Characterization and Evaluation of Biodegradable Film Prepared from Okra Mucilage (Abelmoschus esculentus)

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ABSTRACT
Background
This study was carried out to formulate and assess biodegradable films using okra mucilage as a natural and environmentally friendly substitute for conventional plastic films. Due to its biodegradable and polymer-forming nature, okra mucilage was selected as the main film-forming material.
Objective
To formulate and characterize biodegradable films from okra mucilage (Abelmoschus esculentus) and evaluate their physicochemical, mechanical, and biodegradation properties for potential pharmaceutical and packaging applications.
Materials and Methods
The prepared films were examined for various parameters including appearance, thickness, loss on drying, surface pH, folding endurance, biodegradability, FTIR, UV spectroscopy and XRD analysis.
Results
The films exhibited a smooth and transparent appearance with good flexibility, consistent thickness, suitable moisture content, and effective biodegradation properties. FTIR and XRD studies indicated the presence of characteristic functional groups and structural features that contribute to the film-forming capability of okra mucilage.
Conclusion
The findings suggest that okra mucilage-based films can serve as a promising biodegradable material for pharmaceutical and sustainable packaging applications.
Keywords: Okra mucilage; biodegradable film; natural polymer; XRD; sustainable packaging; biopolymer; soil biodegradation.
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1. Introduction

Biodegradable films are environmentally friendly polymeric materials that can naturally decompose into simpler substances such as carbon dioxide, water, and biomass through microbial activity. These films are considered sustainable alternatives to petroleum-based plastic films, which persist in the environment for long durations and contribute significantly to pollution. Natural polymers including starch, cellulose, pectin, chitosan, proteins, lipids, gums, and plant mucilage are commonly used for the preparation of biodegradable films because of their biodegradability, renewability, non-toxic nature, and excellent film-forming properties. Due to these advantages, biodegradable films are increasingly applied in packaging, pharmaceutical, biomedical, and agricultural fields [1].

Synthetic plastic films are widely used because they are lightweight, durable, flexible, and inexpensive. However, their non-biodegradable nature creates major environmental concerns. Plastic waste accumulates in soil and aquatic ecosystems, leading to environmental pollution and formation of microplastics that may enter the food chain and affect both animals and humans. In addition, the production and disposal of plastics release harmful chemicals and greenhouse gases, contributing to environmental degradation and climate-related problems. Therefore, the development of biodegradable substitutes has become increasingly necessary for environmental sustainability [2].

Natural polymers derived from plants, animals, and microorganisms are extensively investigated for biodegradable film development because of their eco-friendly nature and good film-forming characteristics. Polysaccharides such as starch, cellulose, pectin, gums, mucilage, and chitosan are commonly preferred due to their abundance and favorable mechanical properties. Protein-based materials including gelatin and casein also contribute to flexible film formation through intermolecular interactions, while lipids are incorporated to improve resistance against moisture. Film formation mainly occurs through hydrogen bonding and interactions between polymer chains, resulting in cohesive and stable biodegradable film matrices [3,4].

Okra mucilage obtained from Abelmoschus esculentus is a natural biopolymer mainly composed of polysaccharides such as galactose, rhamnose, and galacturonic acid. It exhibits excellent viscosity, water-holding ability, elasticity, and gel-forming properties, making it highly suitable for biodegradable film preparation. The polysaccharide chains in okra mucilage interact through hydrogen bonding to produce transparent and flexible films. Additionally, okra mucilage is biodegradable, biocompatible, non-toxic, economical, renewable, and easily available. Previous studies have reported that films prepared from okra mucilage possess satisfactory mechanical strength, thermal stability, swelling behavior, and biodegradability, suggesting their potential application as alternatives to synthetic plastic films in pharmaceutical and packaging industries [5,6].

Biodegradable films have important applications in the pharmaceutical field because of their flexibility, safety, compatibility, and controlled degradation properties. These films are used in drug delivery systems, wound dressings, transdermal patches, pharmaceutical coatings, and packaging materials. Natural polymer-based films help protect pharmaceutical products from moisture, oxygen, and microbial contamination while simultaneously reducing environmental pollution caused by synthetic plastics. Due to its bioadhesive nature and eco-friendly characteristics, okra mucilage has emerged as a promising material for pharmaceutical film applications [7,8].

The increasing environmental burden caused by synthetic plastic waste has generated the need for sustainable and biodegradable alternatives. Although several natural polymers have been explored for biodegradable film production, there remains a demand for economical, renewable, and efficient materials possessing suitable physicochemical and mechanical properties. Okra mucilage is a naturally available polysaccharide with excellent film-forming potential; however, its application in biodegradable film development is still limited. Therefore, the present study focuses on the preparation and evaluation of biodegradable films using okra mucilage as a natural polymeric material to develop environmentally safer alternatives to synthetic plastic films [9,10].

Fig. 1. Abelmoschus esculentus (okra pods, plant material and mucilage film).

The aim of the present study was to formulate and evaluate biodegradable films prepared from okra mucilage as an eco-friendly substitute for synthetic plastic films. The objectives included extraction of mucilage from fresh okra pods, preparation of biodegradable films using the extracted mucilage, evaluation of physical and mechanical characteristics of the films, characterization using analytical techniques such as FTIR, UV spectroscopy and XRD, and assessment of biodegradability and pharmaceutical applications of the prepared films.

2. Materials and Methods

2.1 Materials

The materials used for the preparation of biodegradable films in the present study included sodium alginate, glycerin, gelatin, fresh okra pods and distilled water.

Sodium alginate, used as a primary film-forming polymer, was procured from ACME Chemicals, supplied by ACME Traders, Mumbai (Tel: 022-22082615; Email: chem.acme@gmail.com), and was of laboratory reagent grade with a packaging size of 500 g.

Glycerin was used as a plasticizer to enhance the flexibility and reduce brittleness of the films and was obtained from Poona Chemical Laboratory, located at 207, Mangalwar Peth, Wellesley Road, Pune - 411011.

Gelatin, utilized as a natural polymer to enhance film strength and film-forming properties, was used in the form of gelatin powder (500 g, laboratory reagent grade), which was repackaged by S.D. Lab Chemical Centre, Mumbai - 400002.

Fresh okra (Abelmoschus esculentus) pods used for the extraction of okra mucilage were procured from Kasturba Market, Balives, a local market in Solapur city. Distilled water used in the preparation of biodegradable films was obtained from the college laboratory and was used as a solvent throughout the formulation process. All chemicals and reagents used in the study were of laboratory grade.

2.2 Instruments and Equipment

The instruments and laboratory equipment used during the study included beaker, dropper, china dish, burner, spatula, measuring cylinder, Vernier calliper, hot air oven, pH meter, XRD instrument, UV spectrophotometer and FTIR spectrophotometer.

2.3 Extraction of Okra Mucilage

Fresh mature okra pods (Abelmoschus esculentus) were procured from a local market and thoroughly washed with distilled water to remove surface impurities. Approximately 250 g of okra pods were cut into small pieces and soaked in 500 mL of distilled water for 24 h at cold temperature to facilitate maximum release of mucilage.

Following soaking, the hydrated mass was passed through a suitably sized sieve to separate the mucilage from insoluble plant material. The sieve retained the seeds and fibrous green outer portions of the pods, while the viscous mucilage filtrate was collected in a clean beaker. The obtained mucilage was stored under refrigerated conditions until further use.

The extracted mucilage was subsequently utilized for the preparation of biodegradable films. Depending on the formulation requirement, appropriate quantities of mucilage were used for film casting.

2.4 Preparation of Biodegradable Film

Table 1. Stepwise preparation procedure for biodegradable film.

Step	Procedure
1	Take 5 mL distilled water and heat at 45-50°C with continuous stirring.
2	Add 0.3 g gelatin slowly and stir until completely dissolved.
3	Add 1 g sodium alginate gradually and stir to obtain uniform dispersion.
4	Add 2-3 drops of glycerin and mix thoroughly.
5	Add 5 mL okra mucilage slowly under continuous stirring.
6	Stir continuously to obtain a homogeneous viscous film-forming solution.
7	Pour the solution into a clean leveled petri plate/casting mold.
8	Dry the casted film under controlled conditions until completely dried.
9	Peel off the dried film carefully and store in an airtight container.

Step 1: Preparation of Polymer Solution

Distilled water (5 mL) was taken in a clean and dry beaker and heated at 45-50°C on a magnetic stirrer. Continuous stirring was carried out to obtain proper dissolution and uniform mixing of the polymers. Distilled water was used to avoid interference from impurities and dissolved ions.

Step 2: Addition of Gelatin

Gelatin (0.3 g) was slowly added to the warm water under continuous stirring until a clear and viscous solution was formed. Proper dissolution of gelatin was ensured to avoid lump formation. Gelatin was used as a film-forming polymer to improve flexibility and mechanical strength of the film.

Step 3: Incorporation of Sodium Alginate

Sodium alginate (1 g) was gradually added to the gelatin solution with continuous stirring at controlled temperature. Stirring was continued until a smooth and homogeneous polymeric solution was obtained. Sodium alginate was incorporated to improve film-forming ability, structural stability, and biodegradability.

Step 4: Addition of Glycerin

Approximately 2-3 drops of glycerin were added to the polymeric mixture under continuous stirring. Glycerin was used as a plasticizer to improve flexibility and reduce brittleness of the film. Uniform mixing was maintained to ensure proper distribution throughout the solution.

Step 5: Addition of Okra Mucilage

Extracted okra mucilage (5 mL) was slowly added into the polymeric solution while continuous stirring was maintained at 45-50°C. The mucilage was incorporated to enhance biodegradability, viscosity, and film-forming properties. Proper mixing was carried out to obtain a uniform polymer matrix.

Step 6: Preparation of Homogeneous Film-Forming Solution

The complete polymeric mixture was stirred continuously until a clear, viscous, and homogeneous film-forming solution was obtained. The solution was allowed to stand for a short time, if required, to remove entrapped air bubbles before casting.

Step 7: Casting of Film

The prepared solution was poured onto a clean and leveled glass petri plate or casting surface and spread uniformly to obtain films of even thickness. Care was taken to prevent bubble formation and uneven surfaces during casting.

Step 8: Drying of Film

The casted film solution was dried under controlled conditions until complete evaporation of water occurred and a stable film was formed. Proper drying conditions were maintained to avoid cracking, brittleness, and shrinkage of the film.

Step 9: Removal and Storage of Film

After complete drying, the prepared film was carefully removed from the casting surface and visually inspected for smoothness, flexibility, and transparency. The films were stored in airtight containers or desiccators until further evaluation and characterization studies were performed.

2.5 Characterization of Films

2.5.1 Thickness Measurement

The thickness test was carried out using a Vernier calliper to check the uniformity of the biodegradable film. Uniform thickness is important because it affects the strength, flexibility, and moisture permeability of the film. The thickness was measured at different places on the film, and the average thickness was found to be 0.11 mm. The results showed only small variations in thickness, indicating proper film formation and even distribution of the polymers [5].

Fig. 2. Thickness measurement using Vernier calliper.

2.5.2 pH Test

The pH test was performed using a digital pH meter to determine the acidic or basic nature of the film solution. The prepared film showed a pH value of 7.28, which indicates a nearly neutral nature. Neutral pH is beneficial because it improves the stability and compatibility of the film for pharmaceutical and packaging applications. The result also suggests proper mixing of okra mucilage, sodium alginate, gelatin, and glycerin in the formulation [5].

Fig. 3. pH test of the prepared film solution.

2.5.3 Folding Endurance

The folding endurance test was done to evaluate the flexibility and durability of the biodegradable film. In this test, the film was folded repeatedly at the same place until it broke. The prepared film showed good folding endurance, which indicates that the film was flexible and not brittle. The addition of glycerin acted as a plasticizer and improved the flexibility of the film [5].

Fig. 4. Folding endurance test of the biodegradable film.

2.5.4 Loss on Drying (LOD)

The loss on drying (LOD) test was carried out to determine the amount of moisture present in the biodegradable film. Moisture content affects the flexibility, stability, and shelf life of the film. The prepared film showed an LOD value of 3%, indicating low moisture content and good stability during storage. Lower moisture content also helps in reducing microbial growth while maintaining suitable flexibility [5].

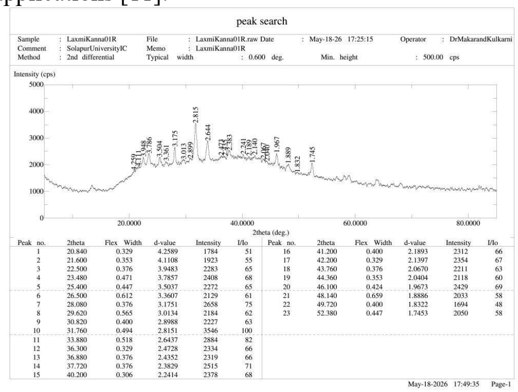
Fig. 5. Loss on drying test of the prepared film.

2.6 Analytical Characterization

2.6.1 X-Ray Diffraction (XRD) Study

X-ray diffraction (XRD) analysis is an important technique used to study the internal structure and crystallinity of biodegradable films prepared from okra mucilage. This method helps identify whether the film possesses crystalline or amorphous characteristics by analyzing the diffraction pattern produced by X-rays. The crystalline portions of the film contribute to higher mechanical strength and structural stability, whereas the amorphous regions improve flexibility, swelling capacity, and biodegradability.

Okra mucilage-based films generally exhibit semi-crystalline nature because of the polysaccharide composition present in the natural polymer. The appearance of broad diffraction peaks in the XRD spectrum indicates amorphous behaviour, while distinct sharp peaks suggest ordered crystalline arrangements within the polymer matrix. Such semi-crystalline properties are considered beneficial because they provide a suitable balance between flexibility and mechanical durability, making the films appropriate for biodegradable packaging applications [11].



Peak no.	2theta	Flex Width	d-value	Intensity	I/Io	Peak no.	2theta	Flex Width	d-value	Intensity	I/Io
1	20.840	0.329	4.2589	1784	51	16	41.200	0.400	2.1893	2312	66
2	21.600	0.353	4.1108	1923	55	17	42.200	0.329	2.1397	2354	67
3	22.500	0.376	3.9483	2283	65	18	43.760	0.376	2.0670	2211	63
4	23.480	0.471	3.7857	2408	68	19	44.360	0.353	2.0404	2118	60
5	25.400	0.447	3.5037	2272	65	20	46.100	0.424	1.9673	2429	69
6	26.500	0.612	3.3607	2129	61	21	48.140	0.659	1.8886	2033	58
7	28.080	0.376	3.1751	2658	75	22	49.720	0.400	1.8322	1694	48
8	29.620	0.565	3.0134	2184	62	23	52.380	0.447	1.7453	2050	58
9	30.820	0.400	2.8988	2227	63						
10	31.760	0.494	2.8151	3546	100						
11	33.880	0.518	2.6437	2884	82						
12	36.300	0.329	2.4728	2334	66						
13	36.880	0.376	2.4352	2319	66						
14	37.720	0.376	2.3829	2515	71						
15	40.200	0.306	2.2414	2378	68						

Fig. 6. XRD diffractogram of the prepared biodegradable film.

Table 2. Major XRD diffraction peaks observed.

Peak group	2θ values observed
Group I	20.84°, 21.60°, 22.50°, 23.48°, 25.40°, 26.50°, 28.08°
Group II	29.62°, 30.82°, 31.76°, 33.88°, 36.30°, 37.72°, 40.20°
Group III	41.20°, 42.20°, 43.76°, 46.10°, 48.14°, 49.72°, 52.38°

The highest intensity peak was observed at 31.76° with intensity 3546 cps. The XRD diffractogram exhibited multiple diffraction peaks indicating partially crystalline nature of the prepared material. The presence of broad and moderately intense peaks suggests semi-crystalline polymeric behaviour commonly observed in natural polysaccharide-based biopolymer films.

The intense peak at 31.76° indicates ordered molecular arrangement in certain regions of the polymer matrix, while the overall broad diffraction profile indicates significant amorphous characteristics due to natural polysaccharide chains. This semi-crystalline behaviour is advantageous because crystalline regions provide strength, whereas amorphous regions provide flexibility and biodegradability.

2.6.2 Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared spectroscopy (FTIR) is widely used to identify the chemical functional groups and molecular interactions present in biodegradable films. This technique helps confirm the presence of important chemical groups such as hydroxyl, carbonyl, and polysaccharide components responsible for film formation and stability. FTIR analysis is also useful for studying compatibility between different polymers and plasticizers used in the formulation.

The FTIR spectra of okra mucilage-based films usually display broad absorption bands related to O-H stretching vibrations, indicating strong hydrogen bonding among polymer chains. Additional peaks corresponding to C-H and C=O groups confirm the presence of natural polysaccharide structures within the film matrix. These intermolecular interactions improve film strength, flexibility, water retention ability, and overall stability. FTIR results also demonstrate that okra mucilage acts as an effective natural polymer suitable for the development of biodegradable films [6].

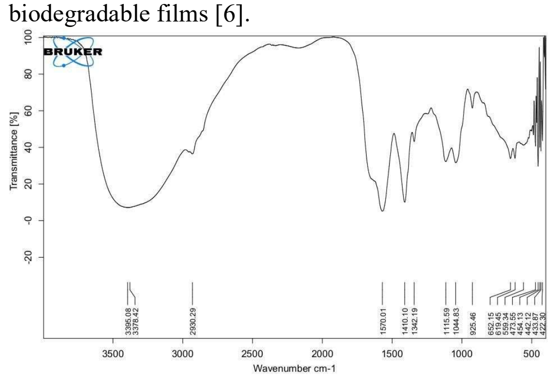


Fig. 7. FTIR spectrum of the prepared biodegradable film.

FTIR analysis confirmed the presence of all major functional groups of the film components. The broad absorption at 3395 cm^{-1} indicates O-H stretching from polysaccharide hydroxyl groups. The peak at 1570 cm^{-1} corresponds to the Amide II band, confirming gelatin incorporation. Sodium alginate was identified by COO^- stretching at 1410 cm^{-1}. The C-O-C stretching at 1115 cm^{-1} and pyranose ring vibration at 925 cm^{-1} confirm the intact polysaccharide structure of okra mucilage. The absence of new covalent bond peaks suggests physical compatibility among film components.

2.6.3 UV Spectroscopy

UV-Visible (UV-Vis) spectroscopy is based on the principle that molecules absorb ultraviolet and visible light at specific wavelengths, causing the excitation of electrons from lower-energy orbitals to higher-energy orbitals. The amount of light absorbed is proportional to the concentration of the absorbing species and follows the Beer-Lambert law. In biodegradable film characterization, UV-Vis spectroscopy is used to evaluate optical properties such as transparency, absorbance, transmittance, and UV-barrier capacity. For okra mucilage-based films, the technique helps assess the film's ability to block harmful UV radiation while maintaining adequate visible-light transparency, which is important for packaging applications [10,11].

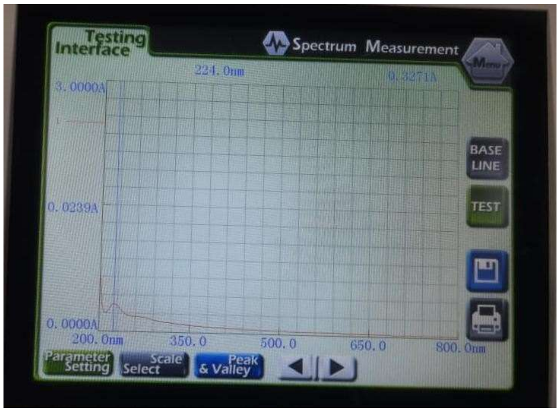


Fig. 8. UV-Visible spectrum of the biodegradable film.

$$T = 10^{-A}$$

$$T = 10^{-0.3271} = 0.4708$$

$$\%T = 0.4708 \times 100 = 47.08\%$$

The UV-Visible spectrum of the biodegradable film showed a maximum absorption peak (λmax) at 224 nm with an absorbance of 0.3271. This indicates the presence of UV-absorbing groups in the film matrix. The calculated transmittance (47.08%) suggests moderate transparency and partial UV-blocking ability. These results indicate that the film possesses suitable optical properties for potential biodegradable packaging applications.

2.7 Biodegradability Study

Biodegradability study determines the ability of the film to decompose naturally by microorganisms under environmental conditions.

For 7 days:

Biodegradation (%) = [(1.53 - 1.05) / 1.53] × 100 = 31.3%

For 14 days:

Biodegradation (%) = [(1.53 - 0.76) / 1.53] × 100 = 50.3%

For 21 days:

Biodegradation (%) = [(1.53 - 0.57) / 1.53] × 100 = 62.7%

For 28 days:

Biodegradation (%) = [(1.53 - 0.30) / 1.53] × 100 = 80.39%

3. Results

3.1 XRD (X-Ray Diffraction Study)

XRD analysis revealed several diffraction peaks with a major peak at 31.76°.

3.2 Visual Characteristics Test (Organoleptic Evaluation)

The prepared biodegradable film was evaluated visually for colour, texture, odor, flexibility, transparency, and surface characteristics. The film showed a brownish-yellow appearance with smooth surface texture and good flexibility.

Table 3. Observation of organoleptic evaluation.

Parameter	Observation
Colour	Brownish yellow
Odor	Odourless
Texture	Smooth and flexible
Surface appearance	Uniformity
Flexibility	Good
Transparency	Transparent

3.3 Thickness Test

The thickness of the prepared film was measured at different locations using a Vernier calliper.

Table 4. Observation table of thickness test.

Reading	Thickness (mm)
T1	0.12
T2	0.11
T3	0.12
T4	0.13
T5	0.10

3.4 Loss on Drying

Table 5. Observation table of LOD.

Parameter	Value
Initial weight	1 g
Final weight	0.97 g
LOD	3%

3.5 pH Test

The pH of the prepared film solution was determined using a digital pH meter.

Table 6. Observation table of pH test.

Parameter	Value
pH	7.28

3.6 Folding Endurance Test

Table 7. Observation table of folding endurance test.

Parameter	Value
Number of folds before breaking	12

3.7 Fourier Transform Infrared Spectroscopy (FTIR)

Table 8. Observation table of FTIR.

Wavenumber (cm^{-1})	Functional group	Interpretation

Wavenumber (cm^{-1})	Functional group	Interpretation
3395	O-H stretching vibration	Indicates the presence of hydroxyl groups from polysaccharides in okra mucilage.
1570	Amide II band	Confirms the incorporation of gelatin into the film matrix.
1410	COO^- stretching vibration	Characteristic peak of sodium alginate, confirming its presence in the film.
1115	C-O-C stretching vibration	Indicates the presence of polysaccharide backbone structure.
925	Pyranose ring vibration	Confirms the intact polysaccharide structure of okra mucilage.

3.8 UV Spectroscopy

Table 9. Observation table of UV absorption.

Parameter	Value
Wavelength of maximum absorption (λmax)	224 nm
Absorbance (A)	0.3271
Transmittance (T)	0.4708
Percentage transmittance (%T)	47.08%
Observation	UV absorption peak at 224 nm

3.9 Biodegradability Study

Table 10. Observation table of biodegradability study.

Days	Initial weight (g)	Final weight (g)	Biodegradability (%)
7 days	1.53	1.05	31.3
14 days	1.53	0.76	50.3
21 days	1.53	0.57	62.7
28 days	1.53	0.30	80.39

4. Discussion

The prepared okra mucilage film showed satisfactory properties suitable for biodegradable film applications. The smooth texture and transparency indicate proper film formation and uniform distribution of the polymer matrix. The low moisture content (3%) may help improve storage stability and reduce microbial growth.

The neutral pH value (7.28) suggests that the film is chemically stable and suitable for pharmaceutical and packaging applications. The folding endurance result showed that the film possesses acceptable flexibility and mechanical strength.

FTIR results confirmed the presence of functional groups responsible for film formation and hydrogen bonding, which contributes to flexibility and stability of the film. XRD analysis showed semi-crystalline behavior, where crystalline regions provide strength while amorphous regions provide flexibility and biodegradability.

The biodegradation study confirmed that the developed film can naturally decompose, reducing environmental pollution caused by conventional plastic materials.

5. Conclusion

This research successfully prepared and assessed a biodegradable film utilizing okra mucilage as a natural polymeric material. The formulated film demonstrated satisfactory physical and mechanical properties, confirming the suitability of okra mucilage for film development. The film possessed a transparent appearance, smooth texture, good flexibility, uniform thickness (0.11 mm), a near-neutral pH value (7.28), and low moisture content (3%), indicating favorable stability and performance.

The characterization studies provided further evidence of successful film formation. FTIR analysis verified the presence of functional groups associated with polymer interactions, whereas XRD analysis indicated a semi-crystalline structure that supported both flexibility and structural integrity. The film also exhibited acceptable folding endurance, reflecting its ability to withstand repeated bending without damage.

Biodegradation studies revealed a gradual reduction in film weight under soil conditions, reaching approximately 80.39% degradation within 28 days. This observation confirms the biodegradable nature of the developed film and its capacity to decompose naturally over time.

Based on the overall findings, okra mucilage can be considered an effective, renewable, and biodegradable biopolymer for film preparation. The developed film showed promising physicochemical, structural, and biodegradation characteristics, highlighting its potential for applications in pharmaceutical formulations and sustainable packaging systems. The outcomes of this study may serve as a useful reference for future investigations aimed at improving and expanding the use of okra mucilage-based biodegradable films.

6. Summary of Findings

The study successfully prepared a biodegradable film utilizing okra mucilage as a natural biopolymer. Evaluation of the film showed favorable characteristics such as a smooth appearance, transparency, flexibility, and consistent thickness (0.11 mm). The measured pH of 7.28 indicated a nearly neutral nature, while the low moisture content (3%) suggested good stability during storage. FTIR analysis verified the presence of functional groups involved in film formation, and XRD results demonstrated a semi-crystalline structure that contributed to the film's mechanical stability and flexibility. Furthermore, the film exhibited satisfactory folding endurance and underwent substantial biodegradation, achieving 80.39% degradation within 28 days. These observations confirm the successful development of a biodegradable film with desirable properties.

7. Significance of the Study

The findings of this research demonstrate the potential of okra mucilage as an effective natural material for biodegradable film production. The study provides evidence that okra mucilage possesses suitable film-forming and biodegradation characteristics, making it a valuable biopolymer for sustainable applications. The results contribute to the growing body of knowledge on plant-based biodegradable materials and support their utilization in pharmaceutical and packaging fields. In addition, this work offers a foundation for future investigations focused on developing environmentally friendly film systems.

8. Future Scope

Further research may be directed toward enhancing the physical and mechanical performance of okra mucilage-based films through formulation optimization or combination with other natural polymers. Future studies can also investigate properties such as water resistance, antimicrobial activity, and long-term stability. The incorporation of active pharmaceutical ingredients and assessment of controlled drug release behavior may broaden their pharmaceutical applications. Moreover, large-scale production studies and advanced characterization techniques could facilitate the practical implementation of these films in packaging, biomedical, and pharmaceutical sectors.

9. References

1. Kumar R, Verma A, Shome A, et al. Impacts of plastic pollution on ecosystem services, sustainable development goals, and need to focus on circular economy and policy interventions. Sustainability. 2021;13(17):9963.
2. Yin Y, Woo MW. Transitioning of petroleum-based plastic food packaging to sustainable bio-based alternatives. Sustainable Food Technology. 2024;2(3):548-566.
3. Ponnusamy PG, Mani S. Material and environmental properties of natural polymers and their composites for packaging applications - A review. Polymers. 2022;14(19):4033.
4. Shiam MA, Islam MS, Ahmad I, Haque SS. A review of plant-derived gums and mucilages: Structural chemistry, film forming properties and application. Journal of Plastic Film & Sheeting. 2025;41(2):195-237.
5. de Alvarenga Pinto Cotrim M, Mottin AC, Ayres E. Preparation and characterization of okra mucilage (Abelmoschus esculentus) edible films. Macromolecular Symposia. 2016;367(1):90-100.
6. Araújo A, Galvão A, Silva Filho C, et al. Okra mucilage and corn starch bio-based film to be applied in food. Polymer Testing. 2018;71:352-361.
7. Popović K, Živanović S, Jevtić I. Biopolymer packaging materials in the pharmaceutical industry. Aidasco Reviews. 2024;2(1):46-56.
8. Shekar BC, et al. Applications of biodegradable polymeric films in pharmaceutical formulations. International Journal of Pharmaceutical Sciences. 2024.
9. Sun Y, Yang W, Shi H, et al. Past, present, and future perspectives of biodegradable films for soil: A 30-year systematic review. Frontiers in Bioengineering and Biotechnology. 2022;10:1006388.
10. Dirpan A, Ainani AF, Djalal M. A review on biopolymer-based biodegradable film for food packaging: trends over the last decade and future research. Polymers. 2023;15(13):2781.
11. Olawuyi IF, Lee WY. Development and characterization of biocomposite films based on polysaccharides derived from okra plant waste for food packaging application. Polymers. 2022 Nov 12;14(22):488.