# Effect of Vegetable Oils on Physical Characteristics of Edible Konjac Films

**Kamontip Ekthamasut and Adisak Akesowan**
**Faculty of Science, The University of the Thai Chamber of Commerce**
**Bangkok, Thailand**

## *Abstract*

*Physical characteristics were investigated in konjac films added with different levels of vegetable oils (corn oil, palm oil and sunflower seed oil). Thickness and color of konjac films were affected ($p < 0.05$) by the incorporation of vegetable oils. Tensile strength decreased with higher levels of vegetable oils, while percentage elongation at break increased. Increasing levels of vegetable oils resulted in decreased water vapor transmission rate (WVTR) and water solubility. The konjac films containing palm oil showed higher WVTR than those of corn oil and sunflower seed oil. The water solubility of konjac films tended to decrease as the level of vegetable oils increases.*

**Keywords:** *Konjac films, edible films, corn oil, palm oil, sunflower seed oil, tensile strength, percent elongation, water vapor transmission rate, water solubility.*

## Introduction

Edible films afford numerous advantages in many industries including confectionery, meat fruits and vegetables and pharmaceutical industries. They have been used to extend shelflife and preserve quality of food products (Gontard *et al.* 1993). Proteins, polysaccharides, lipids, or a combination can be used to produce edible films. Protein and polysaccharide films are good oxygen barriers with good mechanical properties, while lipid films offer limited oxygen barrier properties (McHugh and Krochta 1994). However, a major disadvantage of these films is the high water vapor permeability that is undesirable in edible coatings or packaging materials (Maynes and Krochta 1994; Herald *et al.* 1995).

Konjac flour, a glucomannan polysaccharide, was investigated for its potential use as an edible coating for oxygen barrier to extend shelflife of oranges and eggs, but such film tended to be permeable to water vapor (Ekthamasut and Akesowan 2000). Lai and Padua (1998) reported that lipids have been added to biopolymer film-forming formulation to improve moisture barrier properties of films. Vegetable oils from linseed, perilla, fish or soybean formed resistant coating layers on films. The objective of this study was to investigate changes in physical characteristics of konjac films resulting from addition of different levels of vegetable oils.

## Materials and Methods

### Materials

Konjac flour, produced by the method devised by Akesowan (1997), with a moisture content of 9.52% was used. Vegetable oils including corn oil, palm oil, and sunflower seed oil were purchased from a retail store. Glycerin was obtained from Nasa Lab Co., Ltd.

### Preparation of Konjac Film

A film-forming solution was prepared at room temperature by slowly dissolving 2.5 g of konjac flour in a constantly-stirred mixture of 400 mL of distilled water and 0.75 mL of glycerin as plasticizer. The solution was stirred on a magnetic stirrer for 3 hr. The film-forming solution was strained through cheese choth and then Whatman No. 4 filter paper, respectively. Then, distilled water (100 mL) with different concentrations of each vegetable oil was added into the solution and stirred for 10 min. The mixture solution was filtered through Whatman No. 4 filter paper and poured onto clean, smooth petridish plate (9.5 cm in diameter). Film thickness was controlled by casting the same amounts (40 mL) of film-forming solution. Films were allowed to dry in a hot air oven at 40°C for 24 hr. After drying, the plates were cooled and the films were peeled and kept in a desiccator until further analysis. The experimental konjac films were prepared by using different vegetable oils (corn oil, palm oil, and sunflower oil at various concentrations (0.1, 0.2 and 0.3 g/g konjac flour).

**Film Thickness**

Film thickness was measured with a micrometer. Measurements were taken at three different positions around the film.

**Tensile Strength and Percentage Elongation at Break**

Tensile strength and elongation at break were evaluated with a Lloyd texture analyzer (Model LRX, Lloyd instruments, Hampshire, UK). Initial grip separation was set at 45 mm and cross-head speed was set at 300 mm/min. The films were cut into 10 mm wide × 60 mm long strips using a razor blade. The ends of each of these strips were mounted between grips. Peak force necessary to pull each strip apart was measured. Tensile strength was calculated by dividing the maximum load by the cross-sectional area of the sample. Elongation was calculated as the percentage of change by dividing film elongation at the moment of rupture by initial gauge length (45 mm) (Rhim *et al.* 1999).

**Water Vapor Transmission Rate (WVTR)**

Silica gel was placed in a cup. A film was then sealed onto the cup with grease. The cup was stored in a laboratory desiccator for 24 hr. Initial weight was recorded (expressed as $W_1$), the cup was placed in a hot air oven with a tray filled with water for 12 hr. at 70°C. The weight of the cup was measured and expressed as $W_2$. The WVTR of the film was determined as follow (Kamper and Fennema 1984).

$$\text{WVTR} = \frac{W_2 - W_1}{AT} = \frac{g}{(m^2)(24hr)}$$

Where: $W_2$-$W_1$ is the weight of water absorbed in the cup, A is the area of film, T is the time for weight change.

**Water Solubility**

The film was dried at 105°C for 3 hr. and weighed ($W_1$). After that, the film was immersed in 100 mL of distilled water in a 250 mL beaker and stirred on a magnetic stirrer for 15 hr. The resulting suspension was then filtered through Whatman No. 4 filter paper (already weighed, $a_1$), oven drying (105°C), and then weighed ($a_2$). The percentage of film solubility = $\frac{W_1 - [a_2 - a_1]}{W_1} \times 100$ (Rhim *et al.* 1999).

**Color**

Color value of films was measured with a Hunter Lab digital color difference meter Model D 25 M (Hunter Associates Laboratory, Reston, VA). Films were placed on a white standard plate (L = 93.97, a = -0.91, and b = -0.71). Values for L (lightness), a (redness), and b (yellowness) were recorded.

Total color difference ($\Delta$E), yellowness index (YI), and whiteness index (WI) were calculated as (Bolin and Huxsoll 1991):

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{0.5} \quad (1)$$
$$YI = 142.86\, b/L \quad (2)$$
$$WI = 100-[(100-L)^2 + a^2 + b^2]^{0.5} \quad (3)$$

where $\Delta L = L_{standard} - L_{sample}$ ; $\Delta a = a_{standard} - a_{sample}$ ; $\Delta b = b_{standard} - b_{sample}$. Three measurements were taken on each film.

**Statistical Analysis**

Measurements of each property were triplicated for thickness, tensile strength, elongation, WVTR, water solubility and color.

Statistics on a completely randomized design were determined. When analysis of variance (ANOVA) revealed a significant effect ($p < 0.05$), treatment means were compared using the Duncan's New Multiple Range Test method (Cochran and Cox 1992).

## Results and Discussion

### Thickness and Color Evaluation

Konjac films produced without vegetable oils were smooth and transparent having mean thickness about 21 *mm* (Table 1). When vegetable oils were added, films remained smooth and transparent but became thick, as evidenced in film thickness (Table 1). As increase of concentration of vegetable oils, the higher thickness of films were obtained ($p < 0.05$) due to high amounts of vegetable oils. The film solutions containing sunflower seed oil at 0.3 g/g of konjac flour produced thickener films than those contained corn oil and palm oil at the same concentration.

The lightness (L) value of konjac films was not affected ($p > 0.05$) by the addition of vegetable oils at any levels. In contrast, increased yellowness (b) occurred when increased concentrations of vegetable oils were added. This was somewhat expected because of the yellow color of these vegetable oils. Corn oil is relatively intense in color than palm oil and sunflower seed oil (Giese 1996). Furthermore, the color of vegetable oils affected ($p< 0.05$) on a-value of these films. The greenness (a) increased continuously as vegetable oils increased.

Color changes due to addition of vegetable oils can be described using other color functions, such as E which indicates the degree of total color difference from the standard color plate, YI indicates degree of yellowness, and WI indicates degree of whiteness. The addition of vegetable oils resulted in an increase ($p< 0.05$) in E and YI, but decreased ($p< 0.05$) in WI. The E showed the same trend as YI, indicating color difference of konjac films containing various vegetable oils were mainly due to changes in yellowness.

### Tensile Strength and Elongation

Tensile strength of edible konjac films containing various vegetable oils decreased as oil concentrations increased (Fig 1). This data was similar to the results of Park *et al.* (1994) who reported that tensile strength of laminated edible films containing palmitic acid, lauric acid, and the combination decreased as concentrations of these fatty acids increased. In comparing tensile strength at different types of vegetable oils, differences occurred among these films. Tensile strength of the film containing sunflower seed oil was higher than those of films containing palm oil and corn oil.

Percentage elongation at break, a measure of a extensibility, for konjac films containing various vegetable oils increased as oil concentration increased (Fig 2). It was shown that trends for elongation value of these films were opposite for tensile strength. The addition of vegetable oils resulted in more elastic films. Generally, as the film structure softened, tensile strength decreased and elongation increased. The elongation of the film made with sunflower seed oil was the highest when compared to films made with palm oil and corn oil.

### Water Vapor Transmission Rate and Water Solubility

The amount of vegetable oils added to the film forming solution influenced the WVTR. The addition of vegetable oils improved the WVTR characteristics of the films as evidenced by decrease in WVTR values (Fig 3). As the oil concentration was increased, the WVTR value of films was decreased. These results were in general agreement with the report of Park *et al.* (1994) for effects of fatty acid concentrations on WVTR of laminated edible films. Kamper and Fennema (1984) also reported that increasing the stearic acid concentration resulted in decreased WVTR of edible films. In general, glycerin is used as a plasticizer in this film preparation for improving flexibility of the film. This avoids chipping or cracking of the film during removal from the plate. Glycerin is theorized to reduce internal hydrogen bonding while increasing

Table 1. Film thickness, Hunter color values, total color difference (ΔE), yellowness index (YI) and whiteness index (WI) of konjac films with various types and levels of vegetable oils.

| **Vegetable oils (g/g of konjac flour)** | **Thickness ( *mm* )** | **Hunter color values[d]** | | | **DE** | **YI** | **WI** |
|---|---|---|---|---|---|---|---|
| | | **L** | **a** | **b** | | | |
| <u>Corn oil</u> | | | | | | | |
| 0 | 21$^{b}$ | 92.57$^{a}$ | -1.21$^{a}$ | 0.15$^{c}$ | 1.67$^{c}$ | 0.23$^{c}$ | 92.47$^{a}$ |
| 0.1 | 25$^{b}$ | 92.29$^{a}$ | -2.07$^{b}$ | 1.89$^{b}$ | 3.31$^{b}$ | 2.93$^{b}$ | 91.80$^{b}$ |
| 0.2 | 29$^{a}$ | 92.57$^{a}$ | -2.35$^{b}$ | 1.88$^{b}$ | 3.28$^{b}$ | 2.90$^{b}$ | 91.98$^{ab}$ |
| 0.3 | 31$^{a}$ | 93.14$^{a}$ | -3.60$^{c}$ | 2.96$^{a}$ | 4.63$^{a}$ | 4.54$^{a}$ | 91.71$^{b}$ |
| <u>Palm oil</u> | | | | | | | |
| 0 | 21$^{c}$ | 92.34$^{a}$ | -1.20$^{a}$ | 0.19$^{c}$ | 1.88$^{c}$ | 0.29$^{c}$ | 92.24$^{a}$ |
| 0.1 | 25$^{b}$ | 91.93$^{a}$ | -1.27$^{a}$ | 0.70$^{b}$ | 2.51$^{b}$ | 1.09$^{b}$ | 91.80$^{b}$ |
| 0.2 | 27$^{ab}$ | 91.92$^{a}$ | -1.39$^{a}$ | 1.36$^{a}$ | 2.95$^{a}$ | 2.11$^{a}$ | 91.69$^{b}$ |
| 0.3 | 29$^{a}$ | 92.13$^{a}$ | -1.31$^{a}$ | 1.29$^{a}$ | 2.75$^{a}$ | 2.00$^{a}$ | 91.92$^{b}$ |
| <u>Sunflower seed oil</u> | | | | | | | |
| 0 | 21$^{c}$ | 91.92$^{a}$ | -1.40$^{a}$ | 0.22$^{c}$ | 2.30$^{c}$ | 0.34$^{c}$ | 91.80$^{a}$ |
| 0.1 | 29$^{b}$ | 91.69$^{a}$ | -3.19$^{b}$ | 1.29$^{bc}$ | 3.79$^{b}$ | 2.01$^{b}$ | 91.01$^{ab}$ |
| 0.2 | 31$^{b}$ | 91.91$^{a}$ | -3.55$^{b}$ | 1.75$^{b}$ | 4.16$^{b}$ | 2.72$^{b}$ | 90.99$^{b}$ |
| 0.3 | 38$^{a}$ | 92.18$^{a}$ | -5.04$^{c}$ | 2.79$^{a}$ | 5.70$^{a}$ | 4.32$^{a}$ | 90.29$^{b}$ |

[a, b,c] Means in the same column with different superscripts are different ($p < 0.05$).
[d] Hunter color values: L = lightness (0 = black, 100 = white)
a = redness / greenness (+ = red, – = green)
b = yellowness/blueness (+ = yellow, – = blue)

intermolecular spacing, imparting increased film flexibility while decreasing the barrier properties of films (McHugh and Krochta 1994). How vegetable oils improve WVTR of films was explained by the facts that fatty acids penetrated into space areas or coated on the films, thus allowing for a decreased diffusion rate of water molecules through the films.

The results showed that water vapor transmission through the films was dependent on the degree of saturation of the vegetable oils. When compared among types of vegetable oils, the film composed of palm oil showed the highest WVTR. This may be attributed to the different composition of vegetable oils. Palm oil consists of 50% saturated fatty acid (mostly as 40% palmitic acid (C 16:0), while saturated fatty acids in corn oil and sunflower seed oil are about 14 and 9%, respectively. The main fatty acid of corn oil and sunflower seed oil is linoleic acid (C 18:2) up to 70%, which has longer chain than palmitic acid (Giese 1996). The fatty acids with shorter chain lengths in the films have greater chain mobility and are consequently more permeable to water vapor (Kamper and Fennema 1984).

The change in water solubility of konjac films with different levels of vegetable oils (Fig. 4) showed the same trend as WVTR. The water solubility of these films was decreased by adding vegetable oils. 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.

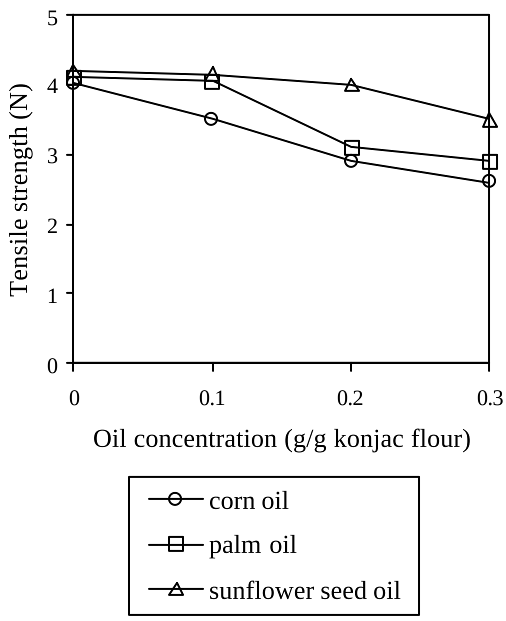


**Fig 1.** Changes of tensile strength of konjac films with various types and levels of vegetable oils.

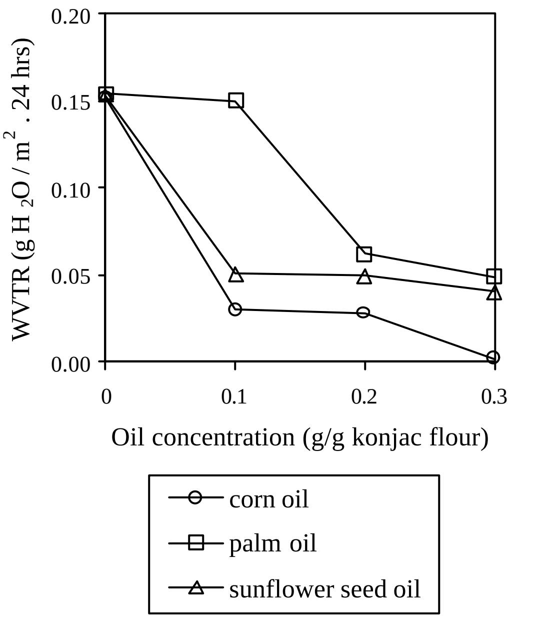


**Fig 3.** Changes of water vapor transmission rate of konjac films with various types and levels of vegetable oils.

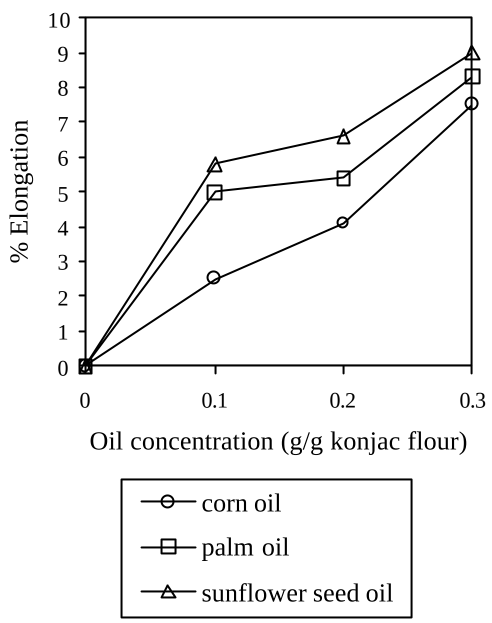


**Fig. 2.** Changes of elongation at break of konjac films with varrious types and levels of vegetable oil

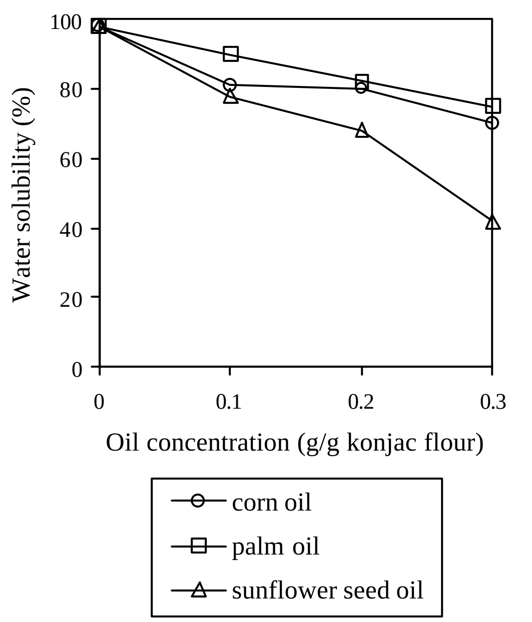


**Fig 4.** Changes of water solubility of konjac films with various types and levels of vegetable oils.

## Conclusion

The addition of vegetable oils affected physical characteristics including tensile strength, percent elongation, color, and WVTR of konjac films. WVTR could be decreased with higher levels of vegetable oils. The improvement of such functional properties of konjac films may increase their use in food applications. That konjac films are edible, degradable, and nontoxic would make them more attractive.

## References


Akesowan, A. 1997. Production of low fat pork sausage substituted with konjac flour. Food 27: 36-43.

Bolin, H.R.; and Huxsoll, C.C. 1991. Control of minimally processed carrot *(Dascus carota*) surface discoloration caused by abrasion peeling. J. Food Sci. 56: 416-8.

Cochran, W.G.; and Cox, G.M. 1992. Experimental Design. 2nd ed. Wiley, New York.

Ekthamasut, K.; and Akesowan, A. 2000. Edible konjac flour films: Preparation, properties and applications. Food 30: 44-51.

Giese, J. 1996. Fats, oils, and fat replacers. Food Technol. 50: 78-83.

Gontard, N ; Guilbert, S ; and Cuq, J. 1993. Water and glycerol as plasticizers affect mechanical and water vapor barrier properties of an edible wheat gluten film. J. Food Sci. 58: 206-11.

Herald, T.J.; Gnanasambandam, R.; Mcguire, B.H.; and Hachmeister, K.A. 1995. Degradable wheat gluten films: Preparation, properties and applications. J. Food Sci. 60: 1147-50, 1156.

Kamper, S.L.; and Fennema, O. 1984. Water vapor permeability of edible bilayer films. J. Food Sci. 49: 1478-81, 1485.

Lai, H.M.; and Padua, G.W. 1998. Water vapor barrier properties of zein films plasticized with oleie acid. Cereal Chem. 75: 194-9.

Maynes, J.R.; and Krochta, J.M. 1994. Properties of edible films from total milk protein. J. Food Sci. 59: 909-11.

McHugh, T. H.; and Krochta, J.M. 1994. Sorbitol vs glycerol-plasticized whey protein edible films: Integrated oxygen permeability and tensile property evaluation. J. Agric. Food Chem. 42: 841-5.

Park, J.W.;Testin, R.F.; Park, H.J.; Vergano, P.J.; and Weller, C.L. 1994. Fatty acid concentration effect on tensile strength, elongation, and water vapor permeability of laminated edible films. J. Food Sci. 59: 916-9.

Rhim, J.W.; Wu, Y.; Weller, C.L.; and Schnepf, M. 1999. Physical characteristics of a composite film of soy protein isolate and propyleneglycol alginate. J. Food Sci. 64: 149-52.