Physical, mechanical, and microstructure properties of whey edible films incorporated with Virgin Coconut Oil (VCO)

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Abstract. The edible film is a thin layer derived from edible materials and formed on top of food components serving as an inhibitor of mass transfer (e.g., moisture, oxygen, fat, and dissolved substances), a carrier of foodstuffs, and an additive to improve food handling. Virgin Coconut Oil (VCO) contains lactic acid bacteria that are probiotics and anti-microbial, adding edible whey film to utilize cheese waste into biodegradable packaging. The research aims to study the effect of VCO on barrier, mechanical, and microstructure whey edible films. This research used whey, VCO, glycerol, and Carboxymethyl Cellulose (CMC). The treatment in this study was the addition of VCO namely A (0%), B (0.5%), C (1%), D (1.5%) and E (2%). The result of the research showed that whey edible films with the addition VCO affected (P<0.05) physical properties (thickness and solubility time) and no effect (P>0.05) on mechanical properties (tensile strength and elongation) and microstructure.

Keywords: edible film, whey, VCO, physical, microstructure

1. Introduction

Packaging becomes a part of people's lives, especially food products that can impact health. Packaging can prevent damage to the packaged material. Plastic is the most widely used packaging material because of cheap, easy to shape, transparent, and not easily broken. However, the main weakness is monomer transmission contamination in packaged products. In addition, it cannot be destroyed naturally (non-biodegradable) so that it burdens the environment. The edible film is a thin layer derived from edible material, from the food components that serve as a mass transfer inhibitor (e.g., moisture, oxygen, fat, and solutes) and/or as a carrier of food ingredients or additives to improve food handling [1].

This research concern is food security in terms of processing using technology and providing added value from products derived from milk processing waste, in this case, cheese. Additional ingredients such as vegetable oils, essential oils, and extracts are used to improve edible films’ characteristics. Thus, it benefits consumer's health, significantly increases immunity during the COVID-19 pandemic. Based on the background, the research that will be conducted aims to utilize cheese waste into biodegradable packaging, beneficial for health using Virgin Coconut Oil which is recognized to help maintain the stability of the body resistance.

Virgin Coconut Oil (VCO) used has good anti-microbial and antioxidant properties. VCO made by fermentation contains lactic acid bacteria that are probiotic and anti-microbial [2]. In addition, VCO has phenolic compounds that act as good antioxidants. Virgin Coconut Oil contains lauric acid CH3(CH2)10COOH 50% and caprylic acid CH3(CH2)6COOH 7%. Both of these acids are medium-chain saturated fatty acids that are quickly metabolized and have anti-microbial properties. In the body, lauric acid becomes monolaurin, while caprylic acid becomes monocaprine [3]. Thus, lauric acid has a
function, which is converted into monolaurin in the human body. Monolaurin is an antiviral, antibacterial, and anti-protozoal monoglyceride that is used by the immune system of humans and animals to destroy lipid-protecting viruses, such as HIV, herpes, influenza, and various pathogenic bacteria. Capric acid also functions as an immune substance when converted into monocaprine in the human or animal body. Monocaprine has antiviral effects against HIV and herpes simplex and bacteria that are transmitted through sex [3]. The benefits of VCO include as a supplement for food, cosmetics, and pharmaceuticals (drugs) [2], [3].

Research carried out [4] stated that the manufacture of whey edible films with a formulation using Carbo Methyl Cellulose (CMC) for 0.7% and sorbitol 0.15% produces good edible packaging. However, the rigid formed as a result. Furthermore, in research [5], carbomethylcellulose (CMC) as much as 1% and glycerol 3% significantly affected the film thickness but did not affect water content, pH, and solubility. Another study [6] explained that whey edible films with the addition of 0.15% beeswax affected the tensile strength of edible films. Recent research [7] showed that edible film with the addition of turmeric extract (Curcuma domestica) up to 0.6% usage did not affect barrier properties but had a significant effect on antioxidants.

In the manufacture of functional whey edible films, it is necessary to know the physical and microstructural properties of the resulting film. In general, the crucial parameters measured and observed physical characteristics of a packaging film include: thickness and solubility time; Mechanical characteristics of edible films are tensile strength (tensile strength) and (elongation to break) as well as microstructural characteristics [8].

2. Material and methods

2.1 Research material
The research material was Virgin Coconut Oil (VCO), whey from cow milk waste for making edible films, glycerol, CMC, 96% pure ethanol, aquades, and alcohol. The equipment used consisted of a cool box, thermometer, petri dish, ose-needle, incubator, measuring cup, analytical balance, Erlenmeyer, bunsen lamp, test tube, Eppendorf, beaker glass, dropper pipette, oven.

2.2 Research method
Stage 1. Virgin Coconut Oil
Perform proximate review and test [9].
Stage 2. The Creation of Whey Edible Film [5], [8], with the addition of VCO: A (0%), B (0.5%), C (1.0%), D (1.5%) dan E (2.0%) with four replications as a group, then the physical, mechanical and microstructure properties of whey edible films were measured

2.3 Parameter

2.3.1. Physical properties [10]
- Thickness (Digital Micrometer)
- Dissolving Time

2.3.2. Mechanical properties [11]
- Tensile Strength
- Elongation

2.3.3. Microstructure (Scanning Electron Microscope)
2.4 Data analysis
The data were analyzed statistically using ANOVA, and if the treatments showed significantly different results (P<0.05), further tests were carried out using Duncan's Multiple Range Test (DMRT) with the SPPS ver 25 programs.

3. Results and discussion

3.1 Virgin Coconut Oil (VCO)
Virgin Coconut Oil (VCO) is a product obtained from fresh and cooked coconut meat with or without heating, and it does not change the oil. Since 1988 the Research Institute for Coconut and Other Palm Plants (Balitka) has started processing virgin coconut oil/VCO and has produced coconut oil processing technology with gradual heating. The processing only improves the way farmers commonly do, namely through making coconut milk. The oil produced has shallow water and free fatty acid content. It is clear and smells good/typical of coconut oil [2].

The VCO standard from the APCC is still a temporary standard. Therefore, the Philippines, as the largest coconut producing country issues national standards, including a maximum free fatty acid of 0.2%, a maximum moisture content of 0.2%, a maximum peroxide value of 3 meq/kg of oil, and a total microbe of less than Ten cfu, but the ideal characteristics of VCO is clear color (measurement with Lovibond Tintometer: Yellow 1 and Red 0.1), maximum free fatty acid 0.1%, maximum water content 0.1%, maximum peroxide value one meq/kg oil, lauric acid 47-53%, and a characteristic odor. Canada issues the following VCO standards: clear color, characteristic coconut smell, cholesterol <0.2 g/100g, free fatty acids <0.1%, water content <0.15%, saponification number 260, maximum iodine value 9, peroxide value 0.09 meq/kg of oil and a relative density of 0.92 [12], [13].

Table 1. Total phenolic content of VCO.

| No. | Type of VCO    | Total Phenolic Content (µg/mL) |
|-----|----------------|-------------------------------|
| 1.  | Fermented VCO  | 49.56 ± 3.539                 |
| 2.  | Heated VCO     | 59.88 ± 0.515                 |

Source: [14]

Total phenol content in VCO obtained by heating method had higher phenolic acid content of 59.88 g/mL than entire phenol content in VCO got using fermentation method (49.56 g/mL). The difference in the total range of phenolic components in fermented VCO and heated VCO is supposed to be affected by the extracting method of VCO. The coconut milk emulsion used in the fermentation and heating method contains water, oil, and protein (organic) phases.

Phenolic compounds are polar components. In the process of extracting virgin coconut oil using the fermentation method, the separation of oil from protein and water is induced by the addition of yeast (fermipan). At the time of separation, it is suspected that polar phenolic compounds will be attracted to the water and protein layers, so that the content of phenolic compounds obtained is less than the heating method. In the heating process, temperatures above 100°C were used, when the heating temperature reaches the evaporation temperature of water, the components of phenolic compounds that had previously joined in the water phase (polar) will be attracted or join the separated VCO oil. This causes the total phenol content in heating VCO to be richer in phenolic compounds than the fermentation method [12], [14].

Antioxidant activity testing was carried out by measuring the ability of VCO oil in scavenging (scavenging) DPPH radicals. This ability is marked by a change in color from purple to yellow. The result [14] shows the IC50 value of VCO 17.17 g/mL. The smaller the IC50 value, the higher the antioxidant activity.

Coconut milk emulsion contains 3 fused layers, namely water, protein (blondo) and oil. The process of fermentation and heating is used to separate the three layers. In the fermentation process, room temperature is used for separation. This temperature causes accumulation of water content so that
polyphenolic compounds that are polar will be widely distributed in the water layer and polar proteins. Meanwhile, using heating (temperature above 100°C) can cause water evaporation [14].

3.2. Edible film in with addition VCO

![Figure 1. Whey edible film (left = control, right = treatment E).](image)

### 3.2.1. Physical Properties

**Table 2.** The average results of physical properties of whey edible film.

| Treatment | Thickness (mm) | Dissolving time (second) |
|-----------|----------------|--------------------------|
| A         | 0.20<sup>a</sup> | 46.50<sup>a</sup>        |
| B         | 0.25<sup>b</sup> | 62.45<sup>b</sup>        |
| C         | 0.30<sup>c</sup> | 76.35<sup>c</sup>        |
| D         | 0.31<sup>c</sup> | 120.73<sup>d</sup>       |
| E         | 0.34<sup>d</sup> | 170.78<sup>e</sup>       |

From Table 2, it can be seen that the average thickness of the whey edible film with VCO addition in treatments A to E ranged from 0.20-0.34 mm. Based on the results of statistical analysis showed that the addition of VCO had a significant effect (P<0.05) on the thickness and dissolving time of whey-based edible films.

The thickness of the whey edible films increased along with the increase of VCO concentration. It is because the thickness of the film is influenced by the amount of material used in the manufacture of edible films, so that the thickness of edible film will increase. In this study, the concentrations of the ingredients for making edible films were same, except for the treatment given, that is the increase of VCO so that it affected the thickness of the whey edible films produced.

The greater the total amount of solids in the solution, the thicker the resulted film [15]. The results of this study are in line with the results of research [16] that stated that the thickness of the edible film using palm starch increased along with the increase in the concentration of added palm oil.

The thickness of the edible film is an important parameter that affects the use in the manufacture of packaged products. The thickness of the edible film affects the gas permeability. The thicker the edible film, the smaller the gas permeability and better protect the packaged product. Film thickness can also affect other film mechanical properties, such as tensile strength and elongation. However, in its use, the thickness of the edible film must be adjusted to the packaged product [17].

In a previous study [5], the thickness of whey edible films ranged from 0.44-0.59 mm, it was thicker than this study. Then research [6], whey edible films added with lactic acid bacteria isolate from tempeyak with thickness that ranges from 0.134-0.144 mm, thinner than this study. The comparison of the thickness of the edible film in this study with several previous studies showed different results. It is because the thickness of the edible film depends on the type and composition of the material used in its manufacture.
Referring to the Japan Industrial Standard (JIS) Z: 1707: 2019 materials that can be categorized as films are those with a maximum thickness of 0.25 mm. VCO for treatment B (0.5%) in the edible film formula from this study resulted in a film thickness according to these standards.

In Table 3, it can be seen that the average dissolution time of the whey edible film with the addition of VCO in treatment A to treatment E ranged from 46.50-180.70 seconds. Based on the results of statistical analysis showed that the addition of VCO had a significant effect (P<0.05) on the dissolution time of whey edible films. This is because oil is hydrophobic (not easily soluble in water) and tends to be nonpolar. A substance can be dissolved in a solvent if it has the same polarity value that is polar substance that is soluble in a polar solvent and insoluble in a non-polar solvent. VCO is an oil that belongs to the lipid group, namely organic compounds found in nature and insoluble in water, but soluble in non-polar organic solvents, for example diethyl-ether, chloroform and other hydrocarbons [18]. Thus, the more VCO added to the whey edible films, the slower the dissolution time.

This is in line with the solubility results obtained in this study. The more VCO concentration added to the whey edible films, the lower the power or ability to dissolve so it takes longer time. The results of this study are in line with research [15] that stated the increasing the concentration of VCO on edible films from palm flour causes the solubility time to increase. According to him, the solubility of edible films depends on the components and properties of the constituents. If it is added the hydrophobic, the solubility time will be longer, and vice versa if it is added is hydrophilic, it will accelerate the solubility time of the edible film.

Compared with the results of research [5] the dissolving time of whey edible films with 3% glycerol and 1% CMC treatment was 3.24 minutes longer than this study. Furthermore, in research [6], whey edible films with the addition of lactic acid bacteria isolate from tempoyak had faster dissolution time compared to this study, which ranged from 32.46-34.78 seconds.

The solubility of edible films is an important factor in determining the biodegradability when used as packaging. There is an edible film that requires high level of solubility or vice versa depending on the type of product packaged [19].

### 3.2.2. Mechanical properties

| Treatment | Tensile Strength (kg.f/cm²) | Elongation (%) |
|-----------|-----------------------------|----------------|
| A         | 51.99                       | 28.43          |
| B         | 49.94                       | 28.83          |
| C         | 49.91                       | 30.81          |
| D         | 47.87                       | 32.24          |
| E         | 46.91                       | 34.16          |

This research showed the value of tensile strength 46.91-51.99 kg.f/cm2. Likewise with the percent elongation (Elongation) that was between 28.43-34.16%. Tensile strength is the maximum tensile force that a film can withstand until it breaks. While elongation is the maximum length change before the edible film breaks. The elongation percentage represents the maximum stretching ability of the edible film.

Based on the JIS standard 2019, edible film packaging has a minimum of 40 kg.f/cm2, the results of the study showed that the whey edible film meets the standard as food packaging. The tensile strength of edible film is determined by the constituent components, especially plasticizers in this case glycerol. According to [20], glycerol molecules will interfere with the cohesiveness of the molecules making up the material, so that intermolecular interactions decrease and polymer mobility increases. This condition causes the flexibility of edible films to increase. Research [21] states that the use of glycerol in the right amount provides a textural effect because the substance can potentially flex the polymer matrix. Glycerol as a low molecular weight constituent can intersect between polymers. Furthermore, [22] suggested that plasticizers reduce intermolecular bonds between adjacent polymer chains, thereby
increasing the flexibility of edible films. Vanine research showed [23] that the tensile strength decreased with the increase of glycerol concentration (10, 15, 20, 25, 30) g/100g gelatin, ie 18.28 – 8.90 N.

For the elongation value based on the previous JIS 2019 standard that is JIS 1975, edible film packaging has an elongation that is good if it is above 10%. According to [21] stated that, plasticizers decrease the intermolecular strength, thereby increasing the flexibility and elongation properties of the films. And [24] states that tensile strength is inversely proportional to elongation. If the tensile strength increases, the elongation will decrease and conversely.

The results of the study [6] showed that the addition of beeswax on the whey edible film resulted the decrease in tensile strength with the addition of treatment. The tensile strength ranged from 4.39-20.74 kg.f/cm², while the elongation value was 34.2-74.2%. Tensile strength and elongation are influenced by the constituent components, namely the plasticizer. According to [25], the mechanical strength of the Whey Protein Isolate (WPI)-based film decreased with the increase in the ratio of plasticizer to WPI; Simultaneously, the water absorption increases, so that the tensile strength decreases and the elongation increases.

3.2.3. Microstructure Properties

![Figure 2. Scanning Electron Microscope Treatment A (0%) and B (0.5%)](image)

The SEM results showed that the control whey edible film (Figure 2 A) had the starch granules of the CMC stuck to each other because the gelatinization process between starch and glycerol is affected by the heating process during compression. Meanwhile, whey edible film with the addition of 0.5% VCO (Figure 2 B) showed CMC granules covered by layer indicating VCO. It is because the more addition of VCO may cause much trapped oil between the pores of the edible film.

4. Conclusion

Based on the results of physical properties, the addition of VCO had a significant effect (P<0.05) on thickness and dissolving time, while the mechanical properties of whey edible films had no significant effect (P>0.05) on whey-based edible films.

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