



Characteristics of Edible Film Based on Whey Protein with the Addition of Oleogel

Angelina Nawangwulan¹, Garry Kandi Ratulintang¹, Maniek Eirry Sawitri¹,
Ria Dewi Andriani¹, Abdul Manab¹, Premy Puspitawati Rahayu¹, and Aris Sri Widati^{1,*}

¹ Faculty of Animal Science, Universitas Brawijaya, Malang 65145, Indonesia.

*ariswidfptub@ub.ac.id

Abstract. Whey protein film has disadvantages such as easy to tear, high solubility in water, low transparency, low strength and low water vapor resistance. Hydrophobic components such as oleogel are needed to increase stability in the edible film. This study was conducted to investigate the effects of the addition oleogel to the quality of whey protein film. The research method was an experiment using a Completely Randomized Design (CRD) with 6 treatments oleogel concentrations (0%, 1%, 2%, 3%, 4% and 5%) and 3 replications. The observed variables were thickness, solubility, swelling, elongation, elasticity, FTIR and microscopy. The research data obtained was analyzed using analysis of variance (ANOVA). The results showed that the addition of oleogel in whey protein film had very significant effect ($P < 0.01$) on a thickness, solubility, swelling, elongation and elasticity. The average value of thickness is 0.21-0.24 mm, solubility is 65.21-73.12%, swelling is 27.22-35.83%, elongation is 189.64-225.74% and elasticity is 1.2-2,93 Mpa. In this study, it can be concluded that the addition of oleogel can help increase the physical quality of whey protein film.

Keywords: Characteristics, Edible Film, Oleogel, Whey Protein.

1 Introduction

Plastic is a packaging that is widely used to pack chicken meat today. Plastic is considered to be a practical and inexpensive container or packaging in its use so that the demand for the production of plastic and similar non-degradable polymers is also increasing. Plastic and other non-degradable polymers have a low degradation rate, causing environmental and human health problems. Global annual plastic production is estimated to reach 330 million tons in 2020, while in Indonesia plastic production reaches 5.4 million tons per year [1] and around 20% of production is used in the manufacture of packaging in the food industry because plastic has good durability, design flexibility, light weight and low price [2]. The method that can be used as a substitute for plastic or other polymer materials is to produce biodegradable polymers. The biodegradable polymer that is currently widely used is edible film.

Edible film has now become a trend in the food industry because it has become an environmentally friendly packaging that can be eaten. One type of edible film that is widely used today is edible whey protein film. The use of whey protein supports the

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utilization of waste from cheese production. The use of whey protein for edible film formulation has been widely reviewed, because this protein is edible and biodegradable and supports the reuse of cheese making waste [3]. The use of edible whey protein film as packaging for chicken and other poultry can protect meat from lipid oxidation, improve microbiological quality and reduce pathogenic bacteria and inhibit meat spoilage [4]. The addition of other ingredients to edible whey protein film has been widely used with the aim of improving the physical and functional properties of edible film, one of the ingredients that can be used is anthocyanin.

Anthocyanins are a group of water-soluble flavonoid pigments responsible for the red, purple, and blue colors of many fruits, vegetables, and flowers. One of the foods that produce anthocyanins is purple sweet potatoes. Anthocyanins in purple sweet potatoes are mostly 3,5-diglucoside derivatives of cyanidin or peonidin, with caffeoyl, feruloyl and *p*-hydroxybenzoyl residues as additional variants [5]. The high anthocyanin content in purple sweet potatoes is 19.78 mg/100 g in water extract and 158 mg/100 g in acid-ethanol water extract (HCl, 1.5 mM), while cyanidin and peonidin are the main components of purple sweet potato anthocyanins [6]. Anthocyanins extracted from purple sweet potato can add economic and nutritional value to edible films. Anthocyanins provide attractive natural colors to edible films, which can improve the visual appearance of foods. Anthocyanins in natural plants are also sensitive to pH and act as important indicators for assessing food spoilage [7].

Edible whey protein films containing anthocyanins have recently been widely used as food packaging and active packaging because they have several advantages such as physicochemical, antioxidant and antimicrobial properties. Edible whey protein films containing anthocyanins are the result of the development of packaging solutions that not only protect food products but also improve the quality and nutritional value of these products. Edible whey protein films containing anthocyanins have several advantages such as elasticity and excellent barrier properties to oxygen and have hydrophobicity properties [8]. Edible whey protein film containing anthocyanins also has disadvantages such as easy to tear, high solubility in water, low transparency, strength and thermal resistance and low water vapor. The presence of hydrophilic groups in the edible film matrix causes water to be bound so that the water content of the edible film will tend to be high, so hydrophobic components such as oleogel are needed to increase stability in the edible film.

Oleogel is a semi-solid material with viscoelastic properties consisting of a nonpolar liquid phase (oil) and has a gel-like texture [9]. Oleogel is usually produced to compose liquid oil assisted by an oleogelator, resulting in solid-like properties or three-dimensional structures [10]. Oleogel can be formed from vegetable oil stabilized with a thickening agent. Oleogel contains lower trans fat, can produce bioactive compounds and has the potential as an innovative food ingredient [11]. The addition of oleogel to food products can form a three-dimensional network that traps healthy fats with high unsaturated fatty acid content where π - π accumulation, hydrogen bonds, electrostatics and van der Waals interactions [12] can improve the quality and nutritional structure of the product. Considering the importance of ensuring the quality and safety of food products, it is necessary to conduct research related to the use of edible whey protein film

containing anthocyanins and oleogel as environmentally friendly packaging that can increase the shelf life and quality of food products.

2 Materials and Methods

2.1 Materials

The materials used in this study were edible whey protein film containing anthocyanins and oleogel. The materials used in this study were beeswax, glycerol monostearate, palm oil, purple sweet potato flour, 70% ethanol, citric acid, whey protein isolates (WPI), gelatin, glucomannan, glycerol, water. The equipment used in this study were beakers, measuring cups, hot plate magnetic stirrers, knives, sieves, ovens, baking sheets, Whatmann No. 4 filter paper, centrifuges, pipettes, analytical scales, teflon, thermometers, ovens, screw micrometers, petri dishes, desiccators, SEM, Texture Analyzers and FTIR.

2.2 Methods

The research method was an experiment using a Completely Randomized Design (CRD) of 6 treatments with oleogel concentrations (0%, 1%, 2%, 3%, 4% and 5%) and 3 replications, added to edible film whey protein containing anthocyanins.

Preparation of Anthocyanin Extract. The procedure for making purple sweet potato anthocyanin extract based on Ranjbar [13] which was modified using the Microwave Assisted Extraction (MAE) method [14], begins with preparing purple sweet potato flour then filtered using a 100 mesh sieve. Sweet potato flour is weighed 50 grams then dissolved in 500 ml of distilled water that has been given 1.5% citric acid. The purple sweet potato solution is stirred then macerated for 24 hours. The solution is put into a soxhlet tube and put into a microwave at a temperature of 100°C for 10 minutes using the MAE method. The purple sweet potato solution is removed and cooled to room temperature, then transferred to a centrifuge tube. The solution is centrifuged at a speed of 4000 rpm for 15 minutes. The solution is separated between the supernatant and the filtrate and filtered using Whatmann No. 4 paper. The supernatant from the centrifuge was taken and transferred into a rotary tube for rotary evaporation at 80 °C for 30 minutes. The anthocyanin extract solution was transferred into a dark glass bottle and was ready to use.

Preparation of Oleogel. The procedure for making oleogel based on Jeong and Oh [2] begins with preparing beeswax and glyceryl monostearate (GMS) in a ratio of 3:1. The mixture of beeswax and glyceryl monostearate (GMS) is heated at a temperature of 70-80°C until completely dissolved, then palm oil is added to the solution while continuing to stir. The solution is cooled to room temperature for 30 minutes, and solidified in a freezer (- 21°C) for 1 hour and produces oleogel.

Procedure for Making Edible Film. The procedure for making whey protein edible film containing anthocyanins according to Fahrullah [15] and Papadaki [16] which was modified, namely 10 ml glucomannan was dissolved in 20 ml distilled water. The glucomannan solution was stirred using a magnetic stirrer and 2 grams of gelatin powder was added slowly. 3 grams of WPI powder was slowly added into the solution. 30% glycerol was added to the solution. 20% anthocyanin extract was added into the solution. The solution was heated using a hot plate magnetic stirrer. Tween 80 and oleogel were added into the solution according to the treatment (0%, 1%, 2%, 3%, 4%, 5%) in the ratio of 1:4. The solution was heated for 5 minutes. The solution was cooled and then divided into 20 ml. The solution was poured slowly onto Teflon. The solution was allowed to stand at room temperature for 24 hours. The dried edible film was peeled from Teflon and ready for testing.

Analysis Methods.

1. Thickness

Thickness testing in this study is based on Pak [17]. The thickness of the sample was measured using a micrometer screw with an accuracy of 0.01 mm. Measurements were taken at 5 different points. Measurements were repeated up to 3 times.

2. Elongation

Elongation testing in this study is based on Fera [18]. The edible film is cut into a rectangle with a length of 100 mm and a width of 5 mm, then the top and bottom of the edible film are made like a cross-section to be plastered with a tool. Then apply a load to the bottom of the edible film little by little until the edible film breaks, then measure how much the edible film elongates when the edible film breaks, then measure the percentage of elongation.

3. Elasticity

Elasticity testing in this study is based on Fera [18]. The edible film is cut into a rectangle with a length of 100 mm and a width of 5 mm, then the top and bottom of the edible film are made like a cross-section to be plastered with a tool. Then apply a load to the bottom of the edible film little by little until the edible film breaks, then measure how much the edible film elongates when the edible film breaks, then measure the percentage the tensile strength value. After that, the value is entered into the following formula:

$$\text{Elasticity (\%)} = \frac{\text{Tensile strength}}{\text{Elongation}} \quad (1)$$

4. Swelling

Swelling test in this study is based on Putri [19] which was modified. Edible film is cut into 3x2 cm size and weighed (W_0). The sample is put into a petri dish containing cotton soaked in 5 ml of distilled water. Close the petri dish and wait for 1 minute. After 1 minute the sample is removed and reweighed (W_1). The formula for testing absorption or swelling power is as follows:

$$\text{Swelling (\%)} = \frac{W_1 - W_0}{W_0} \times 100\% \quad (2)$$

5. Solubility

Solubility testing in this study is based on Ahmad [20]. The edible film sample was cut into 3x2 cm sizes. The sample and filter paper were dried at 105°C for 24 hours. The filter paper and sample were weighed separately (W1). The sample was placed in a 50 ml centrifuge tube containing 10 ml of distilled water, and soaked for 24 hours at room temperature and stirred slowly. The solution was filtered, the filter paper and insoluble film were dried using an oven at 105°C for 24 hours. After that, the sample was weighed (W2). The solubility can be calculated using the formula:

$$\text{Solubility (\%)} = \frac{W1-W2}{W1} \times 100\% \quad (3)$$

6. FTIR

FTIR testing in this study based on Utami [21]. The sample was prepared and placed on an ATR plate. Optimization was carried out by scanning 32 times in the range of wave numbers 4000–650 cm⁻¹ with a resolution of 16 cm⁻¹. After each measurement, the plate was cleaned with n-hexane twice until no sample was left, then dried with tissue.

7. Microscopy

Microscopy testing using a light microscope based on Novitasari [22]. The sample is cut 1x1 cm. The sample is placed on an object glass, then dripped using a methylene blue solution. Install the microscope on a flat table and a well-lit place. Connect to an electrical installation. Set the objective lens and condenser until the object is visible on the eyepiece. Set the objective badge from 10x to 40x magnification until you get the desired image.

Data Analysis. The research data obtained were analyzed using analysis of variance (ANOVA) and if there were differences in influence, it was continued with Duncan's Multiple Range Test (UJBD).

3 Results and Discussion

3.1 Physical and Mechanical Properties of Edible Films

Table 1. Thickness, Elongation and Elasticity value of Whey Protein Films

Treatments	Thickness (mm)	Elongation (%)	Elasticity (N/mm ²)
P0	0.21 ^a ± 0.007	189.46 ^a ± 1.29	2.93 ^c ± 0.14
P1	0.21 ^a ± 0.007	225.74 ^d ± 5.26	1.64 ^b ± 0.43
P2	0.22 ^a ± 0.018	224.30 ^d ± 5.08	1.52 ^{ab} ± 0.18
P3	0.23 ^b ± 0.004	223.97 ^d ± 3.83	1.31 ^a ± 0.08
P4	0.23 ^b ± 0.002	217.15 ^c ± 2.50	1.20 ^a ± 0.08
P5	0.24 ^b ± 0.002	211.01 ^b ± 2.18	1.27 ^a ± 0.08

Note: Different superscript letters in the same row indicate a very significant difference (P<0.01).

Thickness. Table 1 shows the thickness, elongation, and elasticity value of whey protein films. In this study, the higher thickness value is thought to be due to the addition of higher oleogel concentrations. Oleogel is a semi-solid material that is hydrophobic so when added to the edible film formulation, it will produce a thicker edible film. During film formation, hydrophobic oil particles are usually dispersed in the protein matrix due to poor compatibility between oil and protein molecules which eventually disrupt the formation of protein network [21]. The film network may become looser and the film texture may be more fluffy due to the presence of oil, which may result in an increase in film thickness [23].

The thickness value of edible film also depends on the composition or ingredients used. The use of WPI and glucomannan in edible film formulations will affect the thickness value. Glucomannan is a type of non-gelling polysaccharide that when added to WPI can increase the hydrophobic interaction of myofibrillar proteins and form a denser gel microstructure [6]. Glucomannan will also interact with oleogel. When glucomannan is not added to the formulation, the internal structure of the oleogel becomes looser and there is no interaction between the oleogel and the glucomannan molecule so that it does not form a structure in the network [24].

This study is comparable to Papadaki [16] the more the addition of oleogel which is hydrophobic, the film thickness value will increase, as evidenced by the P0 thickness value of 0.12 mm and the film thickness value after the addition of oil and oleogel up to 7.5% gives a value of 0.17 mm. The thickness value of the karaya gum edible film with the addition of oleogel ranges from 0.050-0.060 mm, where the thickness value increases with the addition of hydrophobic molecules [25]. Based on JIS (1975) in Kong [26] states that plastic for food packaging categorized as a film has a maximum thickness of 0.25 mm so that the thickness of the film in this study has met the JIS (1975) standard.

Elongation. The addition of oil or other lipids to the edible film can increase the elongation value [25]. The elongation value again decreased significantly when more oleogel concentration was added to the formulation, this can be seen in treatments P1-P5 which decreased. The difference in elongation value in this study is due to the use of lipids in the film formulation so that it can form a denser edible film structure [27]. When the oleogel concentration is low, the interaction between the oleogel components and the protein matrix can increase the flexibility and repair the film network, thereby increasing the elongation.

Oleogel will act as a plasticizer, which increases the ability of the material to stretch without breaking easily. When the concentration of oleogel increases, the elongation value decreases. The increase in concentration causes a decrease in the ability of the material as a plasticizer, resulting in a decrease in film elongation, which when exposed to force causes the film to break easily [28]. This statement is supported by Santoso [29] where the higher the concentration of red palm oil, the percent elongation of edible film tends to decrease because red palm oil is non-polar or hydrophobic which affects the decrease in percent elongation. Research conducted by Oko [30] also states that beeswax in oleogel has a crystalline phase where there is an attraction between adjacent fatty acids in the crystal, causing the amount of polymer matrix to increase and form a

film with a tight polymer structure so that the resulting film is strong, but its stretchability is reduced. High elongation values indicate unfavorable characteristics because the resulting film will be difficult to break with low force. The 1975 Japanese Industrial Standard (JIS) states that a good elongation value is $>50\%$, which means that the edible film in this study has met a good standard. In this study, the elongation value of all edible films ranged from 189.46-225.74% so that it has met a good standard.

Elasticity. The elasticity value is the ratio between the elongation value and the tensile strength. The three parameters are related to each other. A decrease in elasticity causes the flexibility of edible film to increase [19]. The decrease in the edible film elasticity value is thought to be due to the oleogel forming component. Palm oil as the main ingredient of oleogel contains unsaturated fatty acids that are hydrophobic, unsaturated fatty acids can regulate fatty acids in the matrix so as to produce an even and dense film and cause the elasticity level to decrease [31]. Beeswax is nonpolar and has very low interactions between edible film polymers resulting in poor tensile properties so that the addition of beeswax and palm oil-based oleogels can reduce the elasticity value of edible films. The inclusion of lipids or oils in protein-based or polysaccharide-based films can disrupt polymer chain-to-chain interactions and produce flexible domains in the film [32].

Research with similar results was also conducted by Galus and Kadzinska [33] where the addition of 0.5% almond oil to edible film can increase the elasticity value (3.4 Mpa), but when the oil concentration is increased to 1.5%, there is a decrease in elasticity value (1.4 Mpa). The presence of the lipid phase causes disruption of the order in the whey protein matrix, resulting in differences in the tensile parameters. Adding the amount of essential oil up to 0.25% can reduce the elastic modulus value [34]. The addition of essential oils of hydrophobic nature to biodegradable films reduces tensile strength and increases elongation. This effect is mainly related to the replacement of some strong polymer-polymer interactions with weaker polymer-oil interactions in the presence of essential oils in the film layer, which weakens the polymer structure and thus reduces the tensile strength of the film [35]. Research with similar results was also conducted by Galus and Kadzinska [33] where the addition of 0.5% almond oil to edible film can increase the elasticity value (3.4 Mpa), but when the oil concentration is increased to 1.5%, there is a decrease in elasticity value (1.4 Mpa). The presence of the lipid phase causes disruption of the order in the whey protein matrix, resulting in differences in the tensile parameters. Adding the amount of essential oil up to 0.25% can reduce the elastic modulus value [34]. The addition of essential oils of hydrophobic nature to biodegradable films reduces tensile strength and increases elongation. This effect is mainly related to the replacement of some strong polymer-polymer interactions with weaker polymer-oil interactions in the presence of essential oils in the film layer, which weakens the polymer structure and thus reduces the tensile strength of the film [35].

3.2 Barriers Properties of Edible Films

Table 2. Solubility and Swelling value of Whey Protein Films

Treatments	Swelling (%)	Solubility (%)
P0	35.83 ^d ± 0.72	73.12 ^d ± 0.72
P1	35.81 ^d ± 0.47	73.31 ^d ± 0.47
P2	34.90 ^c ± 0.81	71.88 ^c ± 0.81
P3	33.17 ^c ± 0.70	69.14 ^b ± 0.70
P4	30.25 ^b ± 0.33	69.98 ^b ± 0.33
P5	27.22 ^a ± 0.30	65.21 ^a ± 0.31

Note: Different superscript letters in the same row indicate a very significant difference ($P < 0.01$).

Swelling. Table 2 shows the solubility and swelling value of whey protein films. The decrease in swelling value is thought to be due to the hydrophobic nature of oleogel. Oleogel is hydrophobic, when added to the whey protein edible film formulation which is hydrophilic will affect the swelling index. Oleogel contains fatty or oil ingredients that are hydrophobic (water repellent), so when oleogel is added, the film structure becomes less permeable to water. This leads to a reduced capacity of the film to absorb and retain water, which in turn decreases the swelling value [36]. This statement is supported by Chen [6], where the addition of oleogel made from palm oil consists mainly of triglycerides, palmitic acid (44-45%), oleic acid (39-40%), linoleic acid (10-11%) can affect its hydrophobicity properties so that it will affect the water absorption properties and swelling index.

The addition of oleogel can also affect the structure and interactions within the whey protein matrix. Oleogel can disrupt the hydrogen bonds formed between water and protein molecules, thereby reducing the interaction with water and reducing the ability of the film to absorb it. Protein-water interactions are reduced because oleogel does not interact with water. This results in a decrease in swelling and the ability of the film to retain moisture. Oleogel as a hydrophobic material will disrupt the balance of hydrophobic-hydrophilic interactions in the film, including reducing the ability of proteins to interact with water through hydrogen bonding [37]. Papadaki [16] stated that increasing the concentration of oil and oleogel into the edible film matrix will reduce the swelling value. The swelling index is significantly affected by the type of hydrophobic component when combined at concentrations exceeding 5%, oleogel has a more pronounced effect on the film in reducing the swelling index (about 70%). The addition of almond oil resulted in a decrease in swelling index of almost 3% [33].

Solubility. Solubility is an important parameter in edible films. Films with poor water resistance will dissolve quickly leading to increased diffusion of components from the surface of most foods, resulting in a low protective effect on food [33]. In this study, the decreasing solubility value was thought to be due to the addition of higher oleogel concentrations. Oleogel is hydrophobic, which when added to the whey protein edible film formulation will reduce its solubility value due to its limited contiguity in a

functional groups. Research conducted by Faradilla [40] also showed similar results where shrimp chitosan edible film detected the appearance of peaks at wavenumbers of 675-995 cm^{-1} which are thought to indicate that the presence of C-H alkene functional groups that usually appear at wavenumbers of 3010-3095 cm^{-1} and 675-995 cm^{-1} . The peak at 705.95-854.47 cm^{-1} that falls within the 690-900 cm^{-1} wavenumber range also indicates the presence of an aromatic ring C-H functional group. This range usually indicates out-of-plane bending vibrations of the C-H bond associated with aromatic rings [41]. A peak appears at 1060.85-1278.81 cm^{-1} which belongs to the 1050-1300 cm^{-1} wave range, indicating the presence of C-O alcohol/ether/carboxylic acid functional groups. Waves of 1050-1300 cm^{-1} indicate the stretching of the C-O functional group in alcohol [42]. In the wave range 1060.85-1278.81 cm^{-1} can also show other C-O functional groups such as esters. The band in the frequency region of 1000-1300 cm^{-1} shows the stretching vibrations of the ester (C-O) group.

There is a peak at 1259.52-1136.07 cm^{-1} which belongs to the wave range of 1180-1360 cm^{-1} , indicating the C-N amine/amide functional group. Amide type I is associated with C=O and C-N group bond stretching vibrations [43]. The absorption peaks corresponding to amide bond stretching vibrations associated with protein networks cover the range between 1200 and 1700 cm^{-1} [44]. The edible film without oleogel produced a peak of 1274.95 cm^{-1} , then there was a shift towards 1259.52 cm^{-1} added with 5% oleogel, which means there is a change in the secondary structure of the protein. With respect to this fact that the peaks in the amide I and II can be used to study the changes in the protein secondary structures.

A peak appeared at a wavenumber of 1473.62 cm^{-1} which is included in the wavenumber range of 1340-1470 cm^{-1} , indicating the C-H alkane functional group. C-H stretches appear at wavenumbers of 2100-2260 cm^{-1} and 1340-1470 cm^{-1} indicating the presence of alkane C-H functional groups [45]. This statement is also supported by Wahdaningsih [42] where there are wave numbers 1380.19 cm^{-1} and 1464.93 cm^{-1} showing the bending vibrations of alkane C-H groups. There is a peak at 1591.27 cm^{-1} which is included in the wave range of 1500-1600 cm^{-1} , indicating the aromatic ring functional group. Edible film containing clove oil has a peak at 1514 cm^{-1} which indicates the presence of aromatic C-C groups. The higher the addition of clove oil, the peak of the aromatic C-C group becomes sharper [46]. A peak appeared at 2873.94-2953.02 cm^{-1} , known to be included in the wave range 2850-2970 cm^{-1} indicating the C-H alkane functional group. The band between 2750 and 3000 cm^{-1} in the spectrum is caused by the attractive bands of CH, CH₂, and CH₃ groups [35].

3.4 Microscopy

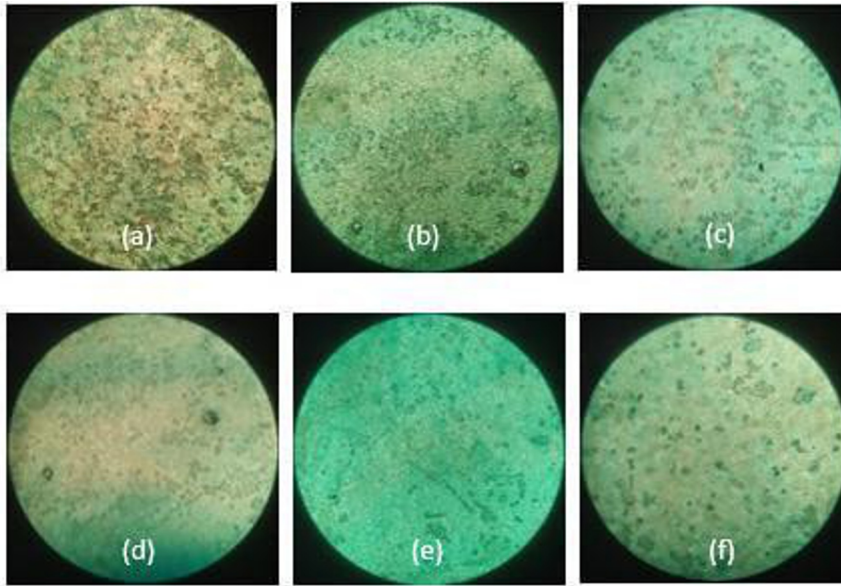


Fig. 2. Microscopy of (a) P0, (b) P1, (c) P2, (d) P3, (e) P4, (f) P5 with 10x Magnification

Microscopy testing using a binocular light microscope with 10X magnification can be seen in Figure 2. In **Fig. 2**, there are several small white dots that are thought to be insoluble WPI particles. This statement is supported by Mohammadian [47] where in the case of WPI films, some small dots like white particles were also observed on the surface of the film which can be attributed to insoluble protein aggregates formed during film preparation and the film enriched with NLE showed a more homogeneous morphology compared to the control WPI film.

In **Fig. 2**, it can be seen that the edible film without the addition of oleogel resulted in a rougher surface than the edible film with the addition of oleogel. The film surface with the addition of oleogel is smoother and flatter. Galus and Kadzinska [33] observed that gelatin films containing 20% olive oil have a more homogeneous surface than films containing 10 or 15% olive oil, this can occur because the microstructure of the lipid-hydrocolloid layer correlates with the stability of lipid droplets during the drying process. Ingredients or compositions in edible film making such as glucomannan will interact with oleogel. When glucomannan molecules meet with oleogel, the distribution of oil droplets increases significantly with smaller droplet size because the presence of glucomannan can make the oil droplets more wrapped in a matrix consisting of glucomannan and protein isolate. The addition of glucomannan to oleogel will make the surface of oleogel become more uniform and have certain plasticity properties. The most irregular structure observed in the film morphology supports the tensile results, which

proves that the different structural arrangement of the components in the film that form the dispersion significantly affects the mechanical and gas barrier properties [48].

4 Conclusion

The addition of oleogel to edible films made from whey protein has a very significant effect on the physical and mechanical characteristics of the film. Oleogel has been shown to increase thickness, reduce solubility and swelling, and improve the surface structure of the film to be smoother and more uniform. Although increasing the concentration of oleogel can reduce the elasticity and elongation values, this actually provides benefits in increasing water resistance and strengthening the film structure. Overall, the addition of oleogel to a certain concentration can improve the physical and functional quality of edible whey protein film, making it more suitable as an alternative to environmentally friendly food packaging and has better resistance to moisture.

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