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Operational Conditions Optimization on Blacu Fabric Dyeing Technology (Case Study: Mordanting influence on Naphtol Color Quality and Mechanical Strength of Blacu Fiber).

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ABSTRACT

This research aims to get the optimum operational condition on blacu staining. More specifically, this research aimed to determine the influence of mordanting time on blacu fabric color quality, which include: the intensity and the differences of blacu colors before and after washing process, as well as the mechanical resistance of the blacu fabric against external load. To get the color intensity as coloring result using naphtol and indigosol and also color differences of blacu fabric as the consequences of washing process, analysis has done by using Difuse Reflectant Visible Ultraviolet (DRUV) instruments. Analysis results using DRUV can indicate four things, namely: color absorption by blacu fabric, color fade resistance of a blacu fabric, the differences between the blacu fabric coloring results which is done with and without mordanting process, and also the color differences on blacu fabric before and after washing process. Based on the results of DRUV analysis obtained, known that the mordanting process that is done before dyeing process using naphthol, will increase the color intensity which is applied to the blacu fabric. Moreover, it also appears that the mordanting process also has decrease fastness of blacu fabric. The color intensity produced from blacu dyeing process using naphthol dye on the range 96.99% - 99.41% (before leaching) and in the range of 92,88% - 99,03% (after leaching). In the meantime, to find out the influence of the mordanting process against mechanical strength of colored blacu fabric, on this experiment also conducted the analysis using autograph instruments. This analysis result will show the maximum robustness of blacu fabric against external load. Based on the results of analysis using autograph, note that the mechanical strength resulting from the dyeing process with naphthol (without mordanting process) varied in the range 20,740.37 N/m^2 – 35,645.93 N/m^2. The highest fabric mechanical strength produced by naphthol yellow, while the lowest fabric mechanical strength produced from dyeing using naphthol red.

Keywords: Fabric, cotton, blacu, dyes, naphtol, mordant

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INTRODUCTION

Cotton is a soft, fluffy staple fiber that grows in a boll, or protective case, around the seeds of cotton plants of the genus Gossypium in the family of Malvaceae. The fiber is almost pure cellulose. The plant is a shrub native to the tropical and subtropical regions around the world, including the Americas, Africa, and India. The greatest diversity of wild cotton species is found in Mexico, followed by Australia and Africa [1]. Blacu fabric or blaco fabric is a kind of cotton fabric which has the lowest quality. This kind of fabric is generally sold in grey or have not been bleached. The blacu fabric is the basic fabric of the mori fabric, i.e. white woven fabric made from cotton and is commonly used as an ingredient for making batik fabric. Basically, there are 2 (two) types of mori fabric, which are the mori fabric that has undergone a whitening process (bleaching) and the mori fabric that has not been bleached [2]. The mori fabric which has not been bleached is known as blacu fabric. Most of the blacu are capable of being produced within the country. The existence of blacu fabric that has sustainability assured, causing the fabric is very potential for processed into various mainstay art products, including batik, which became the hallmark of Indonesia. In addition to the existence continuity which is assured, blacu fabric has flexible nature, so it can be formed into a wide variety of models.

Since getting the recognition from UNESCO as a non cultural heritage objects are native Indonesia in 2009, Indonesia batik industry is growing by leaps and bounds. This development has even reached more than 300 percent in the last 3.5 years, with total revenues reaching 100 billion rupiah per year. But unfortunately, the rapidly development of batik industry is not accompanied by an increase in awareness from batik craftsmen to observe and manage waste production. During this time, wastewater that produced daily by the small medium batik enterprises, directly dumped into a waterways [3]. This condition is certainly very worrying because on average 15-85% of total batik dyes used, not bonded with fabrics fiber and wasted as sewage effluents [4-5]. Large percentage of dye that become an effluents, would magnify the potential of environmental damage that can be inflicted, when in fact batik dyes which passes as effluents still have the potential to be able to reuse [6]. Therefore, it becomes important for doing optimization on batik dyeing process, which one stage of them done by doing mordanting optimization that can maximizes the dye interaction with fabric fiber. The success of this research will be very beneficial in minimizing the amount of dye waste which wasted into the environment.

A mordant is a substance used to set dyes on fabrics or tissue sections by forming a coordination complex with the dye which then attaches to the fabric [7]. The term mordant comes from the present participle of French mordre, “to bite”. In the past, it was thought that a mordant helped the dye bite onto the fiber so that it would hold fast during washing. A mordant is often a polyvalent metal ion [8-9]. The resulting coordination complex of dye and ion is colloidal and can be either acidic or alkaline [10].

Mordants include tannic acid, alum, chrome alum, sodium chloride and certain salts of aluminium chromium, cooper, iron, iodine, potassium, sodium, and tin [11]. The three methods used for mordanting are : (1) pre-mordanting (onchrome) : the substrate is treated with the mordant and then dyed; (2) meta-mordanting (metachrome) : the mordant is added in the dye bath itself; and (3) post-mordanting (afterchrome) : the dyed material is treated with a mordant [12-14]. The type of mordant used changes the shade obtained after dyeing and also affects the fastness property of the dye. The application of mordant, either pre-mordant, meta-mordant or post-mordant methods, is influenced by : (a) the action of the mordant on the substrate : if the mordant and dye methods are harsh (for example, an acidic mordant with an acidic dye), pre-mordanting or post-mordanting limits the potential for damage to the substrate; and (b) the stability of the mordant or dye lake or both : the formation of a stable dye lake means that the mordant can be added in the dye without risk of losing the dye properties (meta-mordanting) [15].

Mordant dyes require a mordant, which improve the fastness of the dye against water, light and perspiration. The choice of mordant is very important as different mordants can change the final color significantly. This is because mordant substances serves to form a bridge between chemical substances in dyes with fiber so that the affinity of dyes substance to the fiber increases [10,16]. Thus, through the deployment of mordanting process before the dyeing process, is expected to be able to minimize the percentage of dye which wasted as waste.

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EXPERIMENTAL

Material

Materials research include : (a) naphtol dyes component, such as : naphtol dyesand salt that was obtained from Namiroh Batik SMEc Sidoarjo East Java Indonesia, sodium hydroxide (NaOH, pellet, ≥98%, Sigma Aldrich); (b) batik raw material, such as : blacu fabric which was obtained from Namiroh Batik SMEc Sidoarjo East Java Indonesia; (c) washing agent, Turkish Red Oil (TRO, boiling point >150 ˚C, sulphonation degree≥4); and (d) mordanting agent, such : alum (Al_2O_3, purity≥17%) and soda ash (Na_2CO_3, density 2.54 g/cm^3).

Instrument

Research equipment includes: a watch glass, spatulas, beaker glass, measuring cups, glass plate and magnetic stirrer. Becide that, in this experiment also used Nicolet IS10 Thermo Scientific Fourier Transform Infra Red, Shimadzu AG-10TE autograph and Shimadzu UV-2401-PC spectrophotometer instrument.

Blacu Fabric Mordanting Process

The Mordant solution was made by dissolving 2 grams of Turkish Red Oil (TRO) in 1 liter water. To ensure the formation of a homogeneous solution, stirring process is done using a magnetic stirrer for 5 minutes. Furthermore, once the mordant solution available, 3 pieces of blacu fabric (10 x 10 cm) put into it and then immersed for 2 hours. Next, blacu fabric rinsed as much as 3 times, each of which uses 1 liter water. The process of blacu fabric mordanting was terminated by drying process for 2 hours. The same procedure is also applied to the mordanting process of blacu fabric with long submergence 4; 6; and 24 hours.

At this stage, to know the influence of treatment using soda ash and alum against blacu fabric quality color, there are numerous samples of blacu fabric which further processed by the following procedure. Process begins with dissolving 2 grams of soda ash and 8 grams of alum in 1 liters boiling water (100 °C). To ensure the formation of a homogeneous solution, the solution was stirred using a magnetic stirrer for 5 minutes. Next, the blacu fabric sample was dipped into the solution and immersed overnight. Blacu fabric samples that have been through this stage, ready for the dyeing process [17].

Naphtol Dye Preparation

Naphthol dyes obtained by dissolving 1,76 gram dye and 0,622 grams of NaOH in 200 mL of boiling water. Then, in a separate place, naphthol salt solution prepared by dissolving 3 grams of salt in 100mL of cold water. Each solution was stirred until homogeneous using a magnetic stirrer for 5 minutes. The same procedure is also used to prepare other kind of naphthol dyes [17].

Blacu Fabric Dyeing with Naphthol Dyes

Blacu fabric dipped in naphthol dye for 30 minutes. After that, the fabric is dried in the sun for 5 minutes. After that, the blacu fabric dipped in naphthol salt for 30 minutes and then aerated for 15minutes. To inhibit the rate of colors washed out, accomplished fabric immersing in the tunjung fixer ($FeSO_4$) for 10 minutes. The process of fabric coloring with naphthol terminated by drying out blacu fabric under the sun for 15 minutes. The solar heat which used to drying out the blacu fabric in this experiment restricted between 11 am - 2 pm [17].

Blacu Fabric Washing Process

The blacu fabric washing solution is made by dissolving 1 gram x-detergent in 100 mL water. To ensure that washing solution has been homogenized, the solution was stirred using magnetic stirrer for 1 minute. Then, after washing solution available, blacu fabric was dipped into the washing solution and marinated for 30 seconds. Leaching process is terminated by drying, where the blacu left in the open air for 1.5 hours [17].

Dyes Functional Groups Analysis

Both kind of blacu fabric, which is blank and colored blacu (as the result of coloring process using naphthol and indigosol dye), then analyzed using FTIR instrument at wave numbers of 4000 – 666 cm^{-1}.

Physical and Chemical Characterization of Blacu Fabric

To determine the physical characteristics (blacu fabric color intensity, before and after washing process) and mechanical strength of the blacu fabric (resistance to stress and strain), conducted an analysis of the blacu fabric, with the following information: (a) measurement of fabric color intensity by scanning Diffuse Reflectant Ultraviolet Visible (DRUV), and (b) measurement of blacu mechanical strength with autograph.

RESULT AND DISCUSSION

Blacu Fabric Mordanting Process

A mordant is a substance used in dyeing to fix the coloured dye on the fabric. The term mordant comes from the Latin word mordere, meaning to bite. Mordants also change the colour properties of dyes. Mordanting is material processing in mordant solution. According to Rashid Djufri (1976), the process of mordanting can be done in three ways: (1) pre-mordanting, performed before immersion; (2) simultaneous mordanting (meta-chrom, mono-chrom), done in conjunction with immersion; and (3) final mordanting (after chrom), carried out after dyeing [17].

In this study, the process of mordanting applied is the kind of pre-mordanting using alum and soda ash. To maximize the formation of complexes between cellulose, soda ash and alum, as well as dyes, has done the washing of fiber using turkish red oil (TRO). This leaching process will eliminate the pollutant on fiber cellulose, which is generally dominated by fat.

Mordanting process relies on the fact that a number of metal elements can serve as a receiver (aseptor) to the giver of the electrons (donor) for the coordinate bonds form or semi polar [18]. In figure 1 appears to the interaction between cellulose fiber, soda ash and alum (hypothetically).

Dyeing is a process of giving color to the textile material evenly and well, in accordance with the desired color. Before dyeing is done, that is important to choose the appropriate color with the fibre substances. Dyeing process can be done with a variety techniques and certain tools anyway. In general, dyeing process consists of dissolving or disperse color substances in water or other medium, then enter the textile material into the dye solution, so it can happen absorption of a color substance into the fibers. The absorption of a color substance into the fibers is exothermic reaction and an equilibrium reaction. Some auxiliary substances such as salt, acids, alkalis or other added into dye solution and then immersion continues until the desired color is obtained. Vickerstaf concluded that in dyeing there is three stages, namely:

The first phase is the phase where the molecules of a colour substance in aqueous solution is always in motion, and which this movement was quickly at a high temperature. Then textile materials was immersed into a dye solution. Textile fibers in aqueous solution had negative charge on the surface, so that in this stage, there are two possibilities, which is the colour substance molecule will be attracted by the fiber or rejected so stay away from fiber. Therefore need the addition of auxiliary substances to induce a color more easily approach the fiber surface. This first phase is often called the diffusion of the color substance in the solution.

In the second phase, the molecules of a color substances that have large enough energy to be able to cope with the retention force of the fiber surface, will be absorbed and stuck to the fiber surface. This event is called adsorption. However, due to the cellulose fibre carries a net negative charge and many dyes used are also anionic. So there is a little affinity for the dye to attach itself to the fibre. Therefore, the existence of mordant in this case is very important. The mordant acts as a chemical bridge. A polyvalent cationic or positively charged ion of the mordant will be joins the negative charge on the fibre and the negative charge on the dye, and so the dye is fixed to the fibre. The interaction between the mordant alum with fiber and naphthol dyes appear in figure 2. The third stage is the most important part in the dyeing process, which is penetration or diffusion color substance from the surface into the fibers center. The third stage is the slowest

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process, so that the measurement of dyeing speed can be done at this stage. Furthermore, to support the hypothesis of an interaction that occurs between the soda ash, alum, cellulose and fibers, the compounds functional groups test has been performed using FTIR. Through this analysis can also note the influence of mordanting on cellulose fiber molecular structure. In figure 3 looks infrared spectra for white cellulose fiber, with and without mordanting process, and also color on cellulose fiber.

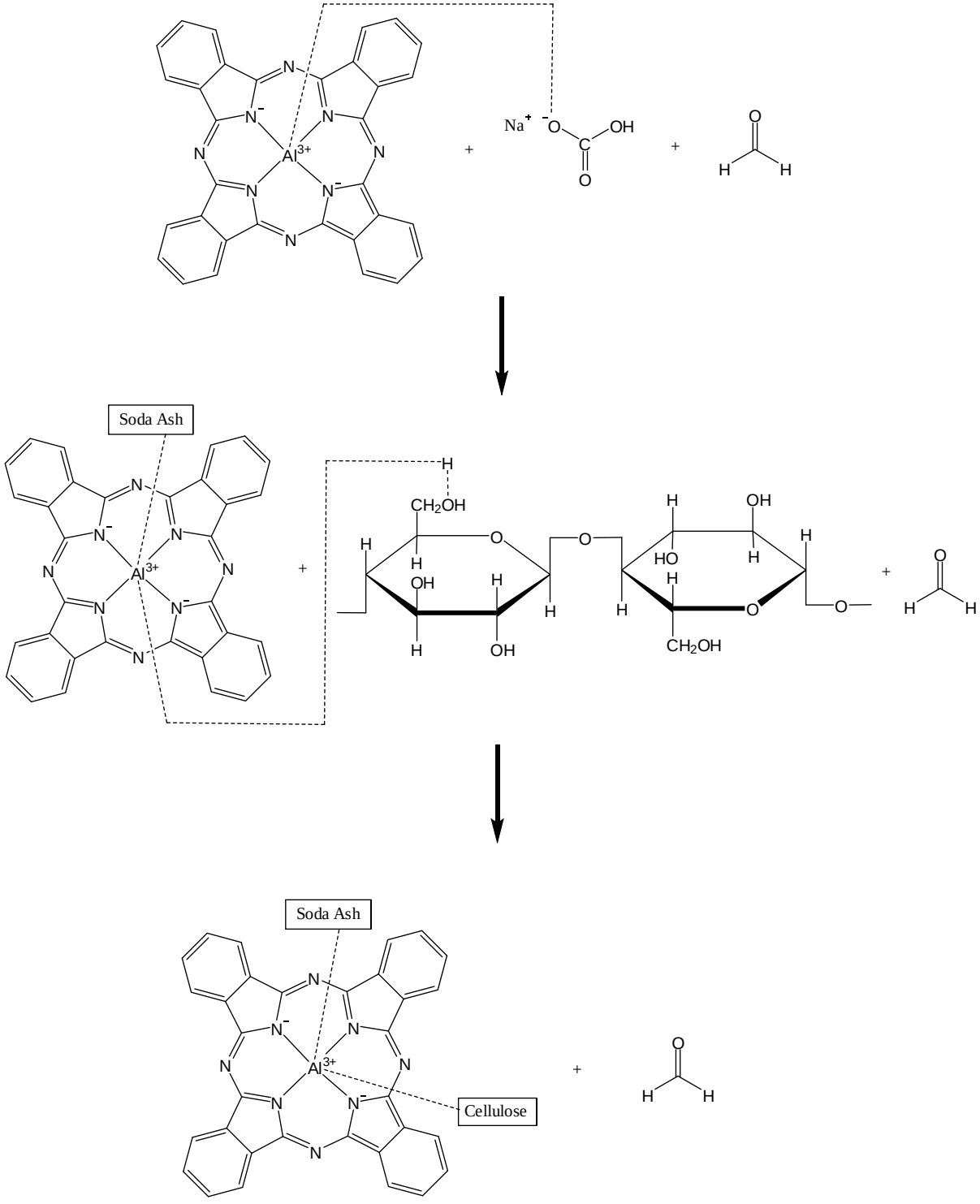

Figure 1: Interaction between alum, soda ash and celullose (hypothetic)

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Blacu Fabric Dyeing with Naphthol Dyes

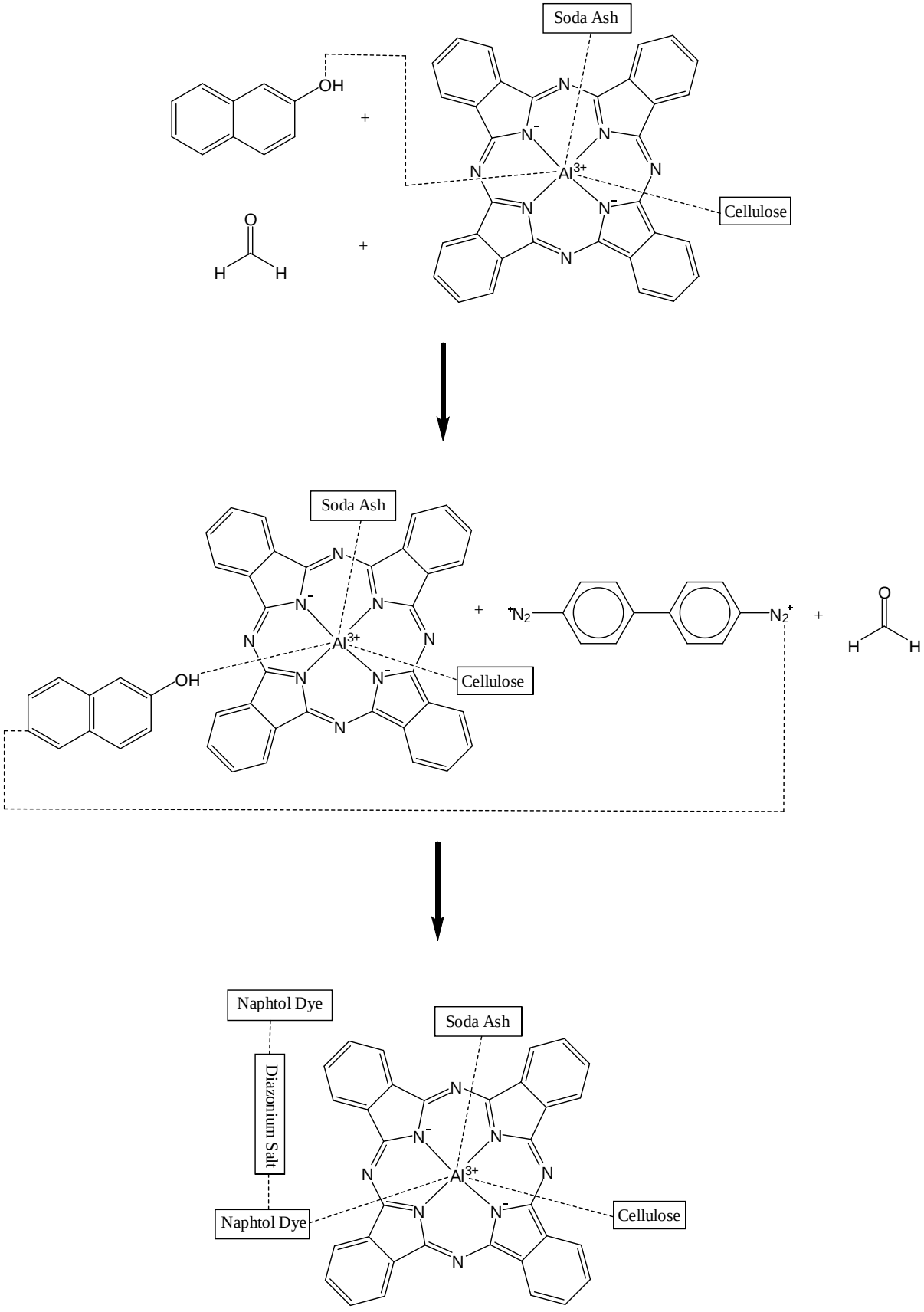

Figure 2: Interaction between mordant alum-soda ash-celullose with naphtol dye (hypothetic)

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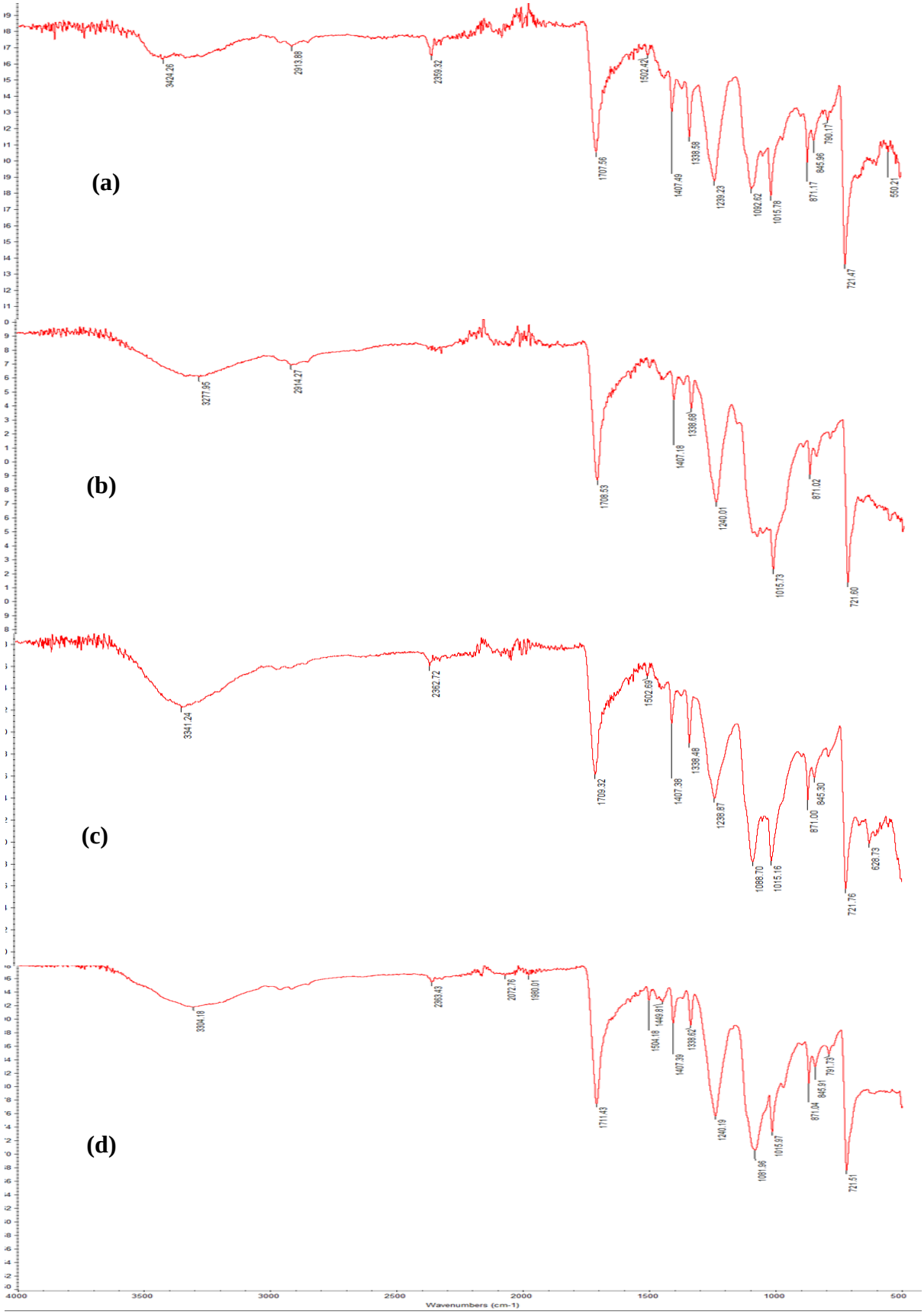

Figure 3: Infra red spectra of white cellulose fiber : (a) without mordanting; (b) with mordanting; and blue naphtol colored cellulose fiber : (c) without mordanting; and (d) with mordanting

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Physical and Chemical Characterization of Blacu Fabric

Characteristics and properties of the fibers is a key parameter in determining the treatment process, both in the equipment, process and procedures selection, and also types of chemical substances are used. During the treatment process, the basic properties of textile fibers will not be lost. Textile processing only intended to fix, enhance, augment and optimize the fiber nature so that becomes the high quality textile material according to the purpose of use. However, not all types of fibers can be processed into textile products. To can be processed into textile products, the fibers must have the following properties : (1) comparison of the length and width of; (2) sufficient force; (3) high flexibility; (4) resistance to stress and strain; (5) has proper orientation to have a cohesion between the fibers; (6) have an absorbance against water; (7) resistance to light and heat; (8) no damaged in leaching; and (9) are available in bulk. Therefore, on this research has been conducted mechanical strength test of white and colored cellulose fiber either with mordanting or not, using the autographs. In figure 4 seem the mechanical strength data of blacu fabric as a dyeing result using naphthol, with and without prior mordanting process using alum and soda ash.

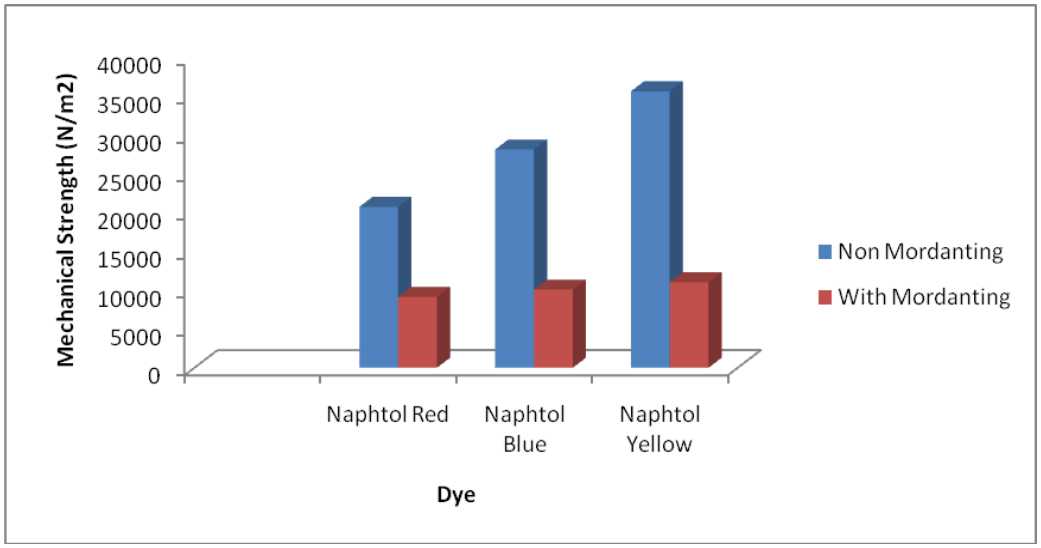

Figure 4: Mechanical strength data of colored blacu fabric, with and without mordanting process using alum and soda ash

Based on the mechanical strength data obtained, it is known that the mechanical strength resulting from the dyeing process with naphthol (without mordanting process) varied in the range 20740.37 N/m^2 – 35,645.93 N/m^2. The highest mechanical strength produced by yellow naphthol, while the lowest mechanical strength produced from dyeing using red naphthol. It can happen cause of the differences in the active group of the molecular structure of each kind of naphthol dye, which can increase the mechanical strength of the blank blacu fabric. In addition, based on the data in figure 5 can also be seen that the dyeing process of blacu fabric which was preceded by mordanting using alum and soda ash appears to have decrease the mechanical strength of blacu fabric 64.28% compared with the mechanical strength of colored blacu fabric which was not preceded by mordanting process.

Color intensity Measurement of Colored Blacu Fabric

Furthermore, because the compatibility level of dye used with the fiber is one of the parameters that will determine whether a given textile treatment through dyeing process using naphthol can improve the quality of fiber is concerned, in this study has been conducted the color intensity measurement of colored blacu fabric samples, before and after leaching process by DRUV instruments. From the results comparison between the color intensity of blacu fabric before and after leaching process using detergent-x, will be known how strong interaction which occurs between the dye used and blacu fabric. The lower differences in color intensity before and after leaching process, the higher quality of textile products produced. In Figure 5 seem the data of blacu fabric color intensity, before and after the leaching process, with and without mordanting process.

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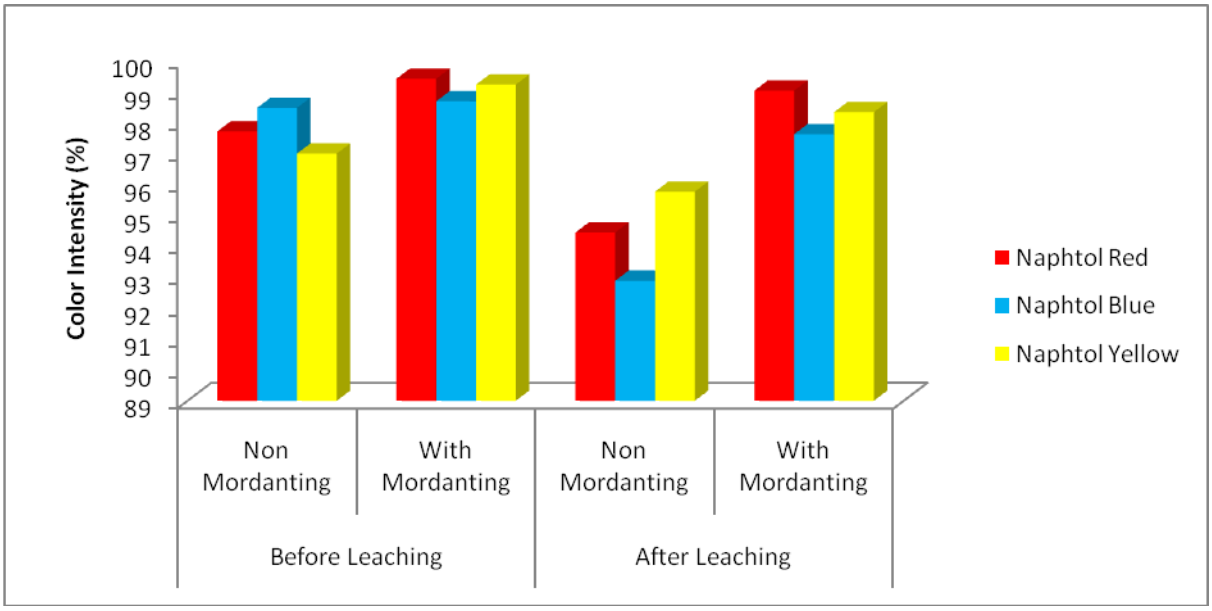

Figure 5: Color intensity of blacu fabric, before and after leaching process, with and without mordanting process

From the data in figure 5, it is known that the mordanting process that is done before dyeing process using naphthol, will increase the color intensity which is applied to the blacu fabric. Such as the color intensity produced from dyeing using red naphthol on the blacu fabric which is not through the mordanting process is equal to 97.71%, in the meantime, the color intensity produced by red naphthol on blacu fabric which through the mordanting stages is 99.41%. Moreover, it also appears that the mordanting process also has decrease fastness of blacu fabric. As in the color intensity which produced from dyeing using red naphthol on blacu fabric which through the mordanting process (before leaching process) is equal to 99.41%, in the meantime, the color intensity that results after the leaching process is 99,03%. Overall, the color intensity produced from blacu dyeing process using naphthol dye on the range 96.99% - 99.41% (before leaching) and in the range of 92,88% - 99,03% (after leaching).

CONCLUSION

Based on the research data obtained, it is noted that: (1) the mechanical strength resulting from the dyeing process with naphthol (without mordanting process) varied in the range 20740.37 N/m^2 – 35645.93 N/m^2. The highest mechanical strength produced by yellow naphthol, while the lowest mechanical strength produced from dyeing using red naphthol; and (2) the mordanting process that is done before dyeing process using naphthol, will increase the color intensity. Moreover, it also appears that the mordanting process also has decrease color fastness of blacu fabric. The color intensity produced from blacu dyeing process using naphthol dye on the range 96.99% - 99.41% (before leaching) and in the range of 92.88% - 99.03% (after leaching).

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