Development of Starch and Protein based Edible Packaging Material

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Abstract—*Currently there has been a much interest in edible film made from renewable and natural polymer such as protein, polysaccharide and lipids. The use of these materials, due to their biodegradable nature, could at least solve the waste problem at some extent. Packaging is an important protection for foods, preventing contamination, and maintains conditions of hygiene. It works as a barrier against external contaminants, mainly pathogens found in the environment. In this research, Edible film was prepared using starch as base material. Starch was partially replaced by protein to increase the mechanical strength of the edible film. Replacement of protein was possible only upto 40% concentration. Water Vapour Transmission Rate increased from 2.743 g/m^2.day in starch film to 3.855 g/m^2.day in 40% protein film. Solubility increased from 52.58% in starch film to 61.72% in 40% protein film. Moisture content increased from 11.549 to 17.931 on wet basis in starch film and 40% protein film respectively. Skin strength was 547.27 g Force for starch film and increased to 1215.65 g Force in 40% protein film.*

Keywords: *Starch film, Protein film, Edible packaging material.*

Highlights

- *Starch film showed better barrier properties.*
- *Protein film showed better mechanical properties*
- *Addition of protein in starch increased the mechanical strength.*
- *Combination of protein and starch as a base material to form edible film could provide good balance between barrier and mechanical properties.*

1. Introduction

Edible films and coatings are defined as any thin material used for wrapping or coating food materials and drugs to extend shelf life of the product which may be consumed together or removed before consumption. The term “edible film” has two main considerations. First part “edible” means, films may be consumed together with foods in contact so they need to cover all properties of safe-food ingredients according to Food and Drug Administration (FDA) having Generally Recognized as Safe (GRAS) status. Latter part “films” means, covering material should have packaging properties which protect the inner part from outer environment and limit gas and water vapor transportation between food material and outside. Because of these quality concerns, film material should be as thin as possible acquiring adequate mechanical properties to protect food material (Erkmen et al., 2018).

An edible film has three major components; film forming material, plasticizer, and additives. Additionally, edible films need a suitable solvent in order to prepare a film forming dispersion (FFD). Mostly water, alcohol or aqueous alcohols are used as solvents according to natural solubility characteristics of film forming materials. Proteins, polysaccharides, lipids and combination or mixture of these are major film forming materials. Most of the edible films are used to minimize moisture loss, and respiration of food materials. Moisture and gas barrier properties are found to be the most important requirements of edible films and coatings for food materials after being food grade (Erkmen et al., 2018).

In the family of renewable source-based polymeric materials, starch is an inexpensive and abundant natural resource. Native starch is a mixture of amylose and a highly branched amylopectin, and its mechanical and physical properties are poor. (Zhao et al., 2008).

Edible films are defined as a thin layer of material which can be consumed and provides a barrier to moisture, oxygen and solute movement for the food. Edible films can be formed as food coatings and free-standing films, and have the potential to be used

with food as gas aroma barrier. Edible films and coatings have received considerable attention in recent years because of their advantages over synthetic films. The main advantage of edible films over traditional synthetics is that they can be consumed with the packaged products. The films are produced exclusively from renewable, edible ingredients and therefore are anticipated to degrade more readily than polymeric materials. The films can enhance the organoleptic properties of packaged foods provided they contain various components (flavorings, colorings, sweeteners). The films can function as carriers for antimicrobial and antioxidant agents. In a similar application they can also be used on the surface of food to control the diffusion rate of preservative substances from the surface to the interior of the food (Bourtoom, 2008).

Edible films can be produced from materials with film forming ability. During manufacturing, film materials must be dispersed and dissolved in a solvent such as water, alcohol or mixture of water and alcohol or a mixture of other solvents. Plasticizers, antimicrobial agents, colors or flavors can be added in this process. In food applications, film solutions could be applied to food by several methods such as dipping, spraying, brushing and panning followed by drying. Components used for the preparation of edible films can be classified into three categories: hydrocolloids (such as proteins, polysaccharides, and alginate), lipids (such as fatty acids, acylglycerol, waxes) and composites (Donhowe and Fennema, 1993).

Plasticizers are often added to film-forming solutions to enhance properties of the final film. These film additives are typically small molecules of low molecular weight and high boiling point that are highly compatible with the polymers. Common food-grade plasticizers such as sorbitol, glycerol, mannitol, sucrose, and polyethylene glycol decrease brittleness and increase flexibility of the film, which is important in packaging applications. The type and concentration of plasticizer influences the properties of protein films, mechanical strength, barrier properties, and elasticity decrease when high levels of plasticizer are used (Cagri et al., 2004).

2. Materials and methods

2.1 Materials

Materials required for this project are Starch and Whey Protein. Starch and Protein for formation of edible film was purchased from market.

2.2 Preparation of Edible Film

Starch was firstly dissolved in distilled water (4-6) gram/100ml, and then the pH value of the prepared solution was adjusted to 7 with 0.1N NaOH then mixed by magnetic stirrer at temperature 85±2˚C. Then a plasticizer glycerol added at concentration 20-30% w/w of starch quantity. Then heat for 30 minutes at same temperature as earlier. Then formed gel poured in to disposable petri plate.

2.3 Film thickness

The films were taken and the thickness was measured by vernier calipers. The thickness was measured from different places of the films.

2.4 Water-Vapor Transmission Rate (WVTR)

Film was cut in round shape and bind on head of test tubes filled half with Silica Gel to absorb moisture. Weight of test tubes is taken after regular time intervals and difference in weight of test tube is noted which was considered equal with the transferred water through the film and adsorbed by the desiccant. The slope of weight loss vs. time was obtained by linear regression. This test was repeated three times for each film specimen. (Jagannath et al., 2002).

2.5 Solubility

For the test films was cut into 2×2 cm^2 sizes, weighted (W_1) and then dry at 100℃ for 24 hrs then weigh (W_2). It was then immerse in distilled water for 24 hrs. After that the films were removed water soaked, weigh (W_3) and dried again for 24 hrs at 100℃. The final weight of the dried film was record (W_4).

Solubility = Initial Weight W_1 – Final Weight W_4/ Initial Dry Weight W_2

2.6 Moisture content

The moisture content was determined by drying in oven at 100℃ for 24 hrs. Small test specimen was cut into 2×2 cm^2 placed and their weights were recorded before and after oven drying. Moisture content was calculated as the percentage of weight loss based on the original weight on the basis of the following formula:

% Moisture = $(M_i – M_d) / M_i$

Here M_i = initial weight of the film M_d = final weight (oven dry)

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2.7 Mechanical Characteristics Analysis (Puncture Test)

The force and the deformation at the breaking point of the film were determined in puncture tests (Sobral et al., 2001). The films were fixed in a rectangular cell and perforated by a 3mm diameter cylindrical probe, moving at 1mm/s. These tests were accomplished with an instrument TA. XT. Plus Texture Analyser. The puncture force F and displacement of the probe D in the puncture were determined with the software.

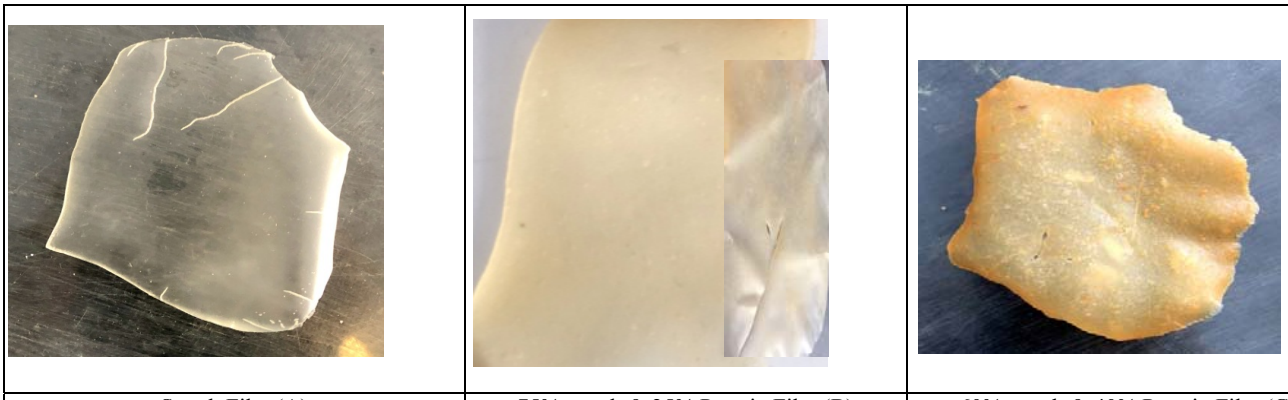
2.8 Stastical analysis

All experiments were performed in duplicate. Statistics on a completely randomized design were performed with the analysis of variance (ANOVA) procedure in SPSS16 software, and mean comparisons were carried out by Duncan's multiple range test ($p < 0.05$) (Park et al. 2018).s

3. RESULT AND DISCUSSION

3.1 Film preparation

The films developed with different combinations of starch and protein provided good quality of films. Film developed with starch was found to be transparent, homogeneous and flexible. Starch was partially replaced with whey protein to increase the mechanical strength of the film but upto 40% of starch replacement was possible after that film was not formed and showed stiffness after drying because of low gelling property in solution. Films with 20% and 40% protein was semi-transparent and flexible. The picture of developed films are given in figure 3.1.



Starch Film (A)	75% starch & 25% Protein Film (B)	60% starch & 40% Protein Film (C)

Fig. 3.1: Different Films of Starch and Protein.

3.2 Film Thickness

Uniform volume 15 ml of solution was taken and poured in patricdish and dried. Film thickness was measured using a screw gauge. Five thickness measurements were taken at random positions of film. The average film thickness of different combination of film was not significantly affected by the composition.

Table 3.1 Thickness of films made up of different compositions of starch and protein

Film	Thickness (Micrometer)
Starch (A)	216±7.528
25% Protein (B)	216±6.321
40% Protein (C)	225±5.321

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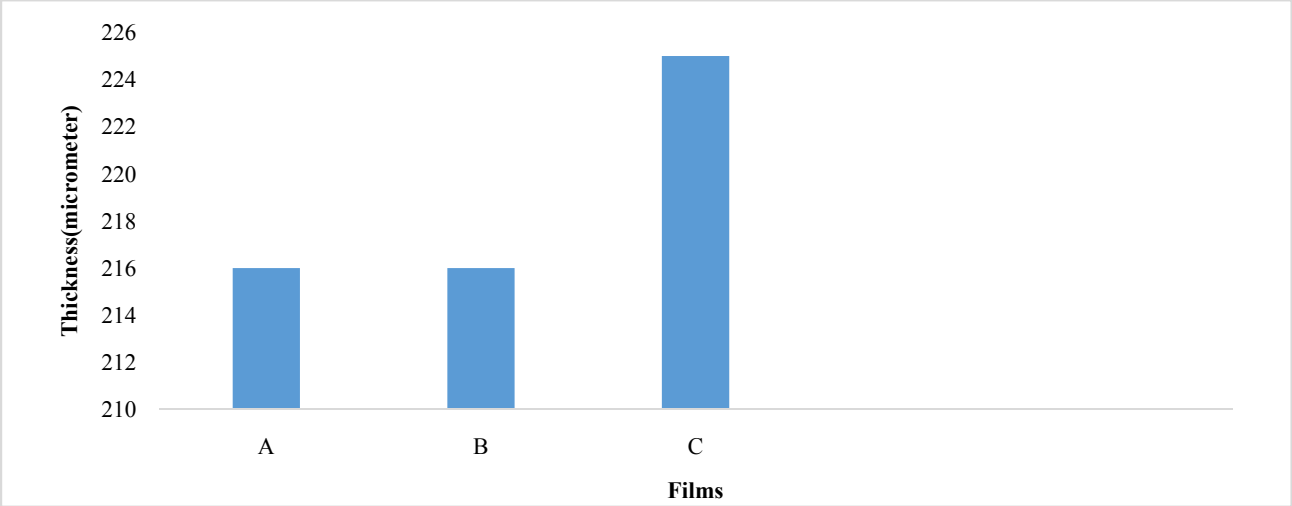

Figure 3.2 Thickness of films made up of different compositions of starch and protein

3.3 Water Vapour Transmission Rate (WVTR)

Water Vapour Transmission Rate WVTR of pure starch film was found 2.743 g/m2.day and increased to 2.793, 3.855 g/m^2.day by addition of protein at 25% and 40% respectively. Film contained 60% starch and 40% protein as a base material showed highest WVTR among all three films. Whey protein has hydrophilic nature (water loving) due to presence of NH_2 groups, so it cause increase in WVTR value whereas starch has hydrophobic nature as its OH groups are bounded in complex form, so it cause decrease in WVTR value.

Table 3.2 WVTR of films made up of Starch, 25% Protein and 40% Protein

Film	WVTR (g/m^2.day)
A (Starch Film)	2.743
B (25% Protein Film)	2.793
C (40% Protein Film)	3.855

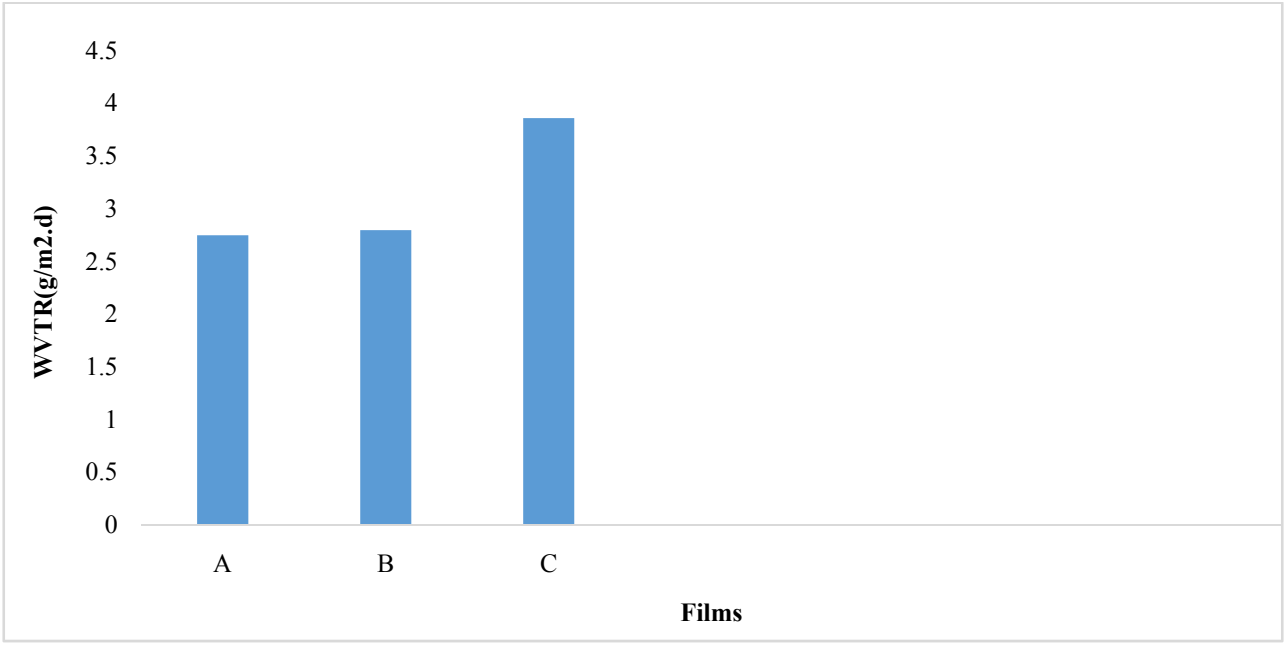

Fig. 3.3: WVTR of films made up of Starch, 25% Protein and 40% Protein

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3.4 Solubility

Film solubility was found lowest 52.58% for pure starch based film, Solubility 57.45 and 61.72% was found for film contained 25% and 40% whey protein respectively. Solubility was significantly increased with increasing concentration of protein, whey protein hydrophilic in nature this could be reason of increased solubility with increased concentration of protein in film.

Table 3.3 Solubility of films made up of Starch, 25% Protein and 40% Protein

Film	Film Solubility %
A (Starch Film)	52.58
B (25% Protein Film)	57.45
C (40% Protein Film)	61.72

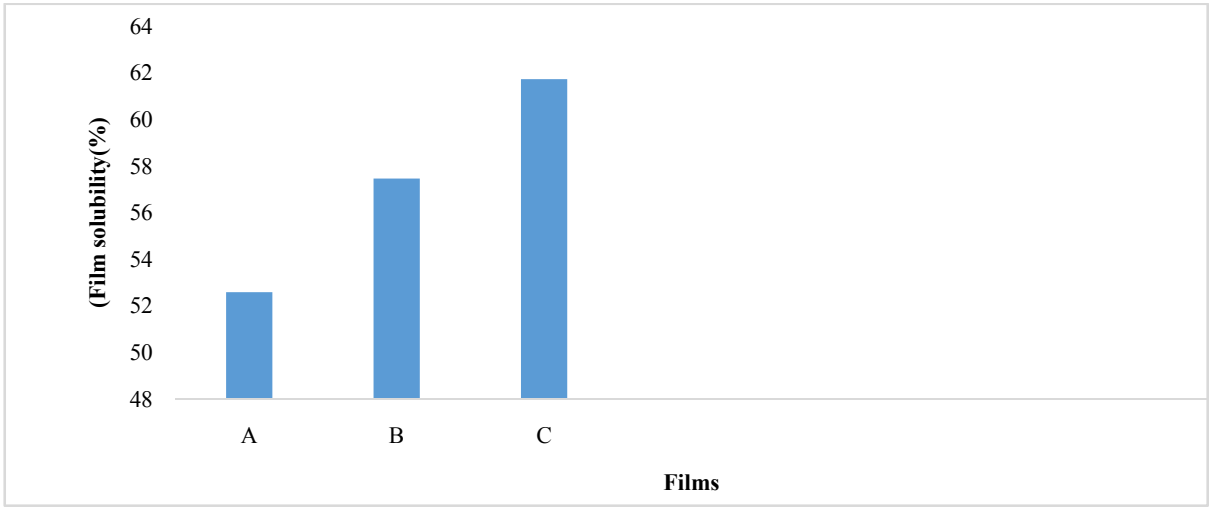

Figure 3.4 - Solubility of films made up of Starch, 25% Protein and 40% Protein

3.5 Moisture Content

Result shows that moisture content of films increases on increasing percentage of protein. Least moisture content is found in pure starch film and highest is found in 40% protein film

Table 3.4 Moisture Content of Films made up of Starch, 25% Protein and 40% Protein

Film	Moisture content (WB)
A (Starch Film)	11.549
B (25% Protein Film)	15.310
C (40% Protein Film)	17.931

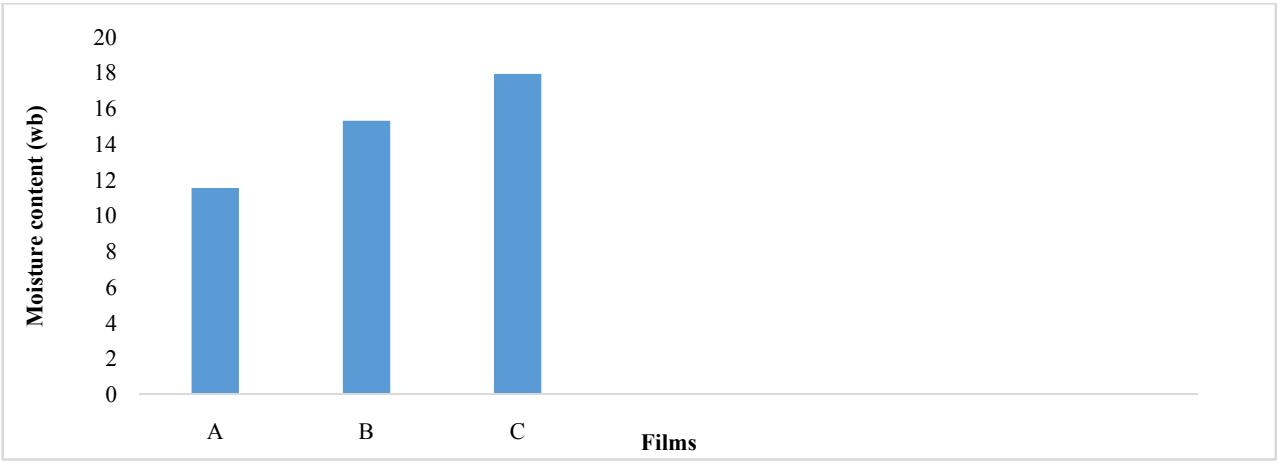

Figure 3.5 - Moisture content of the films made up of Starch, 25% Protein and 40% Protein

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As protein is hydrophilic in nature due to presence of $–NH_2$ groups, it becomes water loving species whereas starch being hydrophobic in nature becomes water repelling species.

3.6 Puncture strength and elasticity

It was done using TA-XT plus Texture Analyser using 3mm diameter cylindrical probe moving at 1mm/sec speed. The puncture force F and displacement of the probe D in the puncture were determined with the software.

Table 3.5 Reading for Rupture force and elasticity

Film	Skin Strength (g Force)	Elasticity (mm)
A (Starch Film)	547.27	7.68
C (25% Protein Film)	800.94	9.63
D (40% Protein Film)	1215.65	10.85

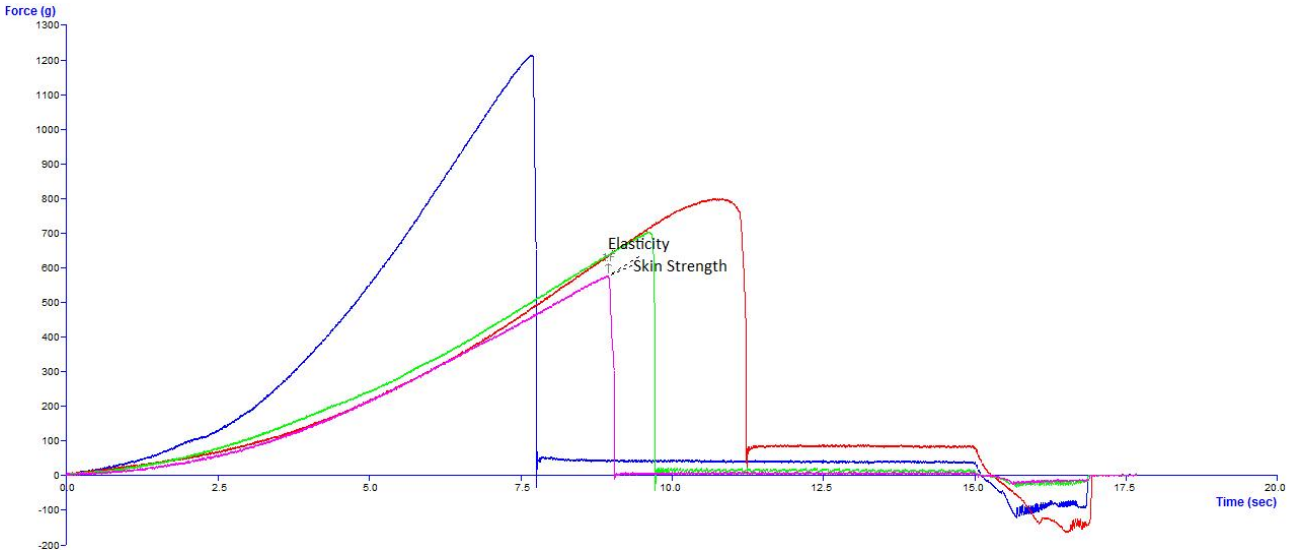

Fig. 3.6: Graph of Puncture Force v/s displacement of probe

Highest force (1215.65g) was required for 40% protein film represented by Blue Color Peak. Least force (547.27g) was recorded for Starch Film represented by Pink Color Peak. Elasticity was maximum (10.85mm) in 40% protein film and minimum in starch film (7.68mm).

4. Conclusion

As Starch film lacks in mechanical properties but it is good at barrier properties. Hence addition of Protein in starch film increases the film mechanical strength and decrease the water vapor transfer rate and solubility.

Declaration of conflict of interest

Authors declare no conflict of interests.

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