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Environmental assessment of corn starch based biodegradable plastic with glycerol and fructose

Lakshmiganthan S.M.[1*], Vadi Seshagiri Rao[1], Sathish Rengarajan[1] and Srividhya S.[2]
[1]Department of Mechanical Engineering, St. Joseph's College of Engineering, Chennai–600119, India
[2]Department of Civil Engineering, Builders Engineering College, Tirupur, 638108
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*to whom all correspondence should be addressed: e-mail: sml.automobile@gmail.com
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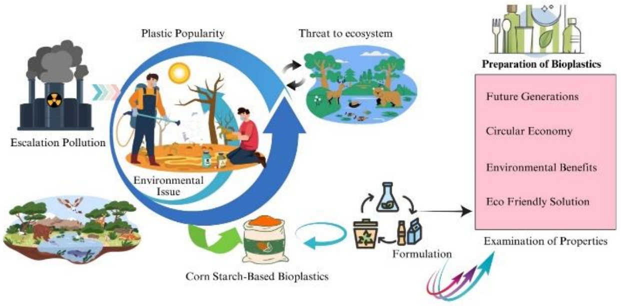
Graphical abstract



Abstract

Plastic has gained significant popularity due to its lightweight, durability, and cost-effectiveness compared to traditional materials like metals and clay. However, its non-biodegradable nature has led to an alarming escalation in environmental pollution, posing a severe threat to ecosystems. To address this issue, the current study evaluates the potential of corn starch-based biodegradable plastics as a sustainable alternative to conventional plastics. This research focuses on the formulation of bioplastics by combining 10% corn starch with plasticizers like glycerol and fructose at varying concentrations (15%, 30%, 45%, and 60% by weight). The bioplastics were prepared using traditional solutions to create eco-friendly materials that reduce reliance on petroleum-based plastics, thereby promoting a greener and more sustainable environment. Key physical and mechanical properties, including water solubility, tensile strength, water absorption, and biodegradability, were thoroughly examined. The findings highlight that bioplastics made from corn starch demonstrate remarkable biodegradability, breaking down naturally without harming the environment. Moreover, these bioplastics exhibit superior mechanical properties, such as enhanced tensile strength and durability, compared to traditional polymers. The environmental benefits of corn starch-based plastics are profound. They significantly reduce industrial waste and lower the risks associated with conventional plastics, such as pollution and resource depletion. Additionally, they offer an economically viable solution for industries seeking sustainable alternatives. By adopting bioplastics derived from renewable resources like corn starch, we can move closer to a circular economy. This shift not only minimizes the environmental footprint but also safeguards ecosystems for future generations.

Keywords: Bioplastic, biodegradability, corn starch, fructose, mechanical properties

1. Introduction

Plastics derived from petroleum are currently widely employed for various applications because they have a wide range of mechanical properties and are relatively inexpensive (Nik *et al*. 2021). In 2014, global plastic production was projected to be 311 million tons, which increased to 381 million tons by 2015. By 2050, this production is expected to quadruple. Although plastics made from petroleum have contributed significantly to the global economy, their inability to decompose poses serious ecological threats. This has been a root cause of numerous environmental hazards (Supian *et al*. 2022; Rana, 2019; Ilyas *et al*. 2021, Geyer *et al*. 2017). In 2015, it was reported that over 300 million tons of waste were generated, with approximately 79% comprising plastics. Of this, only 9% was recyclable, and 12% could be incinerated. Plastics derived from petroleum are among the most pressing ecological issues due to their resistance to recycling and biodegradation. Consequently, finding environmentally friendly substitutes has become a priority. In the current scenario, bio-based plastics with a low environmental impact present a promising alternative to reduce reliance on conventional plastics and their hazardous waste. Biodegradable plastics are produced using natural biopolymers or synthetic bio-based polymers (Jang *et al*. 2020; Suriani *et al*. 2021). Materials derived from plants and animals, such as cellulose, glycolipids, and natural fibers, can reduce the impact of petroleum-based plastics on the environment and mitigate the depletion of oil resources. These biopolymers also help in reducing greenhouse gas emissions, making them suitable for environmental applications (Hazrati *et*

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al. 2021; Bernaerts *et al*. 2019; Omran *et al*. 2021; Syafiq *et al*. 2020).

Starch is one of the most commonly used biopolymers for producing biodegradable biofilms due to its excellent performance, accessibility, and cost-effectiveness. Globally, maize is the primary source of starch, contributing over 85% of the starch production, with other plants like wheat, rice, and potato playing a smaller role (Supian *et al*. 2022; Rana, 2019; Ilyas *et al*. 2021, Geyer *et al*. 2017; Jang *et al*. 2020; Suriani *et al*. 2021; Hazrati *et al*. 2021; Bernaerts *et al*. 2019; Omran *et al*. 2021; Syafiq *et al*. 2020; Chan *et al*. 2021; Jumaidin *et al*. 2021; Diyana *et al*. 2021). Around 70% of a corn granule comprises semi-crystalline starch, with the rest being glucose, protein, oil, and ash. In recent years, starch-based materials have gained attention in packaging applications, driven by concerns over global warming. While the biopolymer market has achieved success, particularly in reducing environmental impact, challenges remain in replacing petroleum-derived plastics due to the poor mechanical properties and moisture sensitivity of biopolymer-based films. Since the early 1800s, plasticizers have been used to enhance the malleability and toughness of polymers (Ghanbarzadeh *et al*. 2010; Waterschoot *et al*. 2015; Ibrahim *et al*. 2019; Sanyang *et al*. 2015; Zentou *et al*. 2019). Plasticizers improve the mobility of polymer macromolecular chains, decreasing the glass transition temperature and enhancing the flexibility and stiffness of plasticized starch films.

The primary role of plasticizers is to reduce the hydrogen bonding affinity within the starch network of amylose and amylopectin, improving the mobility of polymer chains and enhancing the physical characteristics of biopolymers (Shahabi-Ghahfarrokhi *et al*. 2019; Hazrol *et al*. 2021). This results in better processing capabilities, such as reduced second-order transition temperatures and increased cold flexibility. Plasticizers also lower processing temperatures, improving flow properties. Various plasticizers, including fructose, glucose, and sucrose, have been studied for producing biopolymers. Research has shown that films with 25% fructose exhibit excellent mechanical strength. The effect of glycerol concentrations (0%, 20%, and 40%) on corn starch revealed that increasing glycerol reduced tensile strength but improved elongation at break. Polyols like glycerol and sorbitol also increased water vapor permeability (Ibrahim *et al*. 2019; Vieira *et al*. 2011; Versino *et al*. 2011; Mali *et al*. 2006). The combined effect of multiple plasticizers can enhance the characteristics of cellulose acetate films. The current study utilizes corn starch as the primary component, along with glycerol and fructose as plasticizers in varying proportions, to produce an environmentally friendly and sustainable bioplastic film. The outcomes of this investigation into the mechanical characteristics of starch-based bioplastics provide a foundation for further comprehensive research.

2. Problem statement

Traditional plastics contribute to long-term pollution and damage ecosystems because they cannot be decomposed. Traditional plastics take hundreds of years to decompose, during which the materials release many toxic chemicals and microplastics into the environment. Bioplastics are sustainable alternatives that are derived from renewable resources and have improved biodegradability, although this is relative since the environmental benefits associated with bioplastics need much more definition if the product is to be considered better than traditional plastics. Therefore, the main aim in this research is to comparatively analyze and evaluate the impact of both traditional plastics and proposed bioplastics on the environment in terms of decomposition rates, carbon footprint, and overall ecological impact.

3. Experimental methodology

3.1. Materials

The primary resources utilized in this study are easily accessible within the local area. The plasticizer utilized in the study comprised of glycerol and fructose, which were procured from Sakthi vendors located in India. **Table 1** displays the composition of the corn starch used in the current study. In the present investigation, glycerol and fructose were employed as plasticizers in the synthesis of bioplastic with the aim of reducing film brittleness. This was achieved by reducing intermolecular tensions among polymer chains, so enhancing their mobility and ultimately yielding a film with increased elasticity and flexibility.

Table 1. Composition of corn starch

Properties	Moisture Content (%)	Ash Content (%)	Protein (%)	Fat (%)	Fiber (%)	Amylose (%)	Amylopectin (%)	Density (g/ml)	pH
Corn starch	5.82	0.32	0.38	0.32	0.10	20.4	72.66	1.356	6.72

3.2. Preparation of bioplastic film

In this investigation, corn starch (CS) based films were molded using the solution of plasticizer was prepared. **Figure 1** depicts the experimental setup schematically. Initially, both plasticizers were added to 180 ml of distilled water in a beaker. The mixture was then heated in water bath for 20 minutes at 85 °C to form a homogenous solution. Then, 10 g of corn powder was added to the solution at varying plasticizer concentrations (0, 15, 30, 45, and 60%w/v). The solution was brought back to the water bath for 20 minutes at the same temperature, and the mixture was allowed to cool down before being cast on a thermal platform. The mold containers were weighed to ensure uniformity of film thickness. The mixture was desiccated in the oven at 65 °C for 15 hours. The dehydrated films were removed from the mold plates and stored in plastic containers at room temperature for over one week prior to undergoing characterization. Films plasticized with various concentrations of glycerol, fructose, and glycerol/fructose mixtures were given the following designations: G15%, G30%, G45%, and G60%; F15%, F30%, F45%, and F60%; GF15%, GF30%, GF45%, and GF60%; and CCS for the control made from corn starch film. The ratios of material used are listed in **Table 2**.

3.3. Role of plasticizers in biodegradability

Plasticizers, like glycerol and fructose, act in a twofold manner by enhancing the flexibility and processability of bioplastic and, in turn, its degradation. Higher concentrations of plasticizers increase hydrophilicity; thus, water absorption into the material facilitates microbial accessibility, leading to faster biodegradation. The existence of plasticizers increases the amorphous regions within the bioplastic and thus becomes easier for enzymes and microorganisms to attack the chains. The hydrophilic nature of glycerol and fructose attracts moisture, further promoting microbial colonization and degradation. The paper has suggested that the range of plasticizer concentration could be 10%–20% in order to reach a good balance in the mechanical properties and in the biodegradability of the system.

Table 2. Ratios of Glycerol, Fructose and corn starch

Sample	Corn starch (%)	Glycerol (%)	Fructose (%)
CCS	10	-	-
G15	10	15	-
G30	10	30	-
G45	10	45	-
G60	10	60	-
F15	10	-	15
F30	10	-	30
F45	10	-	45
F60	10	-	60
GF15	10	7.5	7.5
GF30	10	15	15
GF45	10	22.5	22.5
GF60	10	30	30

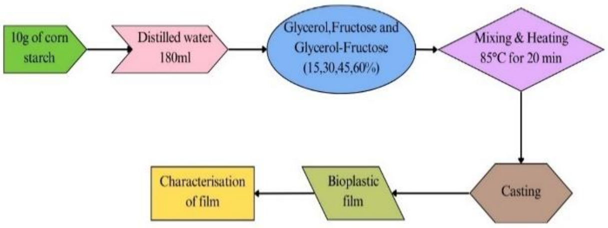


Figure 1. Fabrication process of bioplastics

4. Characterization

4.1. Physical characteristics

4.1.1. Thickness measurement

A digital micrometer with 0.001 mm accuracy was used to measure the thickness of each film sample. The average film thickness was calculated from measurements taken at three points inside each film sample.

4.1.2. Water solubility test

Three samples (30mmx10mm) were selected from each film to test solubility and were dehydrated for 24 hours in an oven at 105 °C. The initial dry weight of the samples is taken (Wsi). Following that, each specimen was incubated for 24 hours at a temperature of 25 °C in a glass beaker with 100 ml of distilled water, with periodic stirring. After that, a portion of the film samples that did not dissolve were taken out of the solution and dried at 110 °C for 24 hours. The weight of insoluble residue is noted (Wsf). Equation (1) has been used to compute the proportion of total soluble matter.

$$\text{Water solubility } (\%) = [(W_{si} - W_{sf})/W_{si}]\times 100 \tag{1}$$

W_{si} and W_{sf}–Initial and final weight of the film (g)

4.1.3. Moisture content

Films moisture content was determined by monitoring their weight changes over time. For each sample three trials were considered and the initial weight of the samples was noted (W_i). Then the samples were dried for 24 hours at 110 °C and the dry weight was noted (W_f). Equation (2) has been applied to determine the moisture level.

W_i and W_f–Initial and final weight of the film (g)

$$\text{Moisture Content}(\%) = \left[(W_i - W_f)/W_i\right]\times 100 \tag{2}$$

4.1.4. Water absorption

The water absorption test was conducted on the bioplastic samples in accordance with the standard D570-98 recommended by the American Society for Testing and Materials. The specimens were carefully measured, and the initial weights were accurately recorded (W_{wi}). Then the samples were placed in the beakers filled with water. The samples were taken out of the water every 10 minutes and the excess water was wiped off. After the samples were dry, the final weights of the samples were measured (W_{wf}). The absorption test was conducted over duration of four hours, during which the weight of water absorbed was recorded. The amount of water absorbed was calculated using (3).

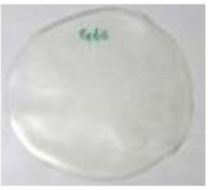
$$\text{Water absorption}(\%)=\left[\left(W_{wi}-W_{wf}\right)/W_{wi}\right]\times 100 \quad (3)$$

W_{wi} and W_{wf} are Initial and final weight of the film (g)

4.2. Tensile test

Tensile strength, elongation at break, and Young's modulus were evaluated using Tinius Olsen H10KL universal Tester according to ASTM D882. A moving cross-head was used to pull the dumbbell shaped specimens apart with a load cell of 250 N and a test speed of 10 mm/min. The samples were prepared in accordance with the specified dimensions outlined in the ASTM standard. Film samples have been cut into dumbbell shapes for each specimen.

Table 3. General appearance of non-plasticized and plasticized CS films

Sample	Plasticizer	% of plasticizer	Film appearance	
CCS	-	-		Transparent, surface cracks, brittle and fragile, difficult to peel
G15	Glycerol	15		More transparent, sticky, not brittle and not fragile, flexible, easy to peel
G30	Glycerol	30		More transparent, more sticky than G15, not brittle and not fragile, flexible, easy to peel
G45	Glycerol	45		More transparent, more sticky than G30, not brittle and not fragile, flexible, easy to peel
G60	Glycerol	60		More transparent, more sticky than G45, not brittle and not fragile, flexible, easy to peel
F15	Fructose	15		Crystal clear, rigid, non-sticky, not brittle and not fragile, flexible, peelable
F30	Fructose	30		Crystal clear, rigid, non-sticky, not brittle and not fragile, Flexible than F15, peelable

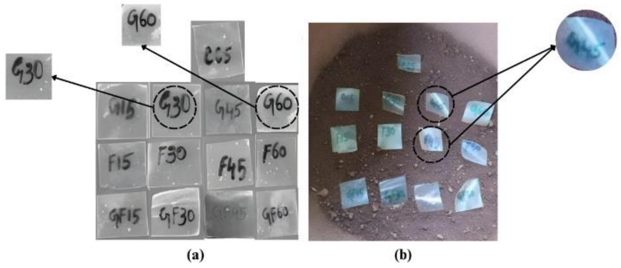
4.3. Environmental characteristics

4.3.1. Biodegradability test

For the soil burial test the sample was cut into pieces of size 4 cm^2. The initial weight of the sample was measured (Wi). Soil sample was collected in a container and the film sample was kept inside the soil at a depth of 3 cm for period of 9 weeks under the room condition. The degradation of sample is measured at 2 weeks, 4 weeks, 6 weeks and 9 weeks respectively. The degradation weight was measured (W_f). The amount of biodegradability of the sample specimen was measured using Equation (4). The test setup of soil burial test was shown in **Figure 2** for all film samples.

$$\textit{Weight Loss}\ (\%) = \left[\left(W_i - W_f\right) / W_i\right] \times 100 \qquad (4)$$

W_i and W_f are the weights of samples before and after the degradation in the soil.



(a) (b)

Figure 2. Soil degradability (a) Sample specimens (b) Samples placed inside the soil

4.3.2. Photodegradation test

Many plastic films are susceptible to photo degradation and oxidation under normal conditions. Photodegradation is the breakdown of a photodegradable molecule resulting from the absorption of photons, especially those wavelengths found in sunlight, including infrared radiation, visible light, and ultraviolet light. **Figure 3** depicts the process of photo degradation of bioplastic film.

Figure 3. Film before and after exposure of sunlight

5. Results and discussion

5.1. Physical characteristics

5.1.1. General appearance of bioplastic films

The visual appearance of non-plasticized and plasticized films with different plasticizers was shown in **Table 3**. The specimen CCS films denote control films without plasticizers. The CCS films were brittle, rigid, and fragile. More number of cracks were observed on the film surface. It is difficult to peel and handle, possibly because of solid hydrogen bonds between the corn starch molecules. It results in brittle and stiff films with surface cracks that give the macromolecular chains less movement.

5.1.2. Thickness of films

Figure 4 shows the variation in film thickness due to different plasticizer concentrations. The results show that the thickness of plasticized films increased when the plasticizer content increased from 15% to 60%, irrespective of the type of plasticizer was employed, and a similar observation was reported (Ibrahim *et al*. 2019). Similar findings were observed and suggested that plasticizers affected the deformation of the intermolecular polymer chain matrix (Sanyang *et al*. 2015). The deformation of the polymer chain matrix resulted in more free volume being provided, which led to an increase in film thickness. Also, the thickness results from different plasticizer types showed that the thicknesses of different plasticized films were very close, even though the molar mass of fructose is almost twice that of glycerol. It is revealed that the plasticizer's molar mass did not significantly affect the film's thickness. This result contradicted the findings reported in earlier investigations, which concluded that the thickness of the plasticized film was highly connected to the molar mass of the plasticizer utilized (Sanyang *et al*. 2015; Zentou *et al*. 2019; Shahabi-Ghahfarrokhi *et al*. 2018; Hazrol *et al*. 2021).

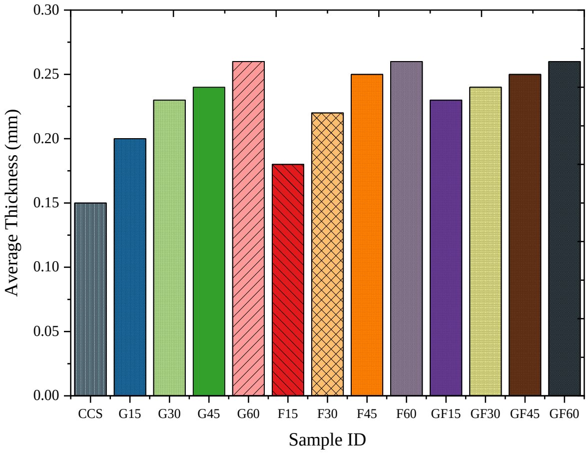


Figure 4. Thickness of bioplastic films

5.1.3. Water solubility

During the characterization of the water solubility test, the thickness of the film is a significant characteristic that should be considered. The thickness of the film is significant for food packaging applications, which occasionally need water insolubility and resistance (Basiak *et al*. 2018). In the same way that the results of the thickness test were observed, similar results were observed for the plasticized films' solubility test. The results of the study indicate that there was a considerable increase in solubility when the concentration of plasticizer was increased from 15% to 60% for all types of plasticizers, as depicted in **Figure 5**. The selected sample exhibits moisture affinity because of polyols which contribute to the weakening bond between polymer molecules and the expansion of the free space volume in the chains. The expansion made the films more soluble because water could more easily penetrate the polymer matrix (Sanyang *et al*. 2015). **Figure 5** also shows that the solubility varied from 32.75 to 48.98% for G-films, 37.4 to 51.2% for F-films, and 33.19 to 52.78% for FG-films, indicating that the results were very consistent throughout plasticizer types. Similar results may be due to the fact that both glycerol and fructose have a strong attraction to water. It was identified that the control specimen film with glycerol and fructose exhibited high water solubility percentage compared to the control specimen.

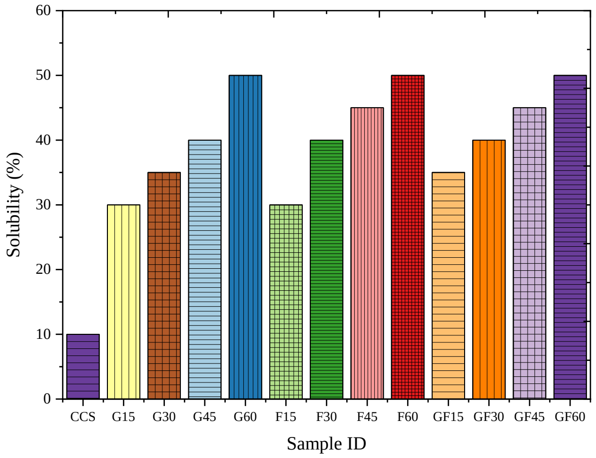


Figure 5. Water solubility of bioplastic films

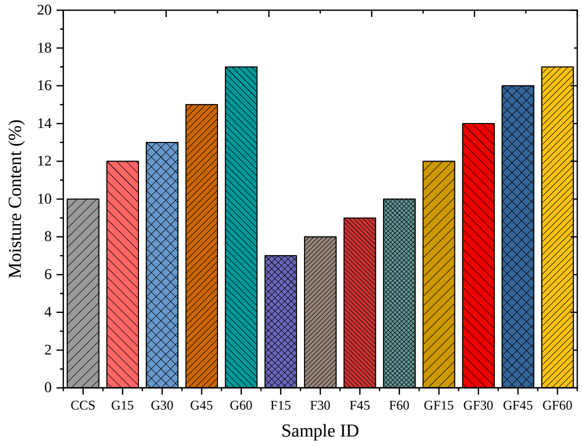


Figure 6. Moisture content of bioplastic films

5.1.4. Moisture content

Figure 6 depicts the moisture content of bioplastic films at various combinations. According to the figure, the G-film was found to have the maximum percentage of moisture content, while the F- film was found to have the lowest moisture content. In addition, the moisture content decreased as the concentration of the F-plasticizer increased from 15 to 60%. In contrast, the moisture content increased considerably from 12.3 to 18.6% as the amount of glycerol plasticizer increased from 15 to 60% in the F-plasticized film. Similar to the Gplasticizer, the increase in the concentration of the combined GF-plasticizer substantially increased the moisture content, with 11.08 and 15.26% observed for GF-plasticizer concentrations of 15% and 60%, respectively. However, the observed rise in the moisture content that occurred due to the addition of GF-plasticizer was significantly lower than the increase that occurred due to the addition of G-plasticizer to the film. When compared to glycerol-containing films, F-plasticized films have less moisture content. Low moisture content could be because the fructose and glucose units of the polymer have a similar molecular structure, which makes it easier for fructose molecules to connect to the intermolecular chains in the film (Ibrahim *et al*. 2019; Sanyang *et al*. 2015; Zentou *et al*. 2019; Shahabi-Ghahfarrokhi *et al*. 2018; Hazrol *et al*. 2021). As a result, there was less chance that the fructose molecules would come into contact with the water molecules. On the other hand, glycerol molecules with hydroxyl groups had a high affinity for water, which made it easier to form hydrogen bonds and keep water in the matrix of G-plasticized films (Cerqueira *et al*. 2012). Thus, fructose and glycerol were water-resistant and water-holding agents, respectively (Hazrol *et al*. 2021).

5.1.5. Water absorption

Starch films require a high capacity for water absorption since water plays such an essential role as a plasticizer. The plasticity of plasticized films increases as the percentage of water in the film increases (Sanyang *et al*. 2015; Zentou *et al*. 2019; Shahabi-Ghahfarrokhi *et al*. 2018; Hazrol *et al*. 2021; Ibrahim *et al*. 2019). Since it has been reported that plasticized samples began dissolving in water after 140 minutes (Bagde *et al*. 2019), the period of biofilm soaked in water was fixed at 120 minutes in this work. The findings of an investigation into the water absorption of plasticized films at various plasticizer concentrations are shown in **Figure 7**. The results indicate that around 30 minutes after immersion, all of the films, including the control film, had attained saturation, at which time further water absorption was minimal. The control sample absorbed about 185.6% more water than the other samples. At 15% plasticizer content, F-film absorbed the most water (173.45%), followed by GF- film at 155.56% and Gplasticized film at 148.45%. Water absorption was also found to decrease as plasticizer concentration was increased across all three categories of plasticized films. The water absorption of F-plasticizer decreased from 173.45 to 126.69% when the plasticizer concentration was raised from 15 to 60%; the water absorption of GF-plasticized film decreased from 148.45 to 113.46%, and the water absorption of G-plasticized film decreased from 155.56 to 72.90%. As a result, compared to G-plasticized and GF-plasticized films, Gplasticized films had greater resistance to water. Because of glycerol's strong hydrophobicity, soluble plasticizers may block the micro-voids in the matrix of the film, resulting in a decrease in water absorption. Hydrophobic plasticizers, on the other hand, might lead to the development of discontinuous regions or various phases in the film's matrix, both of which reduce its flexibility (Kochkina *et al*. 2020).

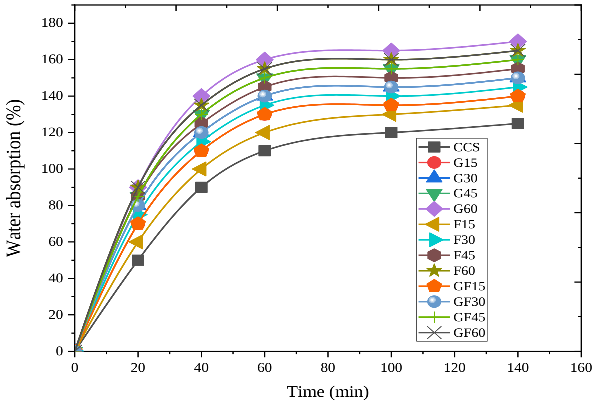


Figure 7. Water absorption of bioplastic films

5.2. Mechanical properties

5.2.1. Tensile strength

At various dosages, the tensile strength, elongation at break, and Young's modulus of different plasticized films were evaluated. **Figure 8** illustrates the effect of varying concentrations of various plasticizers on the tensile strength of CS films. The tensile strength of the F-plasticized film was 22.55 MPa at a concentration of 15%, the tensile strength of the FG plasticized film was 16.65 MPa, and the tensile strength of the G-plasticized film was 5.09 MPa. The findings confirmed the research (Edhirej *et al*. 2017), which revealed that F-plasticized CS film had greater tensile strength when compared to other plasticizers. Tensile strength was considerably diminished when the concentration of plasticizer was increased. The increase in plasticizer concentration from 15% to 60% decreased the tensile strength of the F-plasticized film from 22.55 to 8.67 MPa. G-film's tensile strength reduced from 5.09 to 2.75 MPa in comparison, and FG-film's reduced from 16.65 to 4.52 MPa. In multiple investigations studies (Sanyang *et al*. 2015; Zentou *et al*. 2019; Shahabi-Ghahfarrokhi *et al*. 2018; Hazrol *et al*. 2021; Ibrahim *et al*. 2019), the tensile strength of starch-based films decreased in response to an increase in plasticizer concentration. The incorporation of plasticizers increased the formation of hydrogen bonds between the starch molecules and the plasticizers, thereby weakening the intra molecular interactions between the starch chain molecules (Hazrati *et al*. 2021).

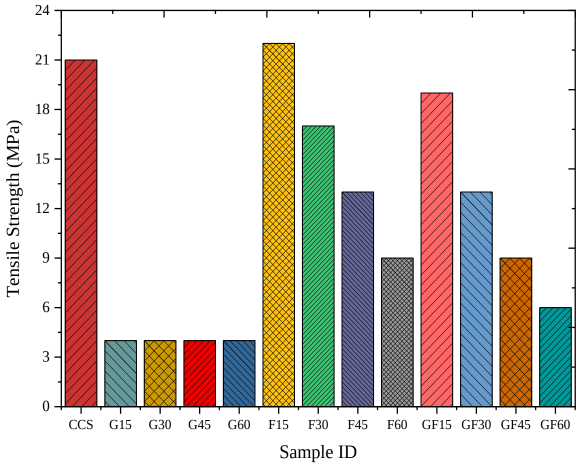


Figure 8. Tensile strength of bioplastic films

Young's modulus analysis was performed to evaluate the stiffness of the films, with a high Young's modulus indicating a material with a high degree of rigidity. According to **Figure 9**, F-plasticized films exhibited the highest Young's modulus, followed by FGplasticized films and G-plasticized films, in that order. Across all tested plasticizers, a decrease in tensile modulus was observed as plasticizer concentration increased from 30% to 60%, indicating that increasing plasticizer content made films less rigid. The rigidity of hydrophilic films decreases with increasing plasticizer concentration (Mali *et al*. 2002). This behavior may be attributable to the structural modifications of the starch network that occurred when plasticizers were added and the film matrix became less dense (Edhirej *et al*. 2017).

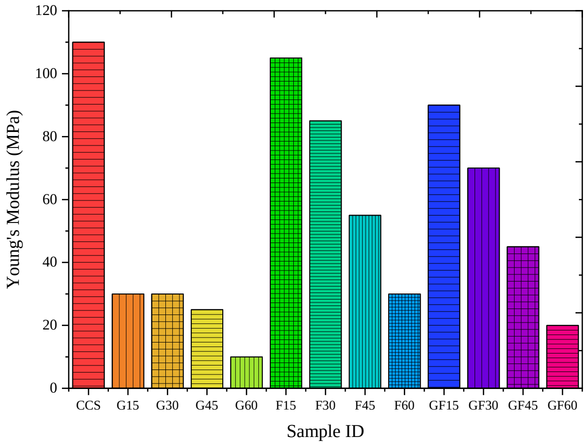


Figure 9. Youngs modulus of bioplastic films

Figure 10 displays that the F-plasticized and FG-plasticized films had greater elongations at break than the G-plasticized film. The elongation at break for F plasticized films was, however, increased by the plasticizer concentration. In contrast, when the plasticizer content was raised from 15 to 60%, a decrease in elongation at break was seen in FG-plasticized films. However, for G-films, where elongation at break values of 37.13% and 35.24% were reported at glycerol plasticizer concentrations of 150% and 60%, respectively, the effect of plasticizer concentration on elongation at break was not statistically significant.

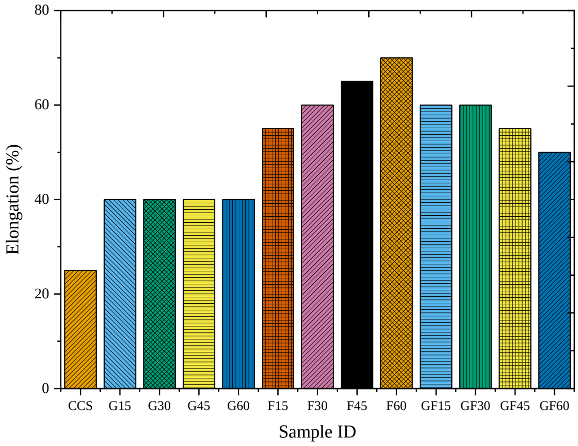


Figure 10. Elongation at break of bioplastic films

5.3. Environmental characteristics

5.3.1. Biodegradability

By measuring the value of material reduced in weight over time, it is possible to determine the rate of biodegradation caused by moisture in the soil and microorganisms (Alamjuri and Yusof, 2022). The weights before and after the test are compared to evaluate the amount of degradation in the soil burial test. After nine weeks of interment, all the composites dropped more weight than two and four weeks of degradation. The material lost more weight due to the increased number of microorganisms present during the extended period the item was buried in the soil (Jumaidin *et al*. 2017). The maximum weight loss of about 82% is achieved after 9 weeks of soil burial with fructose addition.

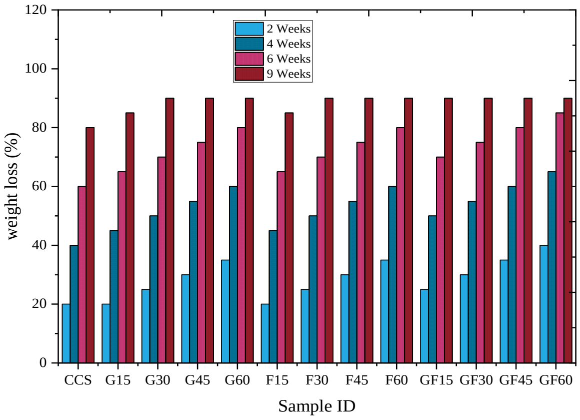


Figure 11. Biodegradability of bioplastics at 2,4,6,9 weeks

6. Conclusions

This research aims to develop an approach to producing environmentally friendly and biodegradable plastic. Evaluations are made for physical, mechanical, and biodegradability characteristics. The test results have led to the following conclusions:

- Corn starch films without plasticizers were fragile and hard to remove from the casting surface. Thus, using plasticizers facilitated reducing breakability and increasing the flexibility of CS films. Plasticizers of various types and dosages were employed to study the influences of CS films. The results revealed that the type and amount of plasticizers affected the thickness, density, and strength of the CS film.
- Gradually increasing the plasticizer concentration from 15% to 60% decreased the water absorption capability of the films, but it increased the film weight and thickness irrespective of the plasticizer form.
- F-plastic films exhibited lower moisture, solubility, and water absorption when compared to G and FG-plasticized films. Regarding physical and mechanical qualities, F-plasticized films demonstrated maximum efficiency. With a tensile stress of 22.55 MPa, the F15-plasticized films exhibited good mechanical strengths.
- Corn starch, fructose, and glycerol content can be optimized to improve the properties and applications of corn-based bioplastics. Furthermore, fillers must be added to improve the characteristics of corn-based bioplastics.
- **Potential limitations of cornstarch-based bioplastic**
- Most of the cornstarch-based bioplastics have inferior tensile strength, flexibility, and toughness compared to petroleum-based plastics. Even though plasticizers improve flexibility, they tend to lower strength and create inconsistencies in performance. Because cornstarch is hydrophilic, the bioplastic has high water absorption, which compromises dimensional stability and usability under humid or wet conditions. Production of cornstarch-based bioplastics is still quite costly, especially when scaled up for industrial applications, making them less competitive with traditional plastics. While the bioplastic performs well in controlled composting conditions, its degradation may be retarded in less friendly environmental conditions, such as marine or landfill settings.

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