Hong Kong Student Science Project Competition 2023

Template of Extended Abstract (Investigation)
(Word Limit: 1,600 words, Pages: 3 pages only)

Team Number: SBBC227

Project Title: Investigating the comparison between bio-based polymers made from gelatin and traditional oil-based plastic (An investigation on the effect of increasing concentrations (1%, 2%, 3%) of polyethylene glycol (PEG) and glycerol on the mechanical properties and chemical composition of a gelatin biopolymer matrix)

Project Type: Investigation

***To our best knowledge, there are similar works in the field*; (if there are,) related research links are as below:**

https://www.sciencedirect.com/science/article/abs/pii/S2214289423000169
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8838392/

The enhancement our project made / the difference with related research are:

We explored the application of plasticizers in food-safe bioplastics by adding chocolate to our film solutions.

I. Background

Every day, oil-based plastics are manufactured, consumed and discarded without a second thought. Over 12 million tonnes of plastic are dumped into the ocean each year (Sherrington, 2018), and it accounts for 18.5% of all terrestrial municipal solid waste (US EPA, 2017). This has a devastating effect on the environment, as microplastics are propagated throughout food chains and the inert nature and high crystallinity of the material means it can take more than 50 years to degrade (Mohanan et al., 2020). We turned towards investigating within the realm of gelatin bioplastics, as it has become an increasingly viable method to combat plastic pollution in recent years.

Gelatin is a protein derived from the hydrolysis of collagen which is an abundant animal protein (Ricard-Blum, 2010). As gelatin can be extracted from many meat byproducts, the plastic films we create are not only biodegradable but also contribute to an external circular economy. Gelatin is most notable for its uses in the food industry due to its hygroscopic properties and exceptional ability to prevent sugar crystallisation and syneresis (Keenan, 2012). It is incredibly versatile in food production to produce a range of textures, suggesting its potential in the wider application of sustainable plastic production. To further enhance the mechanical properties of gelatin bioplastics, biodegradable plasticizers are used to create a flexible and durable film. Glycerol is a notable option, it has a high plasticizing and a high thermal capacity (Bilck et al., 2015). Glycerol is also edible and food-safe, characterising it as a compatible addition to gelatin film-making solutions. Likewise, PEG is an efficient plasticizer as it is biodegradable and soluble in water (Li et al., 2018). Both plasticizers have strengths that align with our goal to create an environmentally sustainable bio-plastic. Previous studies have been conducted to show the independent properties of each plasticizer, but rarely are they compared to determine which is more suitable.

Through this investigation, we hope to pioneer a greater positive mindset towards plastic production by exploring the newly developing field of bioplastics and contributing to the betterment of the environment.

II. Objectives

The aim of this investigation is to assess the physical properties and chemical composition of biofilms made from gelatin with different types of plasticizers (polyethylene glycol and glycerol). We will measure the tensile strength and elongation at the break of the films. The chemical composition will be investigated by conducting an FT-IR analysis. An extension on the applicability of the films will be discussed.

III. Hypothesis

We hypothesize that an increase in PEG and glycerol concentrations in the film solution will cause a decrease in tensile strength, an increase in elongation at break and a decrease in O-H bonds of the films. Tensile strength and elongation at break will be tested by tensile testing. Chemical bonding within the film will be tested by FT-IR analysis.

IV. Methodology

4.1 Materials

The following materials were used for the biofilms: Packaged unflavoured Robertson's gelatin powder, the glycerol and polyethylene glycol (PEG) plasticizers were provided by the Chinese University of Hong Kong. Distilled water was used. The same materials were used for chocolate bioplastic, with the addition of 85% Lindt Chocolate sourced from a local supermarket.

4.2 Methods

4.2.1 Plasticized Plastic Preparation

1. Weigh 9 grams of gelatin in a weigh boat
2. Dissolve the gelatin in 180cm³ of distilled water, and stir with a glass rod
3. Heat the mixture using a hot plate at a temperature of 60°C for ± 15 minutes
4. Measure the respective concentrations of PEG and glycerol (1%, 2%, 3%) into a beaker
5. Pour the gelatin-water mixture into the respective beakers with their corresponding concentrations
6. Use a glass rod to stir the gelatin-water mixture and the PEG/glycerol until thoroughly mixed
7. Measure 20cm³ of each solution into the petri dish and put them into an oven at 60°C for 24 hours

A control experiment is conducted under the same conditions and procedure without the addition of plasticizers.

4.2.2 Chocolate Plastic Film Preparation

1. Weigh 10g of gelatin in a weigh boat
2. Dissolve the gelatin in 40cm³ of water
3. Heat the mixture using a hot plate at a temperature of 60°C for ± 10 minutes
4. Weight 35g of 85% dark chocolate and melt completely on a hot plate
5. Add the gelatin-water mixture to the melted dark chocolate
6. Measure 10g of plasticizer/glycerin and add to the mixture
7. On a hot plate, thoroughly mix the mixture to avoid coagulation
8. Spread evenly across parchment paper and let sit on an ice bath for ± 10 minutes
9. Spread cornstarch over the chocolate film

4.2.3 Tensile Test

Biofilms' tensile strength and elongation at break are tested using a tensile strength machine. The thickness of the films was measured using an electronic micrometre. Films were cut into strips using a cutting mould with dimensions 10 mm by 50 mm. The machine was set to a crosshead speed of 10mm/min and each sample was tested at least once. Silicon plastics were stuck to the ends of the film using double-sided tape to increase grip during tensile testing.

4.4.4 FT-IR Analysis

The films were analysed by an FT-IR device with a range of wavenumbers from 400 cm^{-1} to 4000 cm-1.

V. Results

5.1 Observations

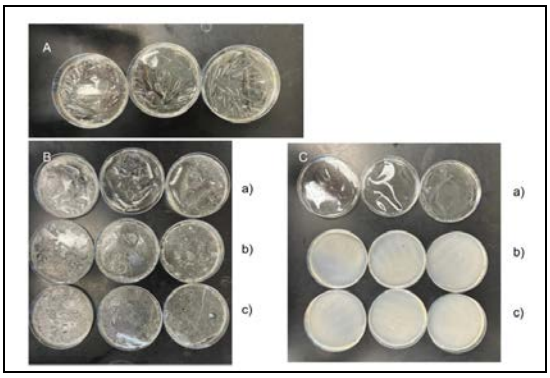

Figure 1. Qualitative Observations (A) pure gelatin films, (B) glycerol plasticized films, (C) PEG plasticized films of respectively (a) 1% (b) 2% (c) 3%

Observations show a range of texture and properties achieved by adjusting the concentration of plastizciers in gelatin films. Pure-gelatin films (A) were fragile and rigid. Glycerol-plasticized (B) also has fractures and air bubbles on the surface of the films. PEG-plasticized films (C) are smooth without any air bubbles. 1% PEG films (C)(a) are the most appealing as they had the best clarity and transparency. Such transparency is attractive for food packages as it allows consumers to view products.

5.2 Mechanical Properties

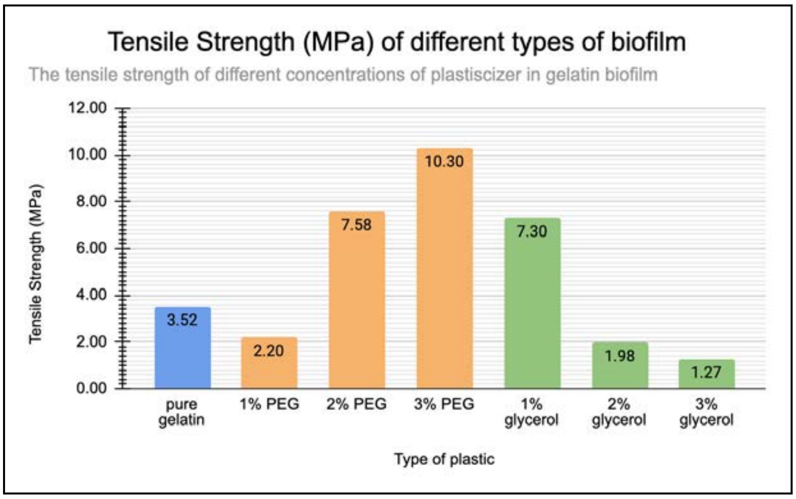

Figure 2. Bar chart showing the tensile strength of pure gelatin film, PEG plasticized films (1%, 2%, 3%) and glycerol plasticized films (1%, 2%, 3%.).

Tensile strength is defined as the maximum stress a material can withstand before breakage. There is an upward trend between the concentration of PEG and the tensile strength of the film. On the contrary, there's a downward trend between the concentration of glycerol to the tensile strength.

The trend in the glycerol-plasticized film is supported by similar studies. Arga Bagus Prsetyo & Sysprayitno (2021) show a corresponding trend in catfish skin gelatin films. This is because the addition of glycerol causes a net decrease in hydrogen bonds in the gelatin matrix (Nor et al., 2017), leading to an increase in chain mobility.

The upward trend of PEG-plasticized films is surprising as relevant studies report a downward trend.

However, the increase in viscosity of the film-making solutions may contribute to the unexpected trend. While this was not observed in the experiment, it can be an oversight in visual judgement. Rheometer can be used to monitor the viscosity in subsequent studies.

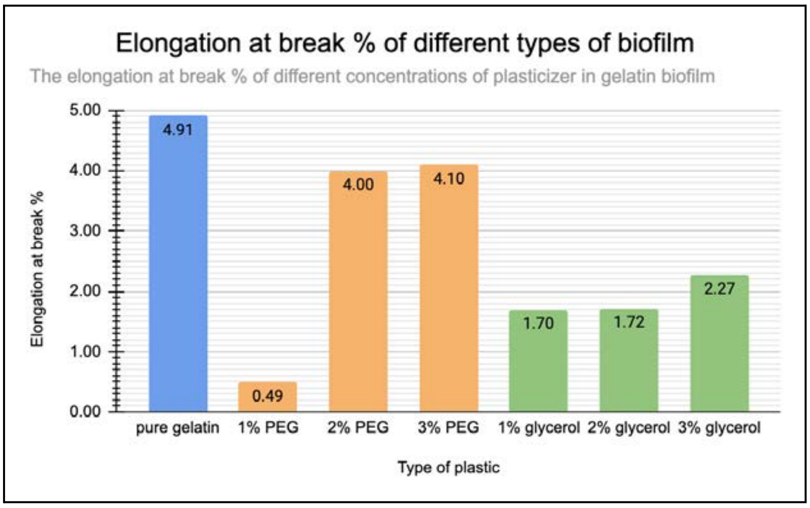

Figure 3. Bar chart showing the elongation at break of pure gelatin film, PEG plasticized films (1%, 2%, 3%) and glycerol plasticized films (1%, 2%, 3%.) Uncertainties are negligible, error bars were not plotted.

Elongation at break is defined as the percentage elongation of the film before breakage. It is a measurement of flexibility. There is an upward elongation at break in both plasticized films. This further supports that plasticizers promote movement and increase chain mobility.

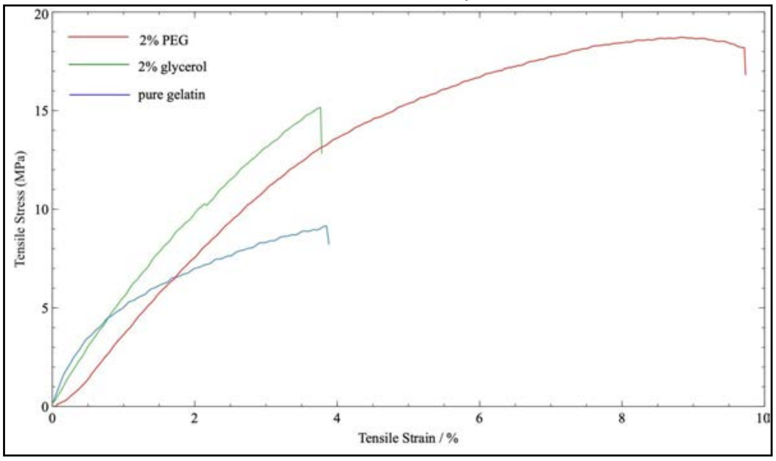

Figure 4. Graph showing tensile strain against tensile stress of pure gelatin films, 2% glycerol films and 2% PEG films.

A stress-strain analysis was to conclude the mechanical properties of the films. From Figure 4, 2% PEG shows the best elongation at break and tensile strength values.

5.4 Chemical Composition

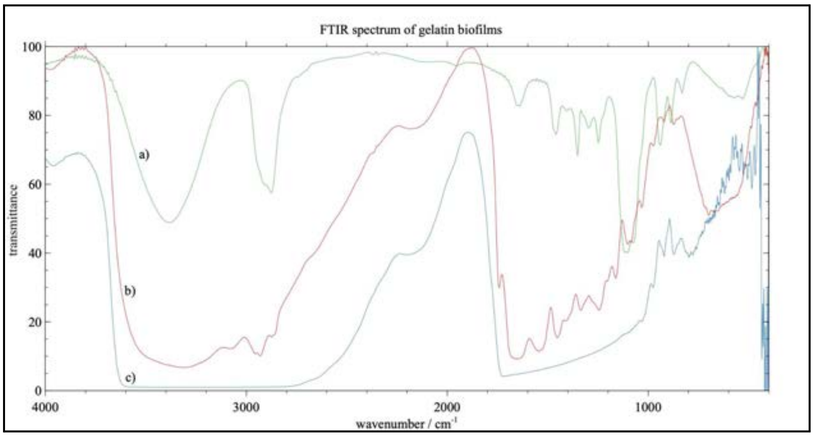

Figure 5. Fourier Transform Infrared Spectroscopy of a) 2% PEG plastic, b) 2% glycerol plastic, and c) pure gelatin film

A FTIR-analysis was conducted to gain an understanding of the chemical bonding within the films. O-H bonds are present at the large and broad absorption peak of 3400 cm^{-1}. Pure-gelatin films have the highest absorption, followed by glycerol-plasticized films. PEG-plasticized films have the least absorption. This supports the effect of PEG in significantly decreasing hydrogen bonding to increased elongation at break. This explains the superior mechanical properties of 2% PEG films in (Figure 4).

5.5 Strengths and Limitations

Precise measuring equipment and a careful methodology were followed to achieve a high standard of data. Still, there are some weaknesses associated with the intrinsic properties of the film. Gelatin and glycerol-plasticized films are fragile and difficult to handle. It was particularly hard to cut them into tensile testing samples while preventing fractures. For this reason, only a small number of samples were tested.

VI. If your team will compete the Sustainable Development Award, please indicate the specific sustainable development goal the project is related to, and provide justification for competing for this award. ***(Word limit: 300 words)***

Plastic pollution has rapidly become one of the most pressing environmental issues, with the increasing amount of plastic being produced overwhelming the world's ability to deal with them. Although people in recent years have been made aware of the adverse impacts of the material, it is undeniable that this type of plastic is not only cost-efficient but convenient for both manufacturers and consumers, hence an apathetic attitude towards a paradigm shift into more environmentally-friendly alternatives.

As current IB students who are all aiming for a future in environmental science, we understand that there needs to be an urgent change in the way we approach sustainability. Not only must our alternatives be biodegradable and renewable, but they must also be economically feasible and easily implementable, targeting **sustainable development goals 11 and 12**. We turned towards investigating within the realm of bioplastics, as it has become an increasingly viable method to combat plastic pollution in recent years.

VII. Conclusion

Polyethylene glycol (PEG) and glycerol of varying concentrations (1%, 2%, 3%) were used to make gelatin biofilms to observe changes in their mechanical properties and chemical composition. Results show that the 3% PEG film showed the best physicochemical properties. It has a tensile strength of 10.30 MPa, an elongation at break of 4.10% and the smallest peak at 3400 cm-1 on the absorption spectrum, representing the O-H group.

☐ **Our project is developed based on previous project and the enhancement is below:**

Figure 6. A photograph showing a PEG plasticized chocolate film.

Thickness (mm)	Tensile Strength (MPa)	Elongation at break %
2.400	0.0591	49.1

Table 1. A table showing the mechanical properties of 2% glycerol concentration in chocolate films, averaged over three measurements.

With the addition of chocolate to glycerol-plasticized films, an opaque, brown “film” was achieved. The chocolate film has a lower tensile strength value compared to the original test samples but showed a considerable increase in elongation at break. It is hypothesized that air bubbles may cause an increase in thickness, distinguishing the product as a “foam” rather than a “film”. Thickness is inversely proportional to the tensile strength, explaining the small value. More amorphous zones in the cross-sectional area of the film allow for more extension.

The combination of existing food products with gelatin shows promising applications in the food industry.

Word Count (excluding all titles, subtitles, annotations ad figures): 1412