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INFLUENCE OF FIBER LENGTH, WEIGHT PERCENTAGE ON WATER HYACINTH POLYMER COMPOSITE MATERIAL PROPERTIES – AQUATIC WASTE INTO COMMERCIAL APPLICATIONS

A. Ajithram, J.T. Winowlin Jappes✉, I. Siva

Kalasalingam Academy of Research and Education, Anand Nagar, Krishnankoil, Virudhunagar-626126, Tamilnadu, India

✉ winowlinjappesjtw@gmail.com

Abstract. The major factors that affect the properties of fiber-reinforced composites are the length and weight percentage of the fibers. In this work, hyacinth fiber is extracted from the parent plant to the novel way of the mechanical-based extraction process. Mechanical experiments like tensile, flexural, impact strength and modulus are processed as per ASTM standards. The 2mm length of hyacinth fiber composite attained 38.456MPa tensile strength, and the flexural strength is attained at 54.76MPa. Then, the fractured surface of the hyacinth composite sample is carried to the scanning electron microscope. This works covers the hyacinth plants into hyacinth fiber reinforced polymer composites especially for commercial applications like particleboard, packaging boards, and it is adopted to convert the environmental threat of aquatic waste into a successful commercial product approach.
Keywords: polymer composite, water hyacinth fiber, mechanical properties, scanning electron microscope, absorption behavior, water hyacinth natural fiber composite

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1. Introduction

Present-day, polymers are frequently used in our day-to-day life. The plastic materials are needed for lightweight and optimum strength for the different kinds of applications. Based upon the properties and uses researchers focus on polymers and polymer-related components, but biodegradability and environment-related problems are the major difficulties of these products. Conventionally, synthetic fiber-reinforced composites are the major replacement for concretes, steel, and some other materials because of their high mechanical strength and low weight ratios, availability, and corrosion-free properties [1]. Furthermore, it can be modified engineering products to get notable properties. Based on synthetic fiber reinforced composites on large-scale industries and fabrication processes health problems and environmental-related problems have occurred. So, the particular alternative of synthetic fibers and products is an essential need. From this concept, natural fibers are a better solution

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and replacement for synthetic fibers [2-3]. Because it is low cost, lightweight, eco-friendly and easy availability. From the analysis of several kinds of literature natural fiber composite is superior to synthetic fiber composite to the environmental problem. Researchers carried their work while using the natural fiber as reinforcement material of the primary phase to combine with the polymer matrix for commercial, householding products as well as applications. This natural fiber composites have an effective replacement of auto insulation field applications, transport panels-related products. The natural fiber-reinforced composite has the better alternative for synthetic polymer composites. From the natural fibers fiber length, weight percentage also plays an important role in mechanical properties [4]. Different lengths and different weight percentages of the fiber reinforcement gained different mechanical strength [5]. Hybrid fiber composites with various ratios and the mechanical performance of sisal/banana hybrid composite and its mechanical strengths with a 4:1 ratio [6]. In this work, banana fiber is used as skin, and sisal fiber is used as a core material. Hybrid composite viscoelastic properties with a 1:1 ratio [7-8]. In this work water hyacinth natural fibers are initially extracted then it is reinforced with epoxy matrix materials concerning different lengths and different weight percentages, and the different lengths of the fiber's effects and their properties.

Water Hyacinth is a free-floating aquatic plant frequently available in local water bodies mainly in tropical and subtropical regions. Water hyacinth is formerly known as the Eichhornia Crassipes from the Pontideriacce family. The most dangerous aquatic weeds in the world list, the hyacinth plant is the topmost one. It has gained very high growth characteristics and it creates so many problems in various departments. Decreases the water levels, changes the physical and chemical properties of the water system. Because from the very minimum of time hyacinth plants are fully covered by the upper surfaces of the water bodies. Mosquito populations and some diseases are mainly caused by the hyacinth plant. Most researchers and environmentalists considered this plant is a serious threat to the environment [9-11]. WH plant contains 65% of cellulose, 30% of hemicellulose contents, and 3.5% of lignin contents are present. A high amount of cellulose and hemicellulose contents clearly explain the utilization of this hyacinth plant into various value-added products and commercial items. [21, 22] Temperature plays a very important role in hyacinth plant growth because in a very high and very low-temperature environment this hyacinth plant did not grow up. Medium temperature and slightly high temperature this plant easily withstands and highly grows up to the entire water surfaces. The hyacinth composites are examined the optimum temperature growth percentage as 24 to 35°C. [23] The beautiful flowers and shapes of the hyacinth plants it is introduced in the state of Bengal, India. But, in the end, it drained to the oxygen level in most of the water bodies. So, automatically fishes and other aquatic animals have died from this hyacinth plant. After the incident, this hyacinth plant is called Blue Devil and Bengal Terror [12-16]. Compared to the previous works published on other natural fiber composites this hyacinth-based composite is a very good alternative for quantity and quality aspects. From this work, the hyacinth fibers are extracted from the new novel mechanical way of fiber extraction machine and the proper fiber length to attain high mechanical strength is investigated in this work.

Nowadays sustainable environment is the main theme of developed and developing countries and they encourage them to utilize green products. Conventionally, aquatic plants are used to purify heavy metals and industrial wastes. Compare to the other aquatic plants WH is the most effective plant to purify and remove high metals from the water. Now, most of the researchers turned into water hyacinth plants from the economic aspects. In poor people regions the people use the WH plant to make handicraft items. In this work, the new novel mechanical way of hyacinth fiber extraction machine is produced. Based on the previous literature the hyacinth fibers are extracted only by the retting and manual way of the extraction process. In this work, a novel way of fiber extraction machine is introduced and the main objective of this work is to find out the proper length to achieve high mechanical strength of composite sample for particleboard and other commercial aspect applications.

2. Materials and Methods

The extraction process of WH fibers. Initially, the water hyacinth plant is identified by southern districts nearby Tamil Nadu, India. After cultivating the hyacinth plant then the plants are separated by their parts like hyacinth stem, petiole, leaves, and roots. The different types of fiber extraction process are tried to extract the hyacinth fibers like the common retting process, chemical extraction, boiling water extraction, manual extraction process. The hyacinth plant fiber extraction and mechanical way of extraction process is shown in the below Figs. 1 and 2.

Fig. 1. The extraction process of water hyacinth fiber

But, the process results in a very low fiber outcome and it takes more time. If the parent hyacinth plant stem is 24cm long, then it adopted to the different extraction methods, but the outcome of the fiber is coming from retting process is 8cm long, hot water boiling 7cm, chemical extraction method is 4 cm, and the manual extraction process is 10cm long [17]. The originality of the length and quantity of the fiber is highly affected by the previous methods. So, in this work hyacinth fiber is extracted with the help of a mechanical way of extraction method. In this method by utilizing the electrical motor with 1HP specification, threaded shaft, normal shaft, monoblock bearings, rounded plates the fiber extraction machine is designed. In this method, the final hyacinth fiber length is moreover the same as the stem length and it reduces 58% of the wastes. Finally, hyacinth plant fiber is extracted with the help of a mechanical way of extraction machine in an effective way.

Fig. 2. Water hyacinth fiber extraction machine

Fabrication of composites. An iron mold of dimensions 300×125×3 mm is used to fabricate a composite specimen. The upper and lower surface of a mold is coated with wax for removing purposes. Water hyacinth fiber has a density of 1.33 grams per cubic centimeter, as determined by SITRA (South India Textile Research Association), Coimbatore. The different fiber lengths (1, 1.5, 2, and 2.5cm) with different weight percentages (20, 25, 30, and 35) are used along with the Epoxy matrix material to fabricate the composite sample with the standard of LY556 and Hardener HY951. This epoxy matrix materials and hardener are purchased from Seenu and company, Coimbatore, Tamil Nadu, India. As the fibers of the hyacinth are arranged and placed on the mold randomly, their lengths vary. Water hyacinth fiber-reinforced composite samples are produced using compression molding machines. The compression molding machine's upper and lower plate temperatures are set to be 110°C and 100°C, the pressure is maintained at 1500PSI (Pounds per Square Inches) for the 2 hours curing time.

Testing Procedures and Standards. By utilizing the Universal Testing Machine tensile strength of the water hyacinth fiber-reinforced composite sample is identified with the ASTM D3039 standard. From this tensile test, the crosshead speed of the UTM machine is maintained at 2mm/min. All the mechanical tests taken from different fiber lengths with different weight percentages on five different composite sample specimens are tested and the average value is considered the strength of the composite samples. The flexural strength was also investigated with the help of the same UTM machine with ASTM D790 standard. From this test, the crosshead speed maintains at 1.5mm/min. By utilizing the Izod impact test machine the impact strength of the hyacinth fiber-reinforced composite sample is identified with ASTM D256. Water and chemical absorption behavior of hyacinth fiber composite is tested with ASTM D 570, and ASTM D standard. From the absorption studies initial weight of the composite sample is weighed with the help of an electronic weighing machine and put into the water, chemical solutions then the samples are wiped out to the water again the sample weight is measured and reported. This procedure is repeated periodically for up to 10 hours. Before initializing the absorption test all the test samples are dried with the help of a hot air oven. Once the specimen weight reaches the constant value then the sample is adopted to the absorption tests. Figures 5 and 6 clearly explains the water and chemical absorption behavior of water hyacinth different length fiber-reinforced to the epoxy matrix material composite samples.

SEM. Water hyacinth fiber-reinforced composite fracture surfaces are investigated with the help of scanning electron microscope VEGA 3 TESCAN. The polymer composite samples are coated before the investigation. The samples are examined with different magnifications, view fields, and 10Kv voltage. Figures 7, and 8 clearly explains the fractured surface of hyacinth fiber-reinforced polymer composite samples.

3. Result and discussion

Mechanical strength. From the mechanical tests, water hyacinth fiber composite samples are produced with different lengths and different weight percentages like 1mm, 1.5mm, 2mm, 2.5mm, and 20, 25, 30, and 35%.

Figures 3-4 clearly explained the different lengths of fibers with respective weight percentages of tensile strengths and peak loads. From this diagram, the tensile strength of the composite is increased to 2mm length and 30 weight ratios of the fiber reinforcement compare to the other length and weight percentages [18]. Further increasing length and weight percentages the strength of the composite is decreased because of low adhesion bonding to the primary phase of reinforcement and secondary phase of the epoxy matrix material, and the quantity of the reinforcement fiber is higher than the matrix material. The raw epoxy matrix composite attained 16.28MPa tensile strength. Investigation of the tensile strength of the water hyacinth fiber composite 2mm length and 30 weight percentage of the sample is attained at 38.456MPa highest strength and higher peak load compared to the others.

a) b)

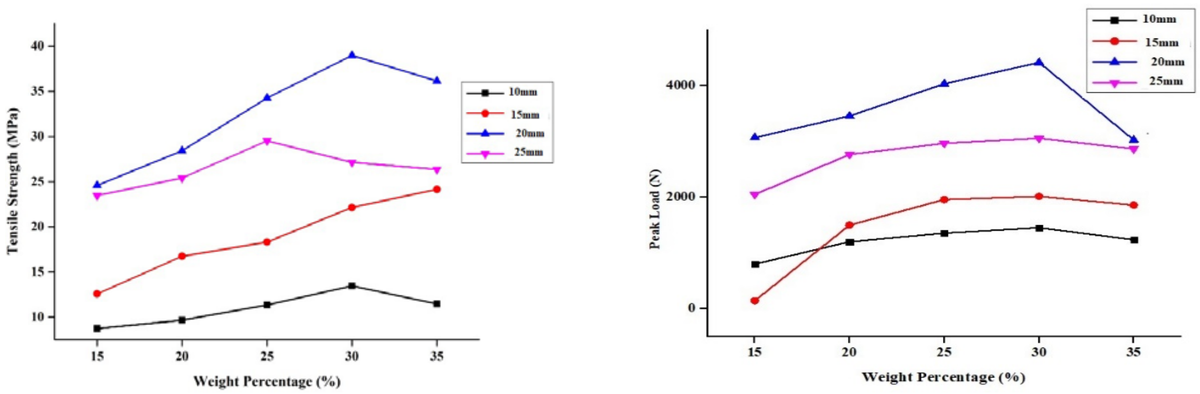

Fig. 3. Tensile strength (a) and modulus (b) of water hyacinth composite

Figures 4 (a, b) clearly explain the flexural strength and flexural modulus of hyacinth fiber composite samples. In this test also initially the increment of fiber length leads to the higher strength on a particular length (2mm). Furtherly increasing the length reduces the strength of the composite sample. The neat epoxy matrix composite attained 29.65MPa flexural strength. In this flexural strength also 2mm length and 30 weight percentage of the composite sample attained the highest flexural strength (54.76MPa) and flexural modulus (3.51GPa) compare to the other samples.

a) b) c)

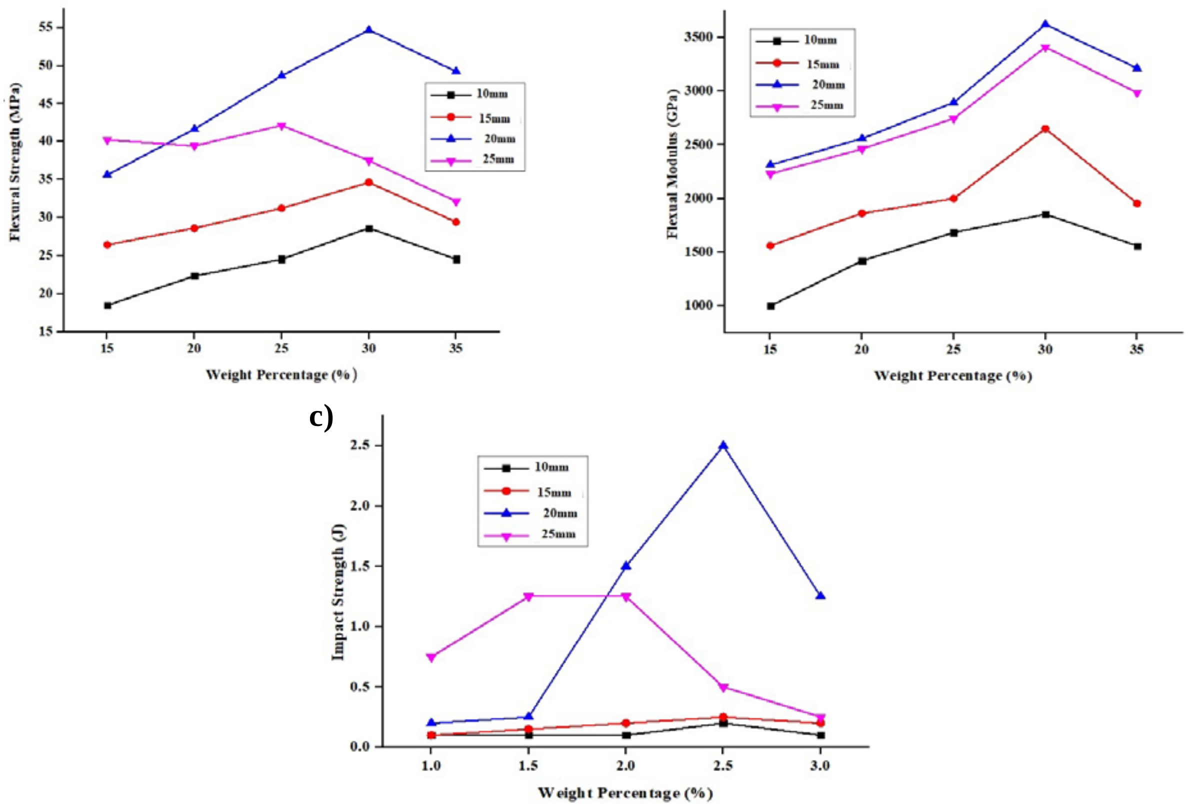

Fig. 4. Flexural strength (a), modulus (b), and impact strength (c) of WH composite

The results of impact strength are clearly explained in Fig. 4(c). In this test also 2mm of fiber length and 30 weight percentage of the composite sample have gained high impact strength compared to the others. The highest impact strength was achieved at 2.4J concerning the 3mm thickness of the composite samples. Figures 3-4 clearly explains the mechanical strength of the different lengths, the different weight percentages of the water hyacinth fiber-reinforced composite samples. Based on the above results the mechanical properties of hyacinth fiber-reinforced polymer composite are better than the coir and palm fibers [19-20]. From this manuscript work, the maximum error values are about 5% only. Handling of primary and secondary materials, mixing setup and usage of material, placing material into a square mold, are the factors behind the error chances on mechanical strength. The error values are clearly indicated on the mechanical strength graph. It is caused by the fact the mechanical strength of composite samples reduces after 30% reinforcement is added due to agglomeration effects between reinforcement and matrix. Consequently, there is a minimum amount of compression force that is absorbed by the sample of hyacinth composite by 35% due to the de-bonding properties of the excess fiber material to the reinforcement phase. Based on the results of the mechanical strength of hyacinth fiber composites it was clearly understood this hyacinth-based composites have higher mechanical strength compared to the sisal fiber composites. These hyacinth-based composites have a higher hardness value compared to the banana composites. The strength of both composites is clearly mentioned in Table 1.

Water and chemical absorption studies. The effect of increasing the fiber length and fiber weight percentage of water hyacinth fiber-reinforced composite samples are clearly explained in Figs. 5-6.

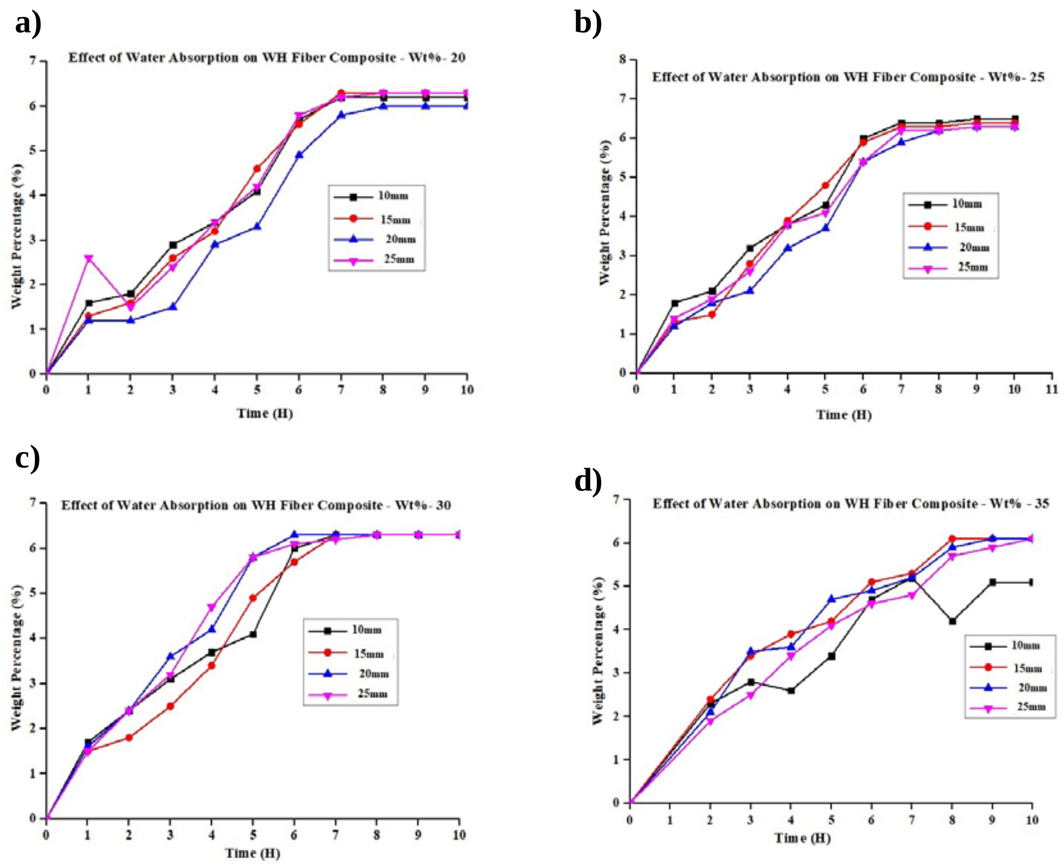

Fig. 5. 20% (a), 25% (b), 30% (c), and 35%(d) water absorption test of different length of WH composite

Figures 5 shows that the water absorption behavior of the samples and Figs. 6 shows that the chemical absorption behavior of the samples. The results of all graphs clearly show that the increment of the length of the fibers leads to the absorption behavior of both water and chemical solutions. In this test, 2mm length with 30 weight percent of the composite sample attained the optimum absorption of water and chemical solutions compared to the other samples. Further increasing the fiber, the sample intake, the more water because of the hydrophilic nature of the samples. Compare to the banana fiber reinforced epoxy composite this hyacinth fiber-reinforced composite sample has a lesser intake of the absorption behavior. Compared to the coir-based composites and sisal/banana hybrid composites these hyacinth-based composites have slightly affected both water and chemical solutions. The values of water and chemical absorption for the above composite samples are clearly explained in below Table 1.

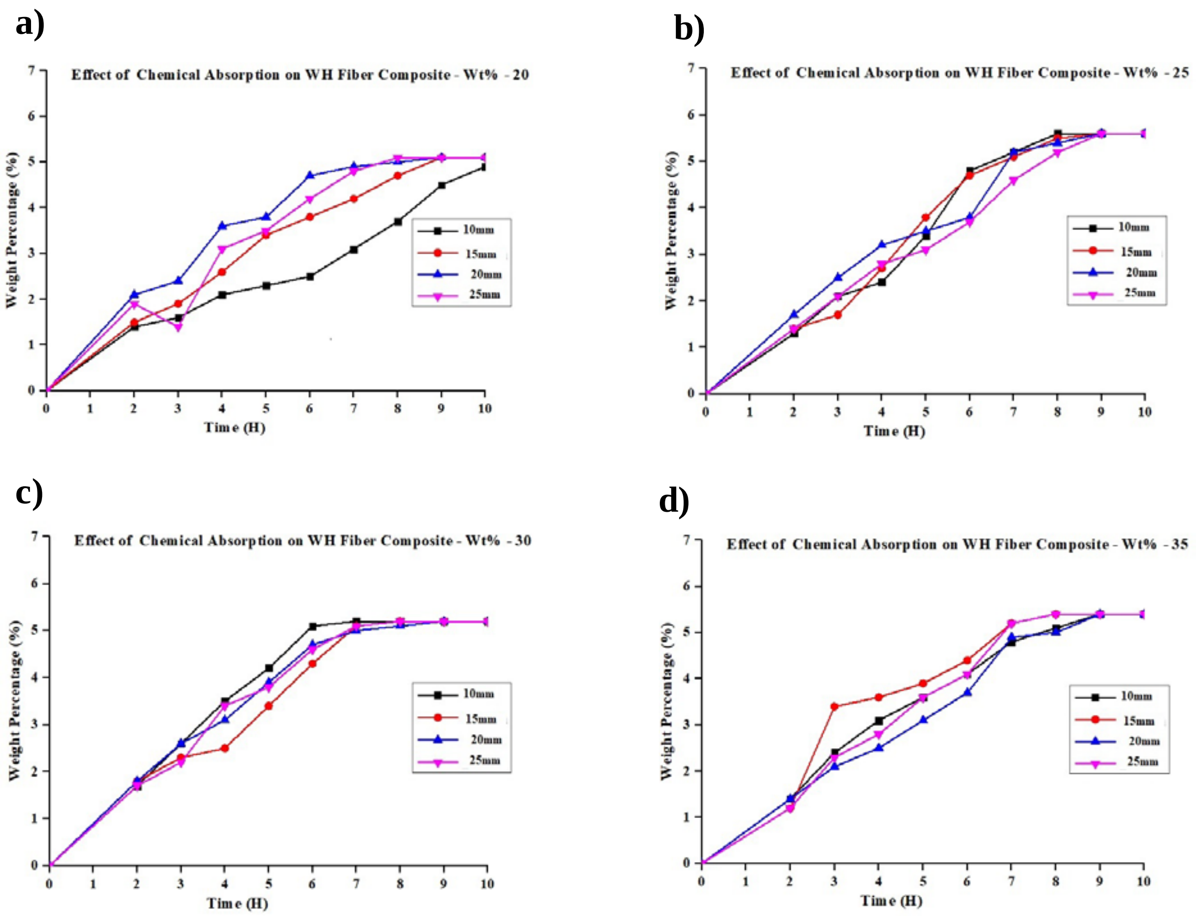

Fig. 6. 20% (a), 25% (b), 30% (c), and 35%(d) chemical absorption test of different length of WH composite

Surface morphology study. WH fiber composite fractured surfaces are investigated after the mechanical testing by utilizing the scanning electron microscope. The fractured images are shown in Figs. 7 and 8. Figure 7 (a) shows that the tensile failure of the hyacinth fiber composite specimen and the fibers are pulled out to the matrix phase. It is evident that the reinforcements are poorly bonded to the matrix materials, external particles are in minimal quantity, and some voids are visible. Figure 7(b) shows that flexural failure like bending fracture. Figure 7(c) shows that the composite specimen under the impact test. The holes explained the fiber pulled out to the matrix phase and some porosity occurred on the composite specimen. Figure 8 clearly explained the 20mm length of the hyacinth fiber reinforced with a 30 weight percent of the composite sample. There is a hard surface to the powder, which increases its bonding ability with reinforcement and matrix materials. It shows that the fiber clusters and very low interface of the secondary phase. This poor bonding automatically decreases the mechanical properties. During the agglomeration process and de-bonding process of primary and secondary phases, the increased reinforcement percentages are pulled from the matrix phase and cause some minute cracks on the region of the primary and secondary phases of the composite sample.

Table 1. Comparative results on hyacinth fiber composites, and other natural fiber composites

S.No	Fiber Composites	Mechanical Strength (MPa)	Hardness Values (Shore D)	Water Absorption (Increasing Wt%)	Chemical Absorption (Increasing Wt%)	Reference
1	Present Work (Hyacinth Fiber Composite)	18-38	90-98	1.2	1.4	-
2	Sisal Fiber Composite	16-34	77-85	1.8	1.2	24
3	Banana Fiber Composite	18-44	84-96	1.4	1.4	25
4	Coir Fiber Composite	22-34	66-92	2.1	1.6	26
5	Sisal/Banana Hybrid Composites	16-40	92-99	1.6	1.1	18

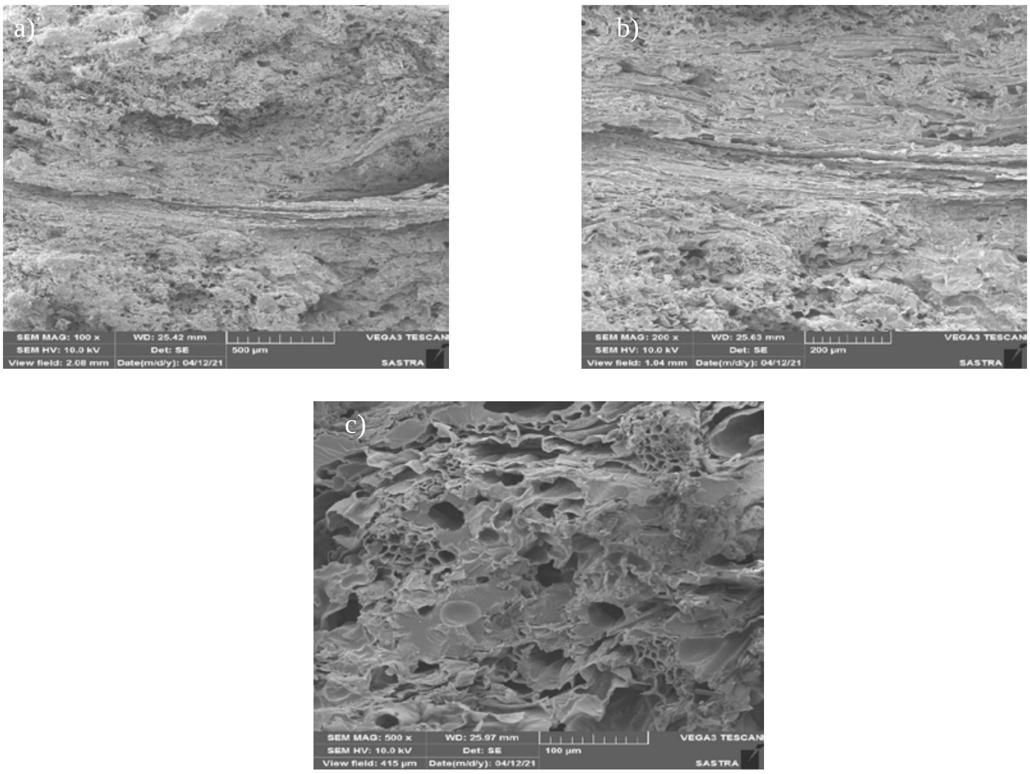

Fig. 7. SEM images of WH composite sample after mechanical testing

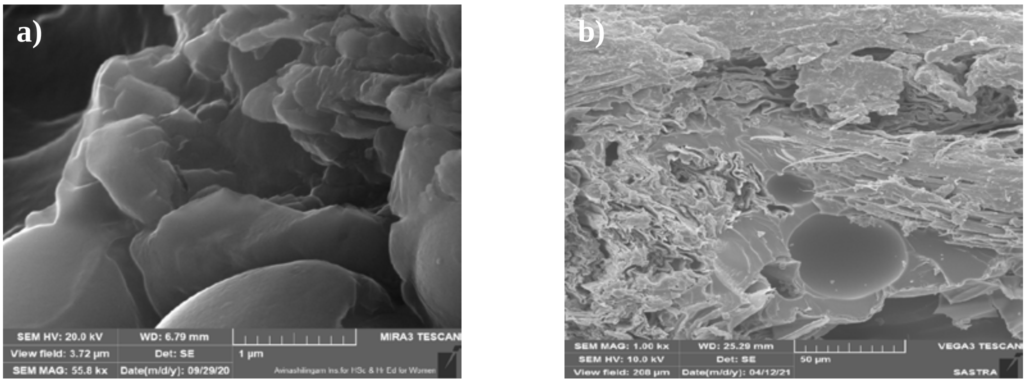

Fig. 8. Proper bonding (30%) and poor interference (35%) image of WH composite

4. Conclusion

Based on the findings of this work the following conclusion is to be done:

- The proper fiber length and reinforcement weight percentage (fiber weight ratios) are 20mm and 30% respectively for Water hyacinth fiber and epoxy composite
- The mixing ratio of fiber and matrix material is 30:70
- Water absorption and chemical absorption behavior of water hyacinth fiber-reinforced epoxy polymer composite is nearer than 5percentage of all length variations of fibers.
- The water and chemical intake behavior of the composites are highly affected by the fiber weight ratios and respective lengths.
- SEM images clearly explained the higher fiber content (above 30%) leads to a poor interface of the primary (reinforcement) and secondary (matrix) phase of the composite.

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THE AUTHORS

A Ajithram
e-mail: winowlinjappesjtw@gmail.com
ORCID: 0000-0002-3169-0302

J.T. WINOWLIN JAPPES
e-mail: ajjithram867@gmail.com
ORCID: 0000-0001-5400-7425

I. Siva
e-mail: isiva@klu.ac.in
ORCID: 0000-0001-7505-1273