


# Evaluation of Physical and Mechanical Properties of Gelatin-Pectin Films Reinforced with Banana Peel Extract for Improved Food Packaging Material

Nausheen Wajid<sup>1</sup>, Fariha Ibrahim<sup>2</sup> , Iffat Imran<sup>1</sup>,  
Muhammad Asif Asghar<sup>3</sup>

<sup>1</sup>Department of Biomedical Engineering, Ziauddin University, Karachi, Pakistan

<sup>2</sup>Department of Biotechnology, Bahria University, Karachi, Pakistan

<sup>3</sup>Food and Marine Resources Research Centre, PCSIR

## ABSTRACT

**Background:** Plastics are a rapidly increasing component of municipal solid waste as they do not decompose easily and thus causes an adverse effect to the surroundings. To overcome this, the use of bioplastics as packaging material particularly in the food industry is increasing. Currently, an innovative, eco-compatible and cost-effective protocol has been developed to synthesize a bio-based composite film using gelatin (G) loaded with pectin (P) and banana peel extract (BPE), and it was subsequently assessed for its physical and mechanical properties.

**Methods:** The casting solution procedure was used to produce the biodegradable food packaging films with different blends: G, G + P and G + P + BPE. Glycerol was used as a plasticizer. The physical tests included thickness, film moisture, swelling index and solubility. The mechanical tests were elongation at break, young's modulus and tensile strength.

**Results:** The final G + P + BPE composite film became thicker (0.145 mm as compared to 0.084 mm). The moisture content increased to 26.19 % while the solubility in water decreased (95.11% to 55.77% respectively) and swelling index lowered to 53.21% from 67.66%. The elongation at break was suppressed to 8.215%, however the young's modulus and tensile strength appeared high 74.52 MPa and 14.87 N/mm<sup>2</sup> respectively.

**Conclusion:** The acquired results has shown the blended film has the potential to be used as a bioactive edible packaging material to maintain the viability of packaged food.

**Keywords:** Edible composite films, Food packaging, Gelatin + Pectin-based films, Mechanical properties, Physical properties

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**Corresponding Email:** farihaibrahim.buhsck@bahria.edu.pk

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## INTRODUCTION

The petroleum-based polymers pose a significant hazard to fossil fuel resources and surroundings. Plastics are a rapidly increasing component of municipal solid waste, also a significant part of one-time-use items such as PET bottles, bags and wrappings of products. They do not decompose easily, leaving a negative impact to the land, water ways and air. Owing to this there has been an increased push to adopt the use of bio-plastics as packaging<sup>1-2</sup>. Innovative biopolymer materials have become highly utilized in food and pharmaceutical sectors due to their

broad approval to the consumers. Interestingly, bioplastics have also been established to be useful in their bio-medical benefits and explored to be used in wounds, surgical dressing and contribute to decreasing the use of fossil fuel and sustainability<sup>3-4</sup>.

Gelatin (G) is a polypeptide polymer with a high concentration of glycine, proline and hydroxyproline. Gelatin is extracted from skin and bones from different animals including cows, goats, camels, fishes and insects<sup>5</sup>. Due to its excellent biodegradability and biocompatibility,



used as structural material in food packaging, pharmaceuticals, tissue engineering, etc. as the thermally denatured product of collagen. It becomes more stable by blending it with different biopolymers and nanoparticles to boost the strength and barrier performance<sup>6</sup>. It has a range of unique characteristics such as the capacity to gel, thicken, stabilize, and emulsify. It is healthy, enhances shelf life and gives bioplastics good tensile strength and elasticity. Gelatins have high potency as biodegradable plastic for packaging film<sup>7</sup>. Although polysaccharides like chitosan, cellulose, starch, etc. are well studied as decomposable packaging materials, exploitation of pectin (P) has not been fully harnessed. It is normally obtained from citrus (orange and lemon) peels. It contains an  $\alpha$ -1–4 linked D-galacturonic acid (GalA) polysaccharide backbone. It is inexpensive, has accessibility, biodegradable, renewable, biocompatible, acts as a film forming material and gelling agent. It finds various uses in food, packaging, pharmacy, biomedicine and agriculture. Moreover, it functions as an oxygen and oil barrier, harmless with notable mechanical strength. It is a good candidate material to develop in the future<sup>8-9</sup>. *Musa acuminata* is a banana species which is indigenous to South Asia and is a member of the Musaceae family<sup>10</sup>. In Pakistan it is produced in tonnes and mostly cultivated in Sindh province<sup>11</sup>. Banana fruits outlived 10 to 12 months after planting. The tree is cut after harvesting and new growth of the tree is obtained by the stem and rhizome wasting production of rejected tonnes of fruits. The enormous waste turns into a useful resource for a number of different sectors such as in biofertilizers, biogas, pharmacy, food fortification, bioplastics, etc<sup>12</sup>. According to one study, adding more banana peel powder to PLA composite films enhanced the rate of biodegradation<sup>13</sup>. Agro-waste from banana processing advances nanotechnology, replenishable energy and the creation of biodegradable plastics for a circular economy. This innovative, cost-effective, and environmentally friendly solution relieves strain on the world economy<sup>14</sup>.

Therefore, the aim of this study is to prepare the Gelatin and Pectin films incorporated with banana peels extract and also evaluated their mechanical and physical properties for the effective food packaging material. These films would enhance food safety, quality and improves the shelf-life of food products.

## METHODOLOGY

### *Materials*

Banana peels were obtained from nursery of PCSIR, Karachi city. Copper sulphate (CuSO<sub>4</sub>) and glycerol (GLY) were purchased from Sigma Aldrich, Germany. Gelatin (isolated from piscine skin) was procured from Rossmoor Food Products, Karachi, Pakistan. Pectin from citrus fruits (79 % galacturonic acid and 8 % methoxyl content) was procured from Bin Dawood Flavours Pvt Ltd. The chemicals utilized were of analytical-grade and required no further refinement.

### *Isolation of Banana Peels Extract (BPE)*

The peels were washed with running water and oven dried at 60°C for a day. The peels were pulverized into a fine powder and kept in non-transparent plastic jars at room temperature. Aqueous extraction was done by adding 5 g powder to 50 mL of deionized water, letting it stand for a night and filtered through standard Grade 1 filter paper. The isolated extract was then refrigerated at 4°C to be used further<sup>15</sup>.

### *Fabrication of Gelatin-Pectin with BPE Composite Films*

The casting solution procedure with slight modifications was used to produce the biodegradable food packaging films<sup>9</sup>. The formulation of biopolymer films with their compositions is shown in Table 1. Briefly, for control, 2 g of gelatin powder (G) was solubilized in 30 mL of diH<sub>2</sub>O and mixed for half an hour at low heat. Next, 0.5 mL of glycerol, a plasticizing agent was mixed with the aid of a magnetic stirrer at 60 °C up to the point of complete gelatinization. Also, 0.5 g of pectin (P) powder was added to 30 mL diH<sub>2</sub>O and stirred for 20 min. The magnetic stirrer was used to mix both solutions to produce a G + P composite film. Additionally, 1 mL BPE was incorporated to the blend above (G + P + BPE). The solutions were stirred continuously for half an hour and cast onto glass plates individually. The films were dried for two days at room temperature, then removed from the plates and kept in an air-tight drying vessel for further analysis.

**Table 1: Formulation of biopolymer films with their compositions**

Film formulations	Gelatin (g)	Pectin (g)	Banana peel waste extract (mL)	Glycerol (mL)
Gelatin	2	-	-	0.5
Gelatin + Pectin	1.5	0.5	-	0.5
Gelatin + Pectin + Banana peel extract	1.5	0.5	1	0.5

### Physical Properties of BPE Composite Films

#### Film thickness

Each film thickness was measured through a dial micrometer (Mitutoyo Japan Vernier Caliper 6), ranging from 1-1000 mm. For best precision, four positions on the film were picked randomly and the average values for thickness were considered.

#### Film moisture

The original weight of the film (3 x 3 cm<sup>2</sup>) was noted, left in an oven at 110 °C for 24 h and final weight was noted<sup>16</sup>. FM (%) was obtained through the following formula:

$$FM (\%) = [(W_f - W_i)/W_f] \times 100$$

#### Film solubility

The FS was ascertained by the approach, with slight adjustments<sup>17</sup>. The film's (3 x 3 cm<sup>2</sup>) original weight was noted, followed by drying at 105 °C for half an hour. After this, for 24 h they were immersed in 50 mL dH<sub>2</sub>O at room temperature. After incubation period, the insoluble fraction was removed, dried at 105 °C again for another 24 h and the final weight was calculated. Each film was estimated to find its solubility:

$$FS (\%) = [(W_i - W_f)/W_i] \times 100$$

#### Swelling Index (SI)

The SI of the prepared films has been experimented with minor modifications<sup>18</sup>. The biofilms (3 x 3 cm<sup>2</sup>) weight was noted and placed in 200 mL dH<sub>2</sub>O for 30 min. Excess water was blotted off using a filter paper and weighed again. The calculation of the SI (%) was carried out with help of the given formula:

$$SI (\%) = [(W_f - W_i)/W_f] \times 100$$

### Mechanical Properties of BPE Composite Films

Calculations of the structural characteristics including Young's Modulus, Elongation at break and tensile strength were determined by a texture analyzer (Model 4301, INSTRON Lloyd Instrument Ltd., Fareham, UK) as defined in the procedure of ASTM 828-97. In particular, 10 x 1 cm<sup>2</sup> sized strips of each film specimen were firmly attached in the grips of the analyzer to be tested. The probe was operated at 1,5 and 10 mm/s speed for the conditioning, evaluation and concluding stages, respectively. The probe was operated at the length of 100 mm and an initial force of 5g, while a 10g of load cell was attached to the probe<sup>19</sup>.

### Statistical Analysis

The statistical data were evaluated using Origin 9.4 software (Origin Lab Corporation, Northampton, MA 01,060 USA) and IBM SPSS software (SPSS 26.0 for windows, SPSS Inc., Chicago, IL, USA). Each of the statistical data sets was measured three times and presented by the mean value  $\pm$  standard deviation. Comparison of the recorded data showing significant variations was carried out based on the One-way Analysis of Variance (ANOVA). The level of significance was however established as  $p \leq 0.05$ .

## RESULTS

### Physical Properties of the Films

#### Film thickness

The composite films thickness was recorded with the help of a micrometer at four random points. The results in Table 2 shows the control (G) exhibited the thinnest film (0.084  $\pm$  0.001 mm) while thickness increased with adding pectin (G + P = 0.114  $\pm$  0.001 mm) and banana peel extract (G + P + BPE = 0.145  $\pm$  0.001 mm).

#### Film moisture

The moisture findings in Table 2 increased progressively with formulation modification. The control gelatin exhibited the lowest moisture content (G = 15.95  $\pm$  0.2 %) while the addition of pectin (G + P) and banana peel extract in (G + P + BPE) significantly increased the film moisture to 22.49  $\pm$  0.01 % and 26.19  $\pm$  0.01 % respectively.

**Table 2: Physical characteristics of the formulated food packaging films.**

Film formulations	Thickness (mm)	Film moisture (%)	Swelling index (%)
Gelatin	0.084 ± 0.001	15.95 ± 0.2	67.67 ± 0.7
Gelatin + Pectin	0.114 ± 0.001	22.49 ± 0.01	74.64 ± 0.4
Gelatin + Pectin + Banana peel extract	0.145 ± 0.001	26.19 ± 0.01	53.21 ± 0.3

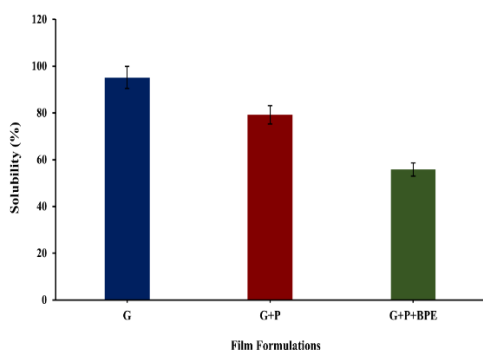
The mean ± standard deviation values of the developed Films.  $P < 0.05$

### Swelling Index (SI)

The results in Table 2 of swelling index varied with composition. The control (G) exhibited SI of  $67.67 \pm 0.7$  %, which increased to  $74.64 \pm 0.4$  % with the incorporation of pectin (G + P). However, the addition of banana peel extract (G + P + BPE) reduced the SI to  $53.21 \pm 0.3$  %.

### Film solubility

Fig. (1) shows the solubility % of three different film compositions (G, G + P, G + P + BPE) in water solvent. Pure gelatin has the highest solubility of 95.45 %. However, with the addition of pectin and banana peel extract decreased the solubility to 79.18 % to 55.77 % respectively.



**Fig.1. Solubility of the formulated food packaging films in solvents. G (Gelatin), G + P (Gelatin + Pectin) & G + P + BPE (Gelatin + Pectin + Banana peel extract)**

## Mechanical Properties of Films

### Tensile strength (TS)

The tensile strength values in Table 3 show that the film's mechanical properties are greatly dominated by the composition. Control gelatin (G) has the lowest tensile strength ( $3.829 \pm 2.37$  N/mm<sup>2</sup>) but elevated to  $12.455 \pm 1.11$  N/mm<sup>2</sup> when pectin (G + P) was added and further boosted to  $14.87 \pm 5.77$  N/mm<sup>2</sup> with the inclusion of banana peel extract in G + P + BPE.

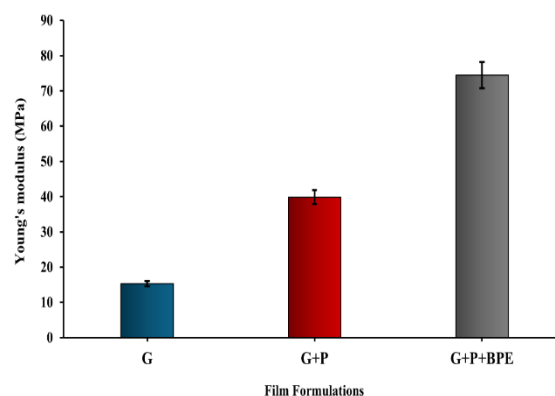
**Table 3: Mechanical characteristic of the formulated food packaging films**

Film formulations	Tensile strength (N/mm <sup>2</sup> )
Gelatin	$3.829 \pm 2.37$
Gelatin + Pectin	$12.455 \pm 1.11$
Gelatin + Pectin + Banana peel extract	$14.87 \pm 5.77$

The mean ± standard deviation values of the developed Films.  $P < 0.05$

### Young's modulus (YM)

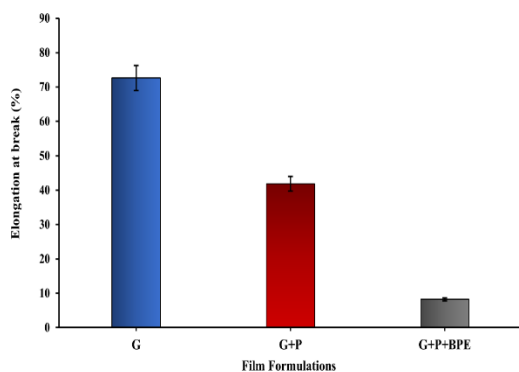
The Young's modulus of the bioplastic films increased progressively with compositional modifications. The control (G) in Fig. (2) has the minimum YM value of 15.32 MPa but the addition of pectin (G + P) significantly elevated to 39.85 MPa. A further pronounced increase was observed for G + P + BPE composite showing the highest value of 74.523 MPa, demonstrating improved rigidity and mechanical strength of films.



**Fig.2. Young's modulus of the formulated food packaging films.**

### Elongation at break (EAB)

Flexibility and stretchability are signified in elongation at break. In Fig. (3), the control (G) exhibited the highest EAB value of 72.65 % and when it is combined with pectin (G + P) the elongation reduced to 41.85 %. A further decline was observed with the addition of the banana peel extract (BPE) to the mixture of G + P + BPE at the value of 8.215 %, reflecting reduced ductility and enhanced rigidity of the films.



**Fig.3. Elongation at break of the developed food packaging films.**

### DISCUSSION

The gelatin-control (G) is the thinnest film because it has low solids content, the ones which contain pectin and banana peel extract (G + P + BPE) are thicker because the total solids and viscosity progressively increased. Banana peel extract contains high levels of polyphenols, starch, cellulose fibers, organic acids, sugars and minerals that interlink with gelatin and pectin to form cross-linkage, hydrogen-bonded network as well as some covalent bonds to form a stronger and more stable film. Correspondingly, banana peel-loquat leaf extract films<sup>19</sup> and G + P-lemon grass essential oil film<sup>9</sup> exhibited indistinguishable results.

The increase of moisture content is attributed to the hydrophilic nature of pectin due to the contribution of polar groups by pectin<sup>9</sup>, and the polysaccharides in BPE further elevates the solid content and polymer interactions due to presence of fibers, phenols and other bioactive compounds that binds G and P. A similar observation was detected in another study about smart banana starch film (BSF) blended with banana peel extract<sup>20-21</sup>. The (G) and (G + P) have the highest swelling because of their high hydrophilic properties and usage of numerous polar groups<sup>22</sup>. The incorporation of (BPE) reduced the swelling index, because the polyphenols and

tannins in BPE form extra interactions with gelatin and pectin chains to form a denser, non-permeable matrix to water<sup>23</sup>. All-in-all, G + P + BPE films exhibit the minimal swelling and the highest structural stability at aqueous conditions. Solubility is highest in gelatin due to their hydrophilic chains, but decreased with incorporation of pectin due to the formation hydrogen bonds with gelatin. The banana peel extract further decreased due to additional cross-linking, which improves the compactness of the networks their hydrophobicity, and dissolution resistance<sup>9,21</sup>.

The gelatin (G) has lowest tensile strength since the polymer chains are rather weak and flexible. The tensile strength enhanced with addition of pectin in (G + P) by reinforcing the network through hydrogen bonding<sup>9</sup>, while banana peel extract in (G + P + BPE) further boosted the film via phenolic compounds promoting cross-linking within the matrix<sup>24</sup> resulting in highest tensile strength. The control (G) has the lowest Young's modulus since it contains loose and flexible protein chains resulting in low stiffness. Inclusion of pectin (G + P) has a strong effect on stiffness as it forms strong hydrogen bonds with gelatin, enhance crosslinking and restrain the mobility of the molecules. BPE addition to G + P + BPE formulation further enhances the stiffness due to polyphenol-induced cross-linking forming a compact and rigid structure<sup>24</sup>. The decrease of elongation at break with the addition of pectin and banana peel extract indicates a substantial loss in ductility. The control (G) possesses good gelatin elongation which is the natural flexibility and when it is combined with pectin (G + P) the elongation reduces because the combination of the two forms a stronger net-work<sup>9</sup>. The addition of the banana peel extract to G + P + BPE slows down the process because the interactions (hydrogen and cross linking) between the polymer networks hinder the movement of the G and P chains resulting in a stronger, but less ductile film<sup>20</sup>.

### CONCLUSION

To conclude, biodegradable G + P + BPE films were developed successfully. The solution casting technique was used to determine mechanical and physical characteristics of bioplastic film at the mixture of gelatin, pectin matrix and banana peel extract (BPE). When compared to the G + P film, the moisture level of the ultimate blend G + P + BPE film were enhanced whereas the swelling index and the solubility were reduced. The Young's modulus

and tensile strength were increased while elongation at break was reduced. The hybrid film is likely to be used as an enhanced food packaging film to increase the shelf life of sealed food.

### Author Contributions

**NW:** Data Collection, Data Analysis and interpretation, Manuscript Writing and Final Approval.

**FI:** Conception & design, Data Analysis and interpretation, and Critical Reviewed.

**II:** Data Collection, Data Analysis and interpretation, and Final Approval.

**MAA:** Conception & design, Data Analysis and interpretation, Critical Reviewed and Final Approval.

### Funding Source

No sources

### Conflict of Interest

No conflict of interests.

### Data Availability

Data will be available on request

### Ethics approval

Not applicable

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