Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 1068-1078

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

The Effectiveness of Natural Luffa Sponge as a Rainwater Filter

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DOI: https://doi.org/10.30880/rtcebe.2022.03.01.122
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: The use of natural materials in the field of construction is becoming increasingly popular these days. The product used in this study is a luffa sponge as the main ingredient in producing rainwater filter. In this study, luffa sponge would be studied for its effectiveness and determine the composite, physical, mechanical properties and ability of luffa sponge as a filter material. Several laboratory studies have been studied and analyzed from journals and articles to support the effectiveness of luffa sponge as a filter material. This test would able to determine the properties and behavior of the luffa sponge. At the end of the study, that luffa sponge is capable of being a rainwater filter material. In conclusion, natural materials can also be a good mechanism or tool for rainwater filters. To make a luffa sponge as an effectiveness material for rainwater filter, the luffa sponge needs a pre-treatment such as a chemically treated with NaOH solution to improve the composite characteristics.

Keywords: Luffa, Luffa Sponge, Rainwater Filter

1. Introduction

Nowadays, water scarcity is one of the world's most pressing issues, mainly in this country. This issue could make it harder for people to go about their actual routine and can impact the industrial sector. Furthermore, the issue of water scarcity is intimately linked to the problem of water quality. Rahmat et al., [1] asserted that urban development, human activity, and industrialization would degrade the water quality, so it cause an inappropriate for use. One of the solutions for these issues is rainwater harvesting. As claimed by Adewumi et al., [2], rainwater harvesting is a system or process of absorbing, transmitting, and storing water through rainfall in the region (on the surface or in the subsurface reservoir) for beneficial uses. Lee et al., [3] indicated that Malaysia constitute the highest amount of rainfall throughout the year, ranging from 2500 mm to 3000 mm. As a consequence, rainwater harvesting may be the best option if there is a shortage of main water sources, as natural precipitation can be utilized for a variety of reasons. The research focuses on the implementation of luffa sponge as a rainwater filter material. The main objective of this study is to to study the effectiveness of luffa sponge as a filter material.

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2. Luffa Sponge

As stated by Alhijazi et al., [4], luffa is planted for harvesting before being cooked and consumed as a vegetable. Usually, luffa can reach all the way through South Asia to Central Asia and East Asia. The appearance of a luffa is similar to a cucumber. Additionally, other than becoming an ingredient for cooking, Sometimes peoples soak dried luffa for a few days before peeling it. The luffa will be a sponge after peeling and can be used for cleaning appliance. An example are such a scrubbed the pan, bath sponge or scrubbing the floor with the bleach. Luffa sponge, formed from the luffa cylindrical plant and having a recycling potential and biodegradability stimulate, is also one such economically feasible and environmentally relevant biological material. It has a fairly consistent stated lifespan but will biodegrade after being disposed of in composting conditions.

This plant has dark green, collected and round leaves with five to seven lobes. The leaves are gathered and have a dark green colour. The fruits are frequently cylindrical, although they can also be stripped and pale inexperienced or pale green in colour. When dried, a net of fibres forms, resulting in a luffa sponge that measures between 30 to 60 cm long and 8 to 10 cm wide. Luffa fibres are used in a wide variety of industrial applications, most notably as engine filters and sound absorbers. Figure 1 shows a dried luffa that has turned into a sponge.

Figure 1: Luffa sponge

2.1 Luffa and Its Composite Materials

The water absorption as well as mechanical properties of sponge-polyester composites, luffa sponge cellulose and nanometer composite materials, and the structure and high conductivity of luffa sponge fibre bundles are of particular importance in the study of luffa sponge fibres and their applications in composite materials. Alhijazi et al., (2020) [4] reported that the lignin and hemicellulose/cellulose chemical composition of the luffa usually consists of inorganic materials, such as glycoside, polypeptides, amino acids, proteins etc. While Adeyanju et al., (2020) [5] stated that the amount of luffa fibres used in composites is determined by their chemical composition. Table 1 shows the chemical composition of luffa fibres.

Table 1 : Chemical Composition of Luffa

Chemical Composition			
Cellulose (%)	Lignin (%)	Hemi Cellulose (%)	Ash (%)
63.0 ± 2.5	11.69 ± 1.2	20.88 ± 1.4	0.4 ± 0.10

From Table 1, Alhijazi et al., [4] suggest that luffa fibres were too good as most other fibres to be used in reinforced composites, particularly in terms of compositional properties. While Adeyanju et al., [5] reported that luffa fibres are approximately equally effective as the majority of alternative fibres for use in reinforced composites, especially in terms of structural properties.

2.2 Filter Potential of Luffa Sponge in Water Quality Analysis

According to Igboro & Daouda, [6] study the luffa sponge filter model as material has been tested for its efficiency in water purification. The filter medium that used which is a luffa sponge has been located at three places in four separate chambers, Starting from the more porous to the lower, e.g. 3,6 and 9 sponges, in the flow direction. The Luffa sponges received changed into reduce to length and mild pressed to form to suit into the compartment provide. At each chamber outlet, a series of tests have been performed on both the influent and effluent to determine the water quality test. In the laboratory, physical, chemical and biological tests were performed by applying standard methods. The alkalinity for the luffa sponge could help to regulate the pH of highly acidic wastewater. Overview of the laboratory test results showed in the Figure 2 :

Parameters		Concentration/intensity				Peak Reductions
		Raw	Filtrate1 (3 sponges)	Filtrate2 (6 sponges)	Filtrate3 (9 sponges)	
Physical	pH	7.85	7.86	8.00	8.47	
	EC	130µmhos/cm	130µmhos/cm	140µmhos/cm	140µmhos/cm	
	TSS	120mg/l	100mg/l	86mg/l	62mg/l	48.33%
	Color	15NSA	15NSA	10NSA	5NSA	66.66%
	Turbidity	39.10NTU	36.10NTU	36NTU	32NTU	18.15%
Chemical	Hardness	42mg/l	36mg/l	-	-	10%
	Chloride	88.62mg/l	74.44mg/l	-	-	16%
	Ammonia Nitrogen	12NAB	10NAB	-	-	16.66%
	Alkalinity	2mg/l	2mg/l			0%
	BOD	0.2mg/l	0.2mg/l	0.17mg/l	0.15mg/l	25%
Heavy metal	Chromium	0.82mg/l	-	-	0.28mg/l	65.85%
	Cadmium	0.13mg/l	-	-	0.091mg/l	30%
	Zinc	0.41mg/l	-	-	0.151mg/l	63.17%
	Nickel	0.3mg/l	-	-	0.08mg/l	73.3%
Biological	MPN	50	40	30	10	80%

Figure 2 : Overview of the laboratory test results

From Figure 2, the result indicates that the luffa cylindrical sponge has a large ability for the elimination of pollutants from water and toughness and microbiological reductions. According to Henini et al., [7], this study has resulted in the improvement and quantification of the physico-chemical phenomena experimental data identified during the adsorption of industrial wastewater. It seemed that the luffa sponge filter media can be considered to be an initial wastewater roughing filter but not a filter medium for water supply.

3. Materials and Methods

3.1 Data Collection

Data collection is the collecting and measurement of relevant variables in a specific framework that allows data to be discussed and results to be evaluated. Data collecting is absolutely important before any field of research can be carried out. At the beginning of the study, the researcher acquires all the required resources through selected topic journals and articles. In this project, the researcher was considered numerous methods or tests from journals and articles to support the effectiveness of luffa sponge as filter material. This test would also identify and analyse luffa sponge composite properties.

According to Bisen et al., [8] in order the extracted of luffa cylindrica is chemically treated with NaOH solution to improve the composite characteristics. Initially, the 5 samples of luffa fibres are cleaned using distilled water and dryed to extract specific pollutants and dirt in environmental condition. The dried fibres are then immersed for 4 hours in NaOH (5%), thus enhancing surface roughness and improving mechanical strengthening with matrix material. Following that, with the tap water including the distilled water, the treated fibre mat is properly washed and allowed to dry for a day at room temperature, followed by the sunlight in 3 - 4 hours.

Multiple tests, such as hardness, flexural, tensile, compression, impact, and so on, are used to define the mechanical properties of luffa fibre. The characteristics of a fibre composite were necessary to assure its suitability for utilization in industrial sectors. Mechanical properties such as impact, tensile, and flexural properties are evaluated for luffa composites.

3.2 Specimen

For this study, usual luffa sponge will be used as a main material to investigate. According to Shen et al., [9] before the luffa become a sponge, the luffa fruits were harvested when their skin had turned brown, indicating that they were fully mature. The dried luffa fruits were slightly compressed laterally in order to split them apart and take the skin from it. After separating the two ends of luffa fruits, the seeds were extracted.

Based on the Shen et al., [10] the natural luffa sponges were bleached with liquid chlorine bleach (4%) for around 1 hour to make them whiter. After that, it will become immersed for around half an hour in clean water and then dried in the sun. The overall diameter obtained with each specimen of dried luffa sponges tested ranged from 55mm to 86mm, based on the variety. As a result, the luffa sponge specimen should have been high enough to minimize the impact of specimen size. For luffa sponge, the maximum size required throughout radial direction is the entire segment of the luffa sponge column. Figure 3 shown a typical cylindrical specimen for a compressive test.

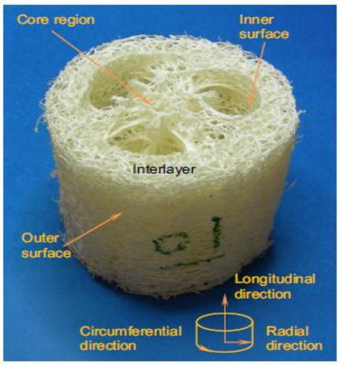

Figure 3: A luffa cylindrical specimen for a compressive test

3.3 Experiment Procedure

The test specimens were prepared in accordance with the ASTM standard in order to evaluate the fabricated composite's elastic property. According to Shen et al., [9] study, uniaxial compressive tests specifically 10^{-3} s^{-3}, were performed at very low pressure rates to achieve the mechanical properties under quasi-static loading.

Several trail experiments were also conducted using a Shimaszu Machine. In order to ensure accuracy of the test results, both machines were measured through the same load cell. An energy efficiency approach was used to calculate the average compressive force, density stress, and energy absorption from displacement and load curves. Displacement and load curves were also measured. A temperature and humidity meter were utilized throughout the tests to measure the temperature and moisture around the test specimens. Most of these experiments were performed on an Instron machine, as indicated in Figure 4:

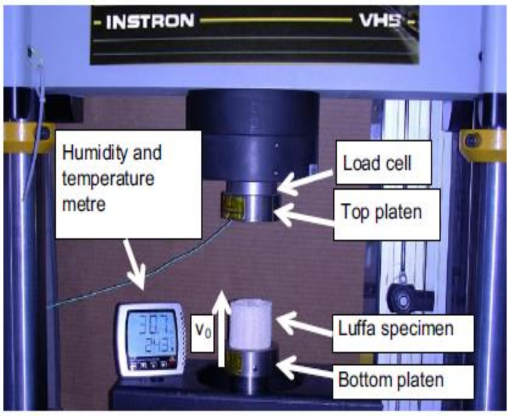

Figure 4: Experimental set-up of a quasi-static test of a luffa sponge column

As a consequence, the luffa sponge would be studied using a sponge cylinder structure made of single fibres. It is based on the dried spongy product obtained from luffa fruits that have been collected after they have reached full maturity, with their skin turning brown as a result of the removal of the pericarp and seeds. It will be possible to determine the mechanical characteristics of single fibres. Because of their relative regularity, single fibres will split from the inner surface of the fabric [10]. An isolated inner surface of single fibres from a luffa sponge is shown in Figure 5:

Figure 5: An Isolated Inner Surface

Based on Chen et al., [11] study, the obtained fibres had a length of roughly 30 mm and a diameter of 0.3–0.5 mm, respectively. It would be tensile tested on an Instron 5943 single column testing machine equipped with a 10 N load cell. The loading process would be governed by displacement, and the rate of loading will be 0.02 mm/s. Then, a fractured sample that a Zeiss Ultra Plus scanning electronic microscope would analyze to identify its micro-structure.

Standard tensile, flexural and impact properties of the luffa fibre composite also can be test. As A.Sree Vineesha, [12] stated that ASTM-D638M is the standard test method for tensile characteristics of fiber-resin composites, ASTM-D790M is the standard test method for flexural characteristics of fiber-resin composites, and ASTM-D256M is the standard test method for impact properties of fiber-resin composites.

Based on Chen et al., [13] study, on the basis of density, luffa sponges can be categorised into two types: LD and HD, which is low density and high density. LD is defined as a density range of 15 to 30 kg/m^2, while HD would be defined as a density range of 31 to 65 kg/m^2. As shown in Figure 6, each luffa sponge structure is made up of four layers: outer, inter, middle, and inner. In compliance with ASTM D 2654-89a standard, bundles of single fibres tied together were weighed then dried inside an air oven at 105 ^{o}C for 4 hours.

4. Results and Discussion

This section would show and elaborate about the result that been collected and calculate from the selected from the journals and articles. The data obtained from tests performed from articles and journals will be shown in the form of graphs, tables and charts to facilitate the process of analyzing the data. From the data, researchers could determine composite material, physical and mechanical properties of luffa sponge.

4.1 Data Analysis

Composites with particle reinforcement that had been treated with NaOH demonstrated higher tensile and flexural strength. Based on Sabarinathan et al., [14] study, the fibre content and bonding between both the fibre and matrix are important parameters for the tensile and flexural strength of the polymer composite. Figure 6 show that the alkali-treated composite has a higher tensile strength with 24 MPa. The average tensile strength ranges between 19 and 24 MPa. When the load is applied along the linen side of the composite laminate, the flexural strength is 59 MPa higher as shown in Figure 7:

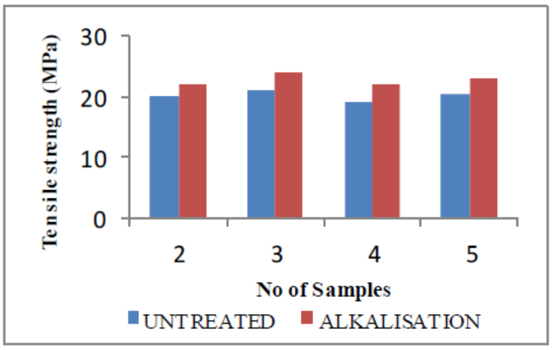

Figure 6: Tensile strength of the composite of Luffa Sponge

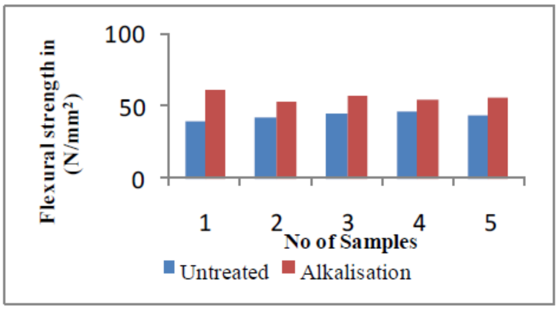

Figure 7: Flexural strength of the composite of Luffa Sponge

The treated fibre demonstrates enhanced composite strength by removing hollocellulose, pectin, wax and other fibre contaminants. The fibre retting process takes place during treatment and the surface is rough so that the binding between the fibre and the resin is good. Demir et al., [15] in their study indicated when comparing the outcomes of the untreated and treated composites, it's possible to see how important the coupling agent treatment works.

4.2 Morphology Studies

The chemical modification affects the surface of the fibres being smooth to irregular, and frequently porous. Figure 8 shows the SEM displaying surfaces of Luffa fibres with and without surface pre-treatments: a) untreated and b) NaOH treated.

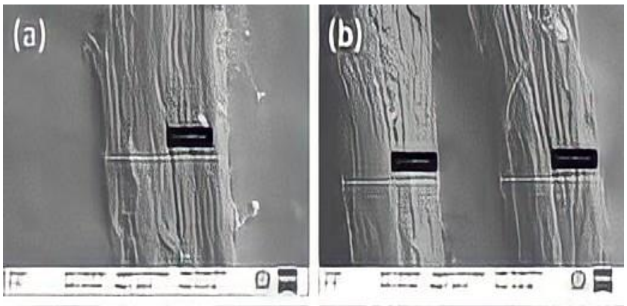

Figure 8: SEM photographs of surfaces of Luffa fibers

It can be observed that from Figure 4. 3 (a) the surface of the untreated fibre is extremely rough, with some contaminants attaching to the fibre surface. On either side, surfaces of chemically pretreated fibres appear smoother with NaOH-treated fibre presenting a little rougher surface with nearly no contaminants on the fibre surface as can see in Figure 4. 3 (b).

4.3 Deformation Features

Based on Shen, Xie, et al., [9] study, the Instron machine obtained force and displacement values. Typical force displacement curves are shown in Figure 9. It clearly indicates a relatively constant compressive force over a long stroke, which is appropriate for energy absorption. The nominal stress (defined as the force applied over the original cross-sectional area of the luffa sponge specimen) and nominal strain (defined as the displacement over the original height of the luffa sponge specimen) was calculated. The deformation patterns indicate that the specimen's overall compression strain is axially along its longitudinal axis, rather than folding the specimen wall.

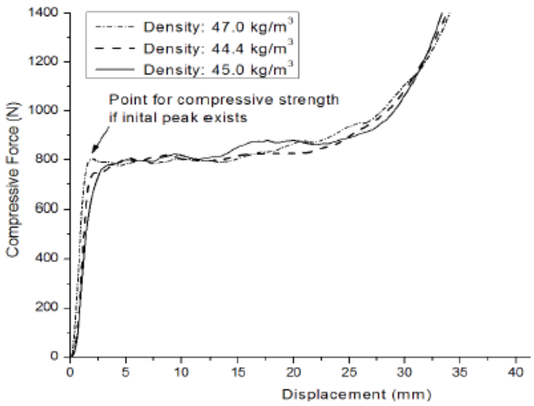

Figure 9: Typical Force-Displacement Curves

Based on those study, deformation of the luffa sponge can still occur. When the luffa sponge is compressed longitudinally, it still has a good abilities of energy absorption.

4.4 Structural Features of a Luffa Sponge

The fibres of the core component are loosely interconnected with one other, compared to the hoop wall, and a thick single fibre runs along the central line of the entire luffa sponge. Because fibre is the fundamental structural element of luffa sponges, it is essential to expose its structure and mechanical behaviour in order to comprehend the sponge's overall mechanical behaviour. The tensile behavior of the single fibres is demonstated in Figure 10:

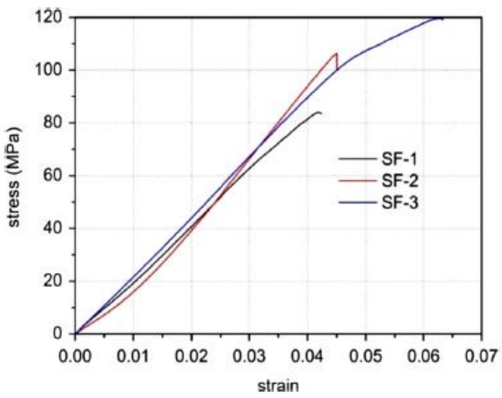

Figure 10: Stress–strain curves of single fibre

From Figure 10: the stress– strain curves of the single fibers are nearly linear-elastic, and the fibres' failure strains are very small, which is around 5%. The curves correspond represent data that are relatively near to the mean. For luffa sponge fibre bundles, the curves demonstrate yielding followed by plastic deformation till breakage strain. As stated by Chen et al., [11] the results have shown that luffa sponge mechanical properties are significantly affected by a degree of crystallinity.

Table 2 presents the mechanical properties of fibre bundles taken from four layers in luffa sponge which is outer layer, inter layer, inner layer and middle layer. In comparing to HD luffa sponge fibre bundles in each layer, LD luffa sponge fibre bundles in the corresponding layer displayed better tensile strength, Young's modulus, and elongation. In other terms, the mechanical properties of single fibre bundles in LD sponge luffa were better to HD sponge luffa.

Table 2: The Mechanical Properties of Luffa Sponge

		Density (kg/m^3)	**Young's Modulus (MPa)**	**Specific Modulus (MPa.m^3/Kg)**	**Tensile Strength (MPa)**	**Elongation (%)**
Luffa Sponge (LD)	Outer layer	458.31	1208	2.64	73.46	4.98
	Inter layer	431.85	958	2.22	53.82	5.16
	Inner layer	468.70	1897	4.05	91.63	9.81
	Middle layer	443.80	918	2.07	61.80	6.27
Luffa Sponge (HD)	Outer layer	391.50	635	1.62	24.03	2.54
	Inter layer	385.46	555	1.44	24.31	3.2
	Inner layer	411.73	1133	2.75	39.91	3.73
	Middle layer	421.90	880	2.09	42.55	6.67

The mechanical properties of fibre bundles are influenced significantly by the degree of fibre aggregation. For example, a higher degree of aggregation of fibre cells occurs in fibre bundles with improved mechanical properties. That was one of the reasons how fibre bundles from HD luffa sponge have a lower mechanical strength than those from LD luffa sponge.

4.5 Moisture Regain

As stated by Chen et al., [16] the moisture regain of fibre bundles from luffa sponge is presented in Table 3. The luffa sponge fibres had a higher moisture regain. The presence of a porous structure, surface grooves, and micro cracks in luffa sponge fibre bundles might contribute to a higher moisture regain.

Table 3: The Moisture Regain of Luffa Sponge Fibres

	Luffa Sponge (LD)				**Luffa Sponge (HD)**			
	Outer Layer	Inter Layer	Inner Layer	Middle Layer	Outer Layer	Inter Layer	Inner Layer	Middle Layer
Moisture Regain (%)	10.4	10.2	10.2	10.9	8.9	7.1	9.3	8.8

From Table 4. 2 in comparison with the HD luffa sponge, LD luffa sponge fibre had higher moisture regain in the range of 10.2–10.9%, as compared to 7.1–9.3% for HD luffa sponge. There were only small differences in moisture regain between four layers of LD luffa sponge fibre, however there were large changes between the corresponding layers of HD luffa sponge fibre. The middle layer of HD luffa sponge fibre had the highest moisture regain of 9.3 %, while the inner layer had the lowest moisture regain of 7.1 %.

4.6 Thickness Swelling

Based on Alhijazi et al., (2020) [4] study, thickness swelling seems to be a significant element of natural fibre composites and following moisture absorption that describes the dimensional stability of these composites. As stated by Akgül et al., (2013) [17] the thickness swelling of luffa fibre increased as the number of luffa layers in the sample grew, with samples with three luffa layers displayed the highest percentage of thickness swelling. Due to the visco-elasticity of the polymer matrix, swelling rates for polymer matrix composites are typically low during the earliest stages of moisture absorption. So, thickness swelling seems to be an important element that defines the composite's stability performance.

5. Conclusion and Recommendation

At the conclusion of this research, it indicates that the luffa sponge contains a resource that is not harmful and eco-friendly and that it has stable properties. It demonstrates that natural materials can also act as an effective mechanism or implement for the development of a rainwater filter.

The study has shown that luffa cylindrica has a significant capacity to remove heavy metals from water as well as to reduce hardness and microbiological contamination. According to these advantages, and despite the fact that it underperforms in terms of decreasing crucial parameters that determine the quality of potable water, it is nevertheless possible to conclude that the luffa sponge filter material still can be utilized as a preliminary rainwater filter.

A list of recommendations has been made in order to provide suggestions on the improvement of the research that could be done in the future:

i. Understanding the engineering properties of various agricultural products such as luffa cylindrica is essential for the design of product for filter material. The engineering properties are like mechanical, physical, atmospheric, fluid, and thermal. All such properties are immensely beneficial to handle, preserve, process, maintain, distribute and market agricultural goods in terms of quality evaluations.

ii. Several parameters of rainwater need to be tested to determine the effect of the discharge such as pH value, chlorine, total dissolved solid, turbidity, hardness, ammonia nitrogen and Biochemical Oxygen Demand (BOD).

iii. To make a luffa sponge as an effectiveness material for rainwater filter, the luffa sponge needs a pre-treatment such a chemically treated with NaOH solution to improve the composite characteristics.

Acknowledgement

The authors would also like to thank the Faculty Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

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