International Food Research Journal 29(5): 1020 - 1031 (October 2022)
Journal homepage: *http://www.ifrj.upm.edu.my*

Physical and antioxidant properties of gelatine film added with sesame, rice bran, and coconut oil

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Article history

Received:
3 December 2020
Received in revised form:
23 December 2021
Accepted:
27 January 2022

Keywords

gelatine film,
physical properties,
antioxidant,
coconut oil,
meat

Abstract

Gelatine is commonly used as packaging in the food industry because it has the proper physical properties. The present work observed that there were no differences in moisture content and solubility of the packaging film after adding 4% of gelatine film with 0.5% of rice bran, sesame, and coconut oil. Meanwhile, water vapour permeability, tensile strength, and elongation of the gelatine films increased when added with the oil. The colour value depended on the colour of the oil added to the gelatine films. The colour value of the gelatine films added with sesame and coconut oil did not differ from the gelatine film without the addition of any oil. The addition of coconut oil to the gelatine film resulted in increased antioxidant activity. Wrapping chicken, pork, and beef with the gelatine films added with all three types of oil showed no differences in pH values for all three types of meat products throughout refrigeration storage for 12 days. Meat wrapped in gelatine film added with coconut oil showed an increase in TBARS, while TBARS were lower in the gelatine film without the addition of any oil or added with rice bran and sesame oil. This indicated that after coconut oil was added to the gelatine film, it decreased oxidation in the meat products during storage.

DOI
https://doi.org/10.47836/ifrj.29.5.05

Introduction

At present, the amount of plastic waste is increasing annually, especially the waste from disposable packaging which is being produced to meet the need for convenience. This non-biodegradable packaging has created a tremendous amount of waste. One type of food packaging that cannot be reused or recycled is wrapping film. This type of film is very useful for selling and storing products because it is highly flexible. It can also be used with a variety of products, and it can resist temperature and climate changes, which makes it popular for a lot of applications. If a film of this quality can be made to degrade naturally, it will significantly reduce the amount of waste. Gelatine is a protein compound with high flexibility, so it can be used to produce films. Gelatine film is less flexible and durable than plastic film, but it can be applied to replace some stretch films. Some properties of gelatine films can also be added or improved over stretch film such as adding antioxidation properties by incorporating natural extracts. This makes gelatine film suitable for use with products that contain large amounts of fats such as meats. The extracts can prevent rancidity, and disposable fresh food can be wrapped with them without causing any environmental impact.

Gelatine film is flexible, and is therefore widely used in the food industry. As a result, many research studies related to the development of gelatine film have been conducted. For example, based on the results of a study on fish wrapped with gelatine film mixed with basil and citronella oils in the ratio of 1:1 with 25% of the surfactant of the oil, it was found that the film had a smooth surface, fewer sequins, and separated into two layers. The reaction among proteins decreased depending on the surfactant used (Tongnuanchan *et al*., 2014). Gelatine film mixed with bergamot and lemongrass oils at 5 - 25% resulted in a film with decreased tensile, elongation, dissolution, and reflectivity. The water vapour permeability rate of the film mixed with kaffir lime oil decreased, but it increased in the film mixed with lemongrass oil. The film surface was porous due to the oil droplets. The properties of this film were

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suitable for packaging materials by selecting the appropriate oil type (Ahmed *et al*., 2012). In addition, gelatine film properties could be improved by adding sunflower oil at 0.3 - 1%, which decreased the water vapour permeability, water solubility, and deformation forces, thus making the film thicker and whiter. Light reflection and water vapour permeability were stable throughout the storage process, which was a result of the reaction between the protein and fat (Perez-Mateos *et al*., 2009). When corn oil was added to the gelatine film, the result was an increase in thickness, tensile strength resistance, and deformation force; a 27.25% increase in oil resulted in decreased water vapour permeability. Based on the inspection on the film's surface, fat granules were found to be widely distributed in the gelatine film (Wang *et al*., 2009). Moreover, with respect to gelatine film which was composed of ginger, turmeric, and Plai oils at 25, 50, and 100% of gelatine, respectively, it was found that the film exhibited high tensile strength, elongation, and was yellowish. In contrast, it showed decreases in water vapour permeability, brightness, and light reflection. The film began to split into two layers (bilayer film) when the oil content was increased to 50%. In terms of antioxidants, it was found that the gelatine film mixed with turmeric and Plai oils yielded DPPH and ABTS values higher than the gelatine film mixed with ginger oil (Tongnuanchan *et al*., 2013). Furthermore, when kaffir lime and lemon oils were added to the gelatine film, it resulted in a decrease in tensile resistance and water vapour permeability, but an increase in elongation. The film surface was smooth, but the cross-section was rough. The films containing lime oil yielded higher ABTS and FRAP values than those containing kaffir lime oil. Therefore, it could be suitable to be applied as a food packaging material that is easily oxidised (Tongnuanchan *et al*., 2012).

Regarding the film made from gelatine and olive oil, it was homogeneous, and granulated fat was observed throughout the film. The addition of oil decreased the water vapour permeability and tensile strength, but its resistance to ultraviolet radiation increased. Therefore, it could also be suitable to be applied as a food packaging material (Ma *et al*., 2012a). Through homogenisation, the film made from gelatine and olive oil prevented water vapour permeability better than the non-homogeneous films. However, the strength, elongation, and reflection decreased (Ma *et al*., 2012b).

In addition to rice bran, sesame, and coconut oils being important sources of biomolecules, they are also fats that contain many vitamins including niacin and vitamin E, which have antioxidation effects. Therefore, they can be mixed with gelatine to produce a film to be used to extend food storage life. It can be considered as a bio-based food packaging container because it is made from renewable natural materials, and will naturally degrade. If it can be developed by improving certain features, its value will increase, and it will be able to be used more efficiently.

The objective of the present work was to study the conditions of the production of 4% gelatine film mixed with three types of oil (rice bran, sesame, and coconut oil) at 0.5%. In addition, it also aimed (i) to investigate the physical properties of the film including moisture content, mechanical properties, colour, and water vapour permeability, (ii) to study its antioxidant activity, and (iii) to apply the film to preserve meat products such as chicken, pork, and beef.

Materials and methods

The production of gelatine film

Gelatine film production was done following the method of Zhang *et al.* (2013) using 20 g of gelatine and different kinds of oil (rice bran, white sesame, and coconut oil) at 0.5% (w/w) in 480 mL of distilled water (Jirukkakul and Sodtipinta, 2017). The mixed solution was blended at 80°C and 100 rpm for 30 min. Then, the speed was increased to 700 rpm for another 30 min. The solution (50 mL) was then poured onto the plate (Paisan Superlene, Co., Ltd., Bangkok, Thailand), and was left to dry at 37°C for 24 h.

The analysis of the physical properties of gelatine film

Moisture content

The moisture content of the film was determined by heating an aluminium cup in an oven at 105°C, and then placing it in a desiccator for 24 h. Next, the film sample was placed in an aluminium cup, and weighed (Wi). After that, the film with the aluminium cup was heated at 105°C for 24 h, and was then re-weighed to determine the final weight (Wf). The moisture content was calculated as [(Wi – Wf) / Wi] × 100.

Tensile strength and elongation

The tensile strength test of the film was determined in accordance with American Standard Testing Method, method no. D882 (ASTM, 1997). Briefly, a sample with 10 mm width and 150 mm length was cut and then stored at 23°C with 50% relative humidity for at least 40 h. Then, the sample was tested by firmly fastening the two ends of the sample to the head of the texture analyser (model TA.XT plus, Stable Micro Systems, Ltd., UK). The test was set to have a pulling speed of 50 mm/min, a load cell of 0.5 kN, and a distance between the grips of 100 mm. The tensile strength value was determined by TS = maximum force / cross-sectional area. The elongation was calculated in percentage.

Colour

Colours were determined using a Hunter Lab spectrocolorimeter. The film was closed with a test cup. Then, the measurements were taken by placing the film at the test point of the machine. The results were reported with the Lab system.

Water vapour permeability

The water vapour permeability of the film was conducted in accordance with American Standard Testing Method, method no. E96 (ASTM, 1995) by cutting the sample into a circle of 6 cm in diameter and then applying a thin sealant at the top of the test cup containing distilled water. The sample was then placed onto the cup, and then, the top part of the cup was closed. The ring cover was closed by tightly turning the screw. The cup was weighed and placed in a water vapour permeability tester. The weight was recorded every 1 h until the weight difference was less than 1%. The water vapour permeability value was calculated using Eq. 1:

$$WVP = \frac{(G/t) \times thickness}{A \times (P_{A1} - P_{A2})} \quad \text{(Eq. 1)}$$

where, G / t = change rate of weight per time (g / day); A = sample surface area (m^2); and P_{A1} - P_{A2} = internal and external pressure difference of test cup (kPa).

Solubility

The film sample (20 × 20 mm) was heated in the hot air oven at 104°C for 24 h before weighing (Wi). Next, the heated film was put in an Erlenmeyer flask containing 50 mL of distilled water, and then, the flask was placed in the shaker (≈2,000 rpm) for 24 h at 25°C. After that, the film sample was filtered through filter paper, and heated in the hot air oven again at 104°C for 24 h, and was then weighed to determine the final weight (Wf) (Ahmed *et al*., 2012). Film solubility percentage (S%) was determined as S (%) = [(Wi – Wf) / Wi] × 100.

Antioxidant

The DPPH sample was determined using Eq. 2 to compare the weight of DPPH with the volume to be used. The volume was adjusted using methanol.

$$g = \frac{m_1 \times v_1 \times mw}{1000} \quad \text{(Eq. 2)}$$

where, g = weight of DPPH; m_1 = DPPH concentration; v_1 = volume to be prepared; and mw = molecular mass (394.4).

Then, 400 mg of the film sample was dissolved in 3 mL of hexane for 15 h. After that, 3 mL of clear solution was removed to measure the UV at 503 nm using a spectrophotometer. Next, 0.5 mL sample of the solution was removed (obtained from UV measurement) and then mixed with 1.5 mL of ethyl acetate. The UV of the solution was measured at 515 nm. Later, 1.5 mL of the UV-measured solution was removed, mixed with 1.5 mL of DPPH, and then incubated in the dark for 30 min. After that, the UV was measured at 515 nm, and calculation was performed to determine the antioxidant (AA%) using Eq. 3:

$$AA\ (\%) = \left(\left(A_{control} - A_{sample}\right) / A_{control}\right) \times 100 \quad \text{(Eq. 3)}$$

where, $A_{control}$ = UV value of the control sample, and A_{sample} = UV value of the experimental sample.

The control sample was derived by removing 1.5 mL of ethyl acetate, and mixing it with 1.5 mL of DPPH. Then it was incubated in the dark for 30 min. Next, the UV was measured at 515 nm.

The preservation of meat products using the gelatine film

Preparation

The meat was wrapped using the gelatine films, and stored at 4°C. The pH, colour, and oxidation reactions were checked every three days for 12 days.

pH

The pH value of the meat was determined by grinding the meat with 90 mL of water, and then using a masticator homogeniser (Compact, IUL Instruments, Spain). Next, the pH was measured using a pH meter (Seven Compact, Mettler Toledo, Thailand).

Colour

The colour value was determined using the Hunter Lab spectrocolorimeter (model TC-P III A, Tokyo Denshoku Co., Ltd., Japan). A 20 g sample of meat was put into a colour measuring cup. The value was reported as L*, a*, and b*. Then, the colour difference was calculated as follows: $\Delta E = (\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$.

Oxidation

TBARS analysis was conducted by weighing 2 g of meat, then adding it to the test tube (a blank was created by using an empty tube without adding any meat). Then, 3 mL of TBA was added and blended by the vortex mixer. Then, 17 mL of the TCA solution was added before it was boiled for 30 s, and then left to cool at room temperature. Then, 5 mL of the top clear solution was removed and placed into a 50-mL centrifuge tube. Then, 5 mL of chloroform was added and mixed by the vortex mixer inside a laboratory chemical fume hood. After that, the solution was centrifuged at 200 *g* for 5 min, then 3 mL of the top clear part was removed and placed into a 15-mL centrifuge tube before adding 3 mL of petroleum ether. Next, the solution was mixed by the vortex mixer inside a laboratory chemical fume hood, and then centrifuged at 200 *g* for 10 min. Finally, using a dropper, the bottom part was removed to measure the spectrum absorption at 532 nm with distilled water being used as blank.

Statistical analysis

The packaging properties were analysed using one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) of SPSS at a confidence level of 95%.

Results

Gelatine film properties

Moisture content is an important physical property of film used in packaging. However, if the film has high moisture content, it will cause mould to grow. Based on the study, every gelatine film sample had a moisture content of only 1.5 - 1.7%, which is considered a low moisture content range (Table 1). However, the film was likely to express good compatibility with water. It was able to absorb moisture from the atmosphere. Therefore, moisture content depends on the storage as well. For example, a gelatine film that is stored at high relative humidity will also have high moisture content (15 - 24%). Since the film's structure is porous, moisture can be absorbed into its structure (Haghighi *et al*., 2019). Therefore, it is also important to consider the water vapour permeability.

The water vapour permeability is a property of water resistance, which is important for the storage of products that are directly related to moisture, and can directly affect storage. Gelatine films have different properties depending on the source, type, and property of the gelatine used to produce them. Most of the gelatine films which Suderman *et al*. (2018) collected were in the range of 0.4 - 9.6 g.mm/m^2.day.kPa. The low water vapour permeability indicated a high resistance. Based on the study, when the gelatine film was mixed with 0.5% oil, the water vapour permeability increased (Table 1).

For proper utilisation, solubility is important for packaging design. Natural protein films have high solubility as well as water vapour permeability, in which the dissolving property changes according to

Table 1. Physical properties of gelatine films added with three types of oil.

Gelatine film	Moisture content (%)	Water vapour permeability (g.mm/m^2.day.kPa)	Solubility (%)	Tensile strength (MPa)	Elongation (%)
Control	1.705 ± 0.059[a]	0.283 ± 0.007[d]	100 ± 0[a]	6.166 ± 1.059[b]	0.986 ± 0.009[b]
Sesame oil	1.624 ± 0.087[ab]	0.461 ± 0.020[b]	97.792 ± 0.976[a]	9.980 ± 4.138[ab]	1.602 ± 0.520[a]
Rice bran oil	1.525 ± 0.056[b]	0.362 ± 0.009[c]	100 ± 0[a]	12.100 ± 2.13[ab]	1.808 ± 0.177[a]
Coconut oil	1.751 ± 0.054[a]	0.648 ± 0.023[a]	97.404 ± 0.308[a]	15.568 ± 3.541[a]	2.368 ± 0.665[a]

Values are mean ± standard deviation (SD) of triplicates (n = 3). Means within the same column with different lowercase superscripts are significantly different ($p < 0.05$).

the type of protein. High solubility is useful for packaging that can be consumed with food, and digested by the body. However, it needs to be stored under moisture-free conditions (Zhang *et al*., 2018). Highly dissolved films have the potential to release important substances (Kaewprachu *et al*., 2018). On the contrary, low dissolving films are useful for coating food products for food processing. The gelatine films obtained in the present work were not significantly different ($p > 0.05$), and they were similar to the gelatine films from Zhang *et al*. (2018) (97 - 98%) due to the addition of only 0.5% oil (Table 1).

The mechanical properties of degradable films depend on the raw materials and additives, as well as the consistency of the moulding. These features are important in the processes of transportation and distribution. The tensile strength and elongation of the gelatine film were 6.17 - 15.57 MPa and 0.98 - 2.37%, respectively. The addition of coconut oil to the gelatine film resulted in higher tensile strength and elongation (Table 1).

Colour is important in determining the general appearance to consumers, and generally divided into three parameters: brightness (L*), reddish/greenish (a*), and yellowish/bluish (b*). The addition of rice bran oil slightly decreased the L* value, whereas the addition of sesame oil and coconut oil resulted in a slightly higher b* value (Table 2).

Plants or natural extracts have been popularly added to biodegradable films as a source of antioxidants, to increase the antioxidant performance of the film, thus extending the shelf life of food storage. To establish good compatibility, it was found that plant extracts such as mint extract, green tea, pomegranate peel, rosemary, grape seed, thyme, and ginkgo could be added to film compositions with better results than oil (Mir *et al*., 2018). Antioxidants can be analysed in many ways, and DPPH radical scavenging capacity is one of the popular methods being utilised to analyse antioxidants in food products. Antioxidant efficiency depends upon the hydrogen atoms obtained from the extracts, and the stability of the radicals. The antioxidants in the gelatine film used in the non-oiled studies did not differ from the gelatine film to which sesame or rice bran oil was added. However, the antioxidants increased when the coconut oil was added ($p < 0.05$) since coconut oil is a saturated oil that is high in antioxidants (Table 2).

The gelatine film applied to the preservation of meat products

Based on the pH of the three types of meat which were wrapped in the gelatine films and stored in a refrigerator, it was found that in all types of the film throughout the 12 days of storage, there were no differences in the pH values. They all showed pH values in the range of 5.5 - 6.4 (Figure 1). For the chicken products during the first three days of storage, the pH slightly decreased due to the occurrence of acids produced by some bacteria which contributed to organic acids from the fermentation. For the beef products, the pH increased on the 12th day due to increases in certain components such as ammonia and amines, which contributed to autolytic and microbial growth (Kaewprachu *et al*., 2018).

In the storage of all three types of meat products, it was found that considerable degrees of colour change (ΔE) had occurred in the first three days (Figure 2). Then over the next three days, there were constant changes, and the ΔE slightly increased after day 6. The ΔE changed due to lipid oxidation and myoglobin oxidation (Kaewprachu *et al*., 2018). In the present work, ΔE did not differ in the gelatine films to which the oil was added and to which no oil was added.

Table 2. Colour and antioxidant of gelatine films added with three types of oil.

Gelatine film	Lightness (L*)	Redness (a*)	Yellowness (b*)	Antioxidant (%)
Control	85.947 ± 0.55[a]	0.050 ± 0.028[a]	2.047 ± 0.706[ab]	7.230 ± 0.915[bc]
Sesame oil	85.363 ± 0.181[a]	0.073 ± 0.056[a]	3.700 ± 0.208[b]	6.583 ± 0.938[c]
Rice bran oil	83.993 ± 0.147[b]	0.070 ± 0.029[a]	1.050 ± 0.906[a]	8.295 ± 0.054[b]
Coconut oil	85.963 ± 0.338[a]	0.157 ± 0.058[a]	3.733 ± 0.872[b]	11.454 ± 0.215[a]

Values are mean ± standard deviation (SD) of triplicates ($n = 3$). Means within the same column with different lowercase superscripts are significantly different ($p < 0.05$).

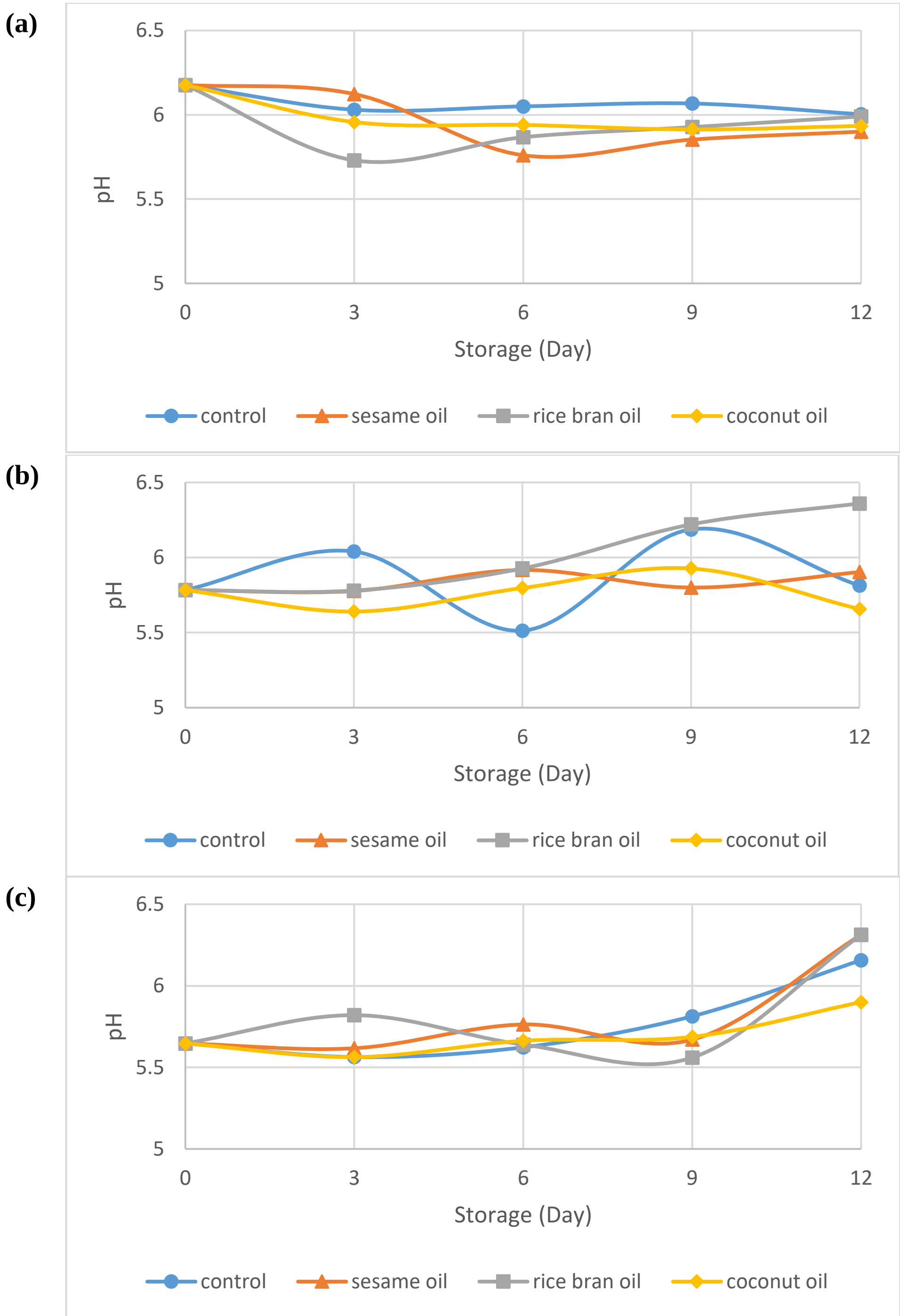

Figure 1. pH of chicken **(a)**, pork **(b)**, and beef **(c)** during storage.

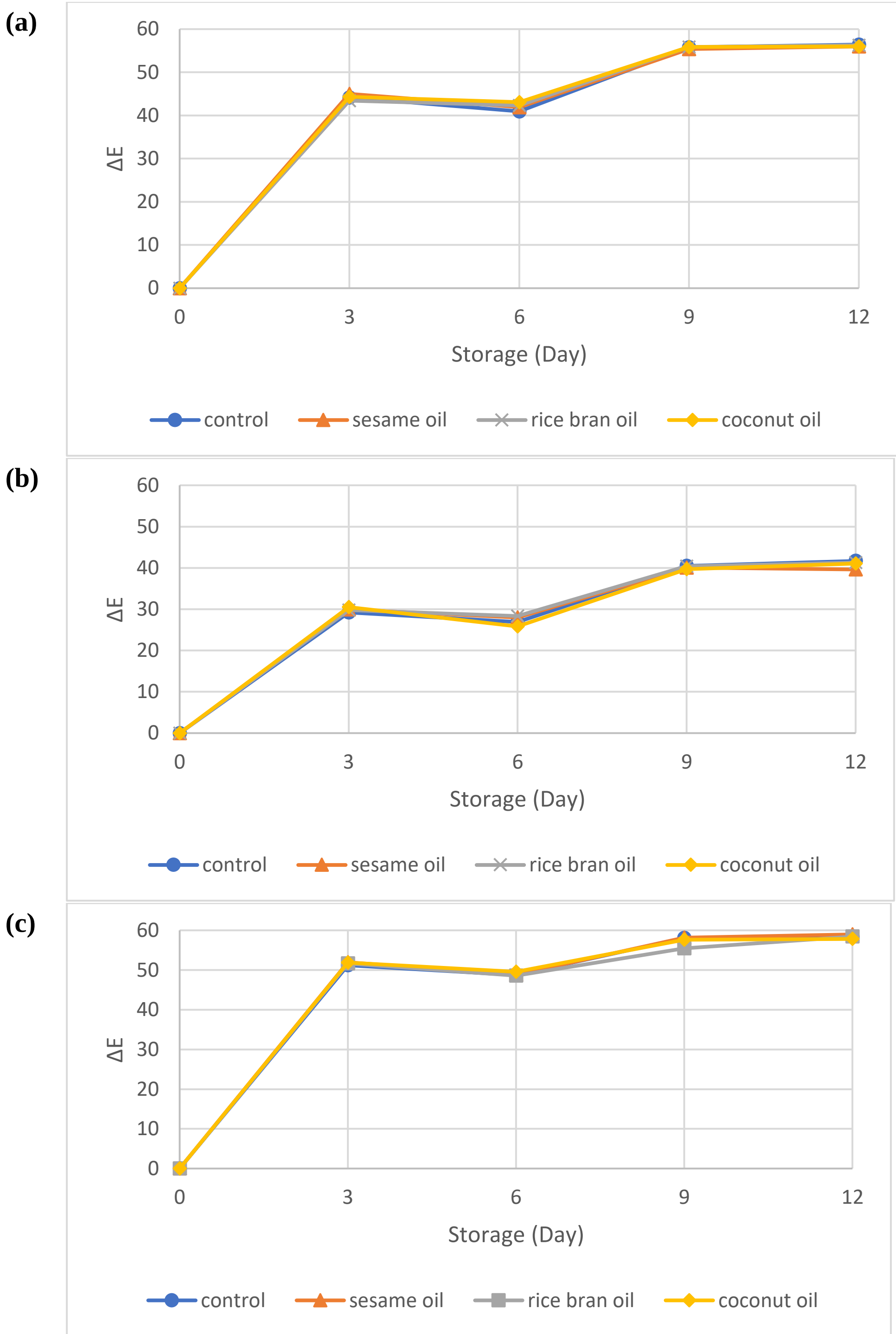

Figure 2. Colour difference of chicken **(a)**, pork **(b)**, and beef **(c)** during storage.

The TBARS assay was used to analyse the second stage of oxidation. Initially, the meat products yielded a TBARS value of 0.1 - 0.92 mg MDA/kg sample, which increased based on the storage period (Figure 3). Regarding the storage of the three types of meat products, it was found that the gelatine film mixed with sesame oil was unsuitable for wrapping the products because it contributed to oxidation. In contrast, the gelatine films mixed with rice bran and coconut oils were similar to the gelatine film to which no oil was added. This was especially true for the pork products which were wrapped in gelatine films mixed with rice bran and coconut oils. These showed lower TBARS values than the gelatine films to which no oil was added. Regarding the gelatine film which was mixed with epigallocatechin gallate, and used to store chicken skin oil, it was able to significantly decrease the occurrence of free fatty acids ($p < 0.05$) (Nilsuwan *et al*., 2019), and was similar to wrapping bacon products with gelatine film. After the rosemary was added, the TBARS increased, but the values were less than the oil-free gelatine film (Zhang *et al*., 2019). When pork was stored in the refrigerator, fat oxidation occurred. However, after the pork was encased in a gelatine film which was mixed with nisin and catechin, it caused a decrease in TBARS (Kaewprachu *et al*., 2018).

Discussion

Based on the present work, when the gelatine film was mixed with 0.5% oil, the water vapour permeability increased. This contributed to the distribution of granulated fat in the film's structure, thus making space spread across the film's surface. This resulted in an uneven film surface which in turn led to intermolecular interactions between molecules. As a result, the polymer was not strong and causing water vapour to pass through the film (Haghighi *et al*., 2019; Hanani *et al*., 2019). In addition, Haghighi *et al*. (2019) argued that oil molecules can cause disruptions in the film's network which in turn can affect the microstructural properties. Likewise, the gelatine film made from chicken had the value of 0.05 - 0.12 g.mm/m^2.day.kPa, which increased from 5 - 20% (Soo and Sarbon, 2018) with the amount of rice flour added or with the addition of carboxymethyl cellulose (CMC). This increased gaps in the composite matrix, thus increasing the water vapour permeability (Nazmi *et al*., 2017). Moreover, the addition of EGCG also increased the water vapour permeability by increasing polar groups. In addition, it also contributed to the binding of the proteins which resulted in discrete form of a network in the film, and led to volume gaps in the polymer matrix (Nilsuwan *et al*., 2018). This was unlike the addition of citric and chitosan acids, which did not affect the water vapour permeability in the gelatine film (Uranga *et al*., 2019). In general, the protein film has a high water vapour permeability rate due to its hydrophilic character, thus resulting in a higher solubility.

The solubility of gelatine films can be decreased by adding other substances to the composition of the film such as rice starch at more than 5% (Soo and Sarbon, 2018). Conversely, when adding hydrophilic plasticisers, the gelatine film's solubility rate increased while the water resistance properties decreased (Chentir *et al*., 2019). Moreover, due to the decrease in cross-linking or interference of protein, the addition of rosemary oil in the gelatine film resulted in increased solubility (Musso *et al*., 2019). The gelatine films obtained in the present work were not significantly different ($p > 0.05$), and they were similar to the gelatine films from Zhang *et al*. (2018) (97 - 98%) due to the addition of only 0.5% oil. Furthermore, adding up to 10% bees or carnauba wax resulted in decreased solubility due to an interaction between the gelatine and the added substances, which made the structure particles become tightly arranged together and have only a little affinity with water (Zhang *et al*., 2019).

The tensile strength and elongation of the gelatine film were 6.17 - 15.57 MPa and 0.98 - 2.37%, respectively. The structure of the gelatine film showed high cross-linking, and it also could regain a large fraction of the triple helix structure. After dissolving, the films therefore had high strength. The addition of rice bran and sesame oils resulted in a slight increase in tensile strength. However, this was no different from the oil-free gelatine film ($p > 0.05$). The film obtained in the present work revealed the same results as the gelatine film of Jridi *et al*. (2019) with a tensile strength of 6.23 MPa. Furthermore, after the blood orange peel extract was added, there was no difference. Conversely, the addition of coconut oil to the gelatine film resulted in higher tensile strength and elongation because it contributed to the strength of the intermolecular bonding and electrostatic interaction between the gelatine and oil. Furthermore, it also depends on the types and sources

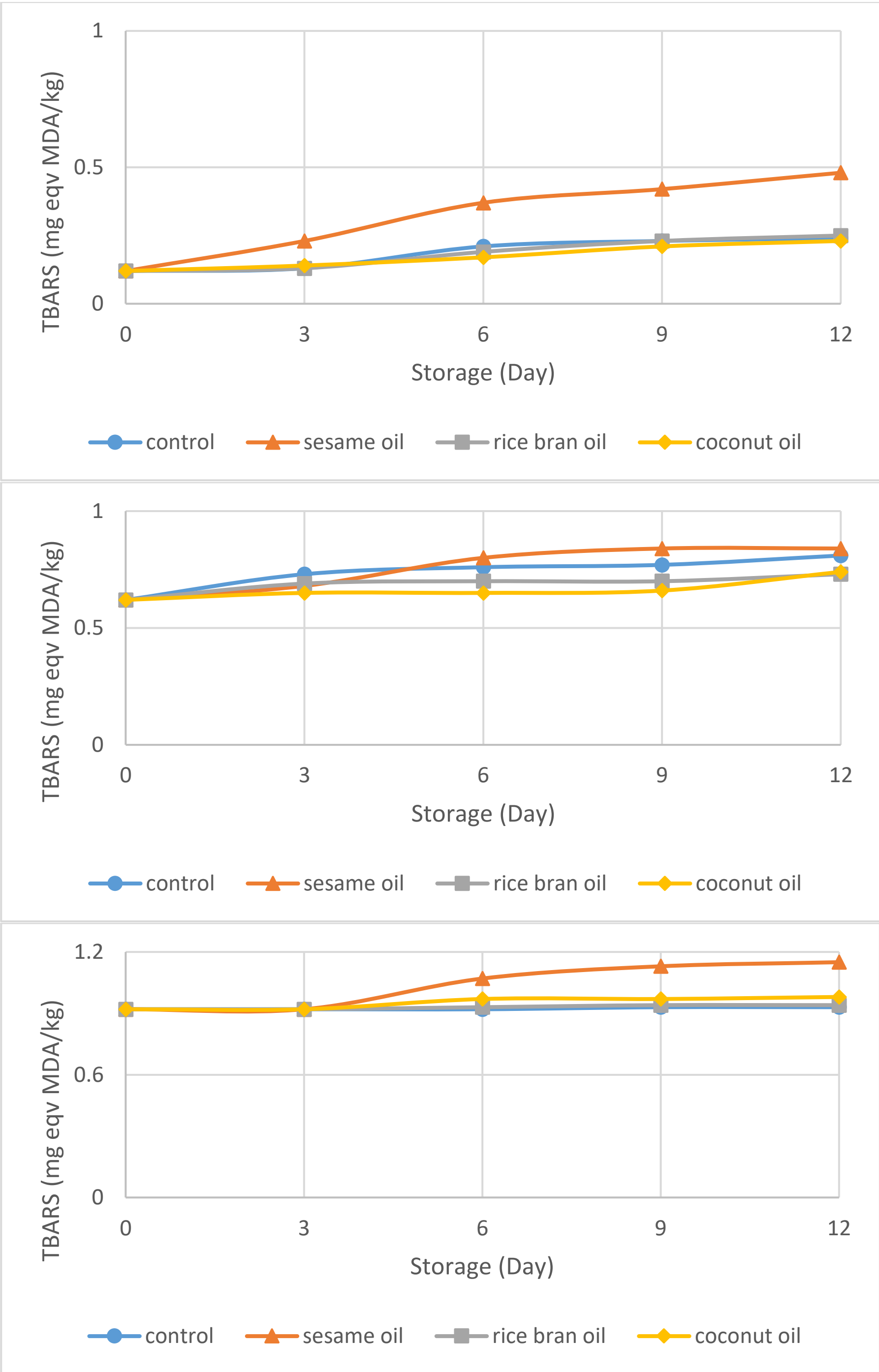

Figure 3. TBARS of chicken **(a)**, pork **(b)**, and beef **(c)** during storage.

of the gelatine which contribute to cross-linking between different types of gelatine (Nazmi *et al*., 2017). The addition of oil to the gelatine film increased the strength of the film from 0.95 to 14.71 MPa (Tongnuanchan *et al*., 2013). With the addition of thyme essential oil to chitosan/gelatine films, it was found that the oil increased the strength of the film, thus resulting in increased tensile strength (Haghighi *et al*., 2019). The addition of rice starch to the gelatine film resulted in an increase in tensile strength and elongation due to increased numbers of hydrogen bonds, decreased molecular mobility, and increased chain entanglement (Soo and Sarbon, 2018). Like the addition of blood orange peel extracts, the addition of sesame, rice bran, and coconut oils resulted in a greater elongation value of the gelatine film since the compositions in the structure were completely compatible (Jridi *et al*., 2019).

The colour change of the gelatine film depended upon the colour and the transparency of the oil or substances added to the film (Haghighi *et al*., 2019). The addition of rice bran oil slightly decreased the L* value, whereas the addition of sesame and coconut oils resulted in a slightly higher b* value. The colour values were close to the gelatine film from Nilsuwan *et al*. (2019) and Kaewprachu *et al*. (2018); that is, the L* values were 90.51 and 90.56, while the b* values were 1.74 and 2.20, respectively. The addition of tomato oil to the gelatine film resulted in increases in a* and b* values (Jirukkakul and Sodtipinta, 2017), while adding mango peel extract and rosemary acid resulted in decreases in the L* and a* values, but an increase in b* value (Mir *et al*., 2018: Zhang *et al*., 2019). The addition of citric acid did not affect the colour value of the film (Uranga *et al*., 2019).

The antioxidants of the film increased when the coconut oil was added ($p < 0.05$) due to coconut oil being a saturated oil which is high in antioxidants, and consistent with adding phycocyanin or pomegranate peel powder in gelatine films. The increase in antioxidant activity was observed because it contains bioactive compounds (Hanani *et al*., 2019). The amine group of the apoprotein reacted with free radicals to convert them, thus making the molecules more stable. Terminating the radical chain reaction by donating protein (Chentir *et al*., 2019) is consistent with Zhang *et al*. (2018) study on gelatine film. It was found that gelatine film exhibited antioxidant activities since gelatine is a protein with a range of polypeptides and peptides, which can provide hydrogen, and can thereby increase the performance of the antioxidants. Yet, when bees or carnauba wax was added, the antioxidant activity did not increase. In short, if the additives are small, such as anthocyanin nanocomplexes, they can increase the antioxidant activity. However, the effects of the antioxidants decreased when the storage temperatures increased (Wang *et al*., 2019). The addition of an antioxidation agent in the form of an acid (Zhang *et al*., 2019) or an extract (Kaewprachu *et al*., 2018; Rasid *et al*., 2018) resulted in more oxidation resistance than the oil. Additionally, the antioxidant activity will increase based on the amount of extract added (Jridi *et al*., 2019). The gelatine film from Shankar *et al*. (2019) showed a DPPH value which was close to that obtained in the present work of 5.7%. Moreover, the value increased when melanin nanoparticles (MNP) were added in accordance with the proportion of concentration added.

For the application of the film, pH slightly decreased due to the occurrence of acids produced by some bacteria, which contributed to organic acids from the fermentation. On the other hand, pH increased due to increases in certain components such as ammonia and amines, which contributed to autolytic and microbial growth (Kaewprachu *et al*., 2018). The ΔE changed due to lipid oxidation and myoglobin oxidation (Kaewprachu *et al*., 2018). In short, the addition of oil or bioactive compounds in the gelatine film could decrease oxidation reactions.

Conclusion

Four percent of gelatine film mixed with 0.5% rice bran, sesame, and coconut oils showed a high solubility value due to the fact that it had good compatibility with water, which contributed to gaps due to oil droplets, thus resulting in increased water vapour permeability and a well-bonded structure for the film. As a result, it had higher strength and tensile strength. The colour values of gelatine film mixed with sesame and coconut oil did not differ from the gelatine film without the addition of any oil. Moreover, the addition of coconut oil to the gelatine film resulted in increased antioxidant activity. When applying the gelatine films to wrap meat such as chicken, pork, and beef products which were mixed with all three types of oil, it was found that all three types of meat products showed no differences in pH values throughout their storage in the refrigerator for 12 days. In addition, there was a lot of colour change (ΔE) in the first three days, but it decreased after that. The meats wrapped in the gelatine film mixed with coconut oil yielded smaller TBARS values than the other meats, or those to which no oil was added. To sum up, the results showed that the gelatine film mixed with coconut oil resulted in decreased oxidation in the meat during storage.

Acknowledgement

The authors would like to thank the National Research Council of Thailand (NRCT) and Division of Research Administration, Khon Kaen University for the financial support. All facilities from the Department of Applied Science are also acknowledged.

References

Ahmed, M., Benjakul, S., Prodpran, T. and Agustini, T. W. 2012. Physico-mechanical and antimicrobial properties of gelatin film from the skin of unicorn leatherjacket incorporated with essential oils. Food Hydrocolloids 28: 189-199.

American Standard Testing Method (ASTM). 1995. E96 - standard test method for water vapor transmission of materials. United States: ASTM.

American Standard Testing Method (ASTM). 1997. D882 - standard test method for tensile properties of thin plastic sheeting. United States: ASTM.

Chentir, I., Kchaou, H., Hamdi, M., Jridi, M., Li, S., Doumandji, A. and Nasri, M. 2019. Biofunctional gelatin-based films incorporated with food grade phycocyanin extracted from the Saharian cyanobacterium *Arthrospira* sp. Food Hydrocolloids 89: 715-725.

Haghighi, H., Biard, S., Bigi, F., Leo, R., Bedin, E., Pfeifer, F., ... and Pulvirenti, A. 2019. Comprehensive characterization of active chitosan-gelatin blend films enriched with different essential oils. Food Hydrocolloids 95: 33-42.

Hanani, Z. A. N., Yee, F. C. and Nor-Khaizura, M. A. R. 2019. Effect of pomegranate (*Punica granatum* L.) peel powder on the antioxidant and antimicrobial properties of fish gelatin films as active packaging. Food Hydrocolloids 89: 253-259.

Jirukkakul, N. and Sodtipinta, J. 2017. Effects of the tomato pomace oil extract on the physical and antioxidant properties of gelatin films. International Journal of Food Engineering 3(2): 1-5.

Jridi, M., Boughriba, S., Abdelhedi, O., Nciri, H., Nasri, R., Kchaou, H., ... and Nasri, M. 2019. Investigation of physicochemical and antioxidant properties of gelatin edible film mixed with blood orange (*Citrus sinensis*) peel extract. Food Packaging and Shelf Life 21: 1-6.

Kaewprachu, P., Amara, C. B., Oulahal, N., Gharsallaoui, A., Joly, C., Tongdeesoontorn, W., ... and Degraeve, P. 2018. Gelatin films with nisin and catechin for minced pork preservation. Food Packaging and Shelf Life 18: 173-183.

Ma, W., Tang, C. H., Yin, S. W., Yang, X. Q., Qi, J. R. and Wei, Z. H. 2012a. Characterization of gelatin based edible films incorporated with olive oil. Food Research International 49: 572-579.

Ma, W., Tang, C. H., Yin, S. W., Yang, X. Q., Qi, J. R. and Xia, N. 2012b. Effect of homogenization condition on properties of gelatin-olive oil composite films. Journal of Food Engineering 113: 136-142.

Mir, S. A., Dar, B. N., Wani, A. A. and Shah, M. A. 2018. Effect of plant extracts on the techno-functional properties of biodegradable packaging films. Trends in Food Science and Technology 80: 141-154.

Musso, Y. S., Salgado, P. R. and Mauri, A. N. 2019. Smart gelatin films prepared using red cabbage (*Brassica oleracea* L.) extracts as solvent. Food Hydrocolloids 89: 674-681.

Nazmi, N. N. Isa, M. I. N. and Sarbon, N. M. 2017. Preparation and characterization of chicken skin gelatin/CMC composite film as compared to bovine gelatin film. Food Bioscience 19: 149-155.

Nilsuwan, K., Benjakul, S. and Prodpran, T. 2018. Properties and antioxidative activity of fish gelatin-based film incorporated with epigallocatechin gallate. Food Hydrocolloids 80: 212-221.

Nilsuwan, K., Benjakul, S., Prodpran, T. and Caba, K. 2019. Fish gelatin monolayer and bilayer films incorporated with epigallocatechin gallate: Properties and their use as pouches for storage of chicken skin oil. Food Hydrocolloids 89: 783-791.

Perez-Mateos, M., Montero, P. and Gomez-Guillen, M. C. 2009. Formulation and stability of biodegradable films made from cod gelatin and sunflower oil blends. Food Hydrocolloids 23: 53-61.

Rasid, N. A. M., Nazmi, N. N. M., Isa, M. I. N. and Sarbon, N. M. 2018. Rheological, functional and antioxidant properties of films forming solution and active gelatin films incorporated with *Centella asiatica* (L.) urban extract. Food Packaging and Shelf Life 18: 115-124.

Shankar, S., Wang, L. and Rhim, J. 2019. Effect of melanin nanoparticles on the mechanical, water vapor barrier, and antioxidant properties of gelatin-based films for food packaging application. Food Packaging and Shelf Life 21: 1-7.

Soo, P. Y. and Sarbon, N. M. 2018. Preparation and characterization of edible chicken skin gelatin film incorporated with rice flour. Food Packaging and Shelf Life 15: 1-8.

Suderman, N., Isa, M. I. N. and Sarbon, N. M. 2018. The effect of plasticizers on the functional properties of biodegradable gelatin-based film: A review. Food Bioscience 24: 111-119.

Tongnuanchan, P., Benjakul, S. and Prodpran, T. 2012. Properties and antioxidant activity of fish skin gelatin film incorporated with citrus essential oils. Food Chemistry 134: 1571-1579.

Tongnuanchan, P., Benjakul, S. and Prodpran, T. 2013. Physico-chemical properties, morphology and antioxidant activity of film from skin gelatin incorporated with root essential oils. Journal of Food Engineering 117: 350-360.

Tongnuanchan, P., Benjakul, S. and Prodpran, T. 2014. Structural, morphological and thermal behavior characterisations of fish gelatin film incorporated with basil and citronella essential oils as affected by surfactants. Food Hydrocolloids 41: 33-43.

Uranga, J., Puertas, A. I., Etxabide, A., Dueñas, M. T., Guerrer, P. and Caba, K. 2019. Citric acid-incorporated fish gelatin/chitosan composite films. Food Hydrocolloids 86: 95-103.

Wang, L., Auty, M. A. E., Rau, A., Kerry, J. F. and Kerry, J. P. 2009. Effect of pH and addition of corn oil on the properties of gelatin based biopolymer films. Journal of Food Engineering 90: 11-19.

Wang, S., Xia, P., Wang, S., Liang, J., Sun, Y., Yue, P. and Gao, X. 2019. Packaging films formulated with gelatin and anthocyanins nanocomplexes: Physical properties, antioxidant activity and its application for olive oil protection. Food Hydrocolloids 96: 617-624.

Zhang, N., Liu, H., Yu, L., Liu, X., Zhang, L., Chen, L. and Shanks, R. 2013. Developing gelatin starch blends for use as capsule materials. Carbohydrate Polymers 92: 455-461.

Zhang, X., Ma, L., Yu, Y., Zhou, H., Guo, T., Dai, H. and Zhang, Y. 2019. Physico-mechanical and antioxidant properties of gelatin film from rabbit skin incorporated with rosemary acid. Food Packaging and Shelf Life 19: 121-130.

Zhang, Y., Simpson, B. K. and Dumont, M. 2018. Effect of beeswax and carnauba wax addition on properties of gelatin films: A comparative study. Food Bioscience 26: 88-95.