Review Article Research for Sisal (*Agave Sp.*) Fibre Production in India. *International Journal of Current Research*, 9(11) 61136-61146.
- [7]. Gbenga, E., Sam, A. (2019). Reviewing the Development of Natural Fiber Polymer Composite: A Case Study of Sisal and Jute. *American Journal of Mechanical and Materials Engineering*, 3(1) 1-10.
doi: 10.11648/j.ajmme.20190301.11
- [8]. Layth Mohammed., Ansari, M.N.M., Grace, P., Mohammad, J., Saiful Islam, M. (2015). A Review on Natural Fiber Reinforced Polymer Composite and Its Applications. *Natural Fiber Reinforced Polymer Composites*. Article ID 243947.
doi: 10.1155/2015/243947
- [9]. Liu, M., Ale, M.T., Kołaczowski, B., Fernando, D., Daniel, G., Anne, S.M., Thygesen, A. (2017). Comparison of Traditional Field Retting and Phlebia Radiata Cel 26 Retting of Hemp Fibres for Fibre-reinforced Composites. *AMB Express*, 7(1) 58.
doi: 10.1186/s13568-017-0355-8
- [10]. Sorieul, M., Dickson, A., Hill, S. J., Pearson, H. (2016). Plant Fibre: Molecular Structure and Biomechanical Properties, of a Complex Living Material, Influencing Its Deconstruction towards a Bio-based Composite. *Materials (Basel, Switzerland)*, 9(8) 618.
doi:10.3390/ma9080618
- [11]. Lucian, Lucian, Ayoub, Ali. (2018). Polysaccharide-based Fibers and Composites, Chemical and Engineering Fundamentals and Industrial Applications. *Springer Book*.
- [12]. Wei, F., Sheng, Y., Xi-Luan, W., Tong-Qi, Y., Run-Cang, Sun. (2017). Manufacture and Application of Lignin-based Carbon Fibers (LCFs) and Lignin-based Carbon Nanofibers (LCNFs). *Green Chemistry*, 8(19) 1794-1827.
doi: 10.1039/C6GC03206K
- [13]. Rakesh Kumar, Sangeeta, O., Aparna, S., (2011). Chemical Modifications of Natural Fiber for Composite Material. Pelagia Research Library, *Der Chemica Sinica*, 2(4) 219-228.
- [14]. Manimekalai, G., Kavitha, S. (2017). A Review on Application of Retting Techniques for Natural Fiber Extraction. *International Journal of Creative Research Thoughts*, 5(4) 372-377.
- [15]. Liu, M., Thygesen, A., Summerscales, J., Anne, M.S. (2017). Targeted Pre-treatment of Hemp Bast Fibres for Optimal Performance in Biocomposite Materials: A Review, *Industrial Crops and Products*, 108, 660-683.
doi:10.1016/j.indcrop.2017.07.027

- [16]. Saha, S.C., Sarkar, A., Sardar, G., Ray, D.P., Roy, G. (2017). Formulation of Grading Parameters and Grading System of Sisal Fibre (*Agave sisalana*). *Journal of Agroecology and Natural Resource Management*, 4(2) 178-180.
- [17]. Abdel-Halim, E.S., Salem S. Al-Deyab. (2011). Low Temperature Bleaching of Cotton Cellulose using Peracetic Acid. *Carbohydrate Polymers*, 86(2) 988-994. doi: 10.1016/j.carbpol.2011.05.051
- [18]. Ashish, H., Pradyumkumar, K., Pooja, K. (2015). Agava Americans Leaf's Fiber." *Fibers*, 3(1) 66-75. doi: 10.3390/fib3010064