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THE USE OF WATER HYACINTH FIBER (*Eichhornia crassipes*) AS AN ALTERNATIVE RAW MATERIAL FOR NETS

Pemanfaatan Serat Eceng Gondok (*Eichhornia Crassipes*) Sebagai Alternatif Bahan Dasar Jaring

Layla Alya Sabhira*, Asep Sahidin, R. Mochamad Candra Wirawan Arief, Zahidah

Fisheries Study Program, Faculty of Fisheries and Marine Sciences, Padjadjaran University

Bandung Sumedang Highway KM 2,1 Jatinangor

*Corresponding Author: layla21001@mail.unpad.ac.id

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ABSTRACT

The research was conducted from August to September 2025. Samples were made on 20–31 August 2025, while the testing process was conducted on 1 September 2025 at the Laboratory of the Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, IPB University. This research aims to analyze the breaking strength of water hyacinth (Eichhornia crassipes) fiber nets, to analyze and compare them with synthetic nylon nets and nets made from other natural fibers, and to analyze the potential of water hyacinth as an alternative raw material for net production. The nets tested consisted of 2, 4, and 6 fibers of water hyacinth with diameters of 3 mm, 4 mm, and 5 mm. The research used three treatments with ten replications, in accordance with SNI ISO 1805:2010. The observed parameter was breaking strength. The results show that nets made of six fibers of water hyacinth have the highest breaking strength, reaching 8,04 kgf, while nets made of four fibers of water hyacinth have the highest breaking strength per diameter and the best efficiency, at 1,66 kgf/mm.

Keywords: Breaking Strength, Natural Fiber, Net, Water Hyacinth

ABSTRAK

Penelitian ini dilaksanakan pada bulan Agustus hingga September 2025. Pembuatan sampel dilakukan pada tanggal 20–31 Agustus 2025, sedangkan pengujian dilaksanakan pada 1 September 2025 di Laboratorium Departemen Pemanfaatan Sumberdaya Perikanan (PSP) Fakultas Perikanan dan Ilmu Kelautan IPB University. Penelitian ini bertujuan untuk menganalisis nilai kekuatan putus (*breaking strength*) jaring berbahan dasar serat eceng gondok (*Eichhornia crassipes*), menganalisis perbandingannya dengan jaring sintetis berbahan nilon serta jaring dari serat alami lainnya, dan menganalisis potensi eceng gondok sebagai bahan alternatif pembuatan jaring. Jaring yang digunakan terdiri atas 2, 4, dan 6 helai serat eceng gondok dengan diameter masing-masing 3 mm, 4 mm, dan 5 mm. Penelitian ini menggunakan tiga perlakuan dengan sepuluh ulangan yang mengacu pada SNI ISO 1805 tahun 2010. Parameter yang diamati adalah kekuatan putus. Hasil pengujian menunjukkan bahwa jaring eceng gondok dengan 6 helai serat memiliki nilai kekuatan putus tertinggi, yaitu 8,04 kgf, sedangkan jaring eceng gondok dengan 4 helai serat memiliki nilai kekuatan putus per diameter tertinggi serta efisiensi terbaik, yaitu 1,66 kgf/mm.

Kata Kunci: Eceng Gondok, Jaring, Kekuatan Putus, Serat Alami

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is a type of aquatic plant that floats on the surface of deep water and roots in shallow water (Prasetyo *et al.,* 2021). This plant is beneficial for water bodies because it can absorb organic and inorganic substances and other heavy metals that are pollutants, but it is also considered an invasive weed (Ratnani *et al.,* 2011; Prasetyo *et al*., 2021). The rapid proliferation of water hyacinth causes environmental problems and river activities such as obstructing water traffic, reducing river water discharge, reducing the amount of light entering the water, causing a decrease in oxygen solubility in the water, and accelerating the process of water silting (Nata *et al*., 2013).

Efforts to suppress water hyacinth growth have been made, including its use in compost, water purification, biogas, paper, straw mushroom growth media, poultry feed, and most recently as fuel briquettes (Karim *et al*., 2014). However, these efforts have not yielded satisfactory results. Water hyacinth control is necessary to suppress or reduce its growth and thus reduce its weediness in aquatic environments.

On the other hand, the challenges of aquaculture and fishing are increasingly diverse, one of which is the use of nylon-based nets. According to Rachmah *et al.* (2015), nylon is widely used by fishermen because of its superior durability, tensile strength, and service life. Research by Jannah *et al*. (2017) stated that the breaking strength of a 0.4 mm diameter nylon monofilament net has an average breaking strength of 6.41 kgf, stronger than nets made from natural fibers such as banana stems, which have a breaking strength of 3 kgf with a net diameter of 1.4 mm (Zaki *et al*., 2015). However, nylon-based nets have disadvantages in their use, such as being difficult to degrade, resulting in non-organic waste that ultimately pollutes the environment, especially the marine environment. Moreover, nylon nets usually float and can drift at varying depths in the ocean (Dewi, 2022).

Kase *et al*. (2023) stated that in Bolok, Kupang, nylon nets dominate seaweed farming waste. Research by Chen *et al*. (2018) shows that aquaculture activities impact the quantity of microplastics in seawater and sediment. Through FTIR (Fourier Transform Infrared Spectroscopy) analysis of microplastic particles from the sample categories used, nylon was found as one of the microplastics found. Pratiwi *et al*. (2023) also conducted research using the same method. The study stated that microplastic fibers were found in the intestines of lemuru fish (*Sardinella lemuru*), yellow scad (*Selaroides leptolepis*), kurisi fish (*Nemipterus leptolepis*), and cawane fish (*Lutjanus madras*), which were landed on Rebo Beach, Bangka Regency and sourced from fishing gear such as nylon fishing lines or fishing nets. Therefore, an appropriate solution is needed that can be used to replace nylon nets with more environmentally friendly nets.

This study provides information on the use of water hyacinth fiber as a raw material for netting, along with an analysis of its breaking strength. This study also presents a comparative analysis of the breaking strength of water hyacinth nets with nylon nets and nets made from other natural fibers. Breaking strength is the maximum force required to break a material using tension and is very important to test because it affects the effectiveness of the net; the higher the breaking strength value, the better the quality of the net (Jannah *et al*., 2017; Zaki *et al*., 2015).

In addition to being a step in combating water hyacinth blooms, this net can also reduce marine debris caused by the use of synthetic nylon-based nets. As a net made from natural fibers, water hyacinth nets have lower strength compared to nylon nets. However, water hyacinth is a plant that contains 60% cellulose, 34.1% hemicellulose, and 17% lignin (Abdel-Fattah and Abdel-Naby 2012; Putera 2012; Tao Ruan 2016), so it can be used as a main component in nets that are more easily degraded and produce fibers with high tensile strength and durability, as well as being a further innovation for the use of natural fibers in aquaculture and environmentally friendly fishing.

RESEARCH METHODS

Time and Place

This research was conducted from August to September 2025. The water hyacinth net samples were made on August 20–31, 2025, while the testing was carried out on September 1, 2025 at the Laboratory of the Department of Fisheries Resource Utilization (PSP), Faculty of Fisheries and Marine Sciences, IPB University.

Tools and Materials

The tools used in the research are as follows.

Table 1. Tools Used

No.	Tool Name	Function
1.	Scissors and knife	Cutting the water hyacinth
2.	Pounder	Pounding the water hyacinth
3.	Wire brush	Separating the fibers from the water hyacinth body
4.	Iron	Ironing the fibers to stiffen them and make them easier to spin
5.	Strength tester	Testing the breaking strength in the breaking strength test
6.	Vernier caliper	Measuring the length and diameter of the sample
7.	Container	Storing the sample
8.	Microscope	Observing the physical properties of the sample

Meanwhile, the materials used in the research are as follows.

Table 2. Materials Used

No.	Material Name	Function
1.	Water hyacinth from Cirata Reservoir Raw material for making nets	Water hyacinth from Cirata Reservoir Raw material for making nets

Research Procedures

1. Fiber Extraction

The process of taking fibers in making nets from water hyacinth which has been adjusted from Khotimah's (2018) research is as follows.

1. Water hyacinth plants were selected based on stem length and origin from the same habitat.
2. The plants were thoroughly washed to remove dirt.
3. To obtain uniform fiber, the stems were pounded until the fiber surface was even.
4. The fibers were dried for 10 (ten) days in the sun until completely dry. This was to reduce the risk of rotting, as water hyacinth contains 90% moisture. The drying time

and process were determined considering that drying too quickly at too high a temperature can cause the fibers to become stiff, brittle, and deformed, while slow and consistent drying maintains the fiber structure (Amin *et al*. 2019).

5. Once dry, the fibers were removed from the water hyacinth plants using a wire brush. A 500-gram water hyacinth stem was brushed longitudinally in the direction of the wire brush, and the fibers would naturally separate from the stem.
6. The fiber ends are trimmed to equalize the overall dimensions and remove any uneven fibers.
7. Ironing is performed for 10 seconds at 100°C to stiffen the fibers and facilitate the spinning process. Too high a temperature can cause the fibers to become dry and brittle (Amin *et al*. 2019).

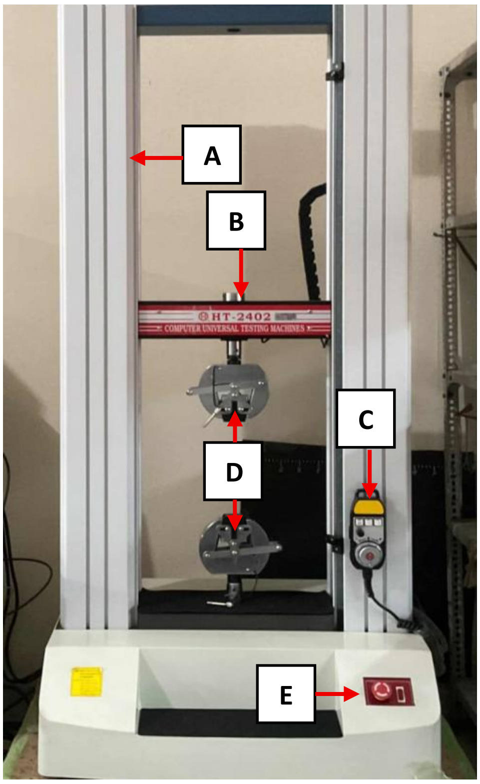
2. Spinning Fibers into Nets

The second procedure in this research is to make yarn and net rope by spinning. Spinning is the process of twisting a single yarn, folded yarn, or net thread component in a spiral direction (Zaki, 2015).

1. The first sample was made with 2 (two) strands of fiber with a diameter of 3 mm which were spun using an S-direction spindle to make a net of 10 (ten) 3 mm diameter. The use of one-way spinning (only S) in the initial spinning is done to unite the individual fibers (Putra & Iskandar, 2014).
2. The second sample was made with 2 (two) strands of fiber with a diameter of 3 mm which were spun using S-spinning to become a 3 mm diameter net of 20 (twenty) pieces, then spun using Z-direction spinning to become a net of 4 (four) strands of 4 mm diameter fiber of 10 (ten) pieces. The use of Z spinning as a combination spinning is done to lock the results of the first spinning, so that the net is denser and does not open easily (Putra & Iskandar, 2014).
3. The third sample was made with 2 (two) strands of fiber with a diameter of 3 mm which were spun using S-direction spinning so that it became a 3 mm diameter net of 30 (twenty) pieces, then spun using Z-direction spinning to become a net of 4 (four) strands of 4 mm diameter fiber totaling 10 (ten) pieces. The remaining 10 (ten) nets of 2 (two) fiber strands are spun again with a net of 4 (four) fiber strands using Z direction spinning so that it becomes a net of 6 (six) fiber strands with a diameter of 5 mm totaling 10 (ten) pieces.
4. The ends of the net are cut to a length of 25 cm each.

3. Use of Tools

The tool used in this study is the Universal Testing Machine (UTM), which can be seen in Figure 1.



Information:

A. Load frames
B. Load cells
C. Manual controller
D. Grip
E. On/off and emergency stop button

Figure 1. Universal Testing Machine (UTM)

The tool is operated in the following manner.

1. The Universal Testing Machine (UTM) is turned on using the "On" button.
2. The net is inserted into the machine and clamped using the grip.
3. The net's tension and slack are adjusted using the manual controller.
4. The machine is operated and the net's breaking strength is tested.

Observation Parameters

The observation parameter in this study is breaking strength which can be determined using the following procedure.

1. Universal Testing Machine (UTM) was used to conduct breaking strength tests based on SNI ISO 1805 2010.
2. The test equipment used had a load cell capacity of 250 kN (kilo Newtons).
3. The samples used were net ropes made from water hyacinth fibers with a width of 3 mm and a thickness of 1 mm, with 2 (two), 4 (four), and 6 (six) fibers, totaling 10 (ten) twills per test, and each strand was 25 cm long.
4. The breaking strength test was conducted by measuring the breaking strength of the water hyacinth fiber net samples.

Data Analysis

The types of data used in this study are primary and secondary data. Primary data were obtained from mechanical properties of net ropes made from water hyacinth fiber in the form of breaking strength and physical properties in the form of net diameter, number of fibers, type of twist, and twist angle. Secondary data were obtained from literature studies. Meanwhile, data analysis used was the Shapiro-Wilk normality test, Levene's test, Welch's One-Way ANOVA (Analysis of Variance) test, and Games-Howell test.

The Shapiro-Wilk Normality Test was chosen for use in this study because the number of data in each research sample was 10 (n<50) (Agustin & Permatasari, 2020), with a total of 30 specimens. This test was also used to determine whether the rope net strength data from each different number of fibers were normally distributed.

Then, the Levene's test was conducted to determine homogeneity of variance, which is based on a research design that produces data with more than two groups. According to Putra *et al.* (2019), the homogeneity of variance test was conducted to determine whether sample groups have similar characteristics (homogeneity).

Furthermore, Welch's One-Way ANOVA was used in this study because it is a modification of One Way ANOVA which was developed as a statistical method to test the mean differences of more than two groups that are only influenced by one factor (independent variable) without assuming homogeneity of variance (heteroscedasticity) (Welch 1951). This test is a parametric test designed to analyze mean differences between groups when the assumption of homoscedasticity is violated (Derrick *et al.*, 2017).

Finally, the Games-Howell test is performed, which is a post-hoc test to compare all pairs of group means after ANOVA (or Welch ANOVA) analysis when the assumption of homogeneity of variance is not met (variances between groups are not equal) and/or sample sizes between groups are unequal. This test is a robust alternative (a method that still provides correct conclusions even though the distribution is not normal) to Tukey HSD when variances are not homogeneous (Games & Howell 1976; Erceg-Hurn & Mirosevich 2008). The Games-Howell test is used in research because it functions to determine whether there is a significant difference between the means of all possible pairs of all groups.

RESULTS

The samples used in the study were nets with 2, 4, and 6 fiber strands with average diameters of 3 mm, 4 mm, and 5 mm, respectively. Based on the twist angle, all samples were categorized as soft-type because they had a twist angle of less than 40° (Komarudin, 2019), namely 35.96°, 24.18°, and 36.86°, respectively. The results showed that the three types of treatments with a total of 30 (thirty) specimens tended to have the same color, namely light brown. This color is the natural color of water hyacinth fibers which is affected by age. Generally, young water hyacinth fibers tend to have brighter colors (Hasibuan *et al.*, 2024). Differences in the physical characteristics of the samples can be seen in Table 3 and Figure 2.

Table 3. Characteristics of Physical Properties and Breaking Strength of Nets Made from Water Hyacinth Fiber

No.	Type of Treatment	Spin Direction	Diameter (mm)	Twist Angle (Degrees)	Breaking Strength Range (kgf)	Average Breaking Strength (kgf)
1.	2 Strand Fiber Mesh	S	3	35,96	1,59–4,98	$3{,}20 \pm 1{,}01^{a}$
2.	4 Strand Fiber Mesh	S dan Z	4	24,18	4,15–10,19	$6{,}64 \pm 1{,}70^{b}$

3.	6 Strand Fiber Mesh	S dan Z	5	36,86	4,51–11,79	8,04±2,44[b]

* Different letters indicate significant differences in treatment at the 95% confidence level using Welch's One-Way ANOVA and Games-Howell tests

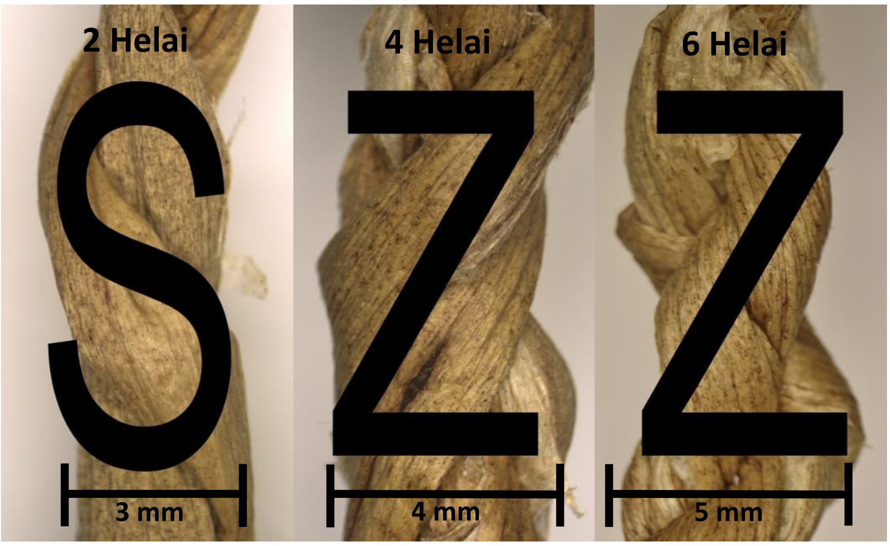


Figure 2. S and Z spinning directions

The twist direction of the 2-strand fiber net sample is S. The 4-strand fiber net sample has S and Z twist directions. The 6-strand fiber net sample has S, Z, and Z twist directions. The S twist or also called the left twist is a twist that forms a diagonal pointing to the top left from the bottom right, while the Z twist or right twist is a twist that forms a diagonal pointing to the top right from the bottom left ((Islam *et al*., 2018).

DISCUSSION

Breaking Strength

Breaking strength was the only mechanical property of the samples tested in this study. Breaking strength is the maximum force required to break a material using tension (Klust 1982 in Zaki 2015). More clearly, the breaking strength of the samples consisting of nets made from water hyacinth fiber with 2, 4, and 6 strands can be seen in Figures 3, 4, and 5.

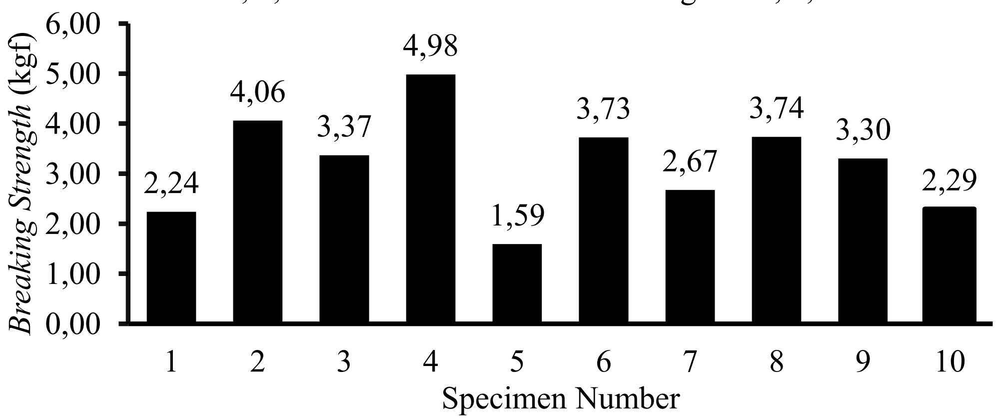


Figure 3. Graph of Strength of 2 Strands of Water Hyacinth Fiber Net

Water hyacinth nets with 2 strands of fiber have breaking strengths of 2.24 kgf; 4.06 kgf; 3.37 kgf; 4.98 kgf; 1.59 kgf; 3.37 kgf; 2.67 kgf; 3.74 kgf; 3.30 kgf; and 2.29 kgf, respectively. The largest breaking strength figure is in specimen number 4 with a breaking strength of 4.98 kgf and the smallest is in specimen number 5 with a breaking strength of 1.59 kgf.

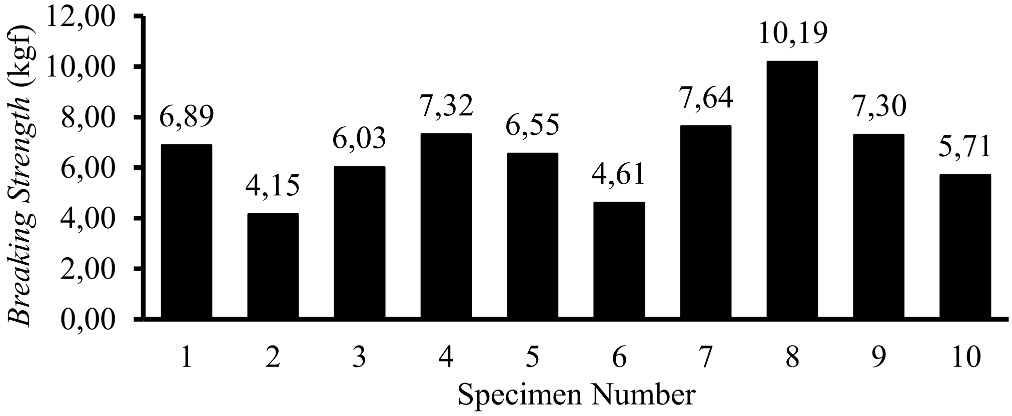


Figure 4. Graph of the Strength of a 4-Strand Water Hyacinth Net

The breaking strength of water hyacinth net with 4 strands of fiber has a breaking strength of 6.89 kgf; 4.15 kgf; 6.03 kgf; 7.32 kgf; 6.55 kgf; 4.61 kgf; 7.64 kgf; 10.19 kgf; 7.30 kgf; 5.71 kgf, respectively. The specimen with the greatest breaking strength is specimen number 8 with a value of 10.19 kgf. Meanwhile, the specimen with the smallest breaking strength is specimen number 2 with a value of 4.15 kgf.

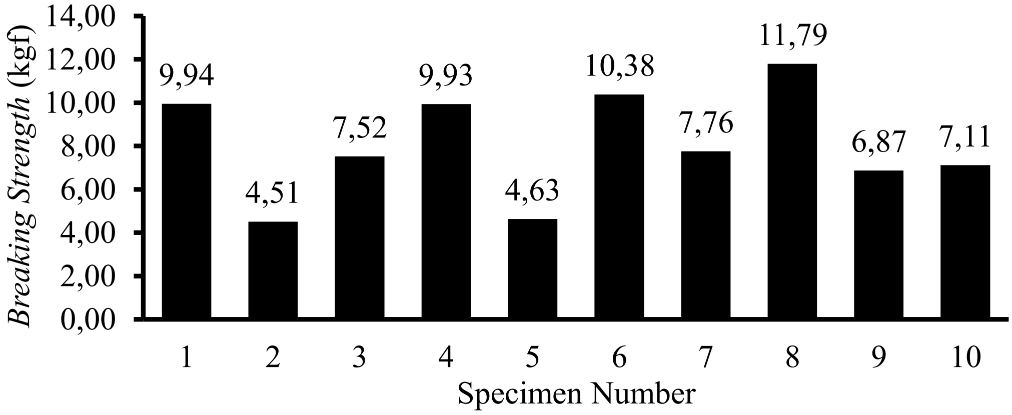


Figure 5. Graph of Strength of 6 Strands of Water Hyacinth Fiber Net

Water hyacinth nets with 6 strands of fiber have breaking strengths of 9.94 kgf; 4.51 kgf; 7.52 kgf; 9.93 kgf; 4.63 kgf; 10.38 kgf; 7.76 kgf; 11.79 kgf; 6.68 kgf; and 7.11 kgf, respectively. The specimen with the greatest breaking strength is specimen number 8 with a breaking strength of 11.79 kgf; while the specimen with the smallest breaking strength is specimen number 2 with a breaking strength of 4.51 kgf.

The average breaking strength of water hyacinth nets consisting of 2, 4, and 6 strands of fiber were 3.20 kgf; 6.64 kgf; and 8.04 kgf, respectively, which can be seen in Table 3. The results of the normality test using the Shapiro-Wilk method showed that the three types of samples were normally distributed, with p-values of 0.943; 0.639; and 0.542 (>0.05) for each treatment. The results of the Levene's homogeneity of variance test showed that the variance between groups was not homogeneous, because it had a p-value of 0.049 (<0.05). The Welch's One-Way ANOVA mean difference test showed that there was a significant difference in net strength between the number of strands of fiber 2, 4, and 6, with a p-value of <0.001 (<0.05).

Then, the Games-Howell follow-up test showed that there was a significant difference between the strength of nets consisting of 2 and 4 strands of fiber with a p-value of <0.001 (<0.05). There was also a significant difference between the strength of nets consisting of 2 and 6 strands of fiber with a p-value of <0.001 (<0.05). However, there was no significant difference between nets with 4 and 6 strands of fiber because the p-value of the test result was 0.319 (>0.05). The notation of significant differences can be seen in Table 3 and the results of all statistical calculations can be seen in Table 4.

Table 4. Results of Statistical Calculations for All Data

Test Stages	Test Type	Statistics		p-value	Criteria (α = 0,05)	Description
Normality Test Homogeneity of Variance Test	Shapiro–Wilk (2 fibers)	W	0,976	0,943	Data is normally distributed because the W value is close to 1 (one) and the p-value is greater than 0.05.	The data is normally distributed because the W value is close to 1 (one) and the p-value is more than 0.05.
	Shapiro–Wilk (4 fibers)	W	0,947	0,639	Data is normally distributed because the W value is close to 1 (one) and the p-value is greater than 0.05.	The data is normally distributed because the W value is close to 1 (one) and the p-value is more than 0.05.
	Shapiro–Wilk (6 fibers)	W	0,939	0,542	Data is normally distributed because the W value is close to 1 (one) and the p-value is greater than 0.05.	The data is normally distributed because the W value is close to 1 (one) and the p-value is more than 0.05.
Mean Difference Test	Levene's Test	F	3,377	0,049	The variance between groups is not homogeneous because the p-value is	The variance between groups is not homogeneous because the p-value is

					less than 0.05.	less than 0.05.
Follow-up Test (Post Hoc)	Welch's One-Way ANOVA	F	25,743	<0,001	There is a significant difference between groups because the p-value is less than 0.05.	There is a significant difference between groups because the p-value is less than 0.05.
Test Stages	Games–Howell: 2 and 4 fibers	Mean Difference /Selisih Rata-Rata	–3,4412	<0,001	Significantly different because the p-value is less than 0.05.	Significantly different because the p-value is less than 0.05
	Games–Howell: 2 and 6 fibers	Mean Difference /Selisih Rata-Rata	–4,8469	<0,001	Significantly different because the p-value is less than 0.05.	Significantly different because the p-value is less than 0.05
	Games–Howell: 4 and 6 fibers	Mean Difference /Selisih Rata-Rata	–1,4057	0,319	Not significantly different because the p-value is greater than 0.05.	Not significantly different because the p-value is more than 0.05

The breaking strength values of 4 and 6 fiber nets were not significantly different due to several factors. The mean difference between the two data sets was small, at –1.4057, and was the smallest compared to the mean strength difference between 2 and 4 fiber nets, which was –3.4412, and 2 and 6 fiber nets, which was –4.8469. The total number of specimens in the study, which was 10 per sample (n<30), is often referred to as a small sample (although there is no definite rule regarding the number of data categories) (Mascha & Vetter 2018), so a larger mean difference is needed for the data to be significantly different. In addition, the standard deviation of the data from the 6 fiber net test results was the largest compared to the other two, so the data variance was also high and the data became too varied, causing the strength values of the 6 fiber net to be scattered.

However, despite the data distribution, based on the average results for the three sample types (see Table 3), there was an increase in net breaking strength due to the increasing number of fiber strands in each treatment. The addition of fiber strands affected the net diameter and breaking strength. This is in line with research by Sari *et al.* (2017), which stated that the larger the net diameter, the greater the breaking strength.

Based on the comparison of the breaking strength of each specimen in 1 (one) sample in the same treatment (see Figures 3, 4, and 5), there are differences in strength even though the specimens have the same length, number of fiber strands, and diameter, which is in line with the results of the Levene test calculations that show non-homogeneous data due to large data variations. This can be caused by differences in the fiber twist slope between one net and another that occurs during the net spinning process, which also affects the twist angle (see Table 3). The fiber twist slope affects the breaking strength of the net sample. The same thing was also stated by Mertová *et al.* (2018) and Ekundayo *et al.* (2024), that the fiber twist slope to the linear axis is one of the important factors that affect the tensile strength of a yarn. The greater the fiber twist slope number, the denser the fiber twist and affects the breaking strength of the net. In this study, it could also be caused by the spinner's ability to spin fiber manually which is not as good as a machine, thus affecting the things mentioned previously.

Furthermore, as the primary raw material, the quality of the water hyacinth fiber used also influences net strength. Nets made from natural fibers are strongly influenced by fiber quality, which influences the net's physical and mechanical properties, including breaking strength (Wardhana & Haryanti 2016; Suparno 2020). Although originating from the same habitat, the Cirata Reservoir, the research samples were made from different water hyacinth individuals, resulting in genetic differences in the fibers. Intraspecific genetic diversity (variation within a species) can result in differences in fiber properties, including fiber strength (Islam *et al*., 2016).

Comparison of Breaking Strength Test Results of Water Hyacinth (*Eichhornia crassipes*) Nets with Nylon Nets and Other Natural Fiber Nets

Differences in raw materials used in netting result in differences in physical and mechanical properties, including the net's breaking strength. Comparing the breaking strength of water hyacinth netting with nylon netting and other natural fiber netting is necessary to analyze the differences in strength and effectiveness of each net, as shown in Table 5.

Table 5. Breaking Strength of Water Hyacinth, Nylon, and Other Natural Fiber Nets (Source: Jannah *et al*. 2017; Schmidt and Queirolo 2019)

No.	Fiber Type	**Diameter (mm)**	**Breaking Strength (kgf)**	**Breaking Strength per Width Ratio (kgf/mm)**	Data Sources
1.	Water Hyacinth 2 Strands Fiber	3	3,20	1,07±0,34	Current Research
2.	Water Hyacinth 4 Strands Fiber	4	6,64	1,66±0,40	Current Research
3.	Water Hyacinth 6 Strands Fiber	5	8,04	1,61±0,49	Current Research
4.	Polyamide Nylon	0,4	6,41	16,02±1,15	Jannah *et al.* (2017)
5.	Hemp	2	18,9	9,45±0,11	Schmidt dan Queirolo (2019)
6.	Cotton	2,5	16,6	6,64±0,09	Schmidt dan Queirolo (2019)

Based on the table, the breaking strength of a 0.4 mm diameter polyamide nylon net is 6.41 kgf (Jannah *et al*. 2017). This net has almost the same strength as a 4-strand water hyacinth net which has a strength of 6.64 kgf. Polyamide nylon net is stronger than a 4-strand water hyacinth net because both have relatively the same strength, which is both at +6 kgf, but have very different diameters. The 4-strand water hyacinth net has a diameter of 4 mm, ten times larger than the diameter of the polyamide nylon net. Polyamide nylon net is also stronger than all water hyacinth nets.

A net made from 2 mm diameter hemp fibers has a breaking strength of 18.9 kgf, significantly higher than that of a water hyacinth net. Meanwhile, a net made from 2.5 mm diameter cotton fibers has a breaking strength of 16.6 kgf, twice the breaking strength of a 6-strand water hyacinth net, which is only 8.04 kgf (Schmidt and Queirolo 2019). Both natural fiber nets also have a breaking strength greater than that of all water hyacinth nets.

Among all nets made from natural fibers, ramie nets are the strongest. This is due to the cellulose content in ramie fibers, which reaches 75%, higher than the cellulose content in water hyacinth fibers, which reaches 60%, thus increasing ramie's tensile strength (Agustina *et al*., 2005; Putera, 2012; Gupta *et al*., 2015). However, water hyacinth fibers contain more lignin, namely 17%, while ramie fibers contain 0.7% lignin, which makes water hyacinth nets more resistant to pressure (Agustina *et al*., 2005; Putera, 2012).

Since diameter affects the breaking strength of the net, the maximum strength per net width indicates the efficiency and durability of the net. A thinner net (smaller diameter) with the same or greater strength will be relatively stronger than a thicker net, allowing the net to be lighter but still strong. The maximum strength per net width of 2-, 4-, and 6-strand water hyacinth nets, nylon polyamide nets, hemp nets, and cotton nets were 1.07 kgf/mm; 1.66 kgf/mm; 1.61 kgf/mm; 16.02 kgf/mm; 9.45 kgf/mm; and 6.64 kgf/mm, respectively. These values are influenced by the strength of each net and its diameter, which can be seen in Table 5.

When ranked from strongest to weakest, nylon polyamide nets are in first place because they have the greatest breaking strength and smallest diameter, then hemp nets are in second place, cotton nets are in third place, 4-strand water hyacinth nets are in fourth place, 6-strand water hyacinth nets are in fifth place, and finally 2-strand water hyacinth nets. 6-strand water hyacinth nets have a greater breaking strength and diameter than 4-strand water hyacinth nets, but have a smaller breaking strength value per net width. Based on this, a large diameter does indeed produce a large breaking strength of the net. However, it does not necessarily mean the net works more efficiently, such as 6-strand water hyacinth nets which have the largest diameter and breaking strength compared to other water hyacinth nets, but have a smaller breaking strength value per net width than 4-strand water hyacinth nets.

Potential and Weaknesses of Water Hyacinth Nets (*Eichhornia crassipes*)

The use of water hyacinth fiber has long been studied. In the fisheries sector, water hyacinth can be used as an alternative raw material for fish feed, as a supplementary feed for tilapia cultivation, and as a nutrient absorber, such as ammonia, nitrate, and phosphate, from organic waste from fish ponds, thereby helping maintain good water quality (Pratiwi & Andhikawati, 2021; Reyes & Alegria, 2023; Laia, 2025). Furthermore, research on the breaking strength of water hyacinth fiber-based nets has become an innovation that not only encompasses conservation and water hyacinth weed control in water bodies but also relates to fishing and aquaculture.

Water hyacinth fiber can be used as an environmentally friendly alternative net. Furthermore, water hyacinth has the potential to be useful not only as an alternative raw material for netting but also as a raw material for making objects requiring strong fibers.

However, water hyacinth nets have several weaknesses, namely their lower breaking strength compared to nylon nets and nets made from other natural fibers such as cotton and hemp. Furthermore, there are limitations in the availability and length of water hyacinth raw materials, so they can only be optimized for making short nets. This is caused by a decrease in net strength at the connection points because tensile forces are concentrated at these points (Januar & Kunchi Mon, 2021). Therefore, if the water hyacinth net is lengthened by connecting it, there will be many connection points, reducing its strength. There are also limitations in the method used in this study, namely manual spinning by hand, so the resulting net density is not optimal and affects the results of the breaking strength test. Therefore, it is necessary to conduct further tests using a spinning method using a machine to determine the appropriate use of water hyacinth nets according to their strength.

Despite its limitations, the use of water hyacinth fiber as a netting material is one of the efforts to control water hyacinth weeds in waters, while also positioning water hyacinth as a source of fiber with abundant cellulose content, thus encouraging the development of various innovations in the use of water hyacinth fiber. Along with the increasing massive new ideas to utilize water hyacinth as a raw material, this effort has the potential to be one solution to the problem of water hyacinth as an aquatic weed. Thus, products made from water hyacinth are expected to continue to emerge, with benefits that are not only limited to the fields that have been widely studied, but also extend to other fields, in line with the development of ideas and technology.

CONCLUSION

Based on the research results, the following conclusions were obtained.

1. The number of fiber strands is directly proportional to the diameter and breaking strength of the net, with the highest value being found in a net sample with 6 fiber strands and a diameter of 5 mm, at 8.06 kgf.
2. The breaking strength of water hyacinth nets is lower than that of nylon, hemp, and cotton nets.
3. Water hyacinth has potential as an alternative raw material for nets, although its strength is still lower than that of hemp and cotton fibers.

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