Egyptian okra Fibers, Extraction, and Investigation

Heba Tollah El Sayed Abo El Naga
Lecturer, spinning and weaving department, Applied Arts, Damietta University
des.hebatollah2020@gmail.com

Abstract:
The need to find environmentally friendly alternatives to synthetic fibers has led to an increase in interest in natural plant fibers over the past few decades.
Bast fibers, a relatively new class of eco-friendly materials that combine technological, financial, and ecological factors, have experienced significant demand in recent years.
Naturally extracted okra fiber was used in this study. After harvesting, the okra stems are treated as agro-waste without benefiting from it. Therefore, the purpose of this study is to utilize agricultural waste to obtain okra bast fiber and decrease the greenhouse gas emissions caused by burning agricultural waste. The chemical composition, physical, and mechanical properties of these fibers were studied as well as the morphology of Egyptian okra fibers, were studied through optical microscopy and scanning electron microscopy (SEM). When comparing the properties of these fibers with some bast fibers, a strong similarity was found between them, such as jute, flax, hemp, and ramie.

Keywords:
Abelmoschus esculentus (Egyptian Okra) Fibers, Agro- Waste, extract (water retting), chemical composition, Physical and Mechanical Properties, Scanning Electron Microscope (SEM), Optical Microscope.

Paper received September 5, 2023, Accepted October 20, 2023, Published on line January 1, 2024

1. Introduction:
Increasing awareness of the damage synthetic materials cause to the environment has led to the development of environmentally friendly materials. The development of such materials that can replace synthetic materials has attracted the attention of researchers. As a result, there is an increase in demand for natural fibers to be used in commerce.[(1)]
The focus of biodegradable and sustainable fibers is on clothing that will benefit from biodegradation and is made from environmentally friendly materials.[(2)] Among the various natural fibers is bast, which is mostly produced or extracted from plants, and considered a significant source of fiber.[(3)]
Bast fibers are mainly composed of lignocellulosic materials. It is extracted from the outer cell layers of different plant species' stems. [(4)], Cellulose, hemicellulose, and lignin are the three biopolymers that make up lignocellulosic materials, along with a few other, smaller substances.[(5)] The ratio of these chemical components varies with age, growth conditions, fiber source, and extraction technique. Bast fibers contain 60–75 percent cellulose, the primary structural element that gives plant cell walls and fiber their tensile strength and stability.[(6)]

Research Problem:
The stem of the okra plant is disposed of as agricultural waste. Without benefiting from it, although it is an abundant source of okra fiber.

Research Importance:
Increasing environmental awareness by exploiting the stems remaining as agro- waste after harvesting the okra to produce bast fibers and decrease the greenhouse gas emissions caused by burning these wastes.

Research Objectives:
Extracting fibers from Egyptian Okra stems and examining its properties.

1.1 Okra (Abelmoschus Esculentus)
Okra (Abelmoschus esculentus) known in many English-speaking countries as lady's fingers. Okra, a commercial vegetable crop, is a member of the Malvaceae family. Although okra can be grown on a variety of soil types, well-drained fertile soils with sufficient organic matter produce a high yield. In the tropics, the crop is frequently grown all year long[(7)]. Okra fibres are extracted from stem wastes that are left behind in fields following the harvest of okra plants.[(8)]
After harvesting the okra, the stems of okra plant remain as agro-wast in many agricultural lands in Egypt. The photos were taken from one of the agricultural areas in Damietta Governorate. Figure (1) (Researcher)

1.2 Extraction of Fibers:
Natural fibres can be extracted using a variety of techniques, including mechanical, chemical, and biological ones. Depending on the volume of fibre produced or the quality and qualities of the fibre bundles obtained, each approach offers a different set of benefits or disadvantages[(9)]. In this study, biological natural retting was used for obtaining okra fibers from stem wastes.

1.3 Microbial Retting or Water Retting:
Water retting is based on microbiological retting, which is one of the most extensively used technique for extracting natural fibres.[(10)] Retting is also known as degumming. It is a chemical procedure to separate individual fibers from non-cellulosic material that has been adhered to them.[(11)]

(a)  (b) 

Figure (1) (a) okra field (b) okra plant's stems after harvesting. (Researcher)

This technique involves submerging clusters of stalks in water. Finally, the water entered the root, increasing the water level inside the stem and causing the topmost skin to burst. This heightened uptake of moist air and decaying bacteria[12] which liberate the bast fibre from the surrounding cortex by dissolving pectin.[13]

The duration of time needed for retting depends on the water temperature, location, season, weather, water depth and source, stalk thickness, and amount of straw in relation to water volume. The stems are watched carefully during retting to prevent excessive fibre material breakdown, which would reduce fibre strength. Retting time, cellulose polymerization level, and fibre strength all have a direct relationship. [14]

2. Experimental

2.1. Materials

The waste stems of the okra plant, which is naturally available, were taken from one of the agricultural lands in Damietta, figure (2).

Figure (2) Waste Stems of the Egyptian Okra Plant

2. 2. Methodology, Extraction of Okra Fibers

The research follows the analytical experimental approach, which aims to extract fibers from Egyptian okra stems and examine their properties. The water retting technique is used to extract okra bast fiber. Following the fresh okra plant's harvest, a number of waste stems are immersed in water for 14 days to promote microbial decomposition, which makes it possible to easily separate the fibres and undesirable items caught in the fibres under running water. Then the fibres were dried in the sunlight. figure (3) shows Egyptian okra fibers after extraction(a) and after drying(b).

a)  b) 

Figure (3) Egyption okra Fibers (a) Fiber after extraction (b)Fibers after drying.

3. Measurement and Characterization

The tests were carried out under standard conditions at the electronic microscope unit at Mansoura University and National Research Center (Textile Research and Technology Institute).

Table.1. Laboratory Tests and Standard Specifications

Test	Standard Specification
Lignin (%)	TAPPI T222om (15)
Ash (%)	ASTM D2584 (16)
Moisture content (%)	ASTM D2654 (17)
Tensile Strength	ASTM D3822(18)

- The percentage of cellulose content in the fiber was determined according to (Earland and D. J. Raven) (19)
- Light microscope was used to show morphology of the fibres.
- SEM JEOL (JSM-6510LV) Fig (4) was used to measure the fibre diameter and morphology of the fibers

Figure (4) Scanning Electronic Microscope (SEM)

4- Results and Discussion:

4-1- Chemical and Physical Properties of Egyptian Okra Fibers.

Table.2. Chemical Composition and Moisture Regain of Egyptian Okra Fibers

Cellulose %	64-69
Hemi cellulose%	17-22
Lignin%	10-12
Ash %	2.105
Moisture content%	7.11

The results of Chemical and Physical properties of Egyptian okra fibers and a comparison with some natural bast fibres is presented in the Table (3)

Table.3. Chemical Composition and Moisture Content of Some Bast Fibres in Comparison to Egyptian Okra Fibers

Bast fiber	Cellulose%	Hemi cellulose%	Lignin%	Moisture content %	ref
Flax	60-81	18.6-20.6	2.2	8-12	(11), (20)

Jute	61-71.5	13.6-20.4	12-13	12.5–13.7	
Hemp	70.2-74	17.9-22.4	3.7-5.7	6.2–12	
Ramie	68.6-76.2	13.1-16.7	0.6-0.7	5–17	
Okra	64-69	17-22	10-12	7.11	This study

It is clear from Table (3) that Chemical composition and moisture content of Egyptian okra fibers are very close to some bast fibers properties (flax, jute, hemp, ramie)

4-2 Egyptian Okra Fibers Diameter:

The diameter was measured using Scanning Electron Microscope. As seen in Figure (5), the diameter of the fibers ranged from (82 µm) to (111.8 µm)

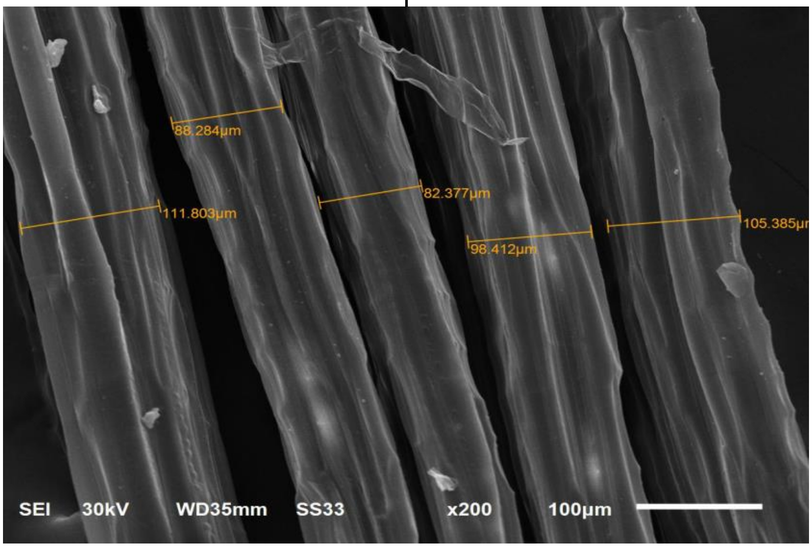

Figure (5) SEM images of Egyptian okra Fibres diameter

4-3 Mechanical Properties of Egyptian Okra Fibers:

five tests have been done for force measurement of Egyptian okra fibres samples, table (4)

Table.4. Mechanical Properties of Egyptian Okra Fibres

Sample No	Ultimate force (N)	Tensile strength (Mpa)	Elongation%	Young modulus (GPa)
1	10.7	506.1172	2.51	20.16
2	8.9	420.976	2.7	15.59
3	8.74	413.4079	2.4	17.22
4	7.39	349.552	2.6	13.44
5	7.77	367.5262	2.61	14.08
Average	8.718	411.5159	2.564	16.098

The results of mechanical properties of Egyptian okra fibers and a comparison with some natural bast fibres is presented in table (5)

Table.5. Mechanical Properties of Some Bast Fibres in Comparison to Egyptian Okra Fibers

Bast fiber	Tensile strength (Mpa)	Elongation%	Young modulus (GPa)	Ref
flax	345–1830	1.2–3.2	27.6–80	(21), (22)
jute	393–800	1.5–1.8	10–55	
hemp	550–1110	1.6	58-70	
Ramie	220–938	2–3	44–128	
Okra	349.552 -506.117	2.4-2.6	13.44- 20.16	This study

It is clear from Table (5) that the mechanical properties of Egyptian okra fibers are very close to some bast fibers properties (flax, jute, hemp, ramie)

4-4 SEM Appearance Cross Section and Longitudinal of Okra Fibres Morphology

The cross section of okra fibers figure (6.a,b) showed the middle lamella, the region at the interface of two cells. Okra fibres show a polygonal shape.

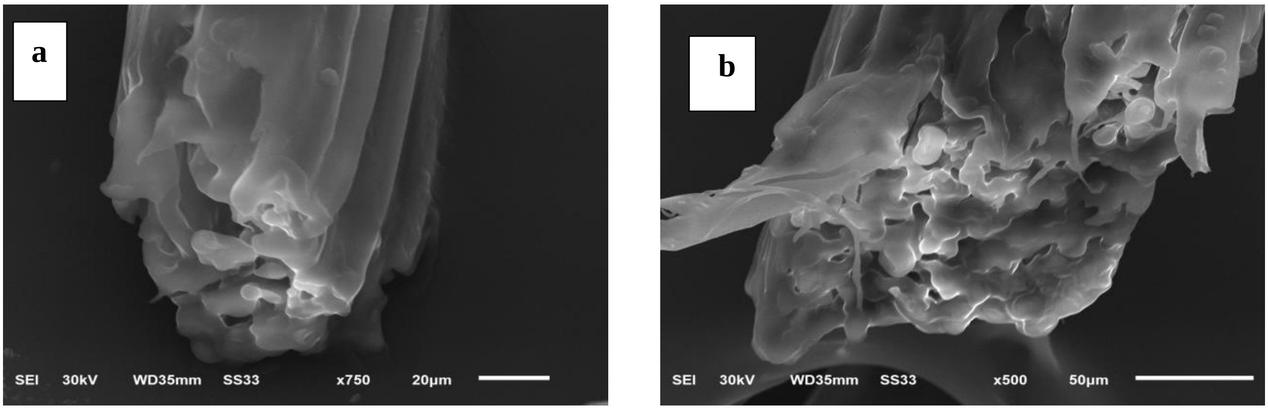

Figure (6. a, b) SEM Images of Egyptian Okra Fibre (Cross-Section)

The longitudinal view of the of Egyptian okra fiber in Figure (7.a,b) shows the surface of the okra fiber, consisting of a bundle of tiny fibers called microfibrils which show orientations parallel to the axis of the fiber and are privately bound together by non-cellulosic substances like pectin, giving the fiber its strength.

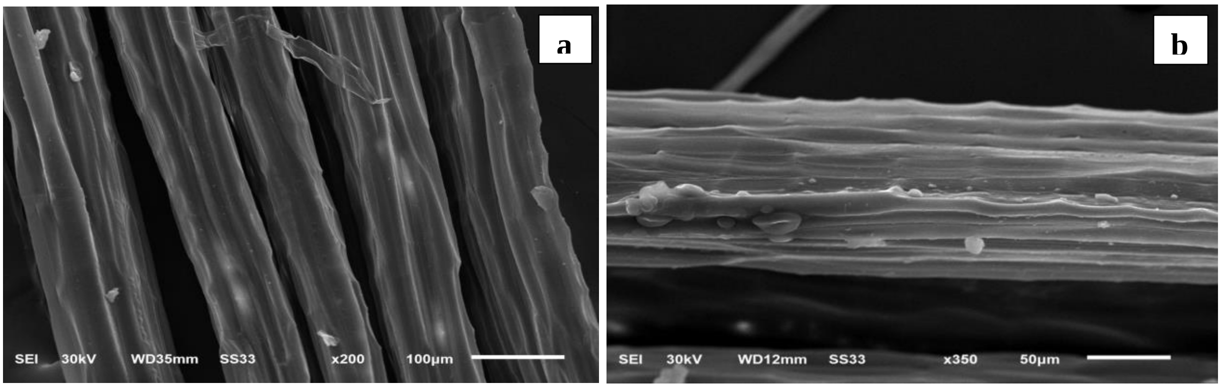

Figure (7. a, b) SEM Images of Egyptian Okra Fibre (Longitudinal)

4-5 Optical Microscopic View of Egyptian Okra Fiber

The fiber capsule was cut using an ultramicrotome into sections approximately 0.5 μm thick and stained with toluidine blue then examination with light microscope.

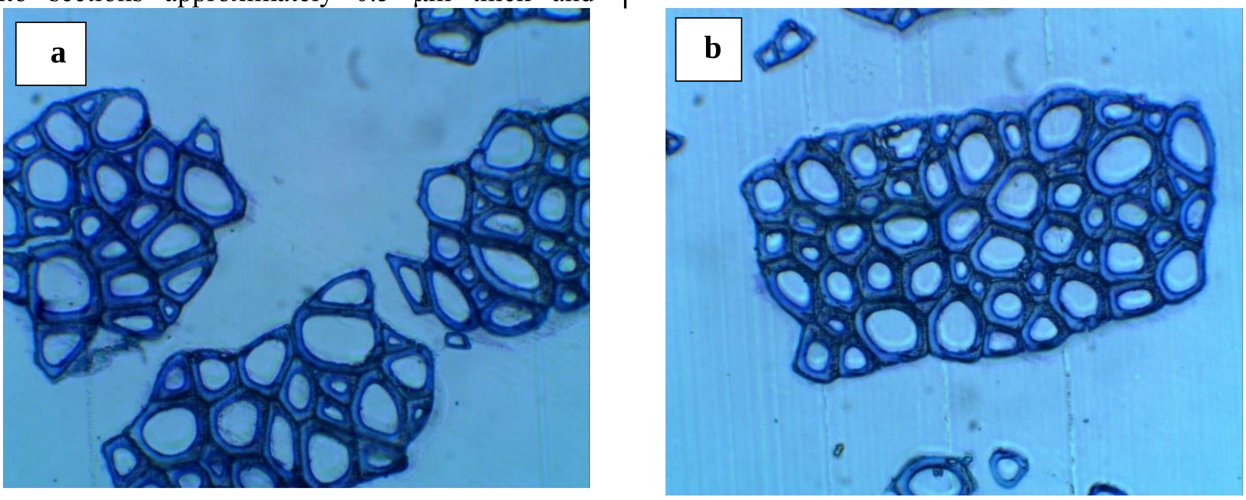

Figure (8. a, b) Optical Micrograph Images of Okra Fibers

optical microscopic view, figure (8.a,b) shows the cross section and structure of an okra fiber, which consists of ultimate fibres or cells. The shape of each ultimate cell ranges from being roughly polygonal to slightly rounded, and it has a central lumen similar to other natural plant fibers.

Conclusion:

The chemical, physical, and mechanical properties of Egyptian okra fibers extracted from the Egyptian Abelmoschus esculentus plant, as well as the morphology of the filaments, were studied. Its properties have been compared to some other bast fibers. It is found that to meet the increasing demand for naturally biodegradable fibers, okra fibers may have great potential to be used as a commercial bast fiber used in applications similar to bast fibers such as jute, flax, hemp, ramie, etc.

This study also creates social awareness in Egyptian society, especially among farmers, by exploiting agricultural waste resulting from harvesting okra and extracting fiber from it, which increases their income from an economic standpoint and reduces the environmental damage resulting from burning these wastes.

References

1- Girijappa Y.G., Rangappa S.M., Parameswaranpillai .J and Siengchin S, Natural Fibers as Sustainable and Renewable Resource for Development of Eco-Friendly Composites: A Comprehensive Review, Front. Mater, 6:226, 2019. doi: 10.3389/fmats.2019.00226

2- Blackburn.R, Biodegradable and Sustainable Fibres, Woodhead Publishing, 1st Edition - November 30, 2005, ISBN: 9781845690991

3- Debnath.S., 3 - Sustainable production of bast fibres, Editor(s): Subramanian Senthilkannan Muthu, In The Textile Institute Book Series, Sustainable Fibres and Textiles, Woodhead Publishing, pp 69-85, 2017, ISBN 9780081020418, https://doi.org/10.1016/B978-0-08-102041-8.00003-2

4- C. H. Lee , A. Khalina , S. H. Lee, and Ming Liu, A Comprehensive Review on Bast Fibre Retting Process for Optimal Performance in Fibre-Reinforced Polymer Composites, Advances in Materials Science and Engineering, Vol 2020, Article ID 6074063, https://doi.org/10.1155/2020/6074063

5- Lobo.F.C.M., Franco.A.R., Fernandes. E.M., Reis, R.L. An Overview of the Antimicrobial Properties of Lignocellulosic Materials. Molecules, 26, 1749. 2021, https://doi.org/10.3390/molecules 26061749

6- Kiruthika.A.V, A review on physico-mechanical properties of bast fibre reinforced polymer composites, Journal of Building Engineering, Vol 9, pp91-99, 2017, ISSN 2352-7102, https://doi.org/10.1016/j.jobe.2016.12.003

7- Abidi. A., Singh. P., Chauhan.V., Tiwari. B., Chauhan. S., Sobita.S., and Bilal. S., An overview on okra (abelmoschus esculentus) and it’s importance as a nutritive vegetable in the world. IJPBS, Vol 4, No 2, pp 227-233. 2018

8- Duman .M.N., Kocak.E.D , Merdan .N., and Mistik.I., Nonwoven production from agricultural okra wastes and investigation of their thermal conductivities, IOP Conf. Ser.: Mater. Sci. Eng. 254 192007, 2017

9- Ganan.P., Zuluaga.R., Velez.J.M, Inaki Mondragon,.I., Biological Natural Retting for Determining the Hierarchical Structuration of Banana Fibers. Macromol. Biosci., vol 4, No 10,pp 978–983,2004 DOI: 10.1002/mabi.200400041

10- Sisti, L., Totaro, G., Vannini, M. and Celli, A., “Retting Process as a Pretreatment for Natural Fibers for the Development of Polymer Composites". In: Kalia, S. (eds) Lignocellulosic Composite Materials. Springer Series on Polymer and Composite Materials. Springer, pp.97–135 ,2018, https://doi.org/10.1007/978-3-319-68696-7_2

11- Paridah. M. T., Ahmed. A. B., SaifulAzry. S. O. A., and Ahmed. Z., "Retting process of some bast plant fibers and its effect on fibre quality: A review," BioRes. 6(4), pp5260-5281, 2011.

12- Mohankumar. D., Veeraswamy. A., Bhuvaneswari .v., Saran. S., Jayaprakash. S., Gogul. M., Sridhar. S., Kathiresan. G., and Rajesh .K. L., Extraction of plant based natural fibers – A mini review. IOP Conference Series: Materials Science and Engineering, 1145. 012023, 2021. DOI 10.1088/1757-899X/1145/1/012023

13- Ntenga. R., Saidjo. S., Wakata. A., Djoda. P., Tango. M., and Mfoumou. E., Extraction, Applications and Characterization of Plant Fibers. IntechOpen. (2022). doi: 10.5772/intechopen.103093

14- Kelechi.E., Emmanuel. A., Babatope, Babaniyi.B., and Samuel.O., Studies on the extraction of naturally-occurring banana fibers. Int J Eng Sci. 2.PP 95-99, 2013.

15- TAPPI Standard Test Methods T222om, “Acid-insoluble lignin in wood and pulp”, 1996 .

16- ASTM D2584-18 “Standard Test Method for Ignition Loss of Cured Reinforced Resins”, ASTM International, PA, available at: www.astm.org.

17- ASTM D2654-22 “Standard Test Methods for Moisture in Textiles”, ASTM International, PA, available at: www.astm.org.

18- ASTM D3822 “Standard Test Method for Tensile Properties of Single Textile Fibers”, ASTM International, PA, available at: www.astm.org.

19- Earland. C., Raven. D., Experiments in Textile and Fibre Chemistry, chpter36(Determination of α-, β- and γ-cellulose), Elsevier Ltd, pp121-129,1970.

20- Gurunathan .T., Mohanty .S, Nayak .S. K., A review of the recent developments in biocomposites based on natural fibres and their application perspectives, Composites Part A: Applied Science and Manufacturing, Vol 77, PP 1-25, 2015, ISSN 1359-835X, https://doi.org/10.1016/j.compositesa.2015.06.007>

21- Pickering .K.L., Aruan .M.G., Le .T.M., A review of recent developments in natural fibre composites and their mechanical performance, Composites Part A: Applied Science and Manufacturing, Vol 83, PP 98-112, 2016,ISSN 1359-835X, https://doi.org/10.1016/j.compositesa.2015.08.038.

22- Ramakrishnan .T., Kumar.S.S. , Chelladurai.S.J. , Gnanasekaran.S. , Geetha .N. K. , Arthanari.R. , Debtera.B. , Effect of Moisture Content on Mechanical Properties of AAM Natural Fiber-Reinforced Isophthalic Polyester Composites, Advances in Materials Science and Engineering, Vol 2022, Article ID 3533143, https://doi.org/10.1155/2022/3533143