Development of biodegradable hybrid composite using water hyacinth and potato extract: a sustainable and green alternative to commercial plastics

Anirban Mallick[1] | Md Abdul Alim[1,2*] | Kaniz Fatima Mishfa[1,2] | Farhana Hossain[1] | Md. Reazuddin Repon[3,4]

[1]Department of Textile Engineering, Khulna University of Engineering & Technology, Khulna -9203, Bangladesh

[2]Department of Materials Science and Engineering, Clemson University, Clemson, South Carolina 29634, USA

[3]Department of Textile Engineering, Daffodil International University, Dhaka-1207, Bangladesh

[4]Department of Production Engineering, Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentų 56, Lt-51424, Kaunas, Lithuania

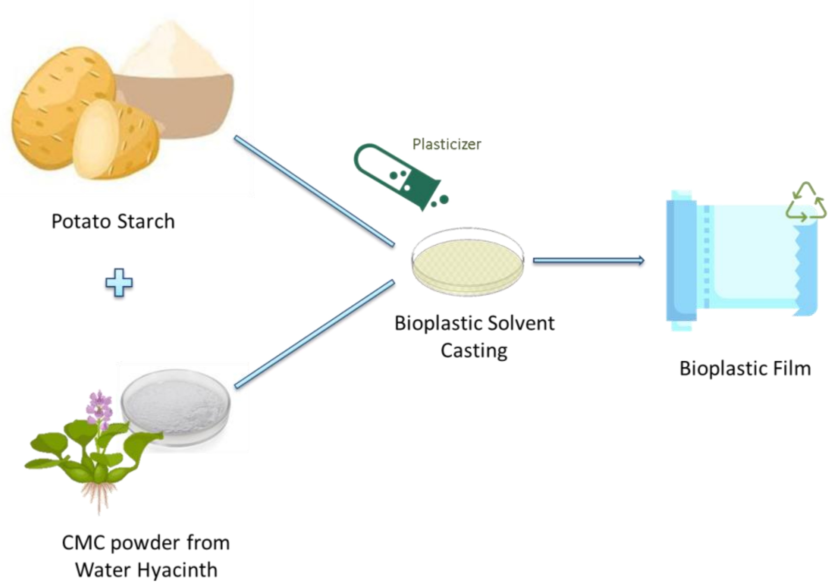
* Corresponding author:

Md. Abdul Alim
Assistant Professor, Department of Textile Engineering,
Khulna University of Engineering & Technology, Khulna -9203, Bangladesh
Email: abdulalim@te.kuet.ac.bd

ABSTRACT

Plastic still remains a vital component of modern manufacturing because of its versatility and inexpensiveness. Nonetheless, there is a growing worldwide concern about the impact of non-biodegradable plastics on the environment. Thus, this study proposes the development of bioplastics derived from water hyacinth (*Eichhornia crassipes*) and potato starch, which offers a sustainable alternative to conventional plastics. There is a growing need because of the environmental challenges created by synthetic plastics. Water hyacinth (WH) is an invasive aquatic plant that grows naturally in different warm parts of the world. Its high cellulose content provides low-cost material for biodegradable plastic production. This thesis focuses on separating cellulose from WH, transforming it into carboxymethylcellulose (CMC), and the formation of bioplastic with potato starch. The produced bioplastic is evaluated through a series of tests that include Fourier Transform Infrared Spectroscopy (FTIR) analysis, Scanning Electron Microscope (SEM), Thermogravimetry/Differential Thermal Analysis (TG/DTA) analysis, mechanical tests, and biodegradability assessments. Adding starch as a reinforcing agent has increased tensile strength from 2.38 to 3.7 MPa. 5% increase of plasticizer has increased 67% ultimate strain. TG/DTA data showed a two-step degradation process with 50% weight loss at 244^0C. The surface found is mostly smooth. The renewable materials used to produce the sample also degraded within 25 days. Following the findings of the tests, the synthesized bioplastic displayed promising physical and thermal properties and better environmental compact ability.

GRAPHICAL ABSTRACT



KEYWORDS:

Bio-waste, composite, natural source, polymer, plastic

HIGHLIGHTS

- Developed bioplastic from water hyacinth cellulose and potato starch.
- Cellulose isolation, synthesized CMC, blended with starch for bioplastic.
- Ultimate strength raised by 67% by adding plasticizer and starch.
- Biodegraded in 25 days, showed good thermal properties.

1 | INTRODUCTION

The explosive rise of plastic manufacturing took place in the 20th century. A wide range of applications have been made possible by the low cost and adaptability of plastics. Since plastics cannot biodegrade so, it is very hazardous to humans, animals, and the environment [1]. Even though polymers of plastic are regarded as biochemically inactive, they can have adverse impacts on both humans and the environment. Plastics can be toxic because of their additives, breakdown products, monomers, etc. It is estimated that by 2050, 1200 million tons of plastic waste will be in landfill [2]. It has emerged as a global environmental challenge, necessitating the development of sustainable alternatives to conventional plastics. It can provide conventional plastic needs and is also easily disposable without affecting the environment. Biobased polymers may be produced using a variety of techniques and ingredients. Bioplastic is typically made using lipids, proteins, and polysaccharides. Different bioplastics can be employed in various areas due to their unique features and properties. Today, different types of biomaterials, like potatoes, vegetable oils, wood, food waste, cereal crops, corn, and others, are used for bioplastic production. Starch-based bioplastics are the most popular nowadays, followed by polylactic acid (PLA) and poly-3-hydroxybutyrate [3]. In this context, the invasive aquatic plant known as water hyacinth presents an intriguing opportunity as a feedstock for synthesizing biodegradable plastics. Water hyacinth is becoming an environmental issue in several water bodies in Bangladesh. Here, it is considered an abundant aquatic plant. The water hyacinth grows quickly, covers the surface of water, and prevents oxygen from dissolving and moving through it. However, water hyacinth has a substantial percentage of cellulose content (around 50%), which makes it an appropriate raw material for making CMC, a vital step in producing bioplastics [4]. Because this cellulose content is water insoluble, carboxymethylation is needed to make it water soluble CMC. However, a significant amount of lignin and hemicellulose prevents it from carboxymethylation reaction. So, alkalization and delignification chemical treatment is also needed. Starch is also a feasible product for sustainable material development because it originated from a plant source and is biodegradable. A plasticizer is used to enhance its lifespan and strain. By mixing these materials, this thesis aims to investigate the synthesis and characterization of biodegradable plastics, focusing on their potential as a sustainable solution for waste management and environmental preservation. Numerous relevant research papers have described the synthesis of biodegradable plastic from alternatives rather than conventional crude oil, natural gas, or coal. Biodegradable plastic can be made from agar, gelatin, starch, etc. biomaterial. Various types of methods are also available. Malin Brodin et al. utilized lignocellulosic materials as sustainable resources to make bioplastics. It has a major potential to replace fossil-based resources [5]. Y Yusmaniar et al. prepared bioplastic from seaweed and blended it with polysaccharides obtained from several types of avocadoes, jackfruit, and durian seed. Their bioplastic films demonstrated promising qualities for bioplastics in the packaging sector [6]. S Anantachaisilp et al. have used water hyacinth as a raw material for making carboxymethylcellulose (CMC), which can be used for bioplastic production, which eventually can replace the non-degradable plastic and reduce the environmental impact. They compared their resulting bioplastic CMC film with Commercial CMC-PEG-based (PEG-Polyethylene glycol) film and found similar properties. Their fabricated film can eventually replace non-biodegradable plastic in the sector of food packaging applications [4]. Jeesica Hermayanti Pratama et al. extracted cellulose powder from Water Hyacinth cellulose to form bioplastic, using it as a reinforcing agent and mixing it with starch. They also added chitosan to increase the mechanical properties of that plastic. They showed that bioplastic derived from starch-cellulose is stronger than bioplastic made from only starch or cellulose [7]. All of these studies will give us more idea about the synthesis of biodegradable plastic from water hyacinth.

This study combines water hyacinth cellulose and potato starch to create bioplastic. While both materials have been used individually for bioplastic production, their combination and detailed study are less common. CMC is synthesized from water hyacinth cellulose, which is not a popular form to make bioplastic. Also, these materials’ specific combinations, optimization of plasticizers, and their ratios offer a unique approach to bioplastic synthesis. The detailed characterization by different tests, including FTIR, SEM, TG/DTA, and mechanical testing, offers a comprehensive evaluation compared to other studies. The evaluation of environmental impacts also adds to the field of sustainability and real-world application.

2 | MATERIALS AND METHODS

2.1 | Materials

The water hyacinth was collected from the Moyur River in Khulna, Bangladesh. Potato starch was extracted manually from potatoes. Sodium hydroxide, sodium hypochlorite, acetic acid, monochloroacetic acid, glycerol, ethanol, and methanol were locally purchased from Dhaka, Bangladesh. All the reagents were of analytical grade and used without further purification.

2.2 | Fabrication Process

At first, water hyacinth was washed with tap water thoroughly to remove dirt and dried for 7 days in the sun to remove moisture content. Then, they were blended and sieved using a blender to produce a fine powder. Starch was manually extracted from the potato.

2.3 | Isolation of Cellulose

To eliminate hemicellulose, 15g dried water hyacinth powder was mixed with 450 ml of 15% (w/v) NaOH with a material-to-liquor ratio of 1:30 and stirred continuously at 50°C. The product was then filtered, cleaned with distilled water to obtain a neutral condition, and allowed to be at room temperature for approximately 48 hours. To eliminate lignin, 15g of the powder was combined with 450 ml of 4% (w/v) $NaClO_2$ with a ratio of 1:30 (M: L), and the mixture was constantly agitated at 80°C for 2.5 hours. After that process, the solution was filtered and washed using water thoroughly. It was dried for two days at room temperature. The obtained material is raw cellulose.

2.4 | CMC preparation

Carboxymethylation was performed using out by a standard slurry technique. After combining 15g of the produced cellulose with 20 milliliters of 65% (w/v) NaOH and 300 milliliters of 95% (v/v) ethanol, the mixture was agitated for 40 minutes at room temperature before 10 grams of monochloroacetic acid were added. After that, the mixture was stirred for three hours at 50°C. Following that, acetic acid was used to neutralize the product. After that, it was washed repeatedly with 70% (v/v) methanol and 70% (v/v) ethanol, respectively, to remove unwanted by-products. The resulting powder, known as as-synthesized CMC, dried naturally for 48 hours.

2.5 | Bioplastic formation

Three bioplastic samples were made with a 5%, 10%, and 15% matrix mixture of CMC and potato starch. The weight ratio of the two materials was 1:0, 3:1, and 3:2 for three samples.

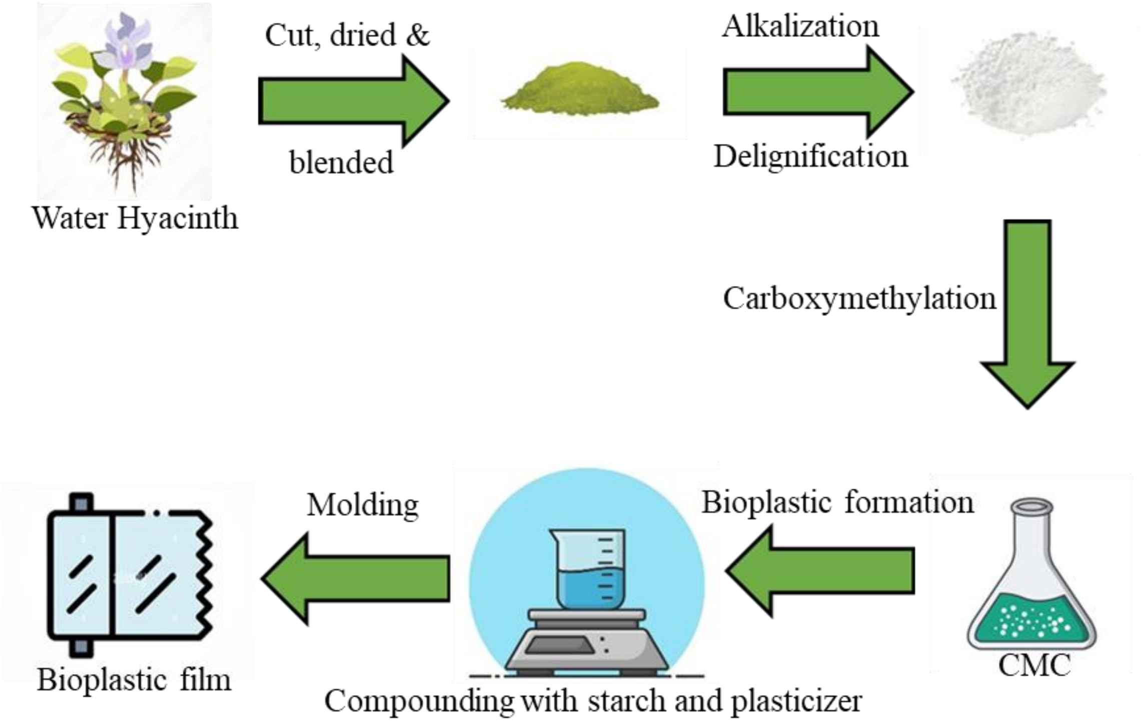


FIGURE 1 Design of the experiment.

The combination of the two materials was heated to 110 to 120^0C and stirred using a hot plate magnetic stirrer at 900 rpm speed. After some time, 2%, 5%, and 7% plasticizers were mixed with the solution for samples a, b, and c. This process continued until it became gelatinization. A petri dish and a tray were used to mold the final gelatinized homogenous mixture. It was allowed to dry at room temperature for one week. Finally, the obtained dried film was bioplastic. Then, it was cut into stripes (**Figure 2**), and different tests and analyses were performed. **Table 1** shows the weight composition used to make three bioplastic samples.

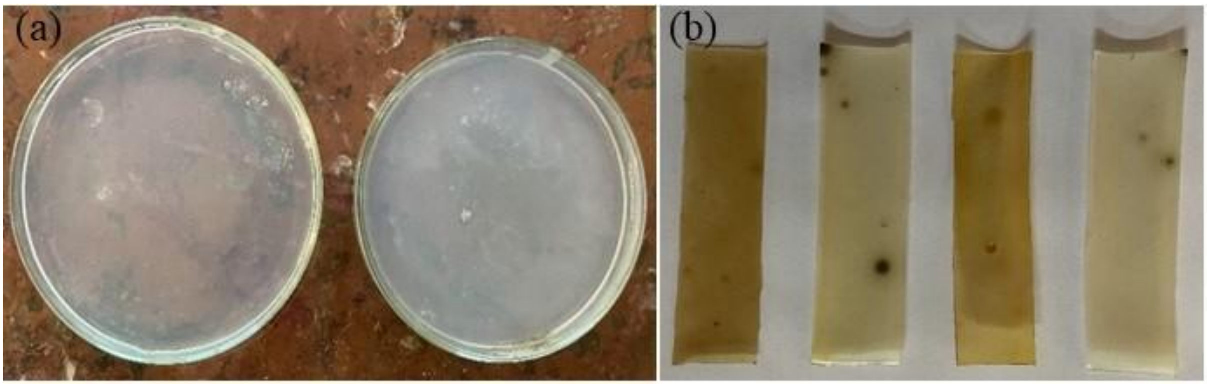


FIGURE 2 Bioplastic molding using petri dish (a) and Sample strip (b).

TABLE 1 Sample specification of bioplastic samples.

Sample Name	Sample %	Ratio (CMC: PS)	CMC (g)	PS (g)	Glycerol (%)
CPS_0	5	1:0	5	0	5
CPS_1	10	3:1	6.67	3.33	2
CPS_2	15	3:2	9	6	7

[PS: Potato Starch]

3 | RESULTS AND DISCUSSION

This study used two separation processes (alkalization and bleaching) to separate WH cellulose from hemicellulose, lignin, and other substances. Cellulose is wrapped by hemicellulose, acts as a bridge between cellulose and lignin, and supports the lignocellulosic structure's rigidity [15]. The first step of the separation process is to eliminate hemicellulose from the cellulose framework. Alkalization by NaOH was carried out. The alkalization process causes oxidation of the material [16]. This step breaks the ester bonds in the complex lignin-carbohydrate network that connects lignin to hemicellulose [17].

The second step was bleaching to remove lignin and other impurities. Sodium hypochlorite (NaOCl) solution was used in this process. When NaOCl is mixed with water, it creates a strong oxidant that dignifies ether and lignin bonds in the lignin structure. The formation of moist yellowish-white pulp indicates a lignin termination reaction. Additionally, the process of oxidation of cellulose to cellulose with carboxylic groups and aldehyde is caused by OH^- and ClO^- [16]. The materials enhancing white color show that the isolation of cellulose was successful [7]. **Table 2** shows that the amount of isolated cellulose obtained using 15g WH powder was 7.29g (48.6%). The WH sample decreased considerably during isolation and lost around 50% mass.

TABLE 2 WH cellulose isolation result

Material	Mass (g)	Wt. Loss (%)
Water Hyacinth mass	15	
Obtained cellulose mass	7.29	51.4

In cellulose structure, long chains of glucose are connected by β-1,4- glycosidic bonds. Strong hydrogen bonds are formed between neighboring glucose units, creating a dense structure [18]. Additionally, cellulose's molecular chain often appears in a crystalline form. This complicated H-bond and crystallinity reduces its reactivity to other potential reactants. So, to produce bioplastic, it is turned into CMC to increase its reactivity and speed up the further production process.

3.1 | Characterization of isolated cellulose

3.1.1 | FTIR analysis

FTIR spectroscopy was used to analyze WH and isolated cellulose from the analysis of functional groups between 4000 and 450 cm^{-1}. Figure 4 compares WH's FTIR spectra before and after chemical treatment. The spectra of the before and after isolation process have different results. In the functional group region, the broad peak at 3439 cm^{-1} and 3467 cm^{-1} of both samples suggested the presence of the hydroxyl (O-H) group [19]. The observed peak of the ─OH group of WH before and after isolation has changed. It suggests that previously existing hydrogen bonds in lignin, hemicellulose, and intra- and inter-cellulose have already been disrupted. The C-H functional group stretching is shown at wavenumbers 2921 cm^{-1} and 2925 cm^{-1}. The vibrational peak around this wavenumber indicates the chain's strength between hemicellulose, lignin, and cellulose. Intensity at this wavenumber is reducing and not extending after the isolation process. The absorption band at 2362 cm^{-1} of WH powder was probably attributed to CO_2 stretching vibration from the lab atmosphere [20]. Based on estimation, the absorption peak around wavenumber 1632 cm^{-1} and 1638 cm^{-1} represents the C=O group originating from the carboxylic group. The process of further oxidation may be intensified by it [7]. Most probably, C─O─C in the pyranose ring is indicated by the vibrations at 1049 cm^{-1} and 1053 cm^{-1} in the fingerprint region [21]. Jeesica Hermayanti Pratama et al. [7] found similar kind of similar functional groups in their study, where they also isolated cellulose from water hyacinth. This FTIR analysis indicates that every functional group's absorption in the FTIR spectra matches the cellulose structure, as demonstrated in **Figure 3**. It proves that the technique used in this research successfully separated cellulose from water hyacinth.

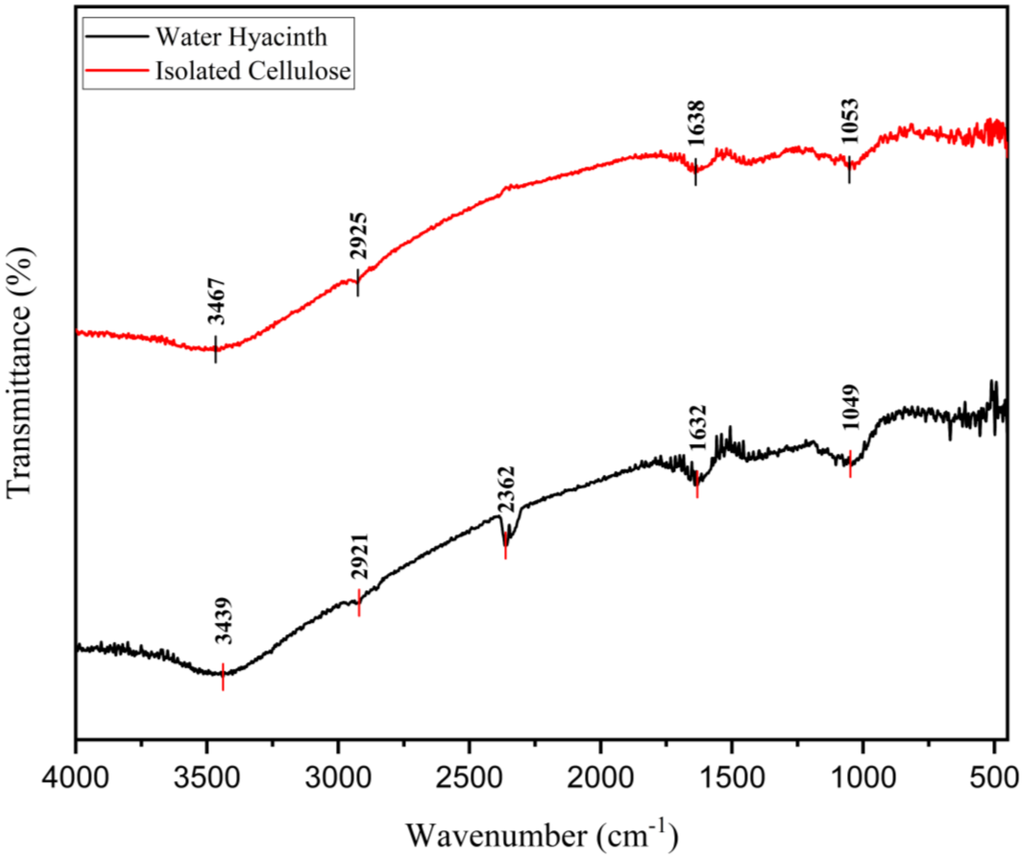


FIGURE 3 FTIR spectra of WH and isolated cellulose.

TABLE 2 FTIR peaks of WH and isolated cellulose.

Region	Peak at wavenumber (cm^{-1})		Functional Group
	Water Hyacinth Powder	Isolated cellulose powder	
Functional group region	3439	3467	O-H
	2921	2925	C-H
	1632	1628	C=O
	2362	-	CO_2

Fingerprint region	1049	1053	C-O-C

3.1.2 | SEM analysis

Figure 4 shows the surface microstructure of the WH powder before and after isolation to see the change in the grain powder. According to the SEM image in **Figure 4**, the morphological structure of the water hyacinth powder (**Figure 4(a-b)**) is thicker than the isolated cellulose powder. As seen in Figure **4(c-d)**, the treated WH powder has a smaller dimension because of thinner fibers and smaller grains [7]. It proves that the hot alkali treatment and delignification process successfully disrupted the bonds of hemicellulose and lignin.

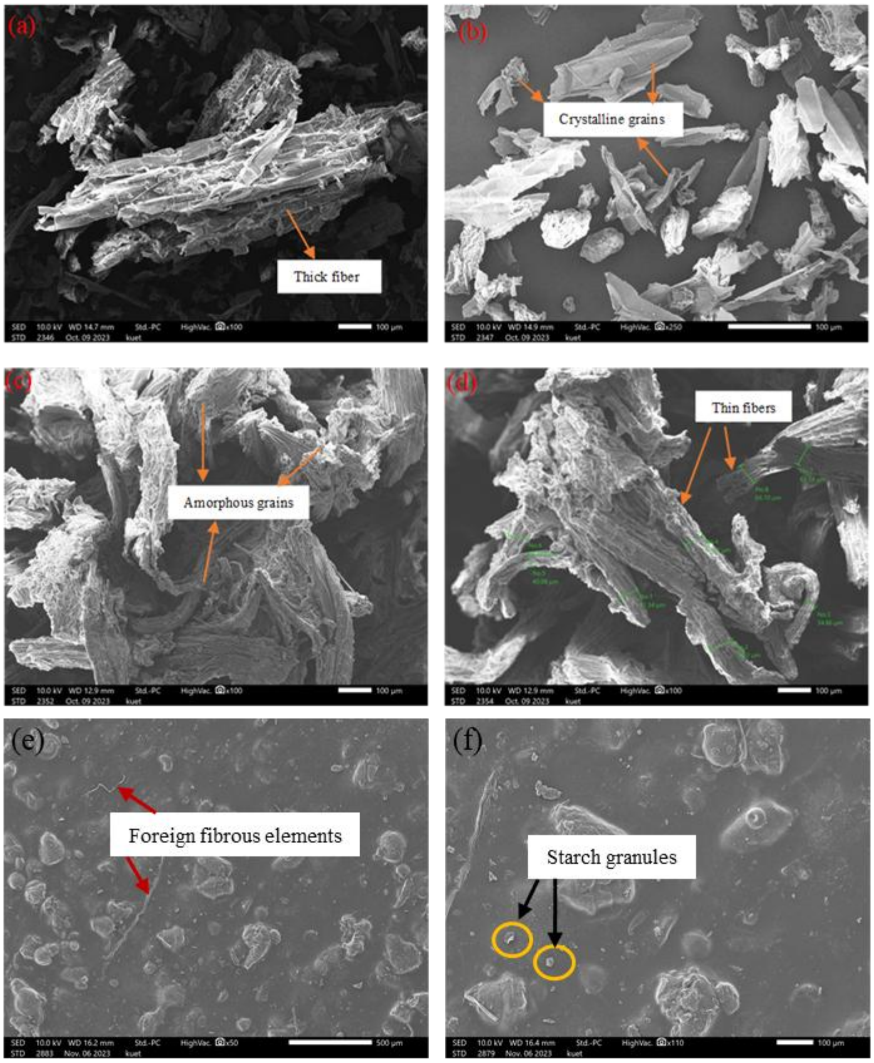


FIGURE 4 SEM images of WH before isolation process (a), (b), and after isolation process (c), (d) and bioplastic at ×50 (e) and ×110 (f) magnification

3.2 | Characterization of bioplastic

3.2.1 | FTIR analysis

The functional group analysis of WH bioplastics is also carried out and shown in **Figure 5**. The figure shows that both samples have similar peaks in the FTIR spectrum. The broad peak observed at wavenumber 3305 cm^{-1} in the spectrum can be attributed to hydroxyl (O-H) groups in the functional group region. A slight peak near 2925 cm^{-1} is due to the stretching of C-H groups, whereas a noticeable band at 1590 cm^{-1} typically corresponded to aromatic C=C stretching vibration. In the fingerprint region, C-O stretching may be caused by the absorption band at wavenumber 1015 cm^{-1} [4], [14], [22].

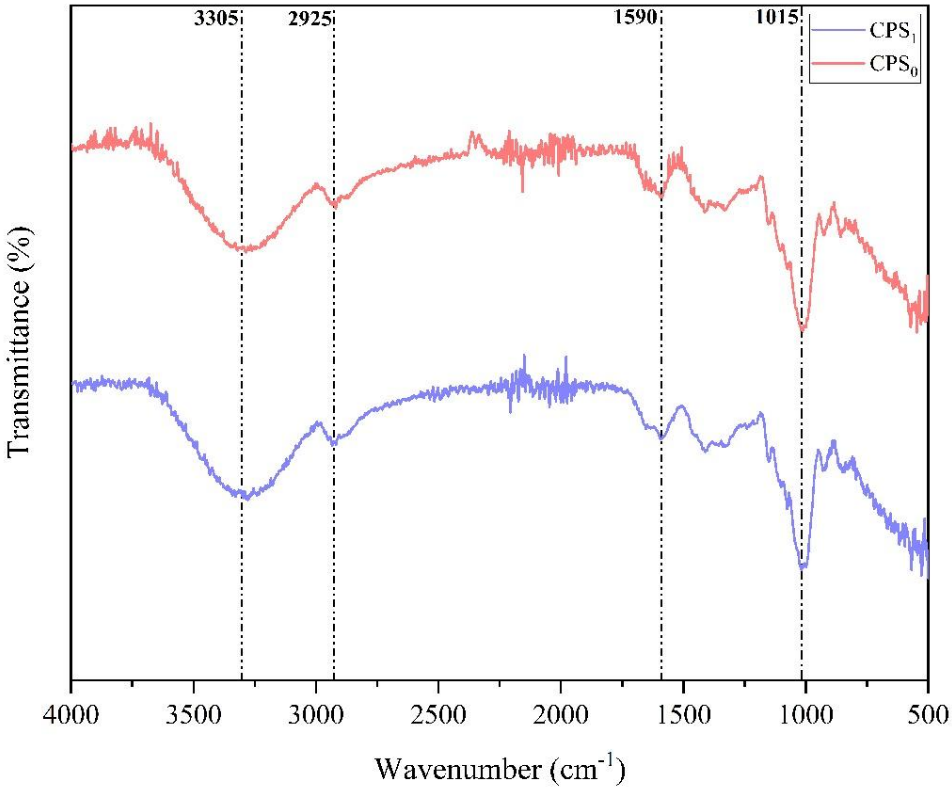


FIGURE 5 FTIR spectra of produced bioplastics. With starch (CPS$_1$), and without starch (CPS$_0$).

TABLE 3 FTIR peaks of produced bioplastic.

Region	Peak at Wavenumbers (cm^{-1})	Functional group

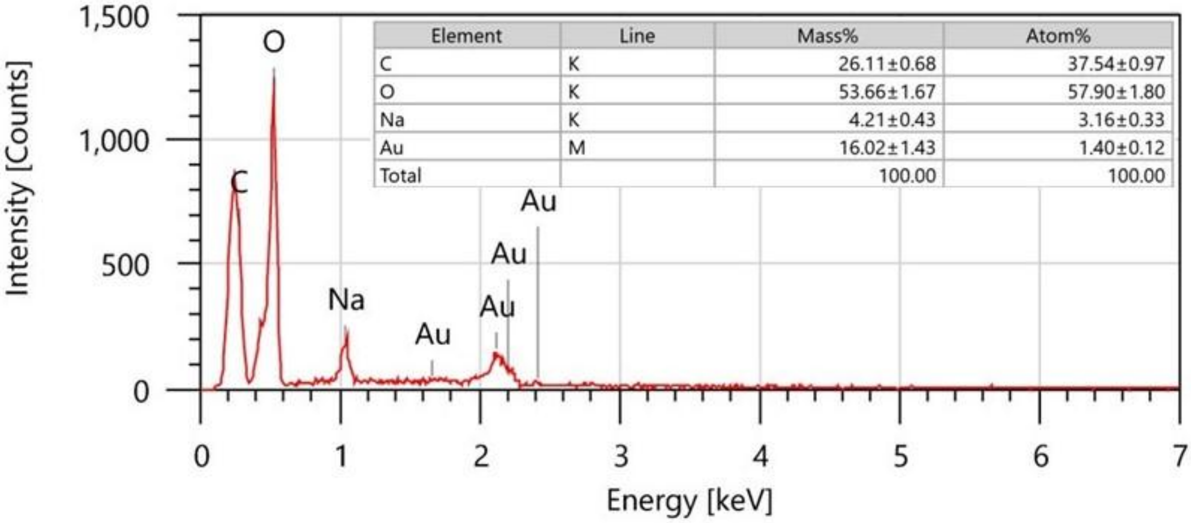
Functional group region	3305	O-H
	2925	C-H
	1590	C=C
Fingerprint region	1015	C-O

3.2.2 | SEM analysis

The surface morphology of the bioplastic was examined by Scanning Electron Microscope (SEM). It features almost a fluctuating and continuous morphology with no craters and holes. It confirms the uniform chemical interaction between CMC, starch, and glycerol. The homogenous mixture was made relatively easier by the CMC powder. However, the surface also consists of some starch particles. Some of the particles were not entirely gelatinized during the bioplastic production process. These starch granules are visible (highlighted by yellow circles) on the surface of the bioplastic. Hernández-Jaimes, C. et al. [23] and Md. Ruhul Amin et al. [24] described results similar to their report where insoluble starch granules were shown in SEM results. Some foreign fibrous elements can be seen in the images marked by the red arrow.

3.2.3 | EDS mapping

Figure 6 features the element composition of bioplastic measured by Energy Dispersive Spectroscopy or EDS. Two dominant elements are primarily found, C and O. They occupy almost 80% of the total material. The presence of carbon and oxygen proves that the bioplastic sample is organic, biodegradable and doesn’t impact the environment badly. Some trace percentage of Na is visible due to its presence in the CMC. A thin layer of Au is used to prevent the charging effect of SEM samples, so the presence of Au is also shown in the EDS result. Every element is distributed randomly across the surface of the material. It shows bioplastic heterogeneity [25].



Element	Line	Mass%	Atom%
C	K	26.11±0.68	37.54±0.97
O	K	53.66±1.67	57.90±1.80
Na	K	4.21±0.43	3.16±0.33
Au	M	16.02±1.43	1.40±0.12
Total		100.00	100.00

FIGURE 6 EDS result of bioplastic.

3.2.4 | TG/DTA analysis

Thermogravimetric analysis (TG) of the WH bioplastic decomposition graph is shown in **Figure 7**. It has shown a two-step decomposition process. In the first stage, the sample's moisture is evaporated at 50-175^{0}C. At this point, the thermal decomposition process occurs due to the evaporation of water, which is likely due to moisture evaporation or volatile component decomposition due to the evaporation of water. In the second stage, the sample underwent thermal decomposition between 175-330^{0}C.

The differential thermal analysis (DTA) curve implies a heat release peak within this temperature range that supports the specimen's thermal decomposition process. After 330°C, the TG curve reaches a plateau, which denotes a level of thermal durability of up to 600 °C. The decomposition graph indicates that 50% weight loss of the bioplastic occurred at 244^{0}C. This result is similar to that of Nurul et al. [26]. $T_{50\%}$ (50% weight loss temperature) is 250^{0}c for their starch-based bioplastic sample. S Anantachaisilp et al. [4] stated in their paper that 41% of mass loss occurred at 275^{0}C for their CMC film. A slight decline in weight loss is observed past 600°C until it stabilizes at approximately 700°C.

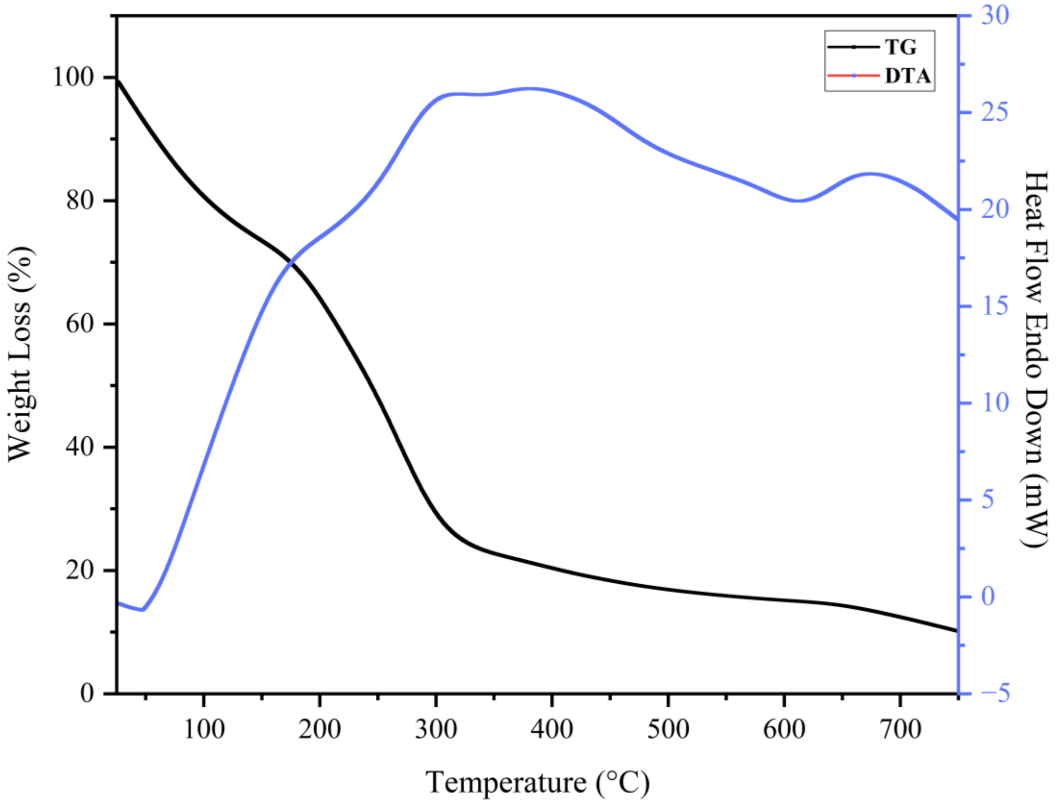


FIGURE 7 TG/DTA curve of WH bioplastic.

3.2.5 | Mechanical properties

Figure 8 shows the stress-strain curve of three bioplastic samples with different compositions and matrices. Sample ‘CPS_2’ showed higher tensile strength than samples ‘CPS_1’, and ‘CPS_0’, reaching a peak stress of approximately 3.7 MPa. This suggests that sample ‘CPS_2’ has a strong intermolecular bonding among the materials. In contrast, samples ‘CPS_1’ and ‘CPS_0’ showed peak stress of approximately respectively 3.4 MPa and 2.38 MPa.

The bar chart of **Figure 9** illustrates the ultimate and break strains for $CPS_{0,}$ $CPS_{1,}$ and CPS_2 specimens. Sample ‘CPS_2’ has the highest ultimate strain of 121% and a breaking strain of 127%, which indicates its superior ductility. Sample ‘CPS_0’ is followed by the ultimate strain of 107% and a breaking strain of 111%. Sample ‘CPS_1’ showed less ductility among the three samples, with an ultimate strain of 39.5% and a breaking strain of 40.5%.

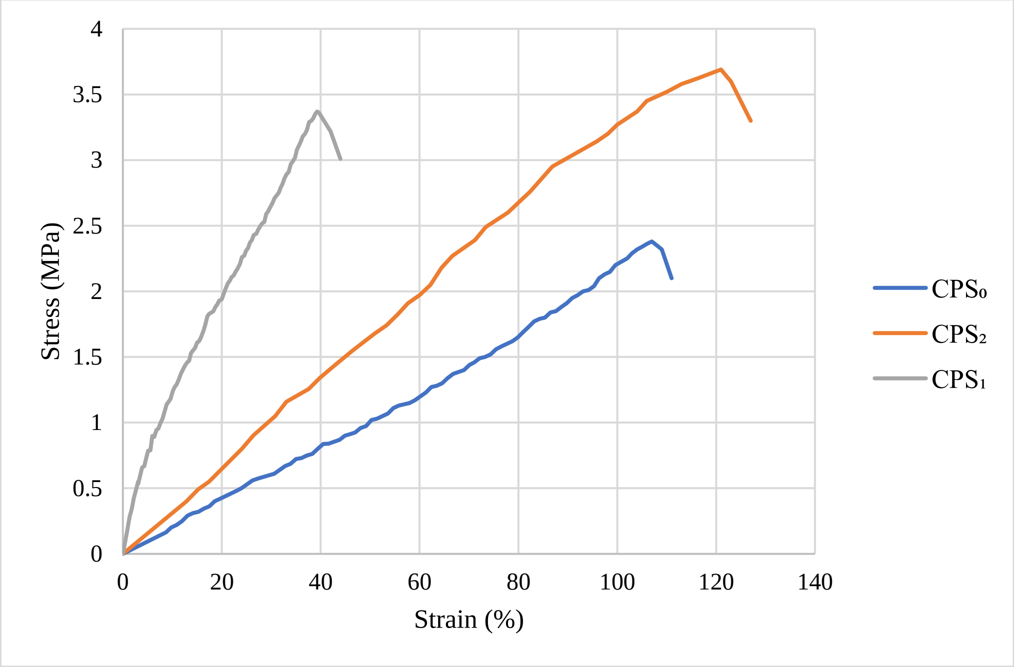


FIGURE 8 Stress vs. strain curve of three bioplastic samples: 10% (CPS_1), 15% (CPS_2), and 5% (CPS_0).

The potato starch works as a reinforcing agent in plastic. Increasing the amount of starch has given the sample more rigidity and tensile strength. Meanwhile, the plasticizer increased the sample's elongation. By analyzing **Figure 9**, we can see that samples CPS_2 and CPS_0 have the ultimate strain of 121% and 107%, respectively, caused by 7% and 5% plasticizers. However, the a has less ultimate strain (39.5%) because of using a 2% plasticizer.

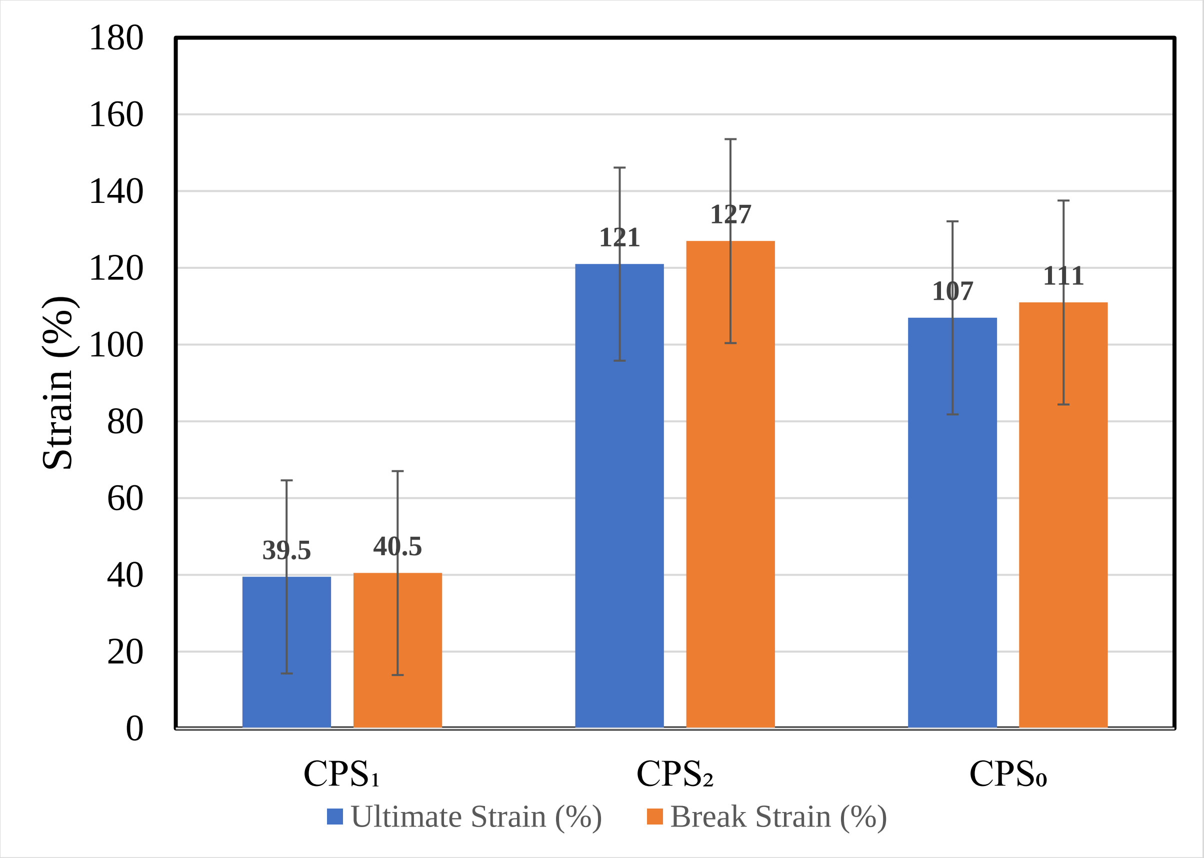


FIGURE 9 Ultimate and break strain of bioplastic samples. 10% (CPS_1), 15% (CPS_2), and 5% (CPS_0).

We can also see that the amount of starch increased the tensile strength of the samples in **Figure 9**. Sample 'CPS_0' has no starch and the lowest tensile strength, whereas sample 'CPS_2' has the highest tensile strength as it contains 40% starch.

3.2.6 | Surface roughness analysis

Surface roughness parameters of the bioplastic are analyzed by ImageJ software using SEM images. **Figure 10** reveals different topographic features of different areas of the sample. The color-coded maps illustrate elevation variation over the sample surface, where green and blue represent valleys and peaks. **Figure 10** 'a' and 'b' exhibit a relatively uniform surface with some slight peaks. However, **Figure 10** 'c' and 'd' show notable elevated regions because of material interaction with foreign fibrous elements, as shown in **Figure 10** of SEM analysis. The small blue peaks indicate no gelatinized starch granules.

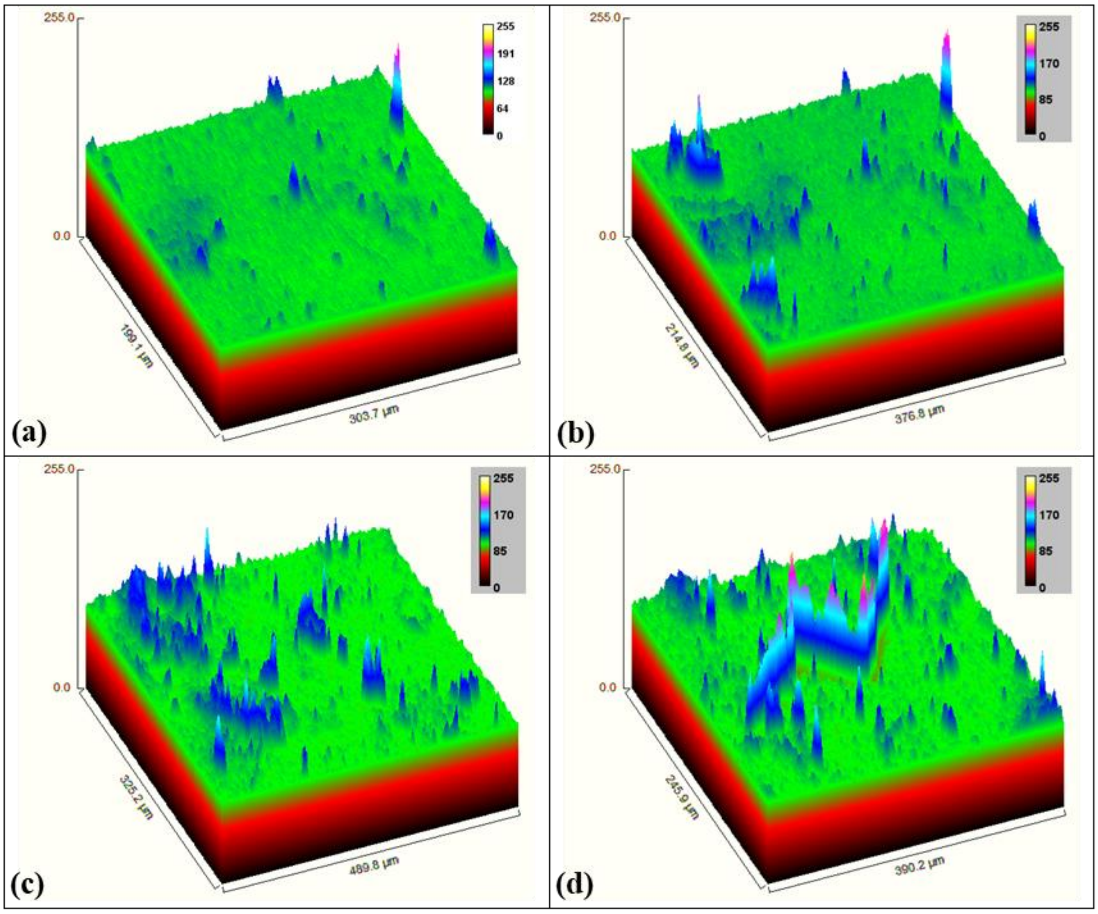


FIGURE 10 Surface roughness profiles of different areas of the bioplastic sample.

3.2.7 | Soil Burial Biodegradation Analysis

The soil burial test was conducted to see the degradation rate of the bioplastic in terms of wt. loss with respect to time. **Figure 11** displays the weight. loss percentage of the samples. Examining the fig, the wt. The loss percentage increases as the number of days increases. 90% wt. the loss was observed after 25 days, which suggests that the sample is decomposing as it increases in time. Tunma et al. [27] showed a similar outcome where their starch-based films decomposed within 14 days. As per European standard EN13432 [28], after six months, they are required to have 90% of their mass broken down into carbon dioxide, water, and biomass. The bioplastic samples degraded faster than the standard so that they can be regarded as biodegradable material.

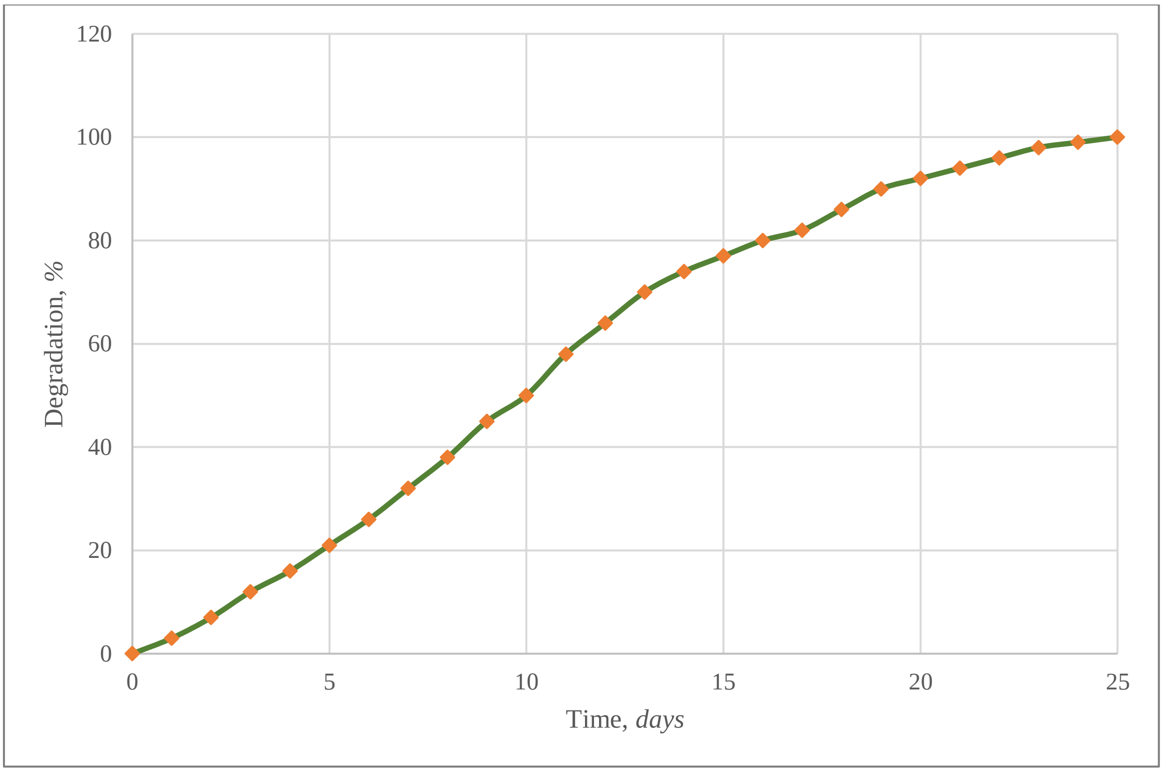


FIGURE 11 Biodegradation of produced sample.

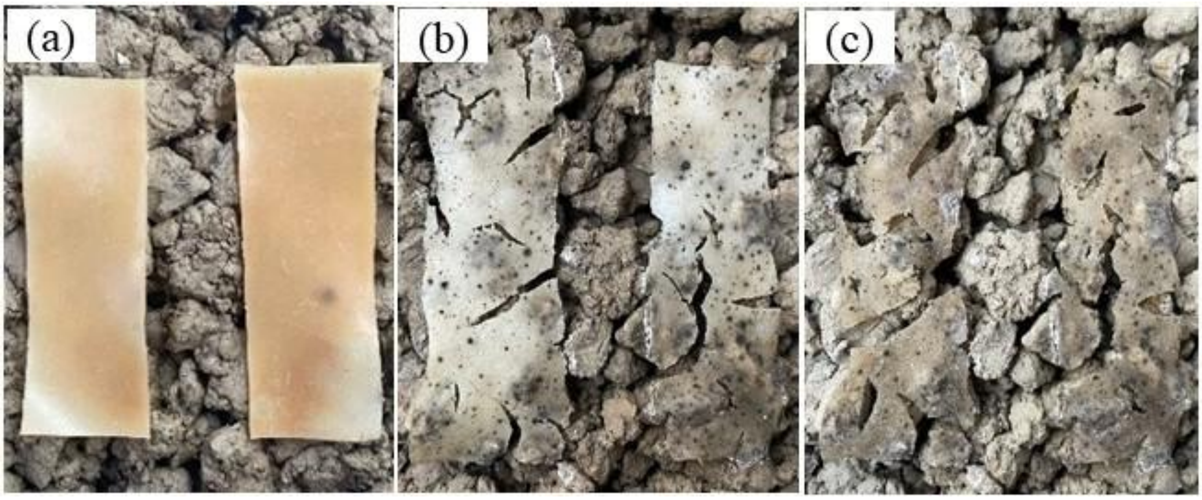


FIGURE 12 Soil burial impact on biodegradation: after 1 day (a), after 12 days (b), and after 20 days (c).

3.3 | Comparative analysis with relative paper

Table 5 demonstrates the comparative analysis with relative research papers. The WH-starch bioplastic provides relatively better physical and elongation properties than similar types of bioplastics like CMC-PEG, starch-cellulose, starch, CS-WHF (CS-Cassava Starch and WHF-Water Hyacinth Fiber), starch-chitosan, etc. [4], [7], [24], [29].

TABLE 5 Comparative analysis of WH bioplastic with relative paper.

Type of material	Tensile Strength (MPa)	Elongation (%)	Refs.
WH-PS	3.7	121	This work
CMC-PEG	2	2	[4]
Starch	3.55	88.1	[24]
CS-WHF	1.226	3.3	[30]
Starch	3.22	53.6	[29]
Starch-Chitosan	5.19	44.6	

3.4 | Comparative analysis with commercial plastics

Widely used plastics in our daily life generally derived from thermoplastics. Polyethylene, polyethylene terephthalate, polypropylene, etc., are the main polymers used. The most commonly found microplastics (MPs) in biota are from these polymers [31]. Every day, humans and wildlife are exposed directly and indirectly to macroplastics, microplastics, and nanoplastics produced from plastics. Many products used in daily life are made from plastic, which has a short lifespan and ends up damaging the environment and affecting terrestrial and marine life. The size of plastic is mainly related to the exposure. Different kinds of materials like monomers, plasticizers, and antioxidants are incorporated with plastic. During manufacturing, storage, or waste disposal, MPs, nanoplastics (NPs), and the incorporated chemicals can encounter food and water, causing quality degradation and safety hazards [32]. The main exposure route is inhalation. Various marine and freshwater species, including vertebrates, can consume MPs [33]. Wright et al. [34] stated that small particles can be carried in humans by the gastrointestinal tract (GIT), lung endocytic pathways, and perception in the GIT. Mucus and fluids tend to trap these particles. Gal et al. [35] reported that plastic contaminated over six hundred and ninety marine species. Additives used in plastics are a major concern for their chronic exposure (Phthalates used in PVC). Polymers in plastic interact with the different tropical organisms, causing growth reduction and a decrease in photosynthesis and chlorophyll concentration. Some monomers used in plastic are also very toxic, such as vinyl chloride. It is considered one of the most health-hazardous monomers used in PVC. However, the produced bioplastic in this study has no environmental concerns. It is derived from organic material and breaks into C and O rather than MPs and NPs. Because of their physical and thermal properties, they cannot replace all commercial plastics. Still, with the right cellulose, starch, and plasticizer formulation, the produced sample can be an alternative to commercial plastics in certain areas without harming the environment.

4 | CONCLUSION

This study effectively demonstrates that developing biodegradable plastic derived from water hyacinth, and potato starch can offer a reliable and sustainable solution to conventional plastics. The separation and utilization of cellulose from water hyacinth were properly achieved, and the potato starch, synthesized CMC, and glycerol were well blended to form the bioplastic product. The successful synthesis process, the right chemical used, and the physical properties of the samples can be confirmed by the characterization report of the FTIR and SEM test. Physical properties, including the tensile strength and elongation of the material, showed that it possesses a good balance between strength and flexibility. Sample ‘CPS_2’ and ‘CPS_0’ demonstrated better ductility, which is important for different applications. Based on surface roughness analysis, the surface was usually smooth, with some areas showing small variations caused by non-gelatinized starch granules and foreign fibrous elements. This area can be improved in further research. The thermogravimetric analysis provided insight into the sample's thermal stability and decomposition characteristics. It indicated that it experiences a primary decomposition stage that suggests its applications where moderate thermal resistance is required. Ultimately, the soil burial test demonstrated the most crucial advantage of bioplastics. The samples showed significant degradation in 25 days, surpassing the EN13432 European standard. The fast biodegradation rate proves their effectiveness in waste management and decreases plastic pollution. This study showcases the potential of converting invasive plants into valuable environmentally friendly bioplastic. It can even help the field of sustainable material science by promoting environmentally friendly alternatives in different industries. To meet global demand, further research could optimize the synthesis process and explore the economic viability of the product.

Authors contributions

Kaniz Fatima Mishfa, Md Abdul Alim, Anirban Mallick, Farhana Hossain and Md. Reazuddin Repon has contributed to conceptualization, methodology, data collection, and original draft preparation. Anirban Mallick, Farhana Hossain, and Md Abdul Alim have contributed to data collection and analysis. Md Abdul Alim, Kaniz Fatima Mishfa and Md. Reazuddin Repon contributed to editing and reviewing. Md Abdul Alim and Md. Reazuddin Repon supervised all stages of preparing the manuscript. All authors have read and agreed to the published final version of this review.

Conflicts of interest

The authors have no relevant conflicts of interest to disclose.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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