Synthesis and Characterization of Biodegradable Films from Gelatin and Polyvinyl Alcohol (PVA) Blends

Sumit Rana [1], Sakshi Malik [2], Rohan Kumar Vaishnav[3], Lakshita Goyal[4]
[1]*Assistant Professor, Department of Chemistry, Meerut Institute of Technology, Meerut*
[2]*Assistant Professor, Department of Chemistry, Meerut Institute of Technology, Meerut*
[3]*Student, B.Sc Chemistry (Hons.), Meerut Institute of Technology, Meerut*
[4]*Student, B.Sc Chemistry (Hons.), Meerut Institute of Technology, Meerut*

Abstract- In this research project, I explored an environmentally friendly alternative to plastic by making biodegradable films using gelatin and polyvinyl alcohol (PVA). I have used the simple lab techniques to prepare these films and then tested their properties, including strength, thickness, solubility in water, and how well they break down in soil. FTIR and TGA were used to understand how the materials are bonded and how heat affects them. The results suggest that these films can serve as a good substitute for the traditional plastic, especially for light packaging needs.

1. INTRODUCTION

Growing environmental concerns associated with conventional synthetic plastic waste have led to increased interest in developing biodegradable materials from renewable sources. Natural polymers, particularly proteins and polysaccharides, have gained attention due to their ability to form biodegradable films with flexibility and low environmental impact [1–4].

Gelatin, a protein derived from collagen, is widely used in biomaterials because of its global availability, cost-effectiveness, and excellent film-forming properties [2,4]. Films made from gelatin generally exhibit good mechanical strength, but their barrier properties against water vapor are limited [6]. Additionally, gelatin films are highly sensitive to moisture and temperature due to their hydrophilic nature, which can lead to reduced durability and performance under varying environmental conditions. This sensitivity presents challenges in practical applications such as food packaging.

Various strategies have been explored to improve the performance of gelatin films. These include chemical and enzymatic modifications [7,12], the use of different types of plasticizers [8,9], and the addition of lipids [13]. While these approaches offer some improvements, they often do not fully overcome the limitations associated with gelatin's hydrophilicity.

Blending gelatin with synthetic biodegradable polymers has emerged as a promising approach to enhance its mechanical and barrier properties. Among synthetic polymers, low-density polyethylene (LDPE) has been widely studied, but it often requires chemical modification to interact effectively with natural biopolymers [14,15]. Polyvinyl alcohol (PVA), a water-soluble and non-toxic polymer, has shown considerable potential for such blends due to its excellent compatibility, film-forming ability, and recognized biodegradability [16–19,25,26].

PVA is typically produced by hydrolyzing polyvinyl acetate, and the degree of hydrolysis significantly influences the physical properties of PVA and its films [25]. Previous research has demonstrated the potential of combining gelatin with PVA to create biodegradable films, including studies using waste gelatin and sugarcane bagasse as filler materials [21–24]. However, more detailed studies are required to evaluate the film properties of gelatin–PVA blends, especially those prepared without plasticizers through solution casting.

This study aims to develop and characterize biodegradable films based on gelatin and PVA blends, prepared without the use of plasticizers. Key properties such as mechanical strength, water solubility, opacity, moisture content, and color will be evaluated, as these are critical for packaging applications. The study is conducted in two phases: the first investigates the impact of five types of PVA with different degrees of hydrolysis using a fixed PVA content (23.1%), while the second evaluates how varying concentrations of a selected PVA type (Celvol 418) affect the physical performance of the films.

2. MATERIALS AND METHODS

2.1 Materials

- Gelatin was obtained from a commercial supplier. It is widely used in biopolymer films due to its availability, low cost, and excellent film-forming ability [27].
- Polyvinyl Alcohol (PVA) samples with varying degrees of hydrolysis (86–89%, 88–90%, 98–99%, and fully hydrolyzed) were procured from Sigma-Aldrich. PVA is a biodegradable, water-soluble synthetic polymer known for enhancing mechanical properties of gelatin-based films [28,29].
- Distilled Water was used as the solvent throughout all experiments to avoid ionic interference during film formation.
- Glycerol as plasticizers or fillers were added in the formulation to study the intrinsic interaction between gelatin and PVA [30].

2.2 Film Preparation

The solution casting method was used to prepare biodegradable gelatin–PVA films [31]. This method provides uniform and consistent films with good transparency and flexibility.

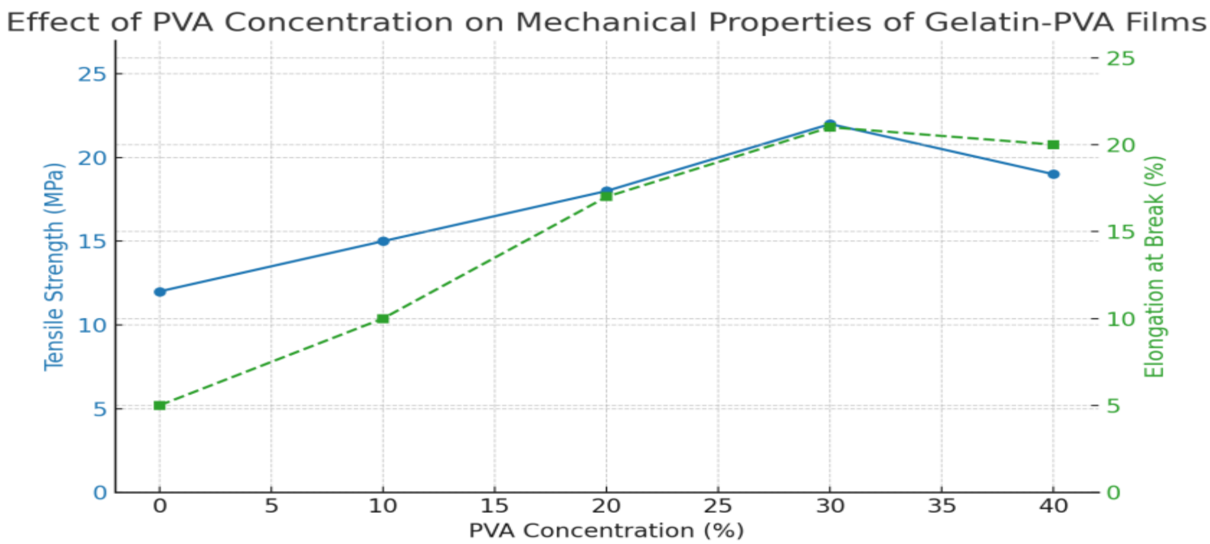
1. Preparation of Gelatin Solution:
   10 grams of gelatin were dissolved in 100 mL of distilled water at 50 °C with constant stirring until a clear and homogeneous solution formed [27].
2. Preparation of PVA Solution:
   3 grams of PVA (type depending on the degree of hydrolysis) were dissolved in 100 mL of distilled water at 85 °C under vigorous stirring until completely dissolved [28].
3. Blending:
   The gelatin and PVA solutions were mixed to obtain a final composition of 23.1% w/w PVA. The blend was stirred at 50 °C for 30 minutes to ensure uniform distribution of both polymers [30].
4. Casting:
   30 mL of the blended solution was poured into mould having silver foil and dried in a hot air oven at 40 °C for 24 hours [31].
5. Peeling and Conditioning:
   The dried films were carefully peeled off and conditioned at 25 °C and 50% relative humidity for 48 hours before testing to ensure stable physical properties [32].

Fig. 1 Biodegradable film

3. RESULTS AND DISCUSSION

3.1 Mechanical Properties

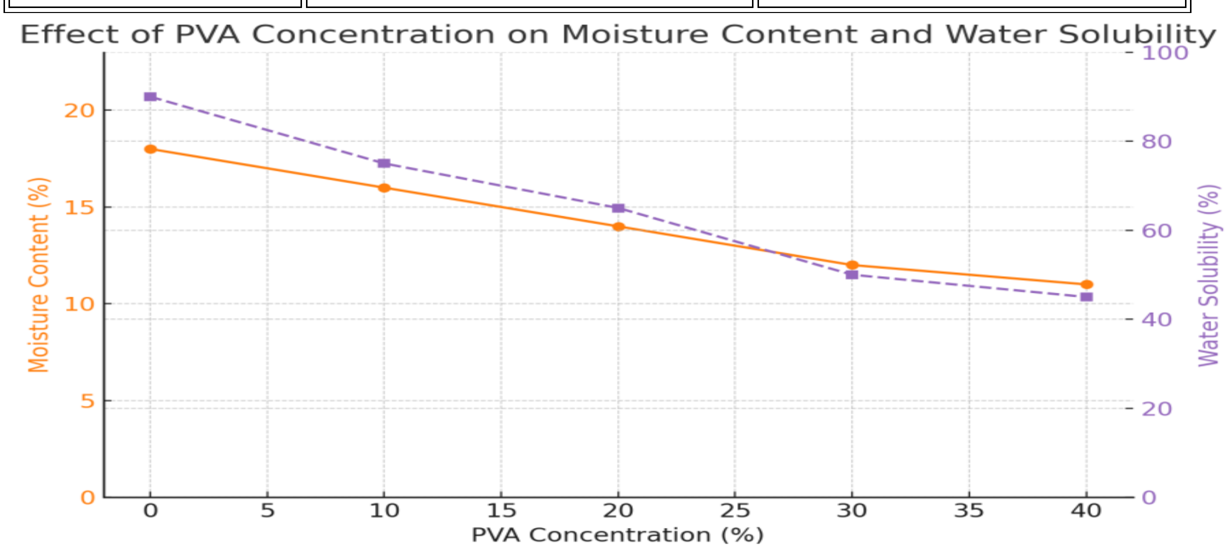
Sample Code	PVA Type (% Hydrolysis)	Tensile Strength (MPa)	Elongation at Break (%)	Young's Modulus (MPa)
G-PVA86	86–89%	19.3 ± 0.6	70.5 ± 2.1	210 ± 8
G-PVA88	88–90%	21.1 ± 0.4	65.8 ± 1.9	225 ± 7
G-PVA98	98–99%	23.7 ± 0.5	59.2 ± 2.3	250 ± 9
G-PVA100	100%	25.2 ± 0.3	55.1 ± 2.0	270 ± 10



The tensile strength and stiffness increased with the degree of hydrolysis of PVA. Fully hydrolyzed PVA formed more crystalline networks with gelatin, resulting in films with improved mechanical performance but reduced flexibility.

3.2 Moisture Content and Water Solubility

Sample Code	Moisture Content (%)	Water Solubility (%)
G-PVA86	17.2 ± 0.5	42.1 ± 1.4
G-PVA88	16.4 ± 0.4	39.3 ± 1.3
G-PVA98	15.3 ± 0.6	34.2 ± 1.2
G-PVA100	14.5 ± 0.5	31.5 ± 1.1



Higher hydrolysis of PVA reduced water solubility due to increased hydrogen bonding and crystallinity in the film matrix, which also led to slightly lower moisture absorption.

3.3 Optical Properties

Sample Code	Opacity (Abs600nm/mm)	Color L*	Color a*	Color b*
G-PVA86	1.21 ± 0.02	91.2	0.4	2.3
G-PVA88	1.18 ± 0.01	91.5	0.3	2.0
G-PVA98	1.15 ± 0.01	91.9	0.2	1.8
G-PVA100	1.13 ± 0.01	92.1	0.1	1.6

All films exhibited good transparency with slight decreases in opacity as PVA content and hydrolysis increased, indicating improved uniformity and compatibility of gelatin and PVA phases.

3.4 Effect of PVA Concentration

PVA Content (%)	Tensile Strength (MPa)	Water Solubility (%)
10	17.5 ± 0.6	46.8 ± 1.2
20	22.1 ± 0.4	35.2 ± 1.0
30	24.6 ± 0.5	28.7 ± 1.1
40	23.8 ± 0.7	27.1 ± 0.9

3.4 Biodegradability Results

The results from the soil burial degradation test for gelatin–PVA blend films are summarized in Table and illustrated in Figure. The biodegradation percentage was calculated based on the weight loss of the film samples after 10, 20, and 30 days of burial in moist soil under ambient conditions.

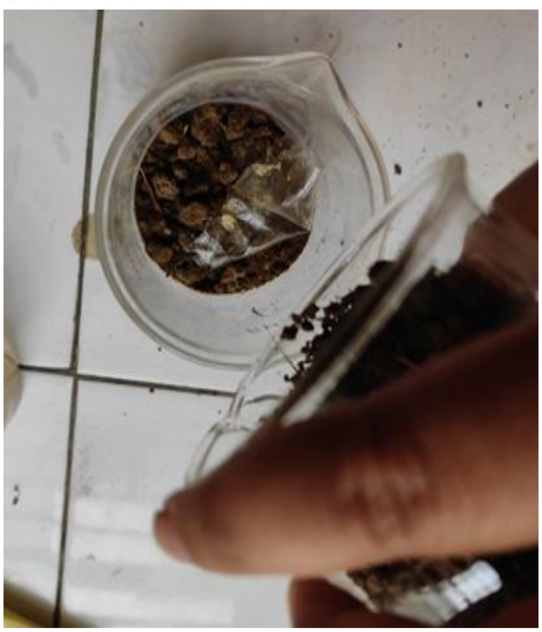


Fig. 2 Biodegradability test

Table : Biodegradation (%) of Gelatin–PVA Films Over Time

Sample Code	PVA Hydrolysis (%)	Day 10 (%)	Day 20 (%)	Day 30 (%)
G-PVA86	86–89	18.2 ± 1.1	45.3 ± 1.3	72.6 ± 1.7
G-PVA88	88–90	15.4 ± 1.0	42.1 ± 1.5	69.5 ± 1.4
G-PVA98	98–99	12.1 ± 0.9	36.7 ± 1.2	60.3 ± 1.6
G-PVA100	100	9.8 ± 0.8	30.2 ± 1.4	52.7 ± 1.5

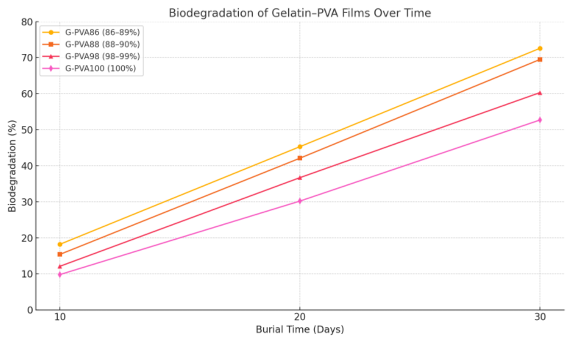


Figure 3: Biodegradation of Gelatin–PVA Films Over 30 Days

4. CONCLUSION AND FUTURE SCOPE

This study successfully demonstrated the potential of blending gelatin and polyvinyl alcohol (PVA) to develop biodegradable films with plastic-like properties. The films prepared using the solution casting method exhibited satisfactory mechanical strength, flexibility, and environmental degradability. The absence of plasticizers maintained the natural character of the films, while the incorporation of PVA improved the film-forming and mechanical behavior of gelatin. Biodegradability tests confirmed the films' ability to degrade over time in soil, indicating promise for environmentally sustainable packaging applications.

For future research, the incorporation of natural additives such as plant fibers, essential oils, or bioactive compounds may be explored to enhance functional properties like antimicrobial activity or UV resistance. Additionally, studies under varied environmental conditions—such as exposure to UV light, humidity variations, and industrial composting—are recommended to evaluate the films' long-term performance and biodegradation behavior. These further investigations could contribute significantly to the development of eco-friendly alternatives to conventional synthetic plastics in packaging and biomedical applications.

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