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Effect of Various Concentrations of Sodium Hydroxide/Hot Alkali Treatment on the Physical Properties of Ramie Fibres

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ABSTRACT

The preparation stages that precede the final treatment with a chemical treatment like alkali determine the physical characteristics of ramie fibres. It modified the hydroxyl group which is responsible for the hydrogen bonding of the fibres. This work examined the pre-treatment of ramie fibres with acetone followed by alkali or hot alkali with various concentrations. The immersion of ramie fibres in certain percentages of sodium hydroxide solution resulted in a good performance of their physical characteristics. The ramie fibres treated with 10% NaOH exhibit the best dispersion stability and low agglomeration or precipitation in water with an amount of 14%. When alkali is applied to ramie fibres, the hydrophilic group on their surface grows, potentially improving the fibre's capacity to absorb water. However, when the concentration is increased to 15%, the dispersion stability of sodium hydroxide performs less well. The fibres' ability to absorb water was diminished and they became brittle due to a high alkali content. In addition to the aforementioned characteristics, the properties of precipitation and water absorption were unaffected by the hot alkaline process for all samples. The hot alkali process (80°C) was not able to generate a further breakdown of hydrogen bonds of the fibres.

1. Introduction

Ramie (Boehmeria Nivea L. Gaud) is a plant that thrives in tropical areas, including Indonesia [1]. Part of the ramie plant can be taken and utilized entirely, where the fibre can be made into quality fabric material with physical properties almost the same as cotton fibre, the leaves are compost and highly nutritious animal feed [2]. In addition, ramie fibre is a material for making high-quality cellulose with a content of 75% of fibre, followed by water content (40.43%), ash (6.74%), hemicellulose (14.39%), lignin (9.98%) [3].

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Many researchers are interested in the study of ramie as a natural fibre material that is non-toxic, and environmentally friendly [4]. Some of the characteristics of ramie fibre, like its ability to absorb water, and its unstable mechanical properties, are drawbacks [5]. These properties also present a challenge and an opportunity for further research, intending to replace synthetic fibres, which are harmful to human health and difficult to recycle [6]. Improvement of the mechanical, thermal, and chemical properties of ramie fibre is carried out by several chemical methods by surface modification such as: soaking in sodium chloride solution, isocyanate, silane treatment, acetylation, mercerization, etherification, enzymatic treatment, peroxide treatment, benzoylation, plasma treatment, ozone treatment, and grafting [5,7,8].

As has been reported in another study [9], the hydroxyl group in cellulose is the main factor in the weak bond with the hydrophobic matrix. An increasing concentration of alkali treatment can lessen this feebleness. This alkali process is also able to reduce wax or fat, and even a hot alkali process can dissolve lignin which cannot be done by the hydrolysed process by acids [10]. Furthermore, a process known as fibrillation will take place, shattering the fibres into smaller pieces and giving them a coarser texture. This enhances surface adhesion and, in turn improves physical properties [11,12]. Another issue arose regarding the concentration of alkali solution: when it was too concentrated, it dissolved the cellulose that was supposed to be extracted from other fibre elements. Certain investigations concluded that a maximum of 18% NaOH maximized cellulose extraction, while concentrations above 20% decreased it [13].

Chemical treatment such as alkali improve also a sedimentation or agglomeration characteristic of the fibres. It is a key factor for fibre applications as an additive in water-based lubricants since could affect the properties of the suspension. One of the factors showing the stability of suspension is dispersion stability. When there is no precipitate or agglomeration, the suspension is stable. This can happen if the substances in the solution have different densities, particle sizes, or other physical properties [14]. If there is more than 30% sedimentation or agglomeration in the glass tube, the suspension is unstable [15].

Pre-treatment of ramie fibre was done by soaking it in acetone solution to remove dirt or residue from the mashing process. It also improves the chemical properties of the fibre surface. This affects the results of the next alkali treatment of fibre in modifying hydrogen bonds. In this work, samples were immersed in different percentages of sodium hydroxide NaOH solution and agitated with a magnetic stirrer at room temperature or hot temperature at 80°C. The outcome of the physical properties of the fibres such as water absorption and agglomeration in water further analysed. One of the sodium hydroxide concentrations yield the best results. A thorough set of experiments is being carried out to verify the author's hypothesis.

2. Methodology

2.1 Preparation and Pre-Treatment of Ramie Fibres

Ramie material in the form of fibre shown in Figure 1 was purchased from Gerai Surya (Lazada order ID 1136481247363937). The fibre was crushed using a glass hammer. The powder obtained appeared in Figure 2 was soaked in acetone solution (EMSURE 1.00014.2500 Supelco-MERCK) for 3 hours, depicted in Figure 3. After being cleaned and rinsed with distilled water to get a PH of about 7, it was left to dry for 48 hours. The powder was filtered in a 0.30 mm sieve (mesh 50) as shown in Figure 4 and weighed to obtain a sample weight of 1 gram each.

Fig. 1. Image of ramie fibres

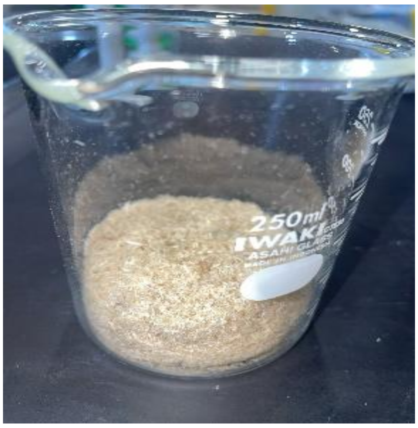

Fig. 2. Image of ramie powder

Fig. 3. Image of a ramie immersed in acetone

Fig. 4. Image of rinsed and filtered ramie

2.2 Alkali Treatment of Ramie Fibres

Samples were immersed in 100 millilitres of sodium hydroxide NaOH (MERCK) solution with solubility percentages: 5%, 10%, and 15%. A magnetic stirrer set at 300 rpm was used to agitate them for six hours, shown in Figure 5. The process runs at both room temperature or hot temperature at 80°C. There will be seven sample variations, as indicated in Table 1. All samples were cooled at room temperature for 24 hours. They were washed and rinsed with distilled water before being dried in an oven at 70°C for 3 hours.

Table 1
Alkali treatment of ramie fibres

Code of Sample	Concentration of NaOH (%)	Temperature (°C)
A1	5	Room
A2	5	80
B1	10	Room
B2	10	80
C1	15	Room
C2	15	80
ST	-	-

2.3 Sedimentation Measurement

Each sample with 1 wt% of ramie fibres added to 99 wt% distilled waters. They were placed into a centrifugal machine in a glass tube (Oregon Type LC-04S), illustrated in Figure 6. The process was carried out at 5000 rpm for 50 minutes. All samples were allowed to settle for 24 hours and photographed.

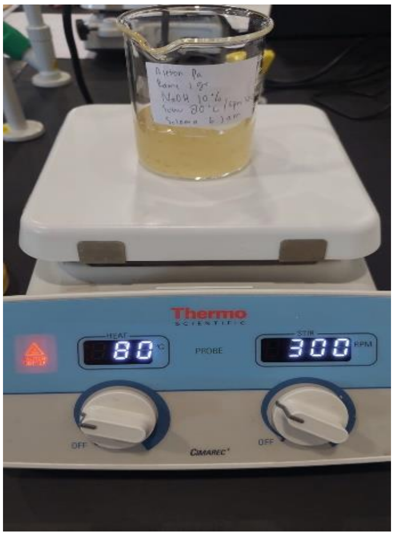

Fig. 5. Image of stirred sample

Fig. 6. Image of centrifuged sample

2.4 Water Absorption

Water absorption (WA) characteristics were done by soaking each 1 wt% of ramie fibres sample in 99 wt% distilled water for 24 hours. They were filtered and let too dry for four hours in the sun. The next step involved 48 hours of drying at room temperature. Weighing is done both before and after the process to determine how much water each sample has absorbed. It was calculated using Eq. (1).

$$\text{WA (\%)} = \frac{(\text{Weight of fibre after traitment})}{(\text{Weight of fibre before traitment})}\ x\ 100 \quad (1)$$

3. Results

The physique properties such as suspension's characteristics of the ramie fibres are influenced by the sodium hydroxide (NaOH) concentration [16]. One of the factors showing the stability of suspension is dispersion stability. When there is no precipitate or agglomeration, the suspension is stable. If there is more than 30% sedimentation or agglomeration in the glass tube, the suspension is unstable [15]. Figure 7 depicts the photo-captured stability investigation of the fibre in different NaOH concentrations. As can be observed, samples B1 and B2 have 14% volume of agglomeration or precipitation in the bottom of the glass tube as indicated in Table 2, compared to more than 30% for the other samples. The alkali process that was introduced caused the hydrogen bonds to break and the amorphous area to terminate [17]. The treatment may result in a decrease in non-cellulosic materials and an increase in the fibres surface area, which may raise the quantity of hydrophilic groups on the fibres surface [18]. The outcome showed that the alkali process's elimination of contaminants like lignin and hemicellulose considerably lowers the ramie fibres diameter and prevents defibrillation [19]. It is well known that ramie fibres have potent hydrophilic qualities [20]. The hydrophilic group on the surface of ramie fibres ameliorates when they were treated with increasing concentrations of alkali, which enhanced the fibre's ability to absorb water [18]. However, the performance of sodium hydroxide's dispersion stability was diminished when the concentration raised to 15%. The 15% NaOH loses its hydrophilicity, which lowers hydrogen bonding and increases the amount of ramie fibre aggregation in water. The results conform to the water absorption capacity as shown in Figure 8, and depicted in Table 2. A high alkali concentration can cause the fibres to became brittle, and less hydrogen bonds [21]. In addition to the aforementioned characteristics, the properties of precipitation and water absorption were unaffected by the hot alkali process for all samples.

Fig. 7. Image of the sample (suspension/dispersion stability)

The usage of biodegradable fibre materials made from ramie, which is highly abundant, is beginning to spread as an alternative to synthetic fibres, which are costly and challenging to recycle. Several studies on the use of natural fibres including coconut coir fibres in practical applications are used to insulate traditional fishermen's fish storage boxes [22]. In this work, the good dispersion stability in water properties of 10% NaOH can be a candidate as a water-based lubricant additive [14].

Table 2
Sedimentation and Water Absorption

Samples	Label	Sedimentation (% volume)	Water Absorption (% wt)
A1	1	32	120
A2	2	32	120
B1	3	14	120
B2	4	14	120
C1	5	32	100
C2	6	32	100
ST	7	32	60

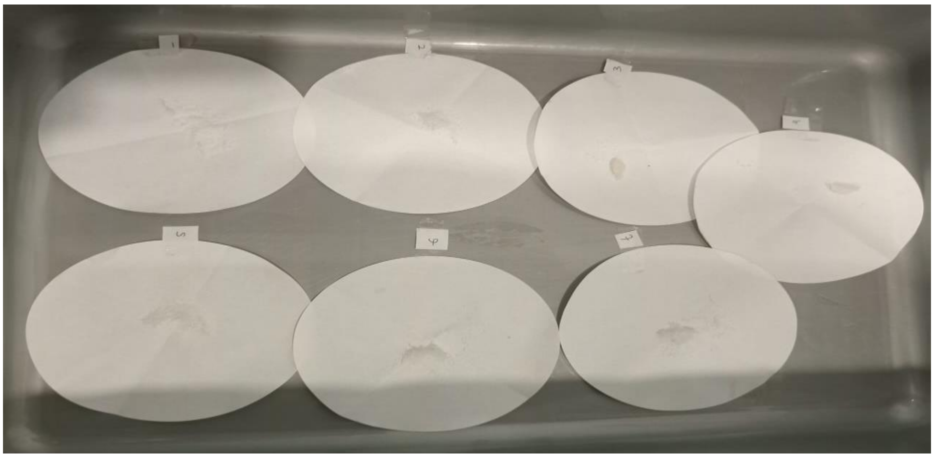

Fig. 8. Image of the sample (water absorption)

4. Conclusions

The concentration of alkali solution determines how well ramie fibres suspend in water. In this study, suspension stability is achieved using the alkali treatment with a concentration of 10% sodium hydroxide, with a quantity of agglomerated precipitate of around 14%. The treatment also modifies the fibre's characteristics to increase its water absorption. Even, fibres treated with 10% NaOH absorb water more than twice as high as untreated fibres. In all of the samples, the alkali process temperature did not affect the agglomeration and water absorption characteristics. Hot alkali (80°C) not able to generate more the breaks down of hydrogen bonds of the fibres.

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