Developing Plant-Based Edible Films for Food Packaging

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Abstract

Background: Plastic packaging has been damaging to the environment and the planet's ecosystems for a long time. Creating a sustainable and biodegradable material with comparable properties to plastic would be groundbreaking in the materials industry and greatly reduce harm by plastic production to the environment. *Aim*: To Develop a sustainable material with comparable properties to current for food packaging. *Methods*: A film was prepared using pea protein isolate that was glycated with pullulan. The effects of the Maillard Reaction on film properties were measured as well for the properties themselves to determine the practicality of film compared to current packaging. *Results*: As the Maillard reaction proceeded, the film experienced several improvements in properties such as color, film texture, tensile strength, elongation, absorbance, water content and water vapor permeability. *Conclusion:* The film that underwent the Millard reaction demonstrated improved properties compared to the control film and may serve as a possible opportunity for producing an environmentally friendly packaging material.

Introduction

- Due to its many benefits, plastic usage has increased in recent years, however, the toxicity of these materials has only contributed to more problems in the environment.
- Creating a sustainable material with similar properties to those of plastic could be revolutionary in the packaging industry as well as extremely advantageous for the environment.
- Protein is a molecule that is readily available and biodegradable. Additionally, protein possesses many physical and chemical properties that allow for functional use when produced into a film.
- ***This study aims to create an edible and sustainable film from pea protein isolate (PPI) by utilizing a glycation reaction with the polysaccharide, pullulan.*** The PPI and Pullulan sugar underwent this Maillard reaction and a process of desiccation to produce the resulting film. This film was then tested for several properties including moisture content, solubility, color, tensile strength, and elongation at break. These film properties were evaluated to evaluate their effectiveness in replacing current packaging materials.
- This study could serve as a promising means to reduce toxic materials from the planet and implement a biodegradable environment-friendly opportunity for food packaging.

Methods

Film Preparation

The film was prepared using 10% PPI solution at pH 7.0 and 5% pullulan at pH 6.5 in a phosphate buffer solution (10.0 mM) mixed in a 1:1 ratio. The mixture is stirred for 2 hours (H) and was heated at 85° C for 48 hrs. The samples were removed every 0,2,4,24, and 48 H. Glycerol was added into solutions (50% total weight of the protein) for the sample. The solution is stirred for 30 min and placed in a vacuum oven for 1 H to exclude air. The solution is poured into a petri dish and dried at room temperature for 24 hrs. Films are peeled and conditioned for stable humidity. Control Pea Protein Isolate (PPI) film sample was prepared using 7.5% PPI and 92.5% Phosphate buffer (10.0 mM) at pH 7.0. The process for producing the control film remained the same.

Film Labels

- **PPI0h**: Control Pea Protein Isolate Film (7.5% PPI and 92.5% Phosphate buffer)
- **Mix0h - Mix48h**: Pullulan and PPI mixture (5% PPI and 2.5% pullulan) removed at 0,2,4,24, and 48 H

Thickness (TH)

TH was determined by using a digital caliper in millimeters (mm) Each film was measured in three different areas and the average was taken.

Moisture Content (MC)

MC was determined by obtaining the original mass of the film sample. The sample is then placed in the oven at 50° C for 24 hrs. After the samples have been dried, the mass is taken again. To obtain MC, the original mass is subtracted by the dried mass, resulting in the mass of the water removed from the sample.

Water Vapor Permeability (WVP)

WVP was measured by obtaining glass tubes containing silica gel beads. The film was placed on top of the tube to create a seal. The tube is then placed in a desiccator and conditioned with a cup of distilled water. These tubes were measured for the weight increase every 2 hrs for 48 hrs. WVP was calculated by the equation below.

$$WVP = \frac{\Delta m \times l}{t \times A \times \Delta P}$$

Δm is the weight gain (g) of the tubes over time; l is film thickness (mm); t is time (h); A is the exposed film area (m2); Δ P is the partial vapor difference of the atmosphere with silica gel and pure water.

Color (C) and Opacity (O)

C was measured by a colorimeter (LabScan XE, HunterLab, VA, US). A black standard plate was used for calibration. HunterLab color parameters, L*, a*, and b* were obtained from EasyMatch QC software. O measured opacity of PPI films and were determined as film absorbance at 304 and 420 nm measured using a spectrophotometer.

Tensile Strength (TS) and Elongation at Break (EAB)

TS and EAB were determined using TA.XTplus texture analyzer (Stable Micro System, Godalming, UK). The distance of separation was 20 mm. TS was calculated by obtaining the maximum force the film can withstand, and EABwas calculated by the ratio of increase in length to original length ×100. Each trial was replicated 3 times.

Results

Figure 1: Maillard Reaction Treated Samples.

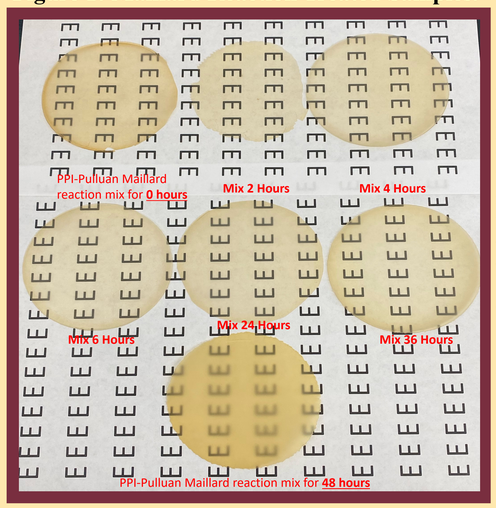


Figure 1: The samples in the figure represent PPI that was glycated with the sugar, Pullulan to produce the resulting film. The samples were removed at different periods: 0H, 2H, 4H, 6H, 24H, and 48 hours. An increase in darkness can be seen in the film as the reaction in the samples was allowed to proceed for longer.

Figure 2: Absorbance of Maillard Reaction Samples

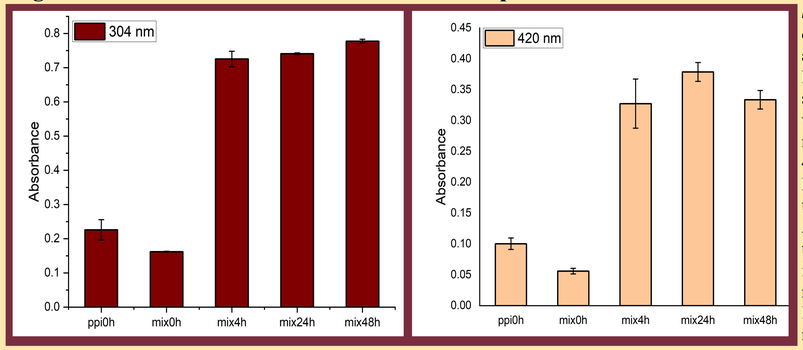


Figure 2: The figure demonstrates the absorbance of Maillard Reaction samples. Absorbance was analyzed at 304 nm (dark red) and 420 nm (peach) for PPI mix samples 0H through 48H. Absorbance values of the mix samples increased as the reaction proceeded longer at both 304 nm and 420 nm.

Table 1: Thickness, Color, & Moisture Content of Maillard Reaction Samples

Treatment	Thickness(mm)	L*	a*	b*	Moisture Content (%)
ppi0h	0.14±0.0	84.33±0.24	3.16±0.10	13.10±0.47	0.273±0.006
mix0h	0.16±0.01	85.85±0.58	2.52±0.31	15.22±1.62	0.240±0.008
mix4h	0.13±0.0	87.22±0.16	0.65±0.02	6.70±0.24	0.251±0.006
mix24h	0.14±0.0	87.05±0.21	0.19±0.03	10.19±0.29	0.254±0.006
mix48h	0.14±0.0	85.89±0.11	-0.35±0.05	19.41±0.17	0.241±0.005

Table 1: The table displays the TH, C, & MC of the Maillard Reaction samples. Thickness remained constant for each treatment at 0.14 mm. L* values represent sample color (black/white). The high L* values mean that the samples were whiter in color. a* values represent sample color (red/green). The decrease in a* values means that the samples changed from a green color to a redder color. b* values represent sample color (yellow/blue). The low b* values mean that the samples were bluer in color and experienced a sight yellowing in color as the reaction proceeded. The moisture content of the film samples have experienced a decrease as the reaction was allowed to proceed for longer.

Figure 3: Film Tensile Strength and Elongation

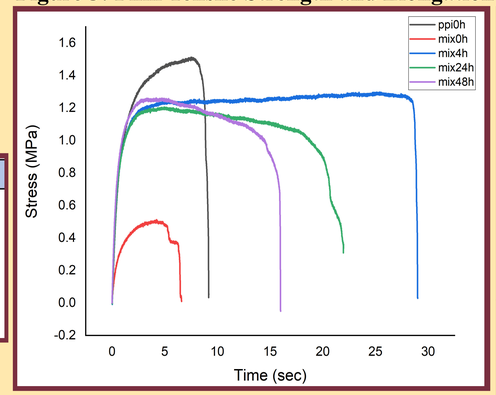


Figure 3: This figure represents the TS & E at break of Maillard Reaction samples. Sample TS increased as the reaction proceeded as the 48 H mix sample withstood the most stress (1.4 Mpa). EAB increased as the reaction proceeded but decreased after the 4 H sample which had the largest elongation

Figure 4: Film Sample Opacity

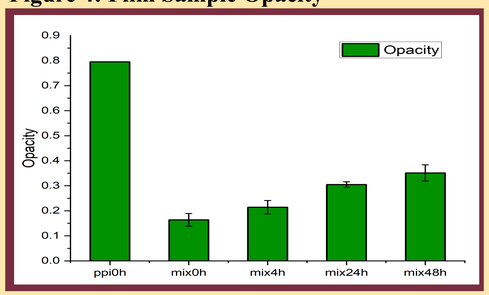


Figure 4: The figure displays the O of the Maillard Reaction film samples. The O of the film increased as the film underwent the reaction for longer. The Maillard Reaction film is still not as dark as the control PPI film. The 48 H sample is the most opaque.

Figure 5: Film Sample Water Vapor Permeability (WVP)

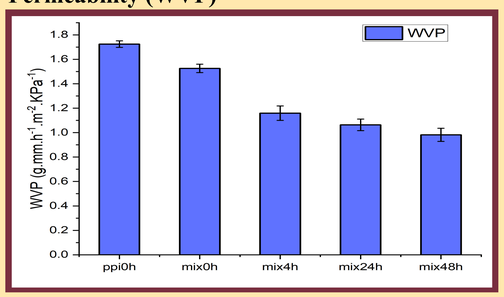
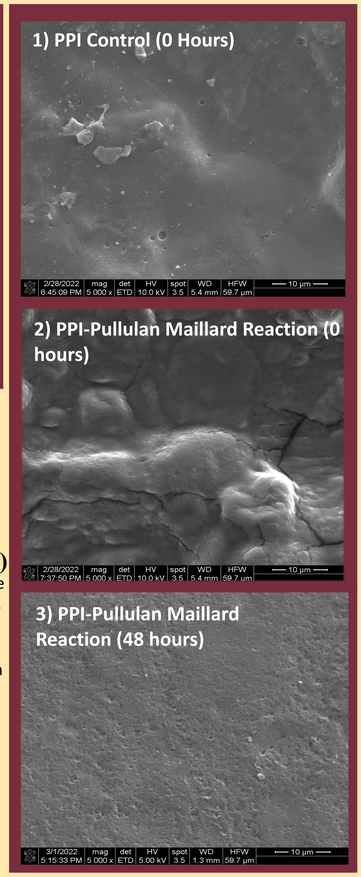


Figure 5: The figure displays the WVP of the Maillard Reaction film. The WVP values decreased as the film underwent the Maillard Reaction for longer. The 48 H sample exhibits the least WVP.

Figure 6: SEM of Maillard Reaction Treated Samples (5000X)

Figure 6: A scanning electron microscope (SEM) was used to capture micro-images of the surface of the film. The images were taken at 5000 X magnification. 1) This image displays the control PPI which is seen to have a relatively smooth surface with minor holes. 2) This image displays the 0 H Maillard Reaction film which has a bumpy surface with many cracks. 3) This image displays the 48 H Maillard Reaction film which has a smoother surface with many smaller holes. The surface of the film is more uniform.



Conclusion

The PPI samples have demonstrated promising qualities in the prospect of being utilized for packaging. The longer the samples remained in treatment, the darker they became (Fig. 1 & 4), confirming that the Maillard reaction occurred. The absorbance values obtained also support this as they increased as the samples underwent treatment (Fig. 2). Thickness was not impacted by the Maillard Reaction. Film color shifted as a* values indicated a redder color as time passed (Tab. 1). The TS of the film increased as the reaction proceeded to 48 H allowing for more stress resistance. The EAB also increased as the reaction proceeded but decreased after the 4-hour sample (Fig. 3). As the samples underwent treatment, the MC and WVP decreased (Tab. 1 & Fig. 5). This signifies that the films became more water-resistant as the Maillard reaction proceeded. The SEM, provided images that exhibit observable changes in surface texture. As the reaction proceeds the film becomes the 48 H film more homogenous and less likely to form large holes and cracks than the 0 H and control film (Fig. 6). While the Maillard reaction film properties do not yet compare to those of current packaging, the film demonstrates several improvements in properties such as previously mentioned. As a result, developing this Maillard reaction film may serve as an ideal starting point to develop an improved packaging material that is sustainable for the environment

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References

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