DEVELOPMENT OF ANTIFUNGAL FINISHES FOR WATER HYACINTH PRODUCTS

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ABSTRACT

This work discusses the research conducted to develop an appropriate agent to enhance the anti-fungal properties of water hyacinth stalks, which are commonly used in handicraft products in Thailand. The objective of the research was to find an agent that would prevent fungal infestations, prolong the shelf life of the products, and ultimately increase the income for the craft makers. The initial experiment involved treating cotton fabrics with three different antifungal solutions: Chitosan, Zinc Pyrithione, and Poly (allylamine hydrochloride). These treated samples were then tested with Aspergillus niger, a common fungal strain, using the standard antifungal test AATCC 30. Among the three finishes, the fabric treated with Poly (allylamine hydrochloride) displayed the highest anti-fungal properties. However, the fabric treated with Zinc Pyrithione effectively inhibited fungal growth but left visible white particles on the fabric. Chitosan, on the other hand, did not significantly inhibit fungal growth. Based on these test results, it was concluded that a solution of Poly (allylamine hydrochloride) can be employed as a finishing agent for water hyacinth to enhance its antifungal properties in water hyacinth-based products. Additionally, it was found that a higher concentration of Poly (allylamine hydrochloride) (100 g/L) is necessary to effectively prevent fungal growth on water hyacinth stalks. By utilizing this research, local Thai communities can enhance the durability and longevity of their water hyacinth handicraft products, reducing the impact of fungal infestations and increasing their income.

KEYWORDS

Poly(allylamine hydrochloride); Antifungal; Water hyacinth.

INTRODUCTION

Water hyacinth, scientifically known as Eichhornia crassipes, is one of the invasive species that flourishes and reproduces in aquatic ecosystems due to its free-floating characteristics. This plant is commonly seen in stagnant swamps, lakes, reservoirs, and rivers, where it multiplies swiftly [1]. Water hyacinth has been causing significant harm to the environment and societies in tropical regions [2-3]. Despite the obstacles presented by these challenges, water hyacinth offers various advantages such as its medicinal properties and potential as an organic bioenergy source for biogas, briquettes, and fertilizer and additionally, it can be transformed into handmade products [4-5]. Although water hyacinth is widely known to contribute to water pollution due to its rapid growth and extensive spread, leading to a decline in water quality [6]. Various innovative strategies are being explored to harness the potential of water hyacinth, particularly utilizing its stalks as a raw material for producing local handicraft items [7]. The water hyacinth stalks were dried in order to be utilized as raw materials for a variety of products, such as handicrafts, furniture, bags, and other goods [8]. Regrettably, these products tend to have a limited shelf-life [9], which restricts income opportunities for handicraft-makers, primarily stems from the absence of anti-fungal properties in dried water hyacinth stalks [10]. It is advisable to store most handicraft products made from dried water hyacinth stalks away from moisture in order to mitigate the risk of potential damage, as exposure to water can result in deformation and a decrease in the strength of the products. Figure 1 depicts the manifestation of fungus on a product crafted from dried water hyacinth stalks. The appearance of fungal growth on the surface of this product provides a visual representation of the issue being addressed in the academic context.

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Figure 1. Fungal growth detected on handicrafts made from dried water hyacinth stalks.

Antifungal agents play a vital role in various industries, including agriculture, healthcare, and textiles, to control fungal growth and prevent associated diseases. Among the different agents available, Chitosan (CS), Zinc Pyrithione (ZnPT), and Poly(allylamine hydrochloride) (PAH) have gained significant attention for their antifungal properties. Chitosan, with its biocompatibility and complete biodegradability, has proven to be effective in inhibiting fungal growth in plants like papaya sprouts [11]. It has also shown potential in managing common cucumber diseases [12] and acting as a preventive measure against crop diseases [13-15]. This makes Chitosan a versatile agent in agricultural practices. Zinc Pyrithione, widely used in shampoos to treat dandruff and seborrheic dermatitis, has gained recognition for its antifungal properties [16-17]. Its effectiveness against fungal infections makes it a valuable component in personal care products. Poly(allylamine hydrochloride) (PAH), popular in the textile industry, has been extensively studied for its antifungal and antibacterial properties [18-20]. Its efficacy in preventing fungal growth on fabrics highlights its potential in improving product quality and increasing the shelf life of textile products.

The continuing research endeavor seeks to enhance antifungal agents and evaluate their efficacy in improving fungal resistance, specifically in relation to dried water hyacinth stalks. The initial phase of the experiment will involve testing these agents on fabric made of 100% cotton. Following this, the chosen agent will be tested on dried water hyacinth stalks. The researchers aim to assist producers in achieving superior product quality by increasing the fungal resistance of dried water hyacinth stalks, thereby extending their shelf life.

EXPERIMENTAL

Materials

In order to compare with 100% cotton fabric, the dry fiber of water hyacinth was utilized. This decision was based on the fact that water hyacinth fiber contains a cellulose content ranging from approximately 55% to 67% [21-23].

Similarly, cotton fibers are considered the purest form of cellulose, the most abundant polymer in nature. Approximately 90% of cotton fibers are composed of cellulose [24]. For the experiment, three anti-fungal solutions were employed, namely Chitosan (CS), Zinc Pyrithione (ZnPT), and Poly (allylamine hydrochloride) (PAH). The primary goal of the initial experiment was to evaluate the antifungal effectiveness of these agents using 100% cotton woven fabric, which has a cellulose content referring to that of dried water hyacinth stalks. This standardization of methodology was crucial to ensure accurate and reliable results.

Evaluation of antifungal treatment activity on 100% cotton fabric

This section employs 100% cotton woven fabric characterized by a plain weave structure, with an approximate weight of 113.23 ± 2.13 grams per square meter (GSM) and a thickness of 0.26 ± 0.005 millimeters (mm). The anti-fungus treatment experiment on 100% cotton fabric involved immersing the fabric in a solution of antifungal agent with a concentration of 50 g/L. All antifungal agents utilized in this study are water-based. Drinking water with a pH range of approximately 6.5 – 7 was utilized to guarantee compatibility and encompass the pH range of the agents as outlined in Table 1. The fabric was dipped and subsequently padded with a wet pickup of 30% by weight, dried, and cured in a hot air convection oven at a temperature of 120 °C for 1 minute, as shown in Figure 2. The experiment also included the preparation of three antifungal agent solutions, each with a concentration of 50 g/L, to evaluate fungal growth. These solutions consisted of Chitosan (CS), Zinc Pyrithione (ZnPT), and Poly (allylamine hydrochloride), as indicated in Table 1.

Circular pieces of antifungal fabrics produced from treatment processing with various solutions were cut to a diameter of approximately 2.45 centimeters. These pieces of fabric were then subjected to laboratory testing according to the AATCC30 Antimicrobial Test standard (Test III) using agar plates infused with Aspergillus niger. In preparation for the growth of the Aspergillus niger strain on agar medium, a solution was created containing 3 g/L of Ammonium nitrate (NH_4NO_3), 2.5 g/L of Potassium dihydrogen phosphate (KH_2PO_4), 2 g/L of Dipotassium hydrogen phosphate (K_2HPO_4), 0.2 g/L of Magnesium sulfate ($MgSO_4$), 0.1 g/L of Ferrous sulfate ($FeSO_4$), and 20 g/L of Agar. This solution was then sterilized under pressure at 121 °C and poured into the growth medium to form a solid gelatinous matrix. The prepared Aspergillus niger was placed onto the matrix and incubated at a temperature of 28 ± 1 °C for a period of 7 to 14 days.

Table 1. Antifungal solution preparation for 100% cotton fabric.

Solution	Agent	Agent [pH]	Water [pH]	Concentration [g/L]	Temperature [C°]	Time [Sec]
1	CS	5.5 – 7.2	6.5 - 7	50	120	60
2	ZnPT	6.5 - 9	6.5 - 7	50	120	60
3	PAH	5.5 - 7	6.5 - 7	50	120	60

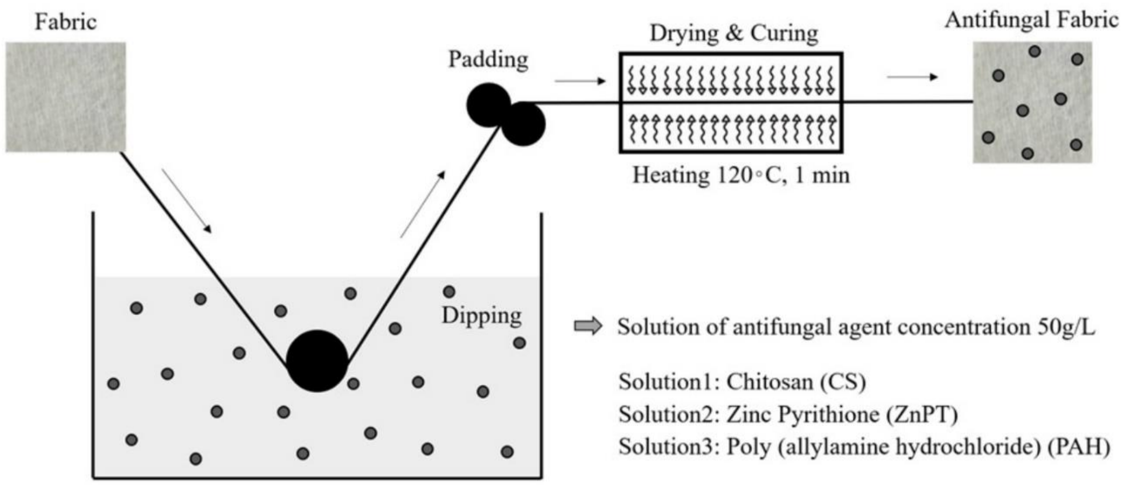


Figure 2. Antifungal treatment methods for cotton fabric with various solutions.

Evaluation of antifungal treatment activity on dried water hyacinth stalks

The experiment was conducted with the objective of creating a treatment to combat fungus in water hyacinth stalks. In the initial stage, the fresh water hyacinth stalks were dried under sunlight for a period of three days before applying the anti-fungus treatment. It was observed that for every one kilogram of fresh water hyacinth stalks, only 150 to 200 grams of dried water hyacinth stalks were obtained. These dried stalks were then prepared for the anti-fungus treatment, where the selection of a suitable anti-fungal solution for fabrics was assessed. The quality of the anti-fungal fabric was determined based on the AATCC30 standard, which influenced the choice of solution for this experiment.

The solution that was identified during the preliminary experiment was used to formulate the anti-fungal treatment for water hyacinth stalks. The dried stalks were immersed and soaked in the solution, employing a method similar to that of cotton fabric, with a concentration of 50 g/L for one minute. Afterward, they went through a 30-minute drying phase, followed by heating with hot air at 120°C for one minute.

Later on, the specimens underwent testing in accordance with the AATCC30 Antimicrobial Test Standard (Test III), using Agar Plate with Aspergillus niger for evaluation. Subsequently, a spraying process was employed to develop an anti-fungus treatment and compare hyacinth stalks.

This development has the potential to improve the quality of products made from water hyacinth and increase their value by incorporating antifungal finishes for water hyacinth fiber products.

RESULTS AND DISCUSSION

The results from the AATCC30 Antimicrobial Test Standard (Test III) results indicated that three 100% cotton fabrics were immersed in the solutions of antifungal agents consisted of Chitosan (CS), Zinc Pyrithione (ZnPT), and Poly (allylamine hydrochloride) (PAH) each with a concentration of 50 g/L. The fabric treated with CS solution did not effectively prevent the growth of the fungus Aspergillus niger, as depicted in Figure 3. Conversely, both ZnPT and PAH demonstrated the ability to inhibit fungal growth, However, the application of ZnPT resulted in the presence of visible white particles on the fabric, indicating that the ZnPT solution exhibits a white color appearance. In contrast, no particles were observed on the fabric treated with PAH due to its transparent nature, as illustrated in Figure 3.

Based on the results obtained from the antimicrobial experiments carried out on cotton fabric, it was concluded that the most effective antifungal agent for water hyacinth stalks is PAH at a concentration of 50 g/L. The methodology involved preparing dried water hyacinth stalks, immersing them in a solution containing PAH at a concentration of 50 g/L for a duration of 1 minute, as depicted in Figure 4. This was followed by a drying period of 30 minutes and a final

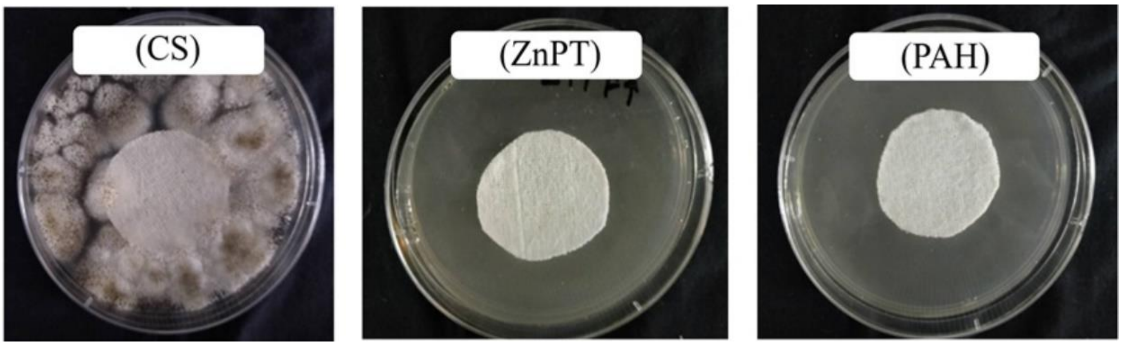


Figure 3. Antimicrobial results of CS, ZnPT, and PAH on cotton fabric at a concentration of 50 g/L.

step of subjecting the stalks to hot air at a temperature of 120°C for one minute.

Based on the findings, it was determined that the dried water hyacinth sample was immersed in a solution with a PAH concentration of 50 g/L for 1 minute. Subsequently, it was tested in the laboratory following the AATCC30 Antimicrobial Test standard (Test III) on an Agar Plate. The results indicated that the treatment was unable to prevent fungal contamination, as illustrated in Figure 5(a).

For sample A, the 100% cotton fabric's high absorbability, which allows it to absorb moisture up to 24-27 times its own weight, made it unable to prevent fungal growth. Consequently, a concentration of 50 g/L of PAH effectively inhibited fungal contamination on the cotton fabric. In contrast, dried water hyacinth stalks have a smooth surface and a lower capacity to absorb the PAH solution at 50 g/L. Therefore, increasing the concentration of PAH could enhance its absorption by the dried water hyacinth stalks, thereby more effectively inhibiting fungal contamination. Moreover, the concentration of PAH can vary based on the application method. The padding method on cotton fabric ensures an even coating without oversaturation, achieving a wet pickup of 30% by weight. Conversely, immersion is a suitable method for coating antifungal agents on dried water hyacinth stalks and can vary depending on factors such as the initial concentration of the PAH solution, the duration of immersion, and the absorption capacity of the dried water hyacinth stalks.

PAH adheres to dried water hyacinth stems through chemical binding via ionic interactions, where the positively charged ammonium groups ($-NH_3^+$) in PAH bind with negatively charged groups on the cell walls of water hyacinth, and through hydrogen bonding, where amine groups in PAH form hydrogen bonds with hydroxyl and carboxyl groups in the water hyacinth. Moreover, the concentration of PAH affects its antifungal efficacy on dried water hyacinth stems, making the appropriate concentration crucial for maximizing effectiveness. Upon analysis of the results, it became evident that the water hyacinth sample, which had been subjected to a brief immersion in a solution containing 50 g/L PAH concentration for a duration of 1 minute, and subsequently subjected to laboratory testing using the AATCC30 Antimicrobial Test standard (Test III) Agar Plate, failed to effectively inhibit fungal contamination. Specifically, the fungus Aspergillus niger exhibited the ability to proliferate, as visually represented in Figure 5(a). These findings underscore the limited antimicrobial efficacy of the tested PAH concentration and need for additional research and an elevation in the PAH concentration suggests a potential avenue for refining the antimicrobial treatment protocol.

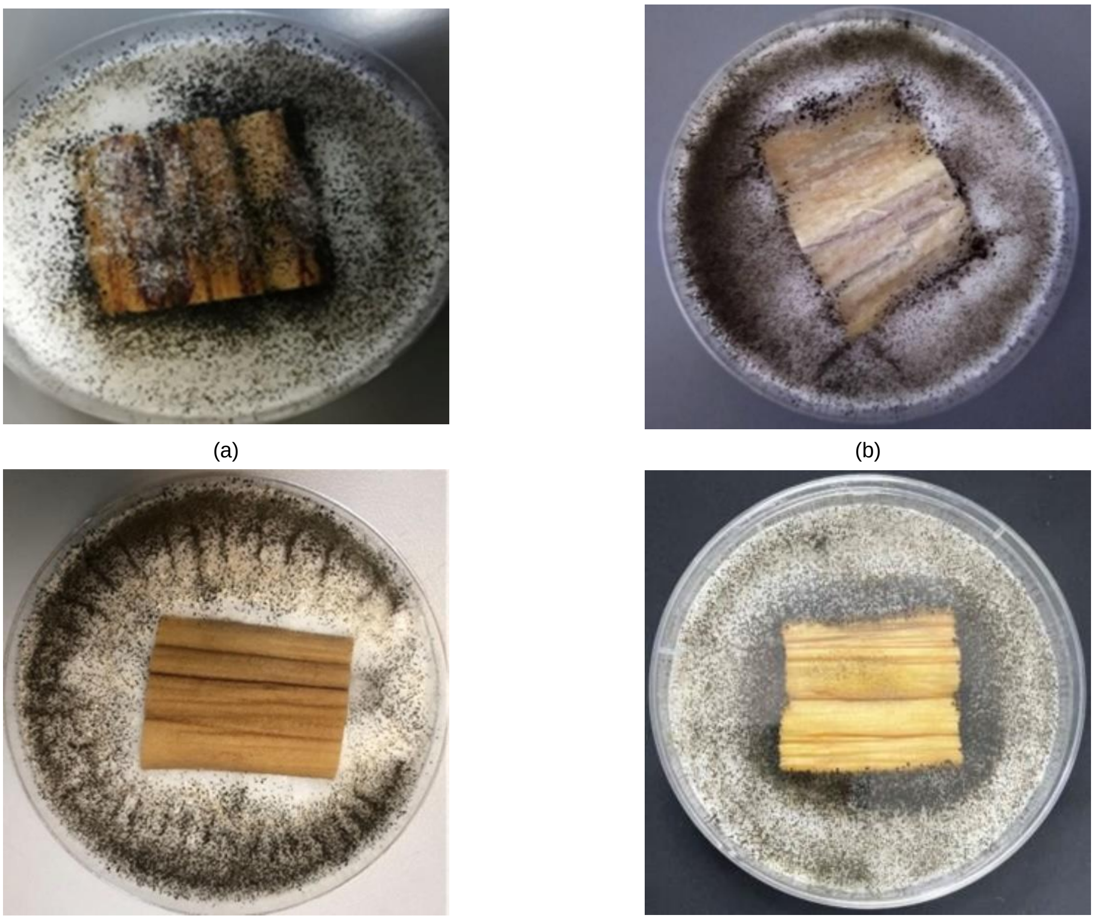
The experiment involved modifying the PAH antifungal concentration according to the information provided in Table 2.

The experimental setup entailed the creation of Sample B with a PAH concentration of 70 g/L and Sample C with a PAH concentration of 100 g/L. Significantly, our analysis unveiled that Sample B retained discernible traces of Aspergillus niger fungus, as depicted in Figure 5(b), indicating the ongoing fungal presence. In contrast, Sample C displayed a conspicuous absence of fungal growth, as clearly depicted in Figure 5(c), emphasizing the effectiveness of the higher PAH concentration in preventing fungal colonization.

Figure 4. Immersion in PAH solution of dried water hyacinth stalks.

Table 2. Preparation of PAH antifungal concentrations for water hyacinth.

Solution	Antifungal Agent	Concentration	Sample
1	PAH	50 g/L	A
2	PAH	70 g/L	B
3	PAH	100 g/L	C



(a) (b) (c) (d)

Figure 5. Antimicrobial result of sample: (a) A with PAH concentration 50 g/L, (b) B with PAH concentration 70 g/L, (c) C with PAH concentration 100 g/L, (d) D after immersion in the water for 1 minute.

To confirm the antimicrobial efficacy of PAH at a concentration of 100 g/L, an additional test was conducted using dried water hyacinth stalks treated with PAH. The experiment involved exposing the dried water hyacinth stalks to water for 1 minute, followed by drying them for 30 minutes and then using hot air at a temperature of 120°C for 1 minute. The fungal resistance of the dried water hyacinth stalks was then assessed according to the AATCC 30 Antimicrobial Test standard (Test III) using an agar plate. The results for Sample D demonstrated that most of the dried water hyacinth stalks' surfaces maintained their fungal resistance, as shown in Figure 5(d).

Based on the experimental results, it is evident that the PAH concentration has an impact on inhibiting the growth of fungi. This can contribute to enhancing the quality of processed products derived from water hyacinth stalks. This observation underscores the potential for incorporating 100 g/L of PAH antifungal agents during the preparatory phase of water hyacinth stalks to ensure their suitability for subsequent product development, ultimately leading to improved quality in water hyacinth-derived products.

In addition to preparing water hyacinth stalks for subsequent product development, the researchers conducted antifungal testing on finished water hyacinth products, as depicted in Figure 6. This was achieved by directly applying antifungal agents using a spray technique to the prepared products. Immersing the finished products in a solution was deemed impractical due to concerns about potential structural integrity alterations caused by excessive solvent absorption. Therefore, a spray technique was employed to evaluate and enhance the protection of water hyacinth-derived products against fungal contamination, utilizing a solution with a concentration of 100 g/L of PAH (Preservative Antifungal Agent with High potency) to assess its effectiveness.

The resistance testing performed on water hyacinth-derived products, using a spray method with a concentration of 100 g/L of PAH of Sample E, demonstrated its capacity to provide protection against fungal contamination, albeit with less efficiency when compared to pretreating the water hyacinth stalks with antifungal agents prior to product formation, as shown in Figure 7. Nevertheless, the test results unequivocally indicate that the spray technique can effectively safeguard products against fungal growth in the absence of prior antifungal solution immersion.

Figure 6. Spray technique of PAH solution on dried water hyacinth stalks.

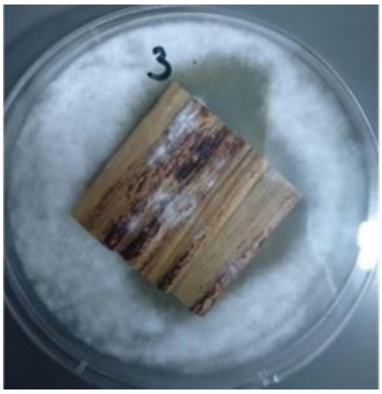


Figure 7. Antimicrobial result of sample E utilizing spray technique at PAH concentration of 100 g/L.

CONCLUSION

The objective of this research was to develop and evaluate antifungal agents for dried water hyacinth stalks. The experiments demonstrated that PAH exhibited efficient antifungal properties, both on 100% cotton fabric with a concentration of 50 g/L and on water hyacinth with a concentration of 100 g/L. The data indicated that the effectiveness of retaining antifungal agents on cotton fabric was superior, as it absorbed the antifungal solution more effectively than dried water hyacinth stalks. Therefore, increasing the concentration of antifungal agents significantly contributes to enabling water hyacinth stalks to effectively resist fungi, requiring a concentration of PAH substances as high as 100 g/L.

In addition to the efficient antifungal effects achieved through immersing dried water hyacinth stalks in a concentrated PAH solution, it is observed that employing the PAH spray technique with the same concentration can also effectively inhibit fungal growth in finished products. This demonstrates that finished water hyacinth products can effectively prevent fungal contamination using the spray technique, extending the product's shelf life and adding value to the water hyacinth product efficiently.

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