



Identification of Microcrystalline Cellulose from Water Hyacinth (*Eichhornia crassipes*) in Limboto Lake

Astin Lukum^{1,*}, Kiran Zikriani¹, La Ode Aman², and Kostiawan Sukamto¹

¹ Department of Chemistry, Universitas Negeri Gorontalo, 96554 Bone Bolango, Indonesia

² Department of Pharmacy, Universitas Negeri Gorontalo, 96128 Kota Gorontalo, Indonesia

*Corresponding author. astin.lukum@ung.ac.id

Abstract. The aim of this research was to determine the microcrystalline cellulose content in water hyacinth collected from Limboto Lake, Gorontalo. The stems of water hyacinth underwent a powder extraction technique to obtain alpha-cellulose, which was subsequently subjected to hydrolysis using HCl at concentrations of 2 N, 2.5 N, 3 N, 3.5 N, and 4 N. The results of microcrystalline cellulose hydrolysis are subsequently identified through several methods, including the use of iodine-potassium iodide solution, organoleptic testing, pH analysis, and qualitative tests involving solubility and starch content. The research results indicated that the alpha-cellulose obtained from the powder extraction technique weighed 320 grams, with microcrystalline cellulose yields of 77.13%, 74.05%, 72.82%, 60.77%, and 60.44% for the respective concentrations of HCl. pH analysis of the hydrolysis products for each HCl concentration revealed pH values of 6.82, 6.72, 6.62, 5.24, and 5.18. Solubility tests were conducted to assess whether the samples contained strong hydrogen bonds, making them insoluble in various solvents. The results showed that microcrystalline cellulose was insoluble in four solvents: water, 95% alcohol, 2 N HCl, 1 N sodium hydroxide, and ether. Qualitative testing for starch or carbohydrate content using iodine demonstrated that microcrystalline cellulose did not contain starch.

Keywords: microcrystalline cellulose, water hyacinth, limboto lake

1 Introduction

Gorontalo Province, located on the northern coast of Sulawesi Island, Indonesia, boasts abundant natural resources, including the captivating Lake Limboto. This lake not only offers breath-taking natural beauty but also plays a crucial role in maintaining the regional ecosystem's balance and supporting the livelihoods of the surrounding communities. However, in recent years, Lake Limboto has faced a significant threat in the form of the rapid proliferation of water hyacinth (*Eichhornia crassipes*), an invasive aquatic plant. Water hyacinth (*Eichhornia crassipes*), belonging to the Pontederiaceae family, is a type of floating aquatic plant whose growth is extremely difficult to control, leading many to consider it a widespread aquatic weed in Indonesian water regions. Water hyacinth is categorized as an aquatic weed due to its rapid proliferation and its ability to adapt to changing environments, allowing it to thrive in both tropical and subtropical regions [1]. The ecological and social issues arising from the proliferation of water hyacinth in Lake Limboto are becoming increasingly urgent to address. Despite its natural

beauty, Lake Limboto also plays a significant ecological role in maintaining the balance of the regional ecosystem [2]. The lake serves as a habitat for various fish species, birds, and other aquatic organisms, contributing not only to biodiversity but also providing crucial resources for the surrounding communities in the form of fisheries and coastal agriculture. Unfortunately, the expansive growth of water hyacinth has posed a threat to the integrity of Lake Limboto's ecosystem. Its invasive nature and rapid proliferation have led to a decline in the lake's water quality and disruptions in its waters [3] [4] [5]. The high oxygen demand of water hyacinth can result in reduced oxygen levels in the water, endangering the lives of fish and other aquatic organisms. Additionally, this plant has the capability to absorb nutrients such as phosphorus and nitrogen from the water, which can lead to lake eutrophication [6] [7]. Eutrophication is a condition in which high nutrient concentrations cause excessive algae growth, ultimately harming freshwater ecosystems and jeopardizing the sustainability of lake fisheries [8]. The social issues associated with water hyacinth cannot be disregarded either. Local fishermen, who depend on the lake for their livelihoods, face serious challenges in accessing the waters and conducting fishing activities. Limited mobility and the additional costs incurred in clearing water hyacinth pose a significant burden on the local economy [9]. Hence, efforts to control and manage the expansion of water hyacinth in Lake Limboto have become imperative. Controlling water hyacinth in Lake Limboto is no easy task. Therefore, a deeper understanding of its key components, such as cellulose, can pave the way for the development of more effective control methods. Cellulose is a primary component in plant cell walls and is a valuable natural resource with various applications in industries like paper production, textiles, and biofuels [10] [11] [12]. Furthermore, the identification of microcrystalline cellulose within water hyacinth could also open up new opportunities in the development of sustainable products and technologies, such as bioplastics, bioenergy, and various value-added products [13], [14] Identifying microcrystalline cellulose in water hyacinth is an essential initial step in comprehending its physicochemical properties. A better understanding of the structure and characteristics of water hyacinth cellulose can aid in designing effective solutions to address the ecological and social issues arising from its excessive growth, especially in Lake Limboto, Gorontalo, Indonesia. Water hyacinth, with its strong fiber properties and composition comprising 8% hemicellulose, 17% lignin, and 60% cellulose, holds tremendous potential [15]. Hemicellulose, as a shorter glucose polymer than cellulose, adds flexibility to water hyacinth fibers, enabling their use in various applications such as paper production and bioenergy [16]. Lignin, providing additional strength to plant cell walls, influences the mechanical and chemical properties of these fibers, and in specific contexts, lignin can add value, especially in biofuel production [17]. Cellulose, being the primary component, with a content of 60%, makes water hyacinth a valuable natural resource. Cellulose finds use in diverse industries, including paper manufacturing, textiles, and other cellulose-based products [18]. Research on the identification of microcrystalline cellulose in water hyacinth from Lake Limboto is highly relevant for resource management. The information gathered from this research can serve as a foundation for more effective policies, inspire technological innovations, and provide valuable knowledge to the local community on how to sustainably utilize water hyacinth to address the ecolog-

ical and social issues associated with its growth in Lake Limboto, Gorontalo Province, Indonesia.

2 Method

2.1 Materials

The materials used in this research include water hyacinth stems sourced from Lake Limboto, Gorontalo, as well as chemicals such as nitric acid (HNO_3) 3.5%, hexane, ethanol, sodium sulfite (Na_2SO_3) 2%, sodium hydroxide (NaOH), hydrogen peroxide (H_2O_2) 2%, hydrochloric acid (HCl) 37%, and distilled water.

2.2 Sample Preparation

Water hyacinth stems were washed and cleaned of impurities, then cut into approximately 1 cm-sized pieces. Subsequently, they were dried under sunlight for approximately 6 days and finely powdered using a blender to obtain coarse powder. Afterward, the coarse powder was sieved through a 100-mesh screen, resulting in water hyacinth stem powder ready to be used as a raw material for microcrystalline cellulose production.

2.3 Cellulose Extraction

500 grams of water hyacinth stem flour were extracted using a heptane-ethanol mixture (1:2 v/v) in a reflux apparatus for 6 hours. After the extraction process was completed, it was allowed to cool to room temperature, and then filtration was performed. The residue obtained from the filtration process was washed with distilled water until it reached a neutral pH, and the solid waste was subsequently dried at room temperature. The water hyacinth stem flour was then mixed with 1 liter of 3.5% nitric acid containing 40 mg of sodium nitrite, and this mixture was placed in a 5-liter beaker glass. The solution was heated in a water bath at 90°C for 2 hours. After heating, the water hyacinth stem flour was washed with distilled water and filtered through filter paper. The residue obtained from the filtration process is combined with a 2% NaOH solution and heated to a temperature of 50°C for 1 hour. After being heated, the solid was washed and filtered. Next, a bleaching process was performed to remove lignin using a 500 mL H_2O_2 solution and it was heated for 10 minutes. The solution was washed and filtered again, and the residue from the filtration was dissolved in 300 mL of 17.5% NaOH solution and heated at 80°C for 30 minutes. The precipitate obtained was washed with water, dried in an oven at 60°C for 1 hour, resulting in -cellulose.

2.4 Microcrystalline Cellulose Extraction

50 grams of cellulose was placed in an Erlenmeyer flask and hydrolyzed using HCl solution (2 N, 2.5 N, 3 N, 3.5 N, and 4 N) by boiling it for 15 minutes. The microcrystalline cellulose produced from this process was then washed with distilled water until

it reached a neutral pH, filtered, and dried in an oven at 57-60°C for 1 hour. The obtained microcrystalline cellulose was subsequently ground and stored in a desiccator at room temperature. The yield of microcrystalline cellulose is obtained from the percentage ratio between the dry weight of microcrystalline cellulose resulting from hydrolysis and the weight of the alpha-cellulose used. The calculation of microcrystalline cellulose yield is based on the dry weight of the material.

$$\% \text{Yield} = \frac{\text{Weight of MC}}{\text{Weight of } \alpha \text{ - cellulose powder}} \quad (1)$$

2.5 Microcrystalline Cellulose Identification

A total of 0.01 grams of the sample was placed in a watch glass container and mixed with 2 mL of iodine-potassium iodide solution. Observations were made regarding any color changes that occurred. If the compound turned blue-violet, it indicated that the sample was Microcrystalline Cellulose (MCC). The organoleptic characteristics of MCC are assessed by placing the sample on a white surface and observing its shape, color, and odor. The pH value determination is carried out by dissolving microcrystalline cellulose in 100 mL of distilled water for 5 minutes. Subsequently, the pH is measured using a pH meter.

2.6 Qualitative Testing (Solubility and Starch)

Solubility testing was conducted using four different solvents: water, 95% alcohol, 2 N HCl, 1 N sodium hydroxide and ether. For the starch test, 10 mg of powder was added to 90 mL of distilled water and heated for 15 minutes. Subsequently, the solution was filtered while still hot. After cooling, 0.1 mL of 0.05 M iodine solution was added to the filtrate.

3 Result and Discussion

3.1 Cellulose Extraction

Powdered water hyacinth is extracted using a mixture of ethanol and n-hexane (2: 1 v / v) to remove extractive substances present in the stem powder of water hyacinth, such as fats, proteins, and others. This extraction process is intended to cleanse or purify the water hyacinth powder from unwanted components, resulting in a higher level of purity for the powder. Furthermore, the residue is acidified with nitric acid, with a small amount of sodium nitrite added because it is known to react very quickly with cellulose. The obtained residue is then subjected to delignification to remove the contained lignin using a sodium hydroxide solution with a pH range of 7-10. This process can dissolve beta cellulose and gamma cellulose while not affecting alpha cellulose. Furthermore, it can effectively dissolve up to 50% the lignin content. The bleaching process, aimed at removing pigments, uses peroxide to eliminate any remaining lignin in the pulp. The bleaching process results in cellulose becoming brighter or whiter in color

[19], [20]. During the alkali heating process using Sodium Hydroxide (NaOH) solution, cellulose pulp or slurry with a yellow-brownish color forms and settles within the NaOH solution. Alkalinization is carried out by immersing the fibers in an alkaline solution, namely sodium hydroxide solution. When subjected to alkali treatment, the fibers turn brown, and the previously white sodium hydroxide solution also changes to brown after the fibers are immersed. This color change indicates that impurities such as lignin and ash that adhere to the water hyacinth fibers dissolve in the NaOH solution [21]. NaOH particles enter the water hyacinth material and break down the lignin and hemicellulose structure, reducing lignin content and increasing cellulose content in water hyacinth [22]. During the alkalinization process, lignin in the fibers reacts with the NaOH alkaline solution. can seen in figure 1.

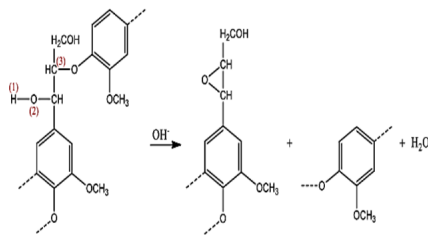


Fig. 1. Alkalinization process

During the alkalinization process, lignin reacts with the dissociated NaOH solution, which forms Na^+ and OH^- ions. The OH^- ions react with H groups in lignin, resulting in the formation of H_2O . This causes oxygen (O) groups to form free and reactive radicals that interact with carbon (C) to create epoxy rings (C-O-C), leading to a series of bond cleavages on the oxygen groups. This reaction produces two separate benzene rings, each with reactive oxygen groups. These reactive oxygen groups then react with Na^+ and dissolve in the alkaline solution, effectively removing lignin during the rinsing process. Therefore, to optimize the properties of cellulose, an alkali treatment is performed using NaOH solution, aiming to eliminate lignin and reduce the fiber's diameter [23]. The alkalinization process leads to the breaking of lignin bonds due to the diffusion of lignin into the alkaline solution, causing lignin to dissolve in the solvent. Additionally, heat is applied during this process at a temperature of 80°C , resulting in the fragmentation of lignin into smaller particles, which detach from cellulose and hemicellulose and subsequently dissolve in the alkaline solvent. Furthermore, hemicellulose undergoes degradation because its degree of polymerization is lower, and its polymer structure is non-linear and branched, making it less crystalline and more susceptible to chemical reactions in the solution. In contrast, cellulose is less susceptible to degradation compared to hemicellulose and lignin due to its crystalline structure, which provides resistance to both chemical and mechanical degradation [24].

3.2 Microcrystalline Cellulose Extraction

During the extraction of microcrystalline cellulose from alpha-cellulose using the hydrolysis method with varying HCl concentrations (2 N, 2.5 N, 3 N, 3.5 N, and 4 N), partial separation occurs in the components of cellulose microfibrils. In this process, the amorphous form of cellulose is broken down, leaving behind the crystalline structure, which is the region of cellulose molecules organized in an orderly manner. The purpose of this process is to cut the polymer into smaller (micro) sizes with a low degree of polymerization, where $n \approx 220$, resulting in microcrystalline cellulose.

There is a change in color before and after heating in the hydrolysis process, where the color of the solution in samples with the addition of HCl 3.5 N and 4 N slightly turns brown. This is due to glucose that dissolves at higher HCl concentrations. The higher the concentration of HCl used, the lower the yield of microcrystalline cellulose produced, while lower HCl concentrations result in higher microcrystalline cellulose yield. This occurs because higher HCl concentrations lead to a more perfect hydrolysis process, resulting in more glucose monomers dissolving during washing [25]. The results can be seen in figure 2.

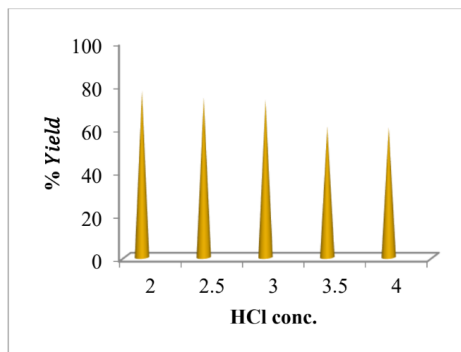


Fig. 2. Percentage Yield of Water Hyacinth MCC

Microcrystalline cellulose is partially purified cellulose derived from α -cellulose obtained as pulp from fibrous plants using mineral acids. This cellulose typically has a degree of polymerization usually less than 400, with no more than 10% of particles having sizes less than 5 μm^2 . Generally, microcrystalline cellulose ranges in length from 1 to 100 μm with a crystallinity percentage ranging from 55 to 85%. Commercially, microcrystalline cellulose can be obtained from wood and non-wood lignocellulosic materials, one of which is water hyacinth [26]. Partial hydrolysis of cellulose will result in microcrystalline cellulose, while complete hydrolysis of cellulose will yield glucose. The use of HCl in hydrolysis leads to the complete gelatinization of all starch and produces a hydrolysate that is easy to filter, along with the development of color due to non-specific catalysis [27]. Impure starch containing protein contaminants will also undergo hydrolysis when HCl is used, which is the cause of the brown color appearing in the product. The observations conducted indicate that all microcrystalline cellulose

samples have the same shape, color, and are odorless when treated with HCl 2 N, 2.5 N, and 3 N. This suggests that the addition of chemical compounds such as acid solutions does not alter the physical appearance of the resulting microcrystalline cellulose product. However, in the case of microcrystalline cellulose treated with HCl 3.5 N and 4 N, there is a change in color, becoming slightly brownish. This change is possibly due to the excessively high acid concentration, which results in the complete hydrolysis of cellulose into glucose and its hardening into caramel. Therefore, further research is necessary to confirm this possibility.

3.3 Microcrystalline Cellulose Identification

A solution of zinc chloride iodine is used in the identification of microcrystalline cellulose due to its distinctive properties when interacting with cellulose. This reaction is known as the cellulose color test. When microcrystalline cellulose powder is placed in a solution of zinc chloride iodine, complex formation and a color change occur. Cellulose is a polymer consisting of long chains of glucose sugar molecules connected by β -1,4-glycosidic bonds. Each glucose unit has hydroxyl groups (-OH) involved in complex formation with iodine ions. Iodine ions (I_3^-) are present in the zinc chloride iodine solution. These ions have the ability to form hydrogen bonds with the hydroxyl groups (-OH) on cellulose. When a sample containing MCC is mixed with a zinc chloride iodine solution, there is an interaction between the hydroxyl groups on cellulose and the iodine ions in the solution. This interaction results in the formation of a complex known as the Cellulose-Iodine Complex [28]. The formation of the Cellulose-Iodine Complex is often accompanied by a color change in the sample. Samples that were initially colorless or had a different color will turn blue or violet. This color change occurs due to the formation of bonds between the hydroxyl groups on cellulose and iodine ions, creating a complex with a different wavelength and optical properties. The blue or violet color change in cellulose from water hyacinth is an indicator that the sample contains microcrystalline cellulose.

Table 1. Results of Identification of MCC

Concentration	Color formed
2.0 N	Blue
2.5 N	Blue
3.0 N	Light Blue
3.5 N	Light Blue
4.0 N	Light Blue

The Cellulose-Iodine Complex has unique characteristics, and the blue or violet color change is used as a distinctive feature in the identification of microcrystalline cellulose in various laboratory and industrial applications. Microcrystalline Cellulose is a material used in various industries, especially in the pharmaceutical, food, and cosmetic industries. One of the key characteristics of microcrystalline cellulose is that it is in the form of a white powder and is odorless [29]. Both of these properties are crucial

in many applications and have various implications. Based on observations, microcrystalline cellulose from water hyacinth is in the form of a white powder and is odorless. Microcrystalline Cellulose must have a very high level of purity for pharmaceutical and food applications. Its natural white color serves as a good indicator of purity. This means that during the production process of microcrystalline cellulose, contaminants and foreign substances are completely removed. This quality is essential in the manufacturing of safe and effective pharmaceutical products. Microcrystalline Cellulose is often used as a filler or binder in pharmaceutical tablets and dietary supplements, making its clean, white appearance highly appreciated. The white color of microcrystalline cellulose makes it compatible with various product formulations. This allows Microcrystalline Cellulose to be used in various products without affecting their final appearance or color. The absence of odor in microcrystalline cellulose makes it a comfortable material to use in products that will be consumed or applied to the skin. Unwanted odors can disrupt the consumer experience. The lack of odor is an additional indication of the purity of microcrystalline cellulose. Unknown or chemical odors can be a sign of contamination or undesirable reactions in the material. Being odorless, microcrystalline cellulose is considered safer to use. Odorless microcrystalline cellulose provides flexibility in products where specific aromas or flavors need to be introduced without mixing with the smell of other ingredients. This gives manufacturers the freedom to create desired flavor and aroma profiles [30]. Microcrystalline Cellulose generally has a relatively neutral pH, typically around 5-7. pH measurements indicate that microcrystalline cellulose derived from water hyacinth hydrolysis at various HCl concentrations falls within the pH range of 5 – 7.5, meeting the required criteria. This means that microcrystalline cellulose is neither too acidic (with a pH below 5) nor too alkaline (with a pH above 7.5). In most industrial applications, particularly in the pharmaceutical, food, and cosmetic sectors, MCC with a near-neutral pH is essential. A pH value lower than

Table 2. pH of Microcrystalline Cellulose

Concentration	pH
2.0 N	6.87
2.5 N	6.72
3.0 N	6.62
3.5 N	5.24
4.0 N	5.18

5 or higher than 7.5 can lead to overreactions, potentially reducing the quality of the resulting microcrystalline cellulose [31]. Overreactions refer to chemical reactions that occur rapidly or more forcefully than desired when two or more chemicals interact. In the context of microcrystalline cellulose, this implies that when microcrystalline cellulose with a pH outside the neutral range is used in formulations with active substances or other materials, there is a high likelihood of overreactions taking place. These overreactions can result in issues such as degradation of active substances, changes in the physical or chemical properties of the product, or a decrease in formulation effectiveness. The use of microcrystalline cellulose with a pH value outside the neutral range

in formulations with active substances can lead to a decrease in the quality of both the microcrystalline cellulose itself and the final products containing it. Microcrystalline cellulose that undergoes overreactions or undesired reactions can lose some of its desired properties, such as binding strength, solubility, or physical stability [32] This can reduce the quality of microcrystalline cellulose used in various applications, including pharmaceuticals, food products, or cosmetics.

3.4 Qualitative Testing (Solubility and Starch)

The solubility test results on the sample of microcrystalline cellulose powder indicate that microcrystalline cellulose is insoluble in five solvents tested, namely distilled water, ether, HCl (hydrochloric acid), NaOH (sodium hydroxide), and alcohol. The strong

Table 3. Microcrystalline Cellulose Solubility Test

Solvents	Observation Result
Distilled Water	Insoluble
Ether	Insoluble
HCl	Insoluble
NaOH	Insoluble
Alcohol	Insoluble

hydrogen bonds between the hydroxyl groups in the adjacent chains of the crystalline structure of microcrystalline cellulose are the primary factor that makes it difficult to dissolve in various solvents [33]. The hydroxyl groups from one glucose unit strongly interact with the hydroxyl groups on other glucose units. These hydrogen bonds lock the glucose chains into a dense crystalline structure. When attempting to dissolve microcrystalline cellulose in solvents, these strong hydrogen bonds hinder the separation and mixing of cellulose molecules with the solvent. The hydroxyl groups on cellulose prefer to interact with other hydroxyl groups rather than dissolve in the solvent. As a result, microcrystalline cellulose remains in its solid form, making it challenging to disperse in solvents like distilled water, ether, HCl, NaOH, and alcohol. Distilled water, which is typically considered a universal solvent for many substances, fails to dissolve microcrystalline cellulose. The strong hydrogen bonds between the hydroxyl groups in cellulose make it less prone to interact with water molecules. As a result, microcrystalline cellulose tends to be insoluble in water due to the stronger hydrogen bonds between cellulose molecules compared to the hydrogen bonds between cellulose and water. This lack of solubility indicates that the substance does not readily interact or mix with water, thereby demonstrating hydrophobic properties. Additionally, when exposed to ether, another common organic solvent, microcrystalline cellulose remained insoluble. This result implies that the cellulose structure exhibits resistance to dissolution in non-polar solvents. Furthermore, tests using HCl and NaOH, which are strong acids and bases, respectively, demonstrated that microcrystalline cellulose did not undergo significant chemical reactions leading to dissolution. Despite the strength of HCl and NaOH as acids and bases, microcrystalline cellulose remains insoluble due

to the hydrogen bonds that firmly hold the cellulose structure together. While HCl and NaOH can interact with cellulose, their strength is insufficient to disrupt the internal hydrogen bonds within cellulose, which would otherwise break down its structure. This suggests that microcrystalline cellulose maintains its structural integrity even when exposed to extreme pH conditions. Finally, alcohol, which is often used as a solvent for various compounds, is also incapable of dissolving microcrystalline cellulose. This is due to the strong hydrogen bonds between the hydroxyl groups on cellulose, reducing its affinity for alcohol, making microcrystalline cellulose less soluble in alcohol as well. These findings can have significant implications in the application of microcrystalline cellulose in various industries. For example, in pharmaceuticals, microcrystalline cellulose can be used as a filler or binder in tablets that need to maintain their integrity in slow-release acidic solvents. Furthermore, the insolubility of microcrystalline cellulose in alcohol can make it a suitable choice for product formulations that should not dissolve in alcohol, such as certain skincare or cosmetic products. The starch test aims to determine whether the sample of microcrystalline cellulose still contains starch or carbohydrates. When a sample containing starch or carbohydrates is reacted with iodine, it will result in a color change to blue. The research results indicated that microcrystalline cellulose from water hyacinth does not contain starch. Microcrystalline

Table 4. Microcrystalline Cellulose Starch Test

Sample	Observation Result
Water Hyacinth MCC	No blue color appears

cellulose must be free from starch or carbohydrates due to critical considerations of quality and purity in various industrial applications. The presence of starch or carbohydrates in microcrystalline cellulose can disrupt the quality of the end product and render it unsuitable for use in the pharmaceutical, food, and cosmetic industries. Firstly, in the pharmaceutical industry, products such as tablets and capsules must meet high purity standards. The presence of starch or carbohydrates in microcrystalline cellulose can create uncertainty in product formulations [34]. This can result in inconsistencies in drug dosages delivered to patients, which can negatively impact the safety and effectiveness of medications. Additionally, starch or carbohydrates can affect the solubility, release rate, and physical stability of pharmaceutical products. Therefore, microcrystalline cellulose used in pharmaceuticals must be completely free from starch or carbohydrate contamination to ensure the quality and safety of the drugs produced. Secondly, in the food and cosmetic industries, the appearance, texture, and other organoleptic properties of the end products are crucial. The presence of starch or carbohydrates in microcrystalline cellulose can alter the appearance and texture of products, which can affect the consumer experience [35]. For example, undesirable changes in color or texture can disrupt the visual appeal or taste of the product. Therefore, microcrystalline cellulose used in food and cosmetic applications must be free from starch or carbohydrates to ensure that the end products meet the aesthetic and organoleptic standards desired by

consumers. Thus, microcrystalline cellulose that is free from starch or carbohydrates is key to maintaining the quality and consistency of products in these various industries.

4 Conclusion

Alpha-cellulose extracted from water hyacinth stems underwent hydrolysis with various concentrations of HCl. The results of microcrystalline cellulose varied according to the concentration of HCl used, with a decrease in yield occurring at higher concentrations. Analysis of pH revealed a decreasing trend in pH values with increasing HCl concentration. Furthermore, solubility tests indicated that microcrystalline cellulose was insoluble in various solvents such as distilled water, ether, HCl, NaOH, and alcohol, indicating the presence of strong hydrogen bonds in its structure. Finally, qualitative testing confirmed the absence of starch or carbohydrates in the microcrystalline cellulose sample. This research provides valuable insights into the characteristics and properties of microcrystalline cellulose obtained from water hyacinth, which can impact its applications across various industries.

References

1. D. Kurniadie, N. Rezkia, D. Widayat, A. Widiawan, L. Duy, D. Prabowo, *Water* **15**, **10** (2023)
2. T. Rahim, H. Hasim, J. Juliana, J. Pascasarj **5**, **1** (2020)
3. A. Gezie, W. Assefa, B. Getnet, W. Anteneh, E. Dejen, S. Mereta, *Biol. Invasions* **20**, **9** (2018)
4. H. Getnet, D. Kifle, T. Fetahi, A. Putra, A. Samad, *Int. J. Fish. Aquat. Stud* **9**, **5** (2021)
5. R. Basaula, H. Sharma, K. Sapkota, *P.A. J* (2022)
6. K. Belete, E. Getu, A. Mekonnen, S. Ethiop, *J. Sci* **45**, **3** (2022)
7. E. Junior, Y. Tang, S. Berg, L. Lamers, S. Kosten. *Biogeosciences discuss* (2016)
8. Z. Svircev, S. Krstic, S. Markovic, J. Plavska, L. Lazic, *Pannonica* **12** (2008)
9. C. Magadza, *Res. Manag* **11**, **4** (2006)
10. M. Bilal, *Bioeng. Biotechnol* **10** (2022)
11. A. Masek, A. Kosmalska, *Bioeng. Biotechnol* **10** (2022)
12. J. Wood, C. Gast, D. Rivett, J. Verran, J. Redfern, *Front. Bioeng. Biotechnol* **10** (2022)
13. M. Murti, M. Sudarsono, H. Suryadi, *Pharmacogn. J* **10**, **6** (2018)
14. R. Yetti, R. Junita, C. Author, *Int. J. Res. Rev* **7**, **7** (2020)
15. S. Chonsakorn, S. Srivorradatpaisan, R. Mongkholrattanasit, *J. Nat. Fibers* **16**, **7** (2019)
16. S. Laoubol, P. Ngermchuklin, M. Leekrajang, *J. Met. Mater. Miner* **32**, **3** (2022)
17. M. Wang, *Acta Polym. Sin* **51**, **6** (2020)
18. J. Singh, *Sci. Pollut. Res. Int* **30**, **8** (2023)
19. S. Susi, M. Ainuri, W. Wagiman, M. Affan, F. Falah, *Eng. Chem* **4** (2023)
20. S. Hidayati, R. Sugiharto, S. Hadi, *Rev. Chim* **70**, **9** (2020)
21. H. Abrial, H. Putra, S. Sapuan, M. Ishak, *Polym. Plast. Technol. Eng* **52**, **5** (2013)
22. T. Nguyen, *ACS Omega* **6**, 40 (2021)
23. R. Pratama, R. Pratama, M. Farid, H. Nurdiansah, J. Tek, *ITS* **6**, **2** (2017)
24. A. Zulfikar, N.S.N.K. Putri, G.N. Tajalla, *SPECTA J. Technol* **4**, **2** (2020)
25. Y. Zhang, Y. Xu, X. Yue, L. Dai, Y. Ni, *J. Wood Chem. Technol* **39**, **4** (2019)
26. R. Neves, H. Ornaghi, A. Zattera, S. Amico, *Polym* **230** (2020)
27. W. Den, V. Sharma, M. Lee, G. Nadadur, R. Varma, *Front. Chem* **6** (2018)

28. K. Tashiro, M. Gakhutishvili, *Polymer (Guildf)* **171** (2019)
29. S. Gharaibeh, W. Obeidat, N. Zoubi, *E-Polymers* **22**, **1** (2022)
30. J. Wang, *Cellulose* **29**, 13 (2022)
31. V. Imramova, N. Koroleva, A. Lorentsson, Y. Chernoberezhskii, *Russ. J. Appl. Chem* **90**, **4** (2017)
32. S. Kim, *Biotechnol. J* **16**, **12** (2021)
33. A. Watanabe, S. Morita, Y. Ozaki, *Appl. Spectrosc* **60**, **6** (2006)
34. A. Shenvi, K. K. E. Subrahmanyam, A. Shabaraya, *Int. J. Drug Regul. Aff* **9**, **4** (2021)
35. S. Mejia, A. Francisco, B. Bohrer, *Meat Sci* **153** (2019)

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