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Bleaching of Xylanase-Treated Bamboo Fibre with Eco-Enzyme Assisted Power Ultrasonic

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Abstract: This study ventured to determine the effectiveness of eco-enzyme bleaching treatment towards xylanase-treated bamboo fibre with the assisted of power ultrasonic since the conventional bleaching treatment produced toxic effluent which will affect the human health. This study aims to produce bamboo fibre from *Schizostachyum grande* (Semeliang) type of bamboo via bamboo fibre extraction machine and determine eco-enzyme bleaching treatment towards xylanase-treated bamboo fibre assisted power ultrasonic at different pre-treatment conditions temperature and processing time. After that, analyse the tensile strength via INSTRON 50 kN Blue Hill 3369 Universal Testing Machine (UTM) and brightness of bleaching treated bamboo fibre via HunterLab Colorimeter. The result revealed that soft *Schizostachyum grande* fibre were easily produced via bamboo fibre extraction machine. Tensile strength shows an increasing trend with the highest value of 553.44 MPa for xylanase-treated bamboo fibre at 80 °C for 60 min. Bamboo fibre treated with eco enzyme shows decreasing trend with the highest tensile strength value of 400.66 MPa at 35 °C for 60 min. The brightness of xylanase-treated bamboo fibre with low concentration eco-enzyme having highest value of 73.66 compared to higher concentration eco-enzyme treated bamboo fibre (74.46) suspected due to the cavitation effects produced by ultrasonic that increased the diffusity and mass transfer rate of xylanase and eco-enzyme into the fibre. This finding can be set as a benchmark of an effective method to bleach bamboo fibre assisted power ultrasonic and xylanase enzyme instead of using hydrogen peroxide that affected the environment and human being.

Keywords: Bamboo Fibre, Bleaching Treatment, Xylanase Enzyme, Ultrasonic Assisted

1. Introduction

Natural bamboo fibres having excellent characteristic such as their coarse and stiff quality. The stiffness of this bamboo fibre comes from the composition of cellulose (45-55 %) and hemicellulose

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(20-25 %), and also lignin content (20-30 %). Thus, lignin content need to be kept at the optimum level in bamboo fibres' refining process [1]. Bamboo fibre is one of renewable sources fibres which is having a huge range of uses. From previous research state that the structure of morphological and the bamboo fibres properties are comparable to standard viscose fibres. Other than that, it also has been reported where the fibre exhibit different crystallinity and orientation [2]. This bamboo fibre have good characteristics such as excellent permeable, rare elasticity, transient absorption, antibacterial, resistance in odour and tougher vertical and horizontal intensity, that give a new journey in the development and production of eco-textiles as well as in bamboo industry [3]. Bamboo fibre also having low density and high mechanical strength compared to others popular natural fibre such as banana, coir, straw and jute. It also has significantly lower specific tensile strength and specific gravity than glass fibres. Bamboo, on the other hand, is a cost-effective fibre for reinforcement [4].

In the process of effective dyeing for all natural fibres, it must reduce or eliminate the yellowness of the fibre. Hot alkaline hydrogen peroxide (H_2O_2) is one of the oxidative bleaching which is most popular method used in bleaching the cellulosic fibres. Nonetheless, significant fibre rupture will be resulted from this chemical bleaching method [5]. Nowadays, hydrogen peroxide is widely used as bleaching agent because of its biodegradability which are replacing the conventional chlorine oxidizing chemicals. Bleaching agents' radical reactions with fibres can result in a decrease in polymerization degree and fibre rupture. Furthermore, removing hydrogen peroxide from fabrics necessitates a large amount of water, which would complicate dyeing process [6]. This chemical bleaching method will produce huge amount of toxic and hazardous pollutants towards environment which goes to the soil and water bodies as effluent. Since conventional methods cannot remove the inorganic materials, the wastewater from these activities acts as a significant source of point contamination [7].

One of the most convenient alternatives is bioprocessing using microbial enzymes of pulp. Xylanases and mannanases are example of hemicellulolytic enzymes which can detach the chromophores bound to carbohydrate and the hemicellulosic components present on the pulp fibres surface will be depolymerised. The effective method for biobleaching is the removal of lignin and hemicelluloses present in wood [8]. Xylanase enzyme are usually used as pre-treatment for bleaching to enhance the effect of bleaching using chemical bleaching agent to minimize the release of chemicals [9]. In a research, xylanase enzyme can oxidize lignin depending on enzyme concentration, pH, temperature and time to brighten the pulp [7]. Eco enzyme is an enzyme from fruit and vegetable wastes which can act as cleaning agent. Dumped waste is often stale, spoiled, and unfit for ingestion. Several studies have showed that up to 80 % of such strong waste can be reused by creating eco enzyme solutions and thus reducing the pollution it creates. Antifungal, antibacterial, insecticidal, and cleaning agents are some of the functions that eco-enzyme performs. Its use can aid in the reduction of organic waste, the reduction of greenhouse gas emissions, and the reduction of landfill garbage [10].

The noble method of using ultrasonic energy to textiles industry was applied since 1990s for dyeing textiles especially for the wet finishing processes. Moreover, the application of ultrasonic energy will be lowering the processing time, energy, chemicals used and in improving quality of product [11]. The ultrasonic frequency range is higher than 16 kHz which it will perform heat transfer in liquids, and the ultrasound-induced cavitation will generate bubbles for cleaning purposes. Morphological changes in fibres will be produced by ultrasonification to increase flexibility and enhance the fibres bonding in the process of paper formation and efficient bleaching of pulp [12]. Ultrasonic and xylanase junction will enhance the mechanical properties such as improving the tensile index, specific elastic modulus and absorption of tensile energy and the opacity also will be improved [13]. Ultrasonic wave treatment has been reported can enhancing the tensile strength and brightness properties of recycled pulp fibres [14].

Therefore, this study focused on bleaching of xylanase-treated bamboo fibre with eco enzyme assisted power ultrasonic. This project is to replace the conventional bleaching process from chemical to fully environmental friendly process. It is believed that this study can give huge impact to environment due to the non-chemical material used in bleaching process which lead to enhancement in effluent.

2. Materials and Methods

2.1 Materials

The main material used is *Schizostachyum grande* (Semeliang) bamboo strip, xylanase enzyme and eco enzyme. The bamboo strip was obtained from Hangterra Bamboo Sdn Bhd and eco enzyme that were used in the experiment was purchased via online platform. The xylanase enzyme (1000 IU/g at an optimum temperature 70-80 °C) was purchased from reseller at Batu Pahat. Table 1 shows the apparatus used in the experiment.

Table 1: Apparatus used

Apparatus	Remark
Decorticator	to produce bamboo fibre
Ultrasonic	assisted bleaching process
Colorimeter	to analyse brightness of fibre
INSTRON 50 kN Blue Hill 3369 Universal Testing Machine	to analyse tensile strength
Drying Oven	to dry bamboo fibre

2.2 Preparation of Bamboo Fibre Sample

The bamboo strips were soaked in tap water for 5 days. The bamboo fibre was then washed with tap water to remove dirt from the strips. After that, the washed strips were segregated based on its thickness. The allowed thickness of the strips should be 0.2-0.3 cm before entering bamboo fibre extraction machine (decorticator). The bamboo strips were thinned using machete and was entered into the machine. The fibre produced were combed using large gap comb and small gap comb to get soft fibres for the treatment.

2.3 Pre-treatment of Bamboo Fibre with Xylanase Enzyme Assisted Sonication

A strip with 3-5 gram of bamboo fibre was immersed with 1000 IU/g of xylanase enzyme at different temperature and the bath was sonicated for different time as shown in Table 1 using sonic power at 180 W. The frequency of the ultrasonic was set up to 60 kHz. Finally, the bamboo fibre sample were washed with distilled water for multiple times prior being air dried until constant weight was obtained [15].

Table 2: Different conditions of the pre-treatment

Time, min	Temperature, °C		
	40	60	80
60	Sample 1	Sample 4	Sample 7
90	Sample 2	Sample 5	Sample 8
120	Sample 3	Sample 6	Sample 9

2.4 Bleaching of Bamboo Fibre using Eco Enzyme Assisted Sonication

The treatment of bamboo fibre starts with immersion in a bath with 50 ml of eco enzyme at a constant temperature of 40 °C. The bath was sonicated for 2 hours using power ultrasonic at 300 W. The frequency of the power ultrasonic was set up to 60 kHz. Finally, the fibre sample were washed with distilled water for multiple times prior being air dried until constant weight was obtained [15].

2.5 Tensile Strength Testing for the Treated Bamboo Fibre

According to ASTM C1557-14 (2014), at room temperature 25 °C, the tensile strength was carried out for control and xylanase treated bamboo fibre with a relatively humidity of 55.0 % by using an INSTRON 50 kN Blue Hill 3369 Universal Testing Machine (UTM). The strain rate was set up at 0.00008 s^{-1} which is 0.48 mm/min [16].

2.6 Brightness Testing for Treated Bamboo Fibre

The brightness test is conducted via HunterLab MiniScan EZ 4500L Colorimeter, used for measuring the reflected colour of samples. HunterLab is colour scales based on the Opponent-Color Theory which having a wavelength range of 400–700 nm. The colorimeter was standardised by reflecting the colorimeter's light through black tile and white tile. The bamboo fibre was ensured to have no gap between the fibre in order to analyse its brightness using colorimeter.

3. Results and Discussion

3.1 Bamboo Fibre Production

The visual and handling properties of fibres extracted from *Schizostachyum grande* bamboo were examined manually. The bamboo fibre produced is suitable to use in the treatment because the fibre is following criteria such as long and soft fibre. If the strip that enter the machine is short, the fibre produced will be clumped between each other and making the fibre difficult to be treated in the treatment. *Schizostachyum grande* bamboo is a most suitable to make fibre because it is the only species with longer internodes than any other commercial Malaysian bamboo. Longer internodes giving advantage in the production of soft and long bamboo fibre and also reducing time in the production of fibres [17]. If a shorter internode type of bamboo used, it will increase difficulties of the bamboo strips to enter the machine. Consequently, lower quality of bamboo fibre will be produced.

3.2 Tensile Strength Analysis for Xylanase-Treated Bamboo Fibre with Eco-Enzyme assisted Ultrasonic

Based on Figure 1, it is shown that the highest tensile strength obtained is from sample 7 (553.44 MPa) which is pre-treated in xylanase enzyme assisted power ultrasonic for 60 min in temperature of 80 °C. Sample 1, sample 4 and sample 9 having the lowest tensile strength compared to untreated bamboo fibre. The pre-treatment of bamboo fibre at 40 °C (sample 1,2,3) shows an increasing trend of graph while for treatment at 80 °C (sample 7,8,9) show the tensile strength decreasing gradually with time.

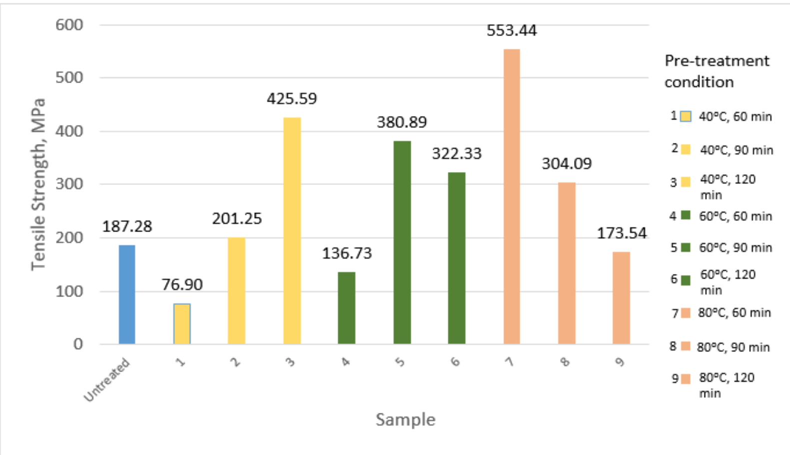

Figure 1: Tensile strength of bamboo fibre with pre-treatment of xylanase enzyme

The xylanase-treated bamboo fibre will increased the tensile strength of the fibre. By the assistance of power ultrasonic, it increased the accessibility of xylanase onto fibres and accelerate fibrillation will via cavitation effect. For sample 1-3, the tensile strength is increasing gradually with processing time. Xylanase is not really active at low temperature, longer processing time is needed for assisted power ultrasonication that enhance the enzyme molecule transportation to the surface of fibre [18]. The cavitation bubbles collapsing causes major structural and mechanical defects in a heterogeneous solid/liquid system. Near the surface, collapse causes an asymmetrical inrush of fluid to fill the void, resulting in a liquid jet directed at the surface. By disrupting of the boundary layers and dislodging the material occupying the inactive sites, the solid catalyst will be activated by these jets and accelerate mass transfer to the bamboo fibre surface. On the surface collapsing, powders enzyme will produces sufficient energy causing fragmentation (even for finely divided metals). Therefore, the surface area for a reaction will increase by using ultrasonic and additional activation are provided through efficient mixing and mass transport will be enhanced [19].

Sample 7-9 showing decreasing trend of tensile strength because the bamboo fibre is exposed to high temperature for a long period of time which lowering the valence bond of the fibres. The increasing of temperature of pre-treatment and bleaching process making the strength of the fibre changed from higher to lower. Increasing temperature causing the valence bond become weak, consequently decreasing the fibre strength [3]. Nevertheless, fibrillation of fibres is improved with the xylanase treatment assisted power ultrasonic. Ultrasonication boosted treatment of xylanase in improving the bamboo fibre mechanical properties [14]. In liquid medium, the formation and rapid bubbles collapse is called cavitation. The collapsing between bubbles will generate higher temperature and pressure (about 10^4 K and 10^3 bar respectively) conditions capable of causing chemical and physical changes. Based on a research, the bubble collapsing will increase the temperature of solvent [19]. Therefore, the trend shows decreasing tensile strength because the enzyme is started to degrade at 80 °C making the enzyme less effective towards the bamboo fibre.

3.3 Tensile Strength Analysis for Eco-Enzyme Treated Bamboo Fibre

Figure 2, shows the tensile strength of bamboo fibre without the pre-treatment of xylanase enzyme. It shows that sample 1 having the highest tensile strength which is 400.66 MPa. On the other hand, the lowest tensile strength obtained is from sample 9 which is only 79.36 MPa. The trend of the graph shows the tensile strength is decreasing with the increasing of temperature and bleaching time.

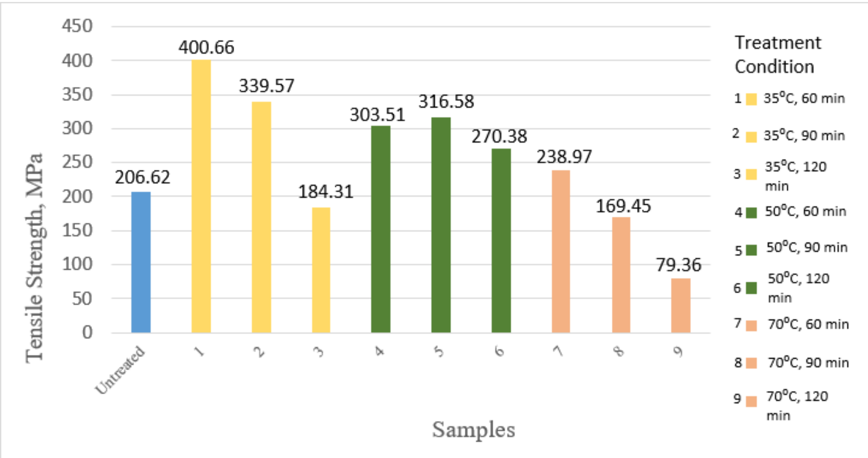

Figure 2: Tensile strength of bamboo fibre without pre-treatment of xylanase enzyme

The tensile strength of the fibres is decreasing because there is an increment of temperature and bleaching time which affected its strength. As the heat temperature increase, the tensile and impact strengths increased, while the tensile and impact strengths declined which resulted in a reduced interaction between the molecules. As a result, when the heat treatment temperature exceeded 50 minutes, the tensile strengths fell [20]. High tensile strength of treated bamboo fibres with only eco enzyme were due to the high load imposed to the fibres. The increased tensile strength of enzyme-treated fibre implies that the cellulose fraction in the fibre is not degraded [21]. The bamboo fibre that undergoes bleaching treatment with xylanase pre-treatment having a better tensile strength compared to bleaching treatment with only eco enzyme. This shows that xylanase enzyme can enhance the tensile strength of bamboo fibre effectively and does not get affected by eco enzyme.

3.4 Brightness Analysis for Xylanase-Treated Bamboo Fibre with Eco-Enzyme assisted Ultrasonic and Bleaching Treatment of Bamboo Fibre with Eco-enzyme

The eco enzyme bleaching process of xylanase-treated bamboo fibre with power ultrasonic having constant temperature of 40 °C, bleaching time for 2 hours, and concentration eco enzyme at 0.0125 v/v (1.25 % v/v). The method is started with the controlled sample where it acted as a referenced to compare bleached and unbleached bamboo fibre. Lower value of lightness indicates darker fibre while higher value of lightness shows the degree of fibre brightness.

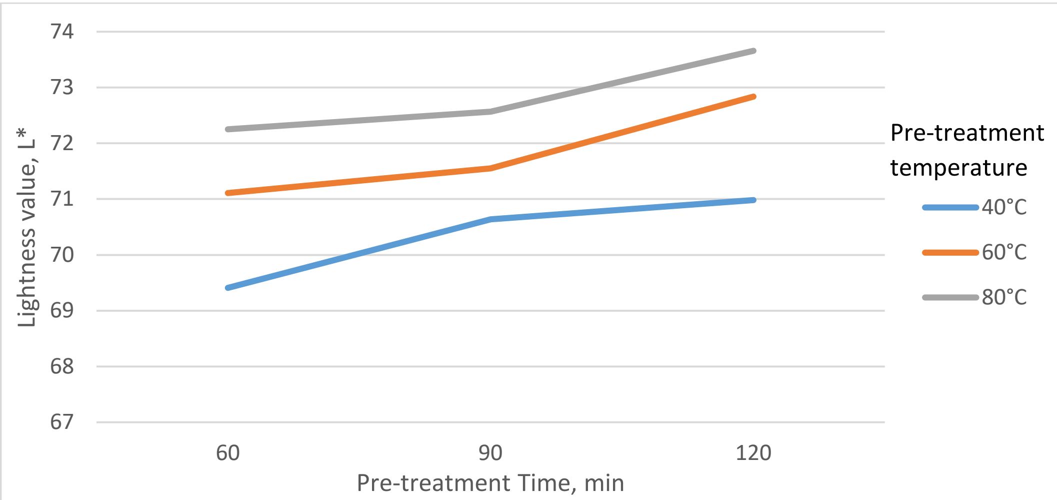

Figure 3: Lightness against time graph for xylanase-treated bamboo fibre with eco enzyme

Based on Figure 3, the trend of the graph shows the lightness value is increasing gradually towards bleaching time and temperature of pre-treatment. The highest lightness obtained is from sample 9 which is 73.66 which the xylanase and ultrasonic assisted pre-treatment time and temperature at 120 mins and 80 °C respectively. The brightness of all sample is higher compare to the untreated/controlled sample.

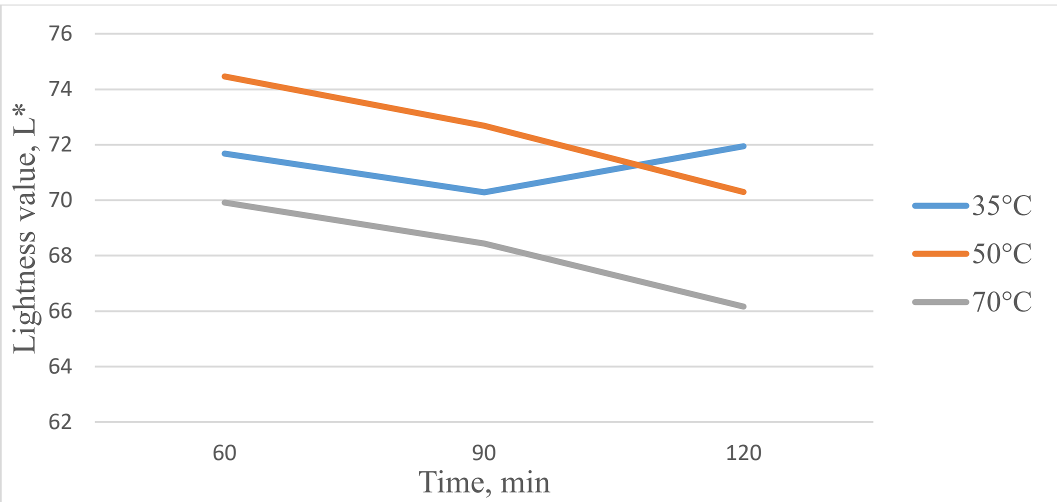

Figure 4: Lightness against time graph for eco enzyme bleaching treatment

Based on Figure 4, the brightness/lightness value is increasing at the earlier part of the treatment that bleached under 35 °C temperature and increasing bleaching time. The brightness of the fibre reached the highest value when it is bleached under temperature of 50 °C and bleached time was 60 min. Consequently, the brightness value started to decrease gradually upon increasing processing time as well as temperature above 50 °C until showing 66.17 brightness value at 70 °C and 120 min.

In contrast, the brightness of bamboo fibre is improving when there has xylanase enzyme pre-treatment compare to non-pre-treatment bleaching process. Bleaching treatment condition of 50 °C and 60 min with eco enzyme have the highest value of brightness which is 74.46. The highest brightness value for xylanase-treated bamboo fibre with eco-enzyme assisted power ultrasonic is 73.66. There is a small difference value since the xylanase-treated bamboo fibre only use 40 °C where the optimum temperature for the eco enzyme is 35-50 °C. The treatment of xylanase-treated bamboo fibre with eco enzyme assisted power ultrasonic are using low concentration of eco-enzyme hence showing little bit lowest brightness value. At 35 °C, the enzyme activity began to increase to temperature of 50 °C and the enzyme is started to denature when the temperature is higher 50 °C with longer bleaching time because of long exposure to heat.

Xylanase enzyme pre-treatment and ultrasonication assisted are giving advantages to the performance of bleaching effect with eco enzyme towards bamboo fibre. The xylanase enzyme oxidises lignin and produces colourless pulp, which gives the fibre its brightness [7]. When xylanase is employed as a pre-treatment agent, it removes xylan from the fibre surface, which is then re-deposited on the fibres. Xylan content on the fibre surface is drastically decreased after enzyme treatment, which increases surface permeability, allowing bleaching agent better access to lignin and so increasing the effectiveness of the bleaching sequence [9]. Based on research, xylanase enzyme will aid the bleaching effect of eco enzyme to penetrate and degrade the colour of bamboo fibre.

Ultrasonication also aided the bleaching process by eco enzyme. Cavitation bubbles will generate shock wave lead to collapsing of bubbles with the fibre surface, creating a perfect mechanism of stirring for reaction of enzyme took place at the layer of liquid at the solid/liquid interface. Sonication can significantly boost the bulky enzyme transportation towards the fibre surface by the agitation of this liquid border layer which resulting in an improvement on the overall reaction rate [18]. Therefore, xylanase-treated bleaching bamboo fibre with eco enzyme giving higher brightness even at low temperature and low concentration compared to bleaching treatment with eco enzyme only which can reduce the energy consumption of the process.

4. Conclusion

This study was conducted with intention to bleach the bamboo fibre with natural bleaching agent of eco enzyme with xylanase pre-treatment and assisted power ultrasonic. The bleaching process of xylanase-treated bamboo fibre with eco enzyme assisted power ultrasonic are in constant temperature, processing time and enzyme concentration but different conditions of pre-treatment. The bamboo fibre was successfully bleached via the treatment of xylanase-treated bamboo fibre with eco-enzyme assisted power ultrasonic. According to the result obtained, xylanase-treated bamboo fibre with eco enzyme assisted power ultrasonic give the best tensile strength of 553.44 MPa with brightness of 72.25 at 80 °C for 60 min. Nevertheless, the highest brightness obtained is 73.66 with low tensile strength of 173.54 MPa at temperature of 80 °C for 120 min with low concentration of eco-enzyme in compare to treatment with only eco-enzyme. The best bleaching treatment conditions was at pre-treatment temperature of 80 °C for 60 min regarding to its best tensile strength (553.44 MPa) and brightness value (72.25).

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