INVESTIGATION THE PHYSICAL, MECHANICAL PROPERTIES OF EDIBLE FILM FROM RICEBERRY FLOUR

HEMSO WALAIPORN*, SUTTIVATTANAVET WANNEE
PLOYPETCHARA THONGKORN

Expert Center of Innovative Health Food, Thailand Institute of Scientific and Technological Research 35 Mu 3 Technopolis, Tambon Khlong Ha, Amphoe Khlong Luang, Pathum Thani 12120, Thailand

*Corresponding author email: Walaiporn@tistr.or.th

Abstract:

Edible film samples containing riceberry flour at 15, 20, 25 and 30% (w/w) with adding glycerol as a plasticizer were extruded. The film properties were investigated. The results showed that the thickness and opacity of film samples decreased while moisture content, a_w, and water solubility increased with an increase in the concentration of glycerol. The colors (L, a*, b*) values of the films were changed with glycerol concentration. The mechanical properties in terms of tensile strength and load at the maximum of the film decreased but elongation at break increased with an increase in the concentration of glycerol. Adding glycerol as a plasticizer affected the physical and mechanical properties of riceberry film depending the concentration of glycerol.

Keywords: Riceberry, Film, Glycerol, Physical Properties, Mechanical Properties

Introduction

Plastic packaging materials such as polyethylene are commonly used in the food industry due to low cost, high strength, and convenience for the production process however polyethylene is non-degradable packaging and becomes the main problem for the environment (Debiagi et al., 2014). Biofilms substituted conventional plastic packaging were interesting because of reducing environmental pollution problems and expanding the shelf life of food products with inhibiting microorganisms' growth (Campos-Requena et al., 2017). Presently, the environmental pollution is the major problems for several organizations to concern especially the food packaging produced from the synthetic materials being substituted by the biodegradable materials. Therefore, using biodegradable or edible film is an alternative material to reduce environmental problems (Noiduang et al., 2015)

Edible film and coating production are increasing for use in the food industries especially fresh food products due to an important part of extending the shelf life according to inhibition moisture transfer, inhibition oxidation occurrence, and retardation respiration. Edible film and coating might be composed of polysaccharides, protein, or lipids (Tassavil et al., 2009).

Riceberry (Oryza Sativa), a deep purple grain rice variety of Thailand, is a crossbreed of Hom Nil rice and Khao Dawk Mali 105 (Sivamaruthi et al., 2018). Riceberry contains many health beneficial compounds such as poly-phenols compounds, anthocyanin, vitamin E, and Gamma-Oryzanol, that compounds act as antioxidants and reduce risk of diseases such as cancer, cardiovascular heart attack, and diabetes (Settapramote et al., 2018). Riceberry flour is a by-product (broken rice) obtained from the milling process, and main component of rice berry flour is starch comprising amylose and amylopectin. Therefore, the starch edible films produced by different amylose-amylopectin content showed different properties such as glass transition temperature, tensile strength, elongation at break, permeability, and morphology of films (Forsell et al., 2002; Wittaya, 2012 and Menzel, 2014).

Most edible film produced from starch such as tapioca and rice were studied due to the amylose-amylopectin composition affecting the gel network formation and the film strength (Imprapai et al., 2010). Moreover, the concentration of starch is an important factor affecting mechanical and physical properties as well as suitability for applied in the food industry (Wu et al., 2002).

Water is the well-known plasticizer for a starch edible film, but water is easy to evaporate resulting in the brittleness of film. Most researchers used glycerol as a plasticizer. The concentration of glycerol around 15-30% could change starch to thermoplastic starch and increase gelatinization temperature since the molecular weight of glycerol was higher than water. Therefore, it could not penetrate between starch granules and increase free space of the amorphous matrix (Belgacem and Gandini, 2008).

Thus, the objective of this research is to investigate the physical and mechanical properties of edible film from riceberry flour.

Materials and Methods

Material

Riceberry was purchased from Pathumthani (Rice wholesaler) and the rice was dried at 50±3°C for 8 h. Then, the rice was milled into riceberry flour at 100 mesh particle size.

Film Preparation

Film samples were prepared by mixing riceberry flour with 15, 20, 25, and 30% glycerol as plasticizer (w/w of starch weight) and adjusted moisture content as 30% (Table 1). After that, the samples were extruded with die and screw as 0.3 mm width and 285 mm length, respectively. The temperature used at barrel 1 and barrel 2 as 110 and 110°C, respectively. The extruded films were dried at 50±3°C in a circulated air oven (Binder Model KMF240, Germany) for 24 h. All film samples were kept in plastic bags at 23±3°C and 50% relative humidity (RH) for not less than 40 h before measurement (Chanpord et al., 2015)

Table 1: Mixed components for extrusion

Condition	Rice Berry Flour (g)	Glycerol (g)	Water (g)
RB15	100	15	30
RB20	100	20	29
RB25	100	25	28
RB30	100	30	27

Film Thickness

The thickness of the film was measured at 5 different positions with a Mitutoyo Electronic digital micrometre, Japan). The averaged thickness was calculated (Domene-López et al., 2019).

Moisture content and Solubility

The moisture content of the film was determined by cutting the film into 1x1 cm. Then, the film was dried at 110°C in an oven (Binder Model ED Series, Germany) until constant weight. The moisture content was calculated using the equation (1):

$$\text{Moisture content } (\%) = ((m_0 - m_1)/m_0) \times 100 \quad (1)$$

where m_0 and m_1 were the weight before and after drying, respectively

The water solubility of the films was measured by placing the dried films in 10 mL tubes and filling with 9 mL of distilled water. The sample stored at 25°C for 24 h before the films were taken out and dried again at 110°C for 5 h. Water solubility was calculated using (Equation (2)):

$$\text{Water solubility } (\%) = ((m_0 - m_f)/m_0) \times 100 \quad (2)$$

where m_f was the weight of final dried film (Domene-López et al.2019).

Color

Color of the film was measured on 5 cm x 5 cm. A CIE colorimeter (Hunter Associates Laboratory, Inc., VA. USA) was used to determine the film L*, a* and b* color value (L* = 0 (black) to 100 (white); a* = -60 (green) to +60 (red); and b* = -60 (blue) to +60 (yellow)) (Bourtoom, 2008).

Opacity

The opacity of the films was determined using the UV VIS spectrophotometer 200V (Hitachi, Japan) at a wavelength of 600 nm. The opacity of the film was calculated following equation:

$$\text{Opacity} = \text{Abs600}/x \quad (3)$$

where x is the thickness of the film (mm) and Abs600 is the absorbance of the film measured at 600 nm (Domene-López et al. 2019).

Mechanical properties

Mechanical properties of the film (tensile strength, maximum load, and percentage of elongation at break, E) were measured following to ASTM D822 Standard test (ASTM) with LLOYD TA plus Material Tester. The film of each formulation was cutting into 100X15 mm. Mechanical properties were recorded during extension at 50 mm/min, with an initial distance between the grips of 50 mm (Zhong & Xia, 2008).

Statistical analysis

All the samples were analyzed statistically using SPSS version 17. Different means were investigated by ANOVA and Duncan's multiple range tests at a level of significance of 0.05.

Results and Discussion

Thickness and opacity

The thickness of riceberry film was decreased with increasing concentration of glycerol (Figure 1). The thickness would be related to the solid content of total mass in the film forming suspension depending on the reordering of molecular chain form more compact matrix in composite starch (Apriyana et al. 2016; Hafnimardiyanti and Armin 2016; Nindjin, Beyrer, and Amani 2015). The films could increase solid concentration in the film-forming dispersion and would become thicker due to the increased total residual mass in the film (Apriyana et al. 2016), this studies showed that the increase in glycerol concentration in the film extrusion would decrease the riceberry flour compositon in the system and would decrease the total solid content in the same weight resulting in a decrease in film thickness.

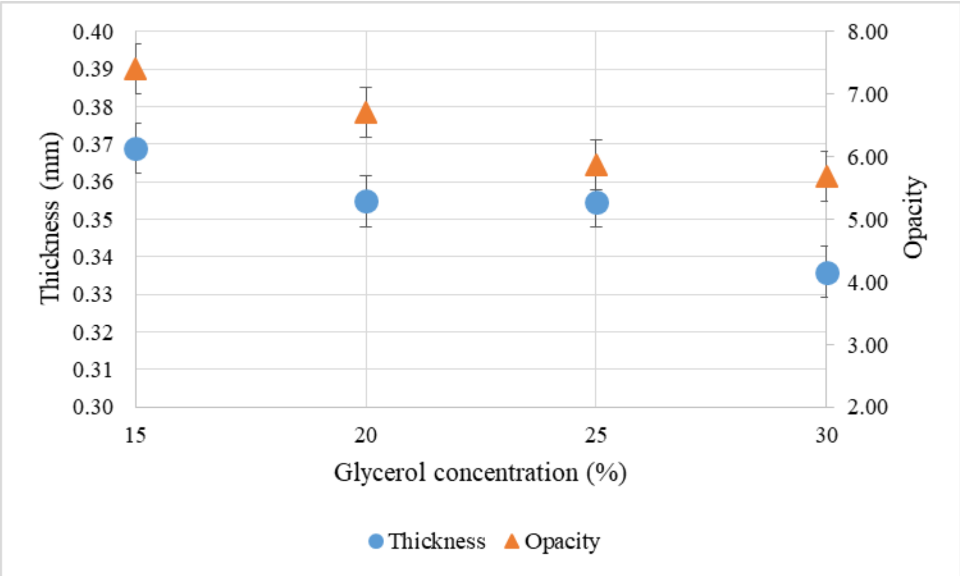

Figure 1: Thickness and Opacity of riceberry film.

The opacity is a conversion value of transparency. The opacity of the riceberry film showed decreased with increasing concentration of glycerol (Figure1) and opacity also had a positive relationship with thickness as similar to Galdeano et al. (2013) that the higher thickness was observed in the higher opacity values in oat starch film. The low glycerol concentration will cause higher opacity due to no other components between the polymer chains and enabling less incident light to pass through the film (Galdeano et al. 2013). Like this study, the higher glycerol concentration would make the thinner film and decrease the opacity of the film. Transparency is an important characteristic of food packaging; the lower in transparency could protect food from the light and would be higher in quality in food packaging film (Saberi et al., 2016). However, the low opacity or high transparency of the film still helps the food products to be easily visible (Galdeano et al. 2013).

Color

The change in color properties of the film was investigated by colorimeter. All of the film samples showed a positive value of L*, a*, and b*(Table 2). Glycerol content affected the color of the film especially 30% glycerol plasticized film showed the highest a* and b* value. It indicated that the film color would be reddish and yellowish. The L* value decreased while a* and b* values increased with an increase in glycerol concentration from 15% to 30%. At low glycerol concentration, amylose chains in starch film system would form crystalline resulting in an opaque film (Fig. 1) while an increase in glycerol concentration would decrease L* value and less opacity due to glycerol acting as a plasticizer and decreasing crystalline in the system (Theamdee and Pansaeng, 2019). Moreover, the hydrophilic and water-holding properties of glycerol (Apriyana et al. 2016) would make it easily evaporated and maintain the riceberry color to remain with the film. However, the film colour was not clearly changed in the sample of 20% and 25% glycerol plasticized film.

Table 2: Color properties of riceberry flour film.

Glycerol (%)	L*	a*	b*
15	30.24±0.53[c]	7.28±0.18[ab]	0.78±0.21[a]
20	28.69±1.16[b]	8.10±1.53[b]	1.83±0.41[b]
25	27.17±0.19[a]	6.72±0.28[ab]	0.40±0.11[a]
30	28.53±0.598[b]	11.03±0.79[c]	3.54±0.60[c]

*Different letters in each column indicates a difference in glycerol concentration, the significant difference at $p \leq 0.05$.

Moisture content, water solubility and Aw

The moisture content of the film increased with an increase in glycerol concentration as the same trends with water solubility and a_w (Table 3). The increase in glycerol concentration could increase moisture content in the system due to a hydrophilic property of starch and glycerol acted as a water holding agent (Apriyana et al. 2016). Moreover, hydroxyl group of glycerol interacted with water by hydrogen bond and would be as a plasticizer, the higher level of plasticizer would increase the film's moisture affinity (Mali et al. 2005).

Table 3: Moisture content, water solubility, and a_w of riceberry flour film.

Glycerol (%)	Moisture content (%)	Solubility	a_w
15	12.89±1.86[a]	33.57±0.97[a]	0.51±0.00[a]
20	13.93±0.66[a]	33.76±2.01[a]	0.51±0.00[a]
25	14.25±0.43[a]	36.38±1.26[b]	0.51±0.00[a]
30	17.53±0.66[b]	38.78±2.71[b]	0.52±0.00[b]

*Different letters in each column indicates a difference in glycerol concentration, the significant difference at $p \leq 0.05$.

The high water solubility in edible products would be advantageous ability during cooking (Laohakunjit and Noomhorm 2004). The water solubility increased with increasing glycerol content similar results to Laohakunjit and Noomhorm (2004) who reported the highest water solubility of the film showed with the highest glycerol addition, and Hafnimardiyanti and Armin (2016) whose results showed the increasing water solubility trends with increasing plasticizer content. The solubility of the edible film is strongly influenced by the hydrophilic property of edible compounds and humidity of the starch film which plasticizer increased space between starch chains attributed to water facilitating migration into film matrix (Hafnimardiyanti and Armin 2016). The film with 30% glycerol addition showed the highest a_w might affect the plasticizing and hygroscopic properties of glycerol which increased mobility region on the film and increased the water up take (Theamdee and Pansaeng, 2019).

However, the film in this study had a_w around 0.51-0.52 which would be safe from microbial (a_w range is optimized for microorganism around 0.70-0.99 (Theamdee and Pansaeng, 2019)).

Mechanical properties

The mechanical properties of the film were depending on re-arrangement and orientation of polymer network that related to inter and intra-molecular interaction in the system and also water induced crystallization or retrogradation of the film (Saberi et al. 2017). The tensile strength and maximum load of the riceberry film decreased while elongation at break increased with increased glycerol concentration (Figure 2). The decrease in tensile strength and increase in elongation with increase plasticizer concentration might be due to plasticizer inhibited strong intermolecular interaction between starch chains and formed hydrogen bonds between plasticizer and starch molecule as a result of increase free volume and decrease mechanical resistant (Apriyana et al. 2016; Bourtoom 2008; Osés et al. 2009).

The increase in elongation at break of the film might relate to moisture content as the result in Table 3 and Figure 2 that showed the same trends as increasing elongation at break and moisture content with increasing plasticizer concentration. These results might because glycerol plasticized film have high hygroscopic character and reduced forces between the adjacent macromolecules according to increase stretch ability (Bourtoom 2008).

Moreover, the lowest tensile strength and the maximum load of the film showed the highest a_w. Mali et al. (2005) reported the stress and Young's modulus decrease with increase RH; at high RH would be high equilibrium moisture content to exert a plasticizing effect to enhance mobility, increase free volume, and increase flexibility.

Thus, glycerol could act as a plasticizer, and the concentration of glycerol was important factor that affected the properties of riceberry flour film. The major of interaction between glycerol and starch in the system might relate to hydrogen bonding between functional groups of both starch and the glycerol as a resulting in an increase in the proportion of glycerol which have more interactions occur between their functional groups (Ajiya et al., 2017)

Conclusion

The properties of extruded riceberry flour film plasticized with glycerol (15, 20, 25, and 30%) were investigated for thickness, opacity, color, moisture content, water solubility, a_w, and mechanical properties. The results of the experiments showed that film thickness decreased with increasing concentration of glycerol, and opacity had a positive relationship with thickness. Moisture content, water solubility, and a_w increased with an increasing in concentration of glycerol. In the mechanical properties of the film, the tensile strength and maximum load of the riceberry flour film decreased, while the elongation at break increased with increasing glycerol concentration. At high glycerol concentration, glycerol had a good ability to act as a plasticizer in riceberry flour film system. Glycerol could affect the physical and mechanical properties of the riceberry flour film based on the concentration of glycerol due to the hydroxyl groups of glycerol formed hydrogen bonds hydrophilic property of glycerol and interacted with the riceberry flour film matrix. As with the extrusion temperature might result in the reduction of substances antioxidants. However, other factors such as extrusion conditions for produced riceberry flour film and antioxidant effect have to study in the future.

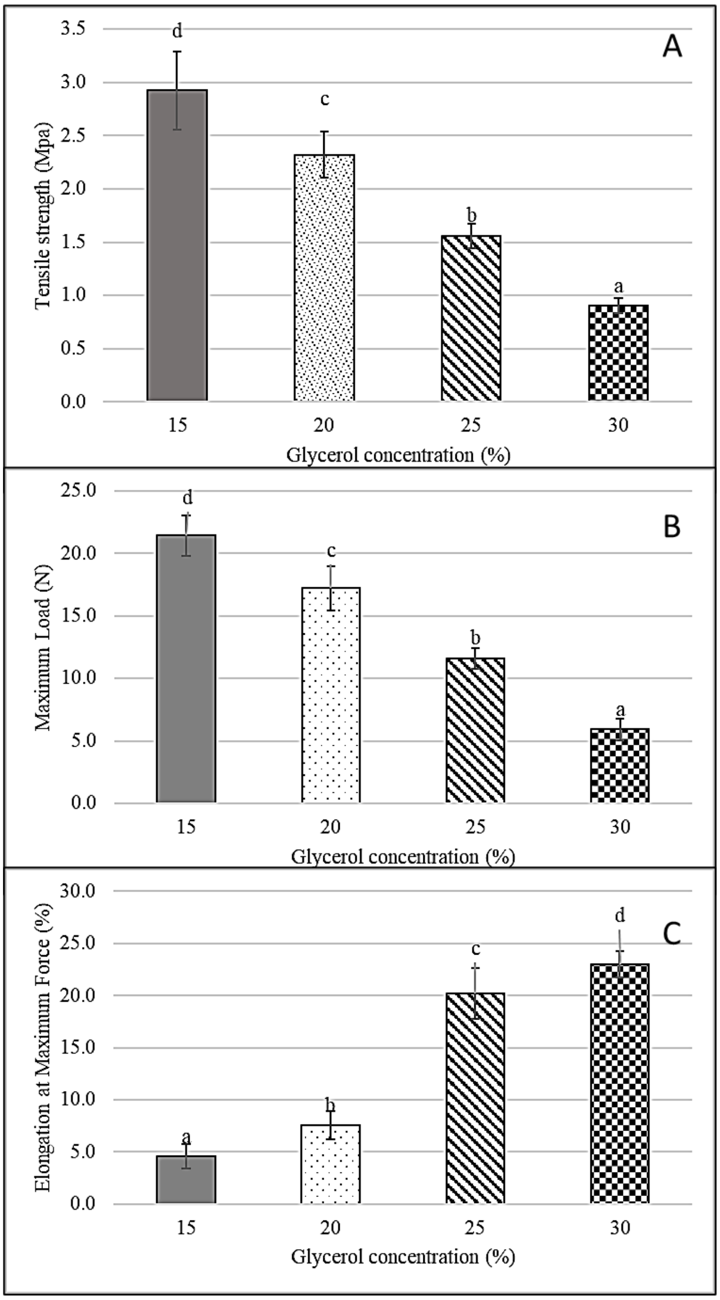

Figure 2: Mechanical properties of riceberry flour film.

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