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Cellulose Extraction from Oil Palm Empty Fruit Bunch: A Comparative Study on Efficiency of Different Bleaching Reagents

Nur Azimah Nor Azlan[a], Mohd Akmali Mokhter[a,b], Nurrulhidayah Salamun[a]*
[a]Department of Chemistry, Universiti Teknologi Malaysia, 81310, Johor Bahru, Johor, Malaysia.
[b]Advanced Membrane Technology Research Centre (AMTEC) [HICoE]
Faculty of Chemical and Energy Engineering
Universiti Teknologi Malaysia
81310 UTM Johor Bahru, MALAYSIA.

*Corresponding author: nurrulhidayah@utm.my

Abstract
Oil palm empty fruit bunch (OPEFB) is the highest byproduct in palm oil production. This byproduct is very beneficial in agriculture and biological field. Extracting cellulose from OPEFB and then subjecting it to various chemical pre-treatments in order to extract its cellulose content using various bleaching reagents is the basis of this research. Hydrogen peroxide was found to be the most effective of the three bleaching reagents, extracting more cellulose than either sodium chlorite or sulphuric acid. The findings of the experiments indicated that the cellulose content of OPEFB ranges between 70-72%. ATR-IR spectrum for all cellulose showed the presence of O-H stretching and C-H stretching at 3300 cm^{-1} and 2900 cm^{-1}. The degree of crystallinity and rigidity of cellulose are verified by the XRD pattern, while its tensile characteristics and thermogravimetric analysis (TGA) contribute to an understanding of cellulose's adaptability, tensile stability and thermal stability. Extraction of cellulose by using peroxide is more preferable since it is more environmentally friendly compared to chlorine that is more toxic.
Keywords: *OPEFB; Cellulose extraction, Chemical Pre-treatments; Bleaching Reagents; Hydrogen peroxide*

1. Introduction

Malaysia is the second in the world in terms of palm oil production and exports after Indonesia with over 19.8 million tonnes produced in 2015 (Akita, H. et al., 2021). The climate and the temperature in Malaysia is suitable for growing the oil palm trees. Besides, agriculture is one of the most popular fields in Malaysia. Oil palm empty fruit bunch (OPEFB) is the highest byproduct in palm oil production.

OPEFB consists of chemical blocks of cellulose, hemicellulose and lignocellulose. Hence, it can be used to produce many products such as bio-products and chemical products due to its compositions. Cellulose is a very beneficial component in OPEFB. There are many benefits of cellulose that can be gained and applied in a variety of industries. Cellulose extraction is very common in the research field since it is a renewable resource due to its good biodegradability and biocompatibility.

Bleaching reagent is important in cellulose extraction though the chemical pre-treatments process of the cellulose. The main purpose of bleaching the cellulose is to enhance the quality to produce the fine product which is the cellulose that has been extracted from OPEFB. The bleaching reagent will decolourize the lignin. Different bleaching reagents with different conditions can yield different amounts of cellulose from the OPEFB. Basically, there are two types of bleaching reagents which are oxidative and reductive bleaching reagents.

For some applications, cellulose is used as adsorbent and separation membranes. Therefore, this research provides a possible method for enhancing the cellulose production efficiency by using three different bleaching reagents during the pre-treatments process of cellulose extraction of OPEFB. However, the bleaching reagents that can extract the highest percentage of cellulose and high quality

of the cellulose should be observed in this research in order to improve the synthesis of cellulose from OPEFB and be more environmentally friendly. In addition, this study can recommend a better way to reduce the waste that has been generated by palm oil industries. Both oxidative and reductive bleaching reagents can be used in the bleaching process. The study of different bleaching reagents that are used for synthesizing the cellulose from OPEFB during the pre-treatment process will yield different percentage of cellulose extraction. The bleaching reagents that are used in this research are sodium chlorite ($NaClO_2$), hydrogen peroxide (H_2O_2) and sulphuric acid (H_2SO_4) solution.

The main purpose of this research is to determine which bleaching reagents are most effective at removing cellulose from OPEFB and to compare those reagents' performance in terms of the percentage of cellulose removed. After several pre-treatments of fibre extraction, the chemical composition of components such as cellulose, hemicellulose and lignin is examined. The extracted cellulose is examined in detail to determine its crystal pattern and the effect of various bleaching reagents on its thermal stability.

2. Literature Review

2.1. Oil Palm Empty Fruit Bunch

The byproduct that was generated by the oil palm can be used in beneficial ways. Oil palm empty fruit bunch (OPEFB) is a byproduct of palm oil production. It is a form of mill waste that also is particularly productive as it supplies nutrients and raises soil organic matter content. Due to its abundance, OPEFB used to be burnt up and thrown away. Hence, this may cause environmental pollution and contribute to give a huge impact to the environment. The combustion of OPEFB will release greenhouse gases.

OPEFB is a natural raw material that has a variety of applications. It can be utilised to increase the absorption of phosphorus in the soil and production of maize grown on Ultisol. By using a set of cleaning, carbonization, and chemical activation reactions, OPEFB is used to make a material that makes carbon work. By replacing chemicals with raw natural materials, this agricultural waste does help a number of industries and keep our environment clean. The percentage of carbohydrates composed in OPEFB is 0.5%, 31.0% and 17.3% respectively (Sudiyani, Y. et al., 2013).

2.2. Cellulose

Since cellulose is a natural biopolymer that is easy to get, it could be used instead of synthetic fiber. Cellulose is a natural linear homopolymer made up of D-anhydroglucose units that are linked at the C1 and C4 carbon atoms by 1,4,b-glycosidic bonds. Carbon, hydrogen, and oxygen are the three parts of its molecules. It is a main composition in the plant cell walls. Polysaccharides and phenolic polymers are present in all lignocellulosic plants. Cellulose and hemicellulose are known as polysaccharides. However, lignin is known as a phenolic polymer. Cellulose also helps the plants keep their structure strong and stiff. The basic strength of a cell wall comes from the molecules of cellulose. Cellulose is found in a variety of natural fibers, including cotton, flax, hemp, jute, and sisal, among others (Morán, J. I. et al., 2008).

2.2.1 Classes of Cellulose Nanomaterials

There are two main types of cellulose nanomaterials (CNs) that can come from plants, animals, or minerals which are cellulose nanocrystals (CNCs) and cellulose nanofibrils. The development of cellulose nanomaterials has helped biomedical applications, sensors, the treatment of waste water, the paper, board, and packaging industries, and other fields (CNMs). These materials have a lot of good qualities, such as a larger surface area, higher mechanical strength and stiffness because of the hydroxyl groups in them and the ability to be recycled. Cellulose nanomaterials, particularly cellulose nanocrystals and cellulose nanofibers, have been developed through a variety of preparation processes that have resulted in materials with distinct structures and physicochemical properties that are being exploited (Mokhena, T. C. et al., 2020).

2.2.1.1 Cellulose Nanocrystals

Cellulose nanocrystals are novel nanomaterials generated from cellulose and it is nature's most plentiful and nearly renewable polymer. Thus, as it has great mechanical, optical, chemical, and rheological characteristics. These nanomaterials have generated considerable interest. They are a sustainable and eco-friendly material that is suitable for many uses. Although these nanocrystals are predominantly hydrophilic in nature, they can be surface designed and synthesized to address a variety of demanding requirements, including the manufacture of commercial nanocomposites with hydrophobic natural polymers. In addition, microcrystalline cellulose was used through colloid milling process to mechanically create rod-like cellulose nanocrystals (CNCs), which were subsequently employed to strengthen rayon filament yarn by viscose mixing and wet spinning (Yao, A. N. et al., 2020).

2.2.1.2 Cellulose Nanofibrils

Cellulose nanofibers (CNF) are very fine cellulose fibers derived from wood. Nanocellulose fibers are extremely thin, measuring only a few nanometers in diameter. They are known to have a particular viscosity, lightweight, robust and durable, and to exhibit very little form change as a result of temperature swings. CNF is a biomass material that is formed from wood-derived fiber (pulp) that has been micro-refined to many hundredths of a micron and smaller. It is the world's most advanced biomass material. CNF is a cellulose fiber that has been fibrillated. Mechanical shearing is used to split the cellulose fibers into a three-dimensional structure of microfibrils with a high surface area. CNFs are often produced through biological or chemical pretreatment, mechanical disintegration, or recombination. CNF is a novel environmentally friendly material that will find widespread application in a variety of fields, including polymer reinforcement, energy production and storage, environmental protection and enhancement, and healthcare. CNF were synthesised using high-pressure homogenization of kraft pulp in the presence of variable molecular weight carboxymethyl cellulose (CMC) (Kim, Y. et al., 2021).

2.2.2 Cellulose Extraction

Basically, there are two methods for extracting the cellulose which are chemical and mechanical methods. Therefore, cellulose can also be extracted through alkalization, acid hyrolysis and bleaching reactions in order to obtain it in nano and micro form. Traditionally, cellulose is obtained from wood using the Kraft pulping process, which includes treating the lignin/hemicellulose matrix with sodium hydroxide and sodium sulphide solutions at high temperatures and pressures to cause semi-chemical breakdown. The sodium chlorite solvent extraction method is commonly used to remove lignin from lignocellulosic material (Poon, J. J. et al., 2020). In order to complete the extraction, this procedure takes 9 hours to extract the cellulose completely. However, after several pretreatment and extraction processes, including acid hydrolysis, micro grinding, cryocrushing, electron spinning, and centrifugal spinning, the cellulose sources yield nano cellulosic derivatives (Vincent, S., & Kandasubramanian, B., 2021).

2.3 Chemical Pretreatments

Chemicals such as acids, alkalis, salts, oxidants and solvents are used in some of the most promising pretreatment procedures. the separation of hemicellulose and lignin, as well as the extraction efficiency of cellulose, differed significantly amongst all pretreatments and the composition and texturality of lignin substructures were used to elucidate the mechanism of pretreatment impact (Cai, Y. H. et al., 2020). Chemical pretreatment is important to remove all the impurities in the desired compound.

2.4 Bleaching Reagents

The term "bleach" refers to a solid or liquid chemical that is used to whiten or remove the natural colour of fibers, yarns, other textiles, and paper from their original colours. After bleaching the raw plant fibers, the cellulose may be removed. Bleaching may be done with a variety of chemicals and at a variety of temperature and pH conditions, resulting in a range of cellulose content (Rizwan, M. et al., 2021). Bleaching can be divided into two categories: oxidative bleaching and reductive bleaching, both of which can be accomplished using oxidising and reductive bleaching reagents, respectively. Bleaching substances damage the chromophores in the objects, altering their colour absorption properties, and causing them to fade.

2.4.1 Oxidative Bleaching

Sulfuric acid, sodium hypochlorite, and other oxidative bleaching reagents are commonly used in bleaching operations. Natural fibers like cotton, fibers, bamboo, and wool, regenerated fibers like bamboo, are all commonly bleached using oxidative methods. Bleach works by releasing oxygen molecules, which is accomplished through a process known as oxidation. It is the conjugated double bonds of the substrate that allow the substrate to absorb visible light and make it a light-absorbing material. As a result, it appears yellower and requires bleaching. When the bleaching procedure is carried out with oxygen, it eliminates the chromophoric sites from the sample, resulting in their being whiter. For instance, the use of a hydrogen peroxide brightening step instead of a chlorine dioxide brightening stage at the end of a bleach sequence resulted in better pulp brightness and less brightness reversion (Camargo, S. et al., 2019).

2.4.2 Reductive Bleaching

A reducing reagent is a substance that reacts with a coloured substance in a reductive manner, turning it colourless and/or soluble. Reduction is a half-reaction where a compounds loses electrons and thereby reduces its oxidation number. Reductive bleaching technology can be used to bleach a variety of fibers including polyamides, polyacrylics, and polyacetates. Thus, compared to oxidative bleaches, reducing bleaches are less damaging to fibers. Reductively bleached substances, on the other hand, can oxidise in the air and revert to their colour before got bleached.

3. Methodology

3.1 Synthesis of Cellulose derived from OPEFB

The OPEFB samples is obtained from an Oil Palm Plantation and will be stored at room temperature. The samples will be crushed using a grinder. Secondly, it is washed 3 times by distilled water. Then, the samples was dried in the oven for 24 hours at 80°C. Next, it is soaked in the mixture of toluene and ethanol for 6 hours. The volume of toluene and ethanol must be in ratio 2 to 1. Then, it is dried in the oven for 24 hours at 80°C. It is digested with 1.0 M NaOH at 80°C for 4 hours. Lastly, it is washed with distilled water until it reached pH 7 and dried it overnight.

3.2 Cellulose Extraction by using H_2SO_4 as Bleaching Reagent

The cellulose is extracted by using acid hydrolysis method. H_2SO_4 solution is used in this method. H_2SO_4 solution (64% (w/w), 1:10 g/ml (cellulose: dilute H_2SO_4) is used to hydrolyse the cellulose for 60 minutes at 45°C with vigorous and continual mechanical stirring. The acidic solution is removed by centrifugation at 10000–12000 rpm for 15 minutes after the hydrolysis reaction and is quenched with excess (10-fold) cold distilled water. Then, the sediment is then collected, reconstituted in distilled water, and dialyzed against distilled water until neutrality is achieved. The pH must be within 6 and 7. Next, to avoid warming, the sample will be centrifuged again after dialysis and then sonicated for 10 minutes in an ice bath. Lastly, the resulting aqueous suspension is kept refrigerated at 4°C.

3.3 Cellulose Extraction by using $NaClO_2$ as Bleaching Reagent

The sample is mixed in a mixture of 10% acetic acid and 1.3% $NaClO_2$. The volume of acetic acid and $NaClO_2$ must be in ratio 1 to 1. The, the sample is washed with 0.1 M NaOH followed by distilled water until pH 6. It is dried in the oven for 24 hours and weighed the final product.

3.4 Cellulose Extraction by using H_2O_2 as Bleaching Reagent

The sample is mixed in a mixture of 20% acetic acid and 10% H_2O_2. The volume of acetic acid and H_2O_2 must be in ratio 1 to 1. Secondly, it will be placed in a water bath for 2 hours at 85°C. Next, the OPEFB fibers that has removed its lignin will be filtered and washed thoroughly with 10% acetic acid followed by distilled water. Then, the recovered cellulose fibres will be light yellow in colour and are re-suspended for 90 minutes at 60°C in 10% H_2O_2 at pH 11. 10% NaOH will be used to alter the pH. Lastly, the resultant white suspension will be filtered and washed many times, and the cellulose insoluble fraction will be obtained, and the weight of product will be determined.

3.5 Cellulose Content

The three primary components of each plant are cellulose, lignin, and hemicellulose. After each pre-treatment of fibres, all of these parts can be separated and extracted. The following equation can be used to calculate the percentage of extracted lignin, hemicellulose and cellulose:

$$\%Lignin = \frac{Weight\ of\ obtained\ lignin}{Weight\ of\ the\ original\ OPEFB} \times 100\%\ \#(1)$$

$$\%Hemicellulose = \frac{Weight\ of\ hollocelulose}{Weight\ of\ the\ original\ OPEFB} \times 100\%\ \#(2)$$

$$\%Cellulose = \frac{Weight\ of\ cellulose}{Weight\ of\ the\ original\ OPEFB} \times 100\%\ \#(3)$$

3.6 Attenuated Total Reflection Infrared (ATR-IR) Spectrometry

The existence of functional groups, components, and bonding type were all determined using ATR-IR analysis. Perkin Elmer (Diamond UTAR) was used to analyse the samples at 2 cm^{-1} resolutions from 4000 to 400 cm^{-1}.

3.7 X-ray Diffraction (XRD) Analysis

The XRD patterns of the bleached fibers will be determined by a Bruker AXS D8 Automatic Powder Diffractometer. XRD patterns will show the crystallinity phase of the bleached fibers. The intensity of diffraction peaks will show the presence of cellulose. The following equation can be used to determine X_C, the crystallinity index.

$$CrI\ (\%) = \frac{Icr - Iam}{Icr} \times 100\%\#(4)$$

In this case, I_{cr} represents the maximum intensity of the crystalline plane, and I_{am} represents the maximum intensity of the amorphous plane.

3.8 Thermogravimetric Analysis (TGA)

TGA (Pyris 1, Perkin Elmer) will be used to determine the thermal stability of raw OPEFB and extracted cellulose. 10 milligrammes of dried OPEFB will be kept under TGA monitoring at a constant temperature of 30-700°C in a nitrogen atmosphere. Before running the samples, a continuous nitrogen flow of 30 $cm^3\ min^{-1}$ will be maintained, proceeded by a furnace rate of flow of 150 $cm^3\ min^{-1}$.

4. Results and discussion

4.1. Composition of the fibers

The percentages of lignin, hemicelluloses, and cellulose in untreated OPEFB varied significantly from those in chemically treated fibers after each treatment. As we go with each chemical treatment, the impurities and unwanted compounds are being extracted in each step, so elimination of by-products gives high cellulose content in return. After each treatment, the colour of the fibers varies, fading from dark brown to pale yellow or white at the end of the bleaching process. Table 1 shows the percentages of each part after different treatments.

Table 1. Comparison of extracted cellulose in three different bleaching reagents

Sample Composition	C-SC (%)	C-HP (%)	C-SA (%)
Cellulose	72.1	72.2	70.7
Hemicellulose	17.5	24.0	16.4
Lignin	10.4	4.8	12.9

Table 2 allows for comparisons to be made between the percentages of cellulose, hemicelluloses, and lignin found in other plants [5]. The findings of the study indicate that OPEFB has a cellulose content that is comparable to Alstonia scholaris, but lower than cotton plant. OPEFB has a cellulose content higher than bamboo plant.

Table 2. Analysis of the lignocellulose content of OPEFB and its comparison to other lingocellulosic species (Rizwan, M. et al., 2021)

Plant's name	Cellulose (%)	Hemicellulose (%)	Lignin (%)
OPEFB	71-72	16-24	5-13
Alstonia scholaris	68-70	10-12	8-9
Cotton	85-90	1-2	1-3
Bamboo	26-43	21-31	15-26

4.2 Cellulose Extraction of Different Bleaching Reagents

Different bleaching reagents affected the extracted cellulose percentage. Based on the result shown in table 1 showed that C-HP (using hydrogen peroxide, H_2O_2) had the highest cellulose content, sample C-SC (using sodium chlorite, $NaClO_2$) had the intermediate cellulose content and sample C-SA (using sulphuric acid, H_2SO_4) had the intermediate cellulose content for both reagents.

4.3 Attenuated Total Reflection Infrared (ATR-IR) Spectrometry

After various chemical treatments on the OPEFB, well-defined peaks were identified, as illustrated in Figure 1.

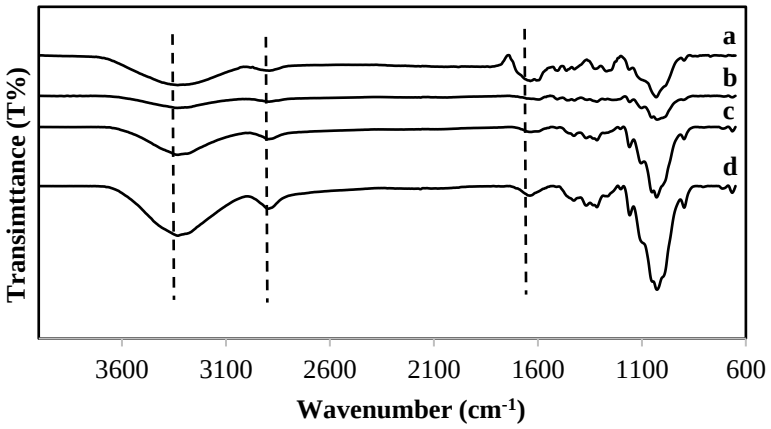

Figure 1. ATR-IR spectra of (a) C-raw, (b) C-SA, (c) C-HP and (d) C-SC

The two main peaks between 2800 and 3400 cm1 strongly show that the cellulosic group is present. The ATR-IR spectrum for all cellulose showed the presence of O-H stretching and C-H stretching at 3300 cm^{-1} and 2900 cm^{-1}, respectively. The first peak at 3300 cm^{-1} is caused by the stretching of the O–H group, and the second peak at 2900 cm^{-1} is caused by the stretching of the C–H group in the cellulosic group. The carbonyl (C=O) stretching vibrations found at 1630 cm^{-1} are another sign that the fibres contain cellulosic material. Table 3 shows the cellulose content of plant fibres treated with different bleaching reagents and how well they absorb water.

Table 3. Infrared Stretching Frequencies

Functional Group	Absorption (cm^{-1})	Compound Class
O-H stretching	3333 - 3323	Alcohol
C-H stretching	2893-2881	Alkane
C=C stretching	1653-1605	Alkene

4.4 X-ray Diffraction (XRD) Analysis

For XRD analysis, the cystallinity index of the cellulose derived from OPEFB were analysed. The XRD patterns of all raw and bleached cellulose exhibit primarily the structure of cellulose, which consists of two different crystal phases. C-HP has been expected to have high crystallinity index compared to C-

SC and C-SA. This is because the cellulose that is bleached through acidic condition is possible to alter the crystalline structure of the cellulose. The distinctive reflection of the crystalline structures of cellulose of OPEFB samples isolated from empty fruit bunches that was treated by three different chemical treatments. Figure 2 displayed the XRD patterns of the cellulose.

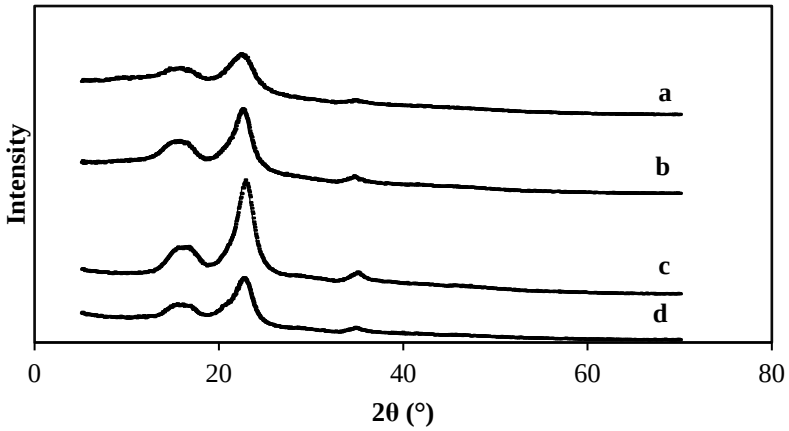

Figure 2. XRD patterns of (a) C-raw, (b) C-SA, (c) C-HP and (d) C-SC

The primary peak corresponds to cellulose's crystalline structure, whereas the amorphous background is distinguished by a shoulder peak with low diffracted intensity. C-raw, C-SA, C-HP, and C-SC had crystallinity indices of 7.5%, 16.5%, 21.1%, and 36.9%, respectively (Table 4).

When the crystallinity peaks of raw OPEFB and C-HP are compared, it can be seen that the diffraction peak has been magnified after the bleaching process. This indicates that the crystallinity of the cellulose has increased after bleached. The cellulose molecules are organised in an orderly lattice at increased crystallinity, and the majority of the OH groups are hydrogen linked. When the cellulose was treated in acidic medium, the breakdown of hydrogen bond will occur. The lignin and hemicellulose was removed but the crystallinity of the cellulose will be reduced in acidic medium compared to alkaline medium.

Among these three bleaching reagents, H_2O_2 has the weakest acidic properties compared to H_2SO_4 and $NaClO_2$. Hence, C-HP has high crystallinity index compared to C-SC and C-SA. However, the result obtained from this research was not the same as expected. This is might due to the low concentration of H_2O_2. Table 4 illustrated the crystallinity index of OPEFB at different bleaching reagents.

Table 4. Crystallinity index of OPEFB at different bleaching reagents

Components	C-Raw	C-SA	C-HP	C-SC
Crystallinity Index, CrI (%)	7.4865	16.440	21.102	36.907

4.5 Thermogravimetric Analysis (TGA)

The thermogravimetric analysis (TGA) curves that were acquired reveal the particular temperatures at which degradation can occur, as shown in Figure 3. Under conditions of inert nitrogen environment, thermogravimetric analysis was utilised in order to assess the cellulose thermal stability. There are three stages that fibres go through as they degrade when subjected to thermal treatment.

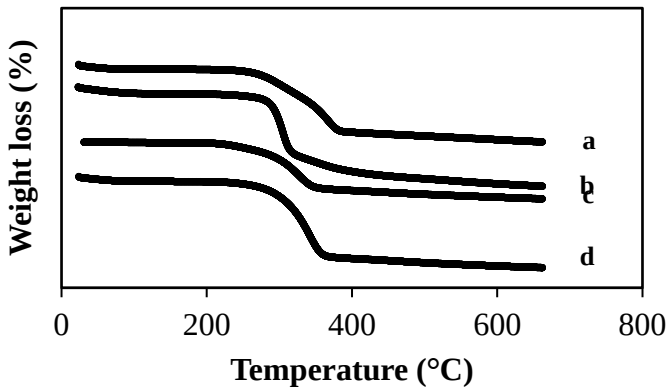

Figure 3. TG curves of (a) C-raw, (b) C-SA, (c) C-HP and (d) C-SC

For C-raw, in the first phase, the surface moisture is evaporated and the sample's total weight lost is 3% at the temperature range 27 to 73°C. The next thermal stage, at 224 to 389°C, the percentage of weight loss is 55% due to the hemicellulose degradation. The last thermal stage occurs at temperature range 392 to 642°C due to cellulose (glycosidic linkage) breakdown.

Next, in the first phase, the surface moisture of the C-HP is evaporated, and at temperatures ranging from 31 to 76°C, 0.02% of the sample's total weight is lost. In the subsequent intermediate thermal stage (190–360°C), hemicellulose degradation is responsible for the majority of weight loss which is 41%, whereas cellulose (glycosidic linkage) breakdown is responsible for weight loss in the final thermal stage (340–370°C).

Then, for C-SC, in the first phase, the surface moisture is evaporated at temperature range 31 to 104°C resulting 3.3% weight loss of the sample. At intermediate thermal stage, 66% weight loss due to hemicellulose degradation and the last thermal stage occurs at the temperature range 377 to 638°C where the breakdown of glycosidic linkage occurs.

Besides, for C-SA, the moisture evaporation occurs at the temperature range 26 to 79°C and the total weight loss is 4.2% At intermediate thermal where the hemicellulose degradation occurs at 267 to 328°C where 53% of total weight loss. The last thermal stage where the glycosidic linkage in cellulose breakdown occurs at the temperature range 328 to 632°C. All bleached samples treated with distinct bleaching reagents exhibit significantly distinct thermal degradation behaviours. Table 5 shows the thermal behaviour of the cellulose that has treated with different bleaching reagents.

Table 5. Thermal behaviour of the cellulose that has treated with different bleaching reagents

Samples	Temperature (°C)						Total
	1st stage	%W loss	2nd stage	%W loss	3rd stage	%W loss	%W loss
C-raw	27-73	3	224-389	55	392-642	8	66
C-HP	31-76	0.02	190-360	41	360-640	9	50
C-SC	31-104	3	326-368	66	377-638	9	78
C-SA	26-99	4	267-328	53	328-632	25	82

Conclusion

In this research, the extraction of cellulose derived from OPEFB by using different bleaching reagents were successfully synthesised and characterised. Chemical methods were used to successfully extract cellulose from OPEFB. OPEFB that were used in this study were treated using various chemical processes, such as bleaching process, alkaline treatment and acid hydrolysis to extract the cellulose. The effects of chemical treatments on the surface and components of OPEFB were observed and determined by the determination of the chemical composition.

The cellulose yield differently by treating OPEFB with three different bleaching reagents which are hydrogen peroxide (H_2O_2), sodium chlorite ($NaClO_2$) and sulphuric acid (H_2SO_4). H_2O_2 method has the highest efficiency to extract the largest amount of cellulose (72.2%) compared to the other methods. According to the findings of the experiments, the percentages of cellulose present in raw OPEFB and OPEFB that have been treated with H_2O_2, $NaClO_2$ and H_2SO_4 are 72.2%, 72.1% and 70.7% percent,

respectively. The effectiveness of chemical treatment in detecting and removing hemicellulose and lignin to get the cellulose, which can be employed in a wide variety of applications, was determined by comparing the chemical composition of the samples before and after treatment.

The characterization of cellulose is important in this research to ensure the cellulose was extracted completely without any impurities to further its application in variety of field. In this research, the cellulose was characterized by using ATR-IR, XRD and TGA. After undergoing chemical treatments, the fibers' ATR-IR spectra provided conclusive evidence that the non-cellulosic components had been eliminated. The finding demonstrated presence of O-H and C-H stretching peaks. According to the findings of XRD, the crystallinity of cellulose was different for each type of bleaching reagents used. In TGA, it shows that the treatments with chemicals improved the thermal stability of OPEFB. From this research, cellulose that has been treated with H_2O_2 has a good thermal stability compared to the cellulose that has been bleached by $NaClO_2$ and H_2SO_4.

Briefly, all the objectives specified for this investigation were attained. The results showed that the chosen method can be used to get cellulose out of empty fruit bunches successfully. Therefore, it is reasonable to infer that H_2O_2 make excellent performance on extracting the cellulose from OPEFB. Hence, this research able to develop an eco-friendly method for extracting cellulose from OPEFB to increase yield.

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