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THE EFFECTS OF DRYING TEMPERATURES AND OIL CONTENTS ON PROPERTIES OF BIODEGRADABLE FILM FROM KONJAC FLOUR

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ABSTRACT

Biodegradable films are material based on a biopolymer. The objectives of this research were to study the effects of drying temperatures and olive oil contents on physical and mechanical properties, water vapor permeability (WVP) and solubility of edible konjac films. The plasticizer contents of olive oil were 0%, 1% and 3%. The drying temperatures of 45 and 55 ºC were applied using a heat pump dryer. The results found the tensile strength and solubility of film were significantly decreased ($p \leq 0.05$) when the oil contents and drying temperature increased. For the elongation and the thickness, these properties were significantly increased ($p \leq 0.05$) by the increase of oil contents and drying temperatures. In addition, water vapor permeability of the film was significantly increased ($p \leq 0.05$) when the oil contents and drying temperatures increased.

INTRODUCTION

Packages are an identify to serve marketing and consumer information purposes, packaging places a physical barrier between food products and the outside environment, especially those susceptible to oxidative and microbiological deterioration. The most common materials used for packaging are paper, fiberboard, plastic, glass, steel, and aluminum. Oil-derived synthetic plastics are commonly used, because they afford various advantages over other packaging materials in terms of sturdiness and low weight [1]. However, they pose a serious global environmental problem by generating large volumes of non-biodegradable waste [2]. Moreover, in addition to safety and environmental issues, recycling of plastics is complicated for technical and economic reasons [3].

Thus, new biodegradable films made from edible biopolymers from renewable sources could become an important factor in reducing the environmental impact of plastic waste [4]. Proteins, lipids, and polysaccharides are the main biopolymers employed to make edible films. Which of these components are present in which proportions determines the properties of the material as a barrier to water vapour, oxygen, carbon dioxide, and lipid transfer in food systems. Films composed primarily of proteins or polysaccharides have suitable overall mechanical and optical properties but are highly sensitive to moisture and exhibit poor water vapour barrier properties [5]. This may represent a drawback when they are applied to food products with high moisture contents, because the films may swell, dissolve, or disintegrate upon contact with the water. However, the concept of bio polymers only is valid if the oil utilization life-cycle is shorter for biopolymers than for synthetic polymers [6].

Edible films from biodegradable material can be formed by two main processes, i.e., casting and extrusion [7]. The film-formation process most often reported in the scientific literature is the casting method. Briefly, it involves dissolving the biopolymer and blending it with plasticizers and/or additives to obtain a film-forming solution, which is cast onto plates and then dried by driving off the solvent. The extrusion method relies on the thermoplastic behaviour of proteins at low moisture levels. Films can be produced by extrusion followed by heat-pressing at temperatures that are ordinarily higher than 80 ºC. This process may affect film properties.

Drying at higher temperatures will affect on quality of the biodegradable film. The physical and chemical properties of the film are changes [8]. This is due to the biodegradable film is a thin sheet. Most types of edible films are prepared by hot air drying (24 h) [9]. Heat pump dryer is one of the fastest drying methods, drying at a low temperature and can reduce moisture in the drying process as well. Their advantages include higher energy efficiency due to the high coefficient of performance and better product quality [10].

The objective of this paper was to investigate the effects of drying temperatures and olive oil contents on properties of biodegradable film. Konjac flour was used as biodegradable base for film forming. Heat pump dryer was used for drying. The drying temperature was applied at 45 and 55 ºC. The olive oil was applied at 1 and 3% by volume. Properties of film were tensile strength, elongation, thickness, solubility and water vapor permeability to testing.

MATERIAL AND METHOD

Film preparation

A film-forming solution was prepared by slowly dissolving weighed amounts of konjac flour (1% w/v) of 100 ml distilled water under constant stirring via the use of a magnetic stirrer at 300 rpm at room temperature for 3 h. The KOH (0.14% w/v) was added before blending for 15 min. The mixture was then left to stand for 1 h at room temperature. The glycerol which was added was arbitrarily set at 30% of the weight of Konjac flour used and blend for 20 min. Olive oil was added amount (1% and 3%w/v) and homogenized at 12,500 rpm for 5 min [12].

Film drying

After which films were prepared. The solution 33.75 g portions were poured and spread onto a level, rectangular Perspex plate fitted with rims around the edge to give a

7.5*13.5 cm film forming area. The solutions were allowed to dry at the temperature of 45 and 55 ºC using a heat pump dryer for approximately 6 h. The dry films obtained were peeled off and stored in a desiccators containing saturated sodium Chloride (NaCl) solution with 75% (RH) at room temperature until analysis.

Film properties determination

Film thickness determination. The film thickness was measured using a micrometer (Mitutoyo, Tokyo, Japan) with an accuracy of 0.001 mm. Each film sample was measured six random positions along the strip; an average value was reported. The mechanical properties and WVP were calculated using the average thickness of each film sample.

Tensile strength and elongation tests.

The measurement of the mechanical properties of konjac films was carried out using a texture analyzer (Textere Analysis model TA.XT.Plus). After conditioning a konjac film, sample was cut into a 25.4 mm wide and 100 mm long strip. Initial grip separation and cross-head speed were set at 60 mm and 20 mm/min respectively. Tensile strength was calculated by dividing the maximum load for breaking the film by its cross-sectional area. Percent elongation was determined by dividing the film elongation at rupture by the initial grip separation.

Water vapor permeability.

Water vapor permeability (WVP) of the films was determined using an aluminum cup with diameter 5.2 cm and height 4.2 cm. Aluminum cup contained 100 g silica gel (0% RH) that was dried in oven at 120 ºC for 1 day. The headspace for the aluminum cup was 1 cm from the opening of the aluminum cup. Films were cut circularly with a diameter slightly larger than the diameter of the aluminum cup. They were covered and sealed using melted paraffin. These aluminum cups were then placed in a desiccators containing distilled water (100% RH). The aluminum cups were weighed at 1 h intervals over a 5 h period. Weight loss graphs were plotted with respect to time. The slope of each line was calculated by linear regression ($r^2 \geq 0.99$). The measured WVP of the films was determined as follows.

$$WVP = (WVTR * t) / DP \qquad (1)$$

Where *WVTR* is the water vapor transmission rate (g m^{-2} h^{-1}) through a film, calculated from the slope of the straight line divided by the exposed film area (m^2) and *t* is the mean film thickness (mm), and *DP* is the partial water vapor pressure difference (Pa) across the two sides of the film. For each type of film, WVP measurements were replicated three times for each batch of films.

Solubility in water.

Solubility is defined as the percentage of film dry matter solubilized. The initial percentage of dry matter was determined by drying 2 cm diameter disks in a hot air oven at 105 ºC during 3 h to determine the weight of film dry matter (W). Disks were cut, weighed and immersed in 100 ml of distilled water, with periodic stirring, during 1 h at room temperature. The remained films were taken out and filter used filter paper No.4 to determine the weight of filter paper (a_1). It was dried by hot air oven at 105 ºC for 25 min to determine the final weight of dry matter (a_2). Solubility is reported as the difference between initial and final dry matter with respect to initial dry matter. The measured solubility in water of the films was determined as follows:

$$\% \text{ solubility in water} = \{W - (a_2 - a_1)\} / W \qquad (2)$$

Where W is weight of film dry matter, a_1 is the weight of filter paper and a_2 the final weight of filter paper dry matter.

RESULTS AND DISCUSSION

The effects of drying temperature and olive oil contents (0%, 1% and 3% w/w konjac) on physical properties, mechanical properties, water vapor permeability and solubility of edible konjac films was investigated. The experimental results are as following.

Mechanical properties

Tensile strength. The tensile strength of Konjac films containing various olive oils decreased as oil concentrations increased. As can be observed in Table 1, the plasticizer additives glycerol and olive oil have an indicated that all additives significantly influenced tensile strength of the films. An increase of olive oil content caused to tensile strength decrease in film. The films mixed with more than 1% of olive oil content presented lower values of tensile strength. Therefore, glycerol and olive oil additive acts as a plasticizer concentration agent, changing film mechanical behavior. But there was no significant difference observed in the tensile strength among films at various olive oil contents at 55(ºC). This data was similar to the results that tensile strength of laminated edible films containing palmitic acid, lauric acid, and the combination decreased as concentrations of these fatty acids increased [13].

Table 1 Tensile strength (N/mm^2) of film obtained from different temperatures and olive oil contents

Olive oil (%w/w)	Temperature (ºC)	
	45	55
0	$12.68^{Aa} \pm 0.46$	$12.02^{Ba} \pm 0.46$
1	$4.56^{Ab} \pm 0.86$	$3.01^{Bb} \pm 0.14$
3	$3.06^{Ac} \pm 0.20$	$2.51^{Bb} \pm 0.03$

A, B. Means in same row with different letters are significantly different ($p \leq 0.05$).
a, b. Means in same column with different letters are significantly different ($p \leq 0.05$).

Elongation.

The elongation at break is a measure of the film's stretch before breaking [14]. It was shown that trends for elongation value of these films were opposite for tensile strength. The addition of olive oils resulted in more elastic films. Generally, as the film structure softened, tensile strength decreased and elongations in all temperature were increased. The results are shown in Table 2.

Table 2 Elongation (%) of film obtained from different temperatures and olive oil contents

Olive oil (%w/w)	Temperature (ºC)	
	45	55
0	$6.88^{Bc} \pm 3.60$	$7.92^{Ac} \pm 1.40$
1	$13.14^{Bb} \pm 1.57$	$24.47^{Ab} \pm 0.73$
3	$27.15^{Ba} \pm 3.03$	$55.12^{Aa} \pm 2.35$

[A, B.] Means in same row with different letters are significantly different ($p \leq 0.05$).
[a, b.] Means in same column with different letters are significantly different ($p \leq 0.05$).

This finding is agreed with the previous report that the glycerol concentration significantly affected the tensile strength and percent elongation of the films [12, 15]. The films without olive oil had the highest tensile strength and lowest percent elongation.

Physical properties

Thickness. Konjac films produced without olive oils were smooth and transparent having mean thickness about 0.04 mm. When olive oils were added, films became thick, as evidenced in film thickness (Table 3). As increase of concentration of olive oils, the higher thickness of films were obtained due to high amounts of olive oils. This is due to olive oil was used as plasticizing agents, to reduce the intermolecular interactions and increase mobility of the macromolecules. There were no significant differences observed in the thickness among films at various olive oil contents when the drying temperature increased.

Table 3 Thickness (mm) of film obtained from different temperatures and olive oil contents.

Olive oil (%w/w)	**Temperature (ºC)**	
	45	**55**
0^{ns}	$0.040^{c} \pm 0.000$	$0.040^{c} \pm 0.000$
1	$0.138^{Bb} \pm 0.000$	$0.170^{Ab} \pm 0.001$
3	$0.269^{Ba} \pm 0.004$	$0.390^{Aa} \pm 0.002$

[A, B.] Means in same row with different letters are significantly different ($p \leq 0.05$).
[a, b.] Means in same column with different letters are significantly ($p \leq 0.05$).
[ns] = non significantly difference

Water vapor permeability.

Indicated that water vapor transfer generally occurs through the hydrophilic portion of the film and depends on the hydrophilic – hydrophobic ratio of the film components. Table 4 shows the WVP of the films. The drying at temperature of 45 ºC has a lower value that drying at 55 ºC. The presence resulted of percentage olive oil are increased caused an increase in film WVP. The effect found in this research may be related to the hydrophilic character and the thickness of the films. Since the WVP were calculated using the average thickness of each film sample (Eq 1). The thicknesses of edible films are increased with the drying temperature and olive oil concentration leading an increase in WVP.

Table 4 WVP (g mm/(kPa h m²)) of film obtained from different temperatures and olive oil contents.

Olive oil (%w/w)	**Temperature (ºC)**	
	45	**55**
0	$0.476^{Bb} \pm 0.030$	$1.276^{Ac} \pm 0.030$
1	$0.560^{Bb} \pm 0.045$	$1.533^{Ab} \pm 0.051$
3	$0.666^{Ba} \pm 0.051$	$2.226^{Aa} \pm 0.100$

[A, B.] Means in same row with different letters are significantly different ($p \leq 0.05$).
[a, b.] Means in same column with different letters are significantly different ($p \leq 0.05$).

Solubility.

The water solubility of these films was decreased by adding olive oils (Table 5). This could be explained by the fact that vegetable oils, with the help of hydrophobic substances that dispersed in the films, changed the polarity of the components [8].

Table 5 Solubility (%) of film obtained from different temperatures and olive oil contents.

Olive oil (%w/w)	**Temperature (ºC)**	
	45	**55**
0	$78.16^{Aa} \pm 0.68$	$70.11^{Ba} \pm 2.39$
1	$56.02^{Ab} \pm 0.19$	$38.51^{Bb} \pm 0.07$
3	$24.45^{Bc} \pm 0.64$	$26.95^{Ac} \pm 0.37$

[A, B.] Means in same row with different letters are significantly different at ($p < 0.05$).
[a, b.] Means in same column with different letters are significantly different at ($p < 0.05$).

CONCLUSIONS

The effect of olive oil content (0%, 1% and 3% w/w konjac) and drying temperature on physical properties, mechanical properties, water vapor permeability and solubility of edible konjac films were studied. The experimental results can be drawn as the following:

1. The elongation, thickness and water vapor permeability were significantly increased with the olive oil content ($p \leq 0.05$).
2. The tensile strength and percent solubility of the films decreased with an increase in the concentration of olive oil content.
3. The olive oil content had statistically significant on the all condition of edible films prepared by different temperature drying.
4. The water vapor permeability of film at the olive oil contents of 0 and 1% w/w at drying of 45 ºC were not statistically significant ($p < 0.05$).

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