Effect of alginate based edible coating enriched with vanilla essential oil on shelf-life of fresh-cut red pitaya (*Hylocereus polyrhizus*)

N A Utama*, C K Setiawan and I Fajri

Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Bantul 55183, Special Region of Yogyakarta – Indonesia

*E-mail: nafi@umy.ac.id

Abstract. Start The research aimed to find out the best concentration from various vanilla essential oil concentration as an antimicrobial agent to inhibit the growth of microbial decomposition and maintain shelf-life of fresh-cut red Pitaya (*Hylocereus polyrhizus*). The experiment was designed with Completely Randomized Design using four treatments as follows: 1) vanilla essential oil 0%, 2) vanilla essential oil 0.1% 3) vanilla essential oil 0.3% and 4) vanilla essential oil 0.6%. The result indicated that vanilla essential oil 0.6% was able to inhibit fresh-cut red Pitaya’s fungal decomposition. The concentration of vanilla essential oil 0.6% could maintain physical quality (weight loss and firmness), chemical (titratable acidity and total soluble solids content) and sensory analysis on fresh-cut Red Pitaya. Edible coating alginate and vanilla essential oil were able to maintain the quality of fresh-cut red Pitaya up to 9 days.

1. Introduction

Red Pitaya or Dragonfruit is becoming known in Indonesia for its high nutritional content and various benefits to health. In addition to its exotic appearance, the red pitaya also has a sweet taste and has multiple benefits to one’s health, such as balancing blood sugar levels, as an anti-carcinogen, to maintain mouth health, and to detect white discharge[1, 2]. As a relatively new horticulture crop, the diversity of red pitaya in Indonesia is still low. One of the regions that implement the red pitaya as a crop is the province of Yogyakarta. One of the developers of red pitaya in Yogyakarta is the Kulon Progo regency, with a production of 839 tons of red pitaya between 2009 and 2012[3]. One of the most sought after red pitaya variations is the red-fleshed variation, because of its sweet taste.

A faster, more modern lifestyle demands more practical food items, which increases the demand for minimally processed food. The production for fresh-cut red pitaya fruits is not yet developed and still has much potential. In addition, to ease the consumers in consuming the food, minimum processing on red pitaya fruits makes it more economical.

Minimally-processed food goes through multiple stages to maintain its fresh qualities, such as peeling and slicing. The process of peeling and slicing increases the metabolism activities such as respiration and the delocalization of enzymes and substrate. This can cause damage to the fruit such as browning, softening, decomposing, and microbial growth, which in turn shortens the shelf life of foods[1, 4].
In most cases, the market for fresh-cut dragon fruit is very niche, appealing mostly for ethnic markets. However, if the shelf-life, quality, and safety of the fresh-cut fruits can be maintained, the market for consumable dragon fruit can be expanded. A report by Goldman et al. [5] suggests that the quality of processed dragon fruit can be maintained using micro-perforated packaging, extending its shelf life in 10-day storage at 6°C. However, the cutting process did not deterioration, as the slices were stuck together in storage, becoming difficult to separate. Therefore, using appropriate coatings on the slices can further improve the slices’ quality and prolong its shelf-life.

The main applications of edible coatings include reducing moisture loss, preventing damage to the products, enhancing their appearance, and incorporating food-enhancing substances such as anti-browning agents, flavoring, colorants, nutrients, spices, and antimicrobial agents[6]. Antimicrobial agents can be incorporated into edible coatings to prevent microbial spoilage, extend the shelf-life of food products, and enhance their overall safety[7-9]. Therefore, the food industry is greatly interested in the use of edible coatings in their food products, especially for fresh and minimally-processed food.

Alginate, a biopolymer created from brown algae, is a potential component in creating edible coatings, producing gels, and stabilizing emulsions. It has water-solvent properties, in addition to being biocompatible and biodegradable. Alginate has a barrier function to oxygen, which will inhibit the oxidation of Lipid in food, as well as restore flavor and texture [10-12]. However, alginate does not possess any antimicrobial properties, which necessitates the addition of antimicrobial agents to inhibit the growth of microbes in the fruit. Recently, several fruit extracts have been proven to have antimicrobial properties, in the form of essential oils.

The usage of various bio-active compounds such as anti-microbial agents, antioxidants, aromatic compounds, nutraceuticals, and probiotics in edible coatings is an innovation [13]. Essential oils such as Citrus, Cinnamon, Menthol, and Vanillin are anti-microbial agents with the potential to be further developed as a food preservative. Vanillin (4-hydroxy-3-methoxy benzaldehyde), because of its functional properties, see wide use in the food, beverage, and pharmaceutical industries [14-16].

The vanilla plant contains the vanillin extract, which is used as an antimicrobial and antioxidant in food preservation. Vanilla has potential as an antioxidant because it is structured as a substituted phenol. In addition, vanillin extract is a derivative of eugenol, which can be made into an antimicrobial agent[17-19]. Research of alginate-based edible coating with an addition of vanillin essential oil as an antimicrobial agent should be done to maintain the quality of fresh-cut red pitaya fruit. The main problem in this research is the effectivity of essential oil as an antimicrobial agent for red pitaya fruits, as well as the effects of alginate with added essential oil. It is theorized that the edible coating treatment with essential oil can inhibit the development of rotting microbes and maintain the quality for fresh-cut red pitaya fruits.

The purpose of this research is to determine the best vanilla essential oil concentration as an antimicrobial agent combines with an alginate-based coating to maintain the quality and prolong the shelf-life of fresh-cut red pitaya fruits.

2. Materials and Methods

This research was performed in the Postharvest Laboratory of the Faculty of Agriculture of Universitas Muhammadiyah Yogyakarta through March to April 2017. Substances used in this research are red pitaya fruit, 2% alginate, 1.5% glycerol, distilled water, dextrose, potatoes, vanilla essential oils, jelly, alcohol, 2% CaCl2, 1% PP Indicator, 0.05% NaOH, 0.01N Iodine, 0.1N NaOH, 1% starch, and 1% chlorine.

This experimental research is the application of vanilla essential oil in alginate-based edible coating on fresh-cut red pitaya fruits in a Completely Randomized Design with a single factor experimental design, which is the concentration of vanilla essential oil made of 4 limitations arranged in 4 treatments: alginate + vanilla essential oil of 0%, 0.1%, 0.3%, and 0.6% concentrations. Each of the 4 treatments is repeated three times to produce 12 test units. Each unit consists of 8 packages of fresh-cut red pitaya,
with each package having 8 slices of fresh-cut red pitaya fruits. The total number of packages adds up to 96 packages.

The observation was done once every 3 days on day 0, 3, 6, 9, 12, and 15. Observed parameters include the physical aspects (weight loss and density), chemical aspects (Vitamin C content, liquefied solids, and titration acid), and organoleptic aspects (taste, color, and flavor) as well as the microbiological content. Data analysis was done by the analysis of variance (ANOVA) method with the SAS software. If there is a visible difference between treatments a second test was performed using Duncan’s Multiple Range Test (DMRT). The results of periodical observation were analyzed using a histogram. Data is then shown in the forms of tables and pictures.

3. Results and Discussion

3.1. Weight Loss

During its shelf-life, the water content of fruit continues to decrease which causes the loss of weight in fruits. According to the tests, there is a visible difference ($p < 0.05$) caused by the application of vanilla essential oil in alginate-based edible coating. This difference was seen on the third day of observation which showed the lowest weight loss percentage of 0.23%. On day 6 through 15, the application of vanilla essential oil did not show a significant difference in weight loss parameters. The results of weight loss observation on every treatment can be seen in table 1.

| Treatment        | Weight loss (%) Days- |
|------------------|-----------------------|
|                  | 3  | 6  | 9  | 12 | 15  |
| Control          | 0.47 a | 0.79 ab | 1.07 a | 1.23 a | 1.48 a |
| EOs vanilla (0.1%) | 0.52 a | 0.87 a | 1.16 a | 1.33 a | 1.56 a |
| EOs vanilla (0.3%) | 0.37 ab | 0.71 ab | 1.00 a | 1.18 a | 1.40 a |
| EOs vanilla (0.6%) | 0.23 b | 0.50 b | 0.88 a | 1.14 a | 1.45 a |

Numbers followed by the same letters in the same column shows no significant difference based on 5% DMRT test.

The weight loss minimum processing pitaya fruits is caused by the water loss from transpiration. Alginate contains hydrophilic properties caused by its low vapor resistance. It is assumed that alginate-based edible coating combined with vanilla essential oil has a better vapor resistance compared to treatment without vanilla essential oil on the third day. Fennema [20] argues that polymers with a high hydrophilic property will produce a vapor-vulnerable film, while polymers with a high hydrophobic property will produce a more resistant film. The vanilla essential oil can increase the hydrophobic properties of alginate edible coating. The more essential oil is added, the more resistant the film will be. This is in line with a study conducted by Miksusanti [21] which states that essential oil made from Chinese Keys (Boesenborgia rotunda) managed to increase the hydrophobic properties of the starch-based edible film, which increased with how much essential oil was added. Increasing the concentration of essential oils causes the decrease of vapor transfer related to fat polarity. Essential oils have good resistance to vapor caused by its non-polar cluster which obstructs the transmission of vapor [20]. Figure 1 shows the histogram of the weight loss percentage during storage.
Figure 1. Weight loss (%) of fresh-cut red pitaya during storage.

From day 6 to 15, vanilla essential oil treatment did not show a significant difference to the fruit’s weight loss parameters. This is due to a decline in the essential oil’s hydrophobic properties because of it’s easily-vaporized nature.

3.2. Firmness

According to the investigatory tables, the application of vanilla essential oil on alginate-based edible coating showed a significant difference (p < 0.05) to the firmness parameter on day 9 and 12 of observation. Table 2 shows that the treatment of edible coating with 0.6% vanilla essential oil performed the best in preserving the firmness of minimum processing red pitaya fruit on day 9 and 12.

Table 2. The firmness of fresh-cut pitaya fruits given various concentrations of vanilla essential oil.

| Treatment               | Firmness (N/mm²) Days |
|-------------------------|-----------------------|
|                         | 0   | 3    | 6    | 9    | 12   | 15   |
| Control                 | 0.06 a | 0.070 a | 0.080 a | 0.063 b | 0.070 b | 0.073 ab |
| EOs vanilla (0.1%)      | 0.06 a | 0.070 a | 0.080 a | 0.073 a | 0.067 b | 0.067 b |
| EOs vanilla (0.3%)      | 0.06 a | 0.077 a | 0.077 a | 0.067 a | 0.080 a | 0.073 ab |
| EOs vanilla (0.6%)      | 0.06 a | 0.067 a | 0.080 a | 0.080 a | 0.080 a | 0.080 a |

Numbers followed by the same letter in the same column shows no significant differences based on 5% DMRT test.

From day 0 to 6, the hardness level of fruit was stable. The hardness of minimum-processed red pitaya fruit can stagnate on storage because of obstruction on respiration and metabolism, which reduces the processing of carbohydrate into liquefied essence in the air, which makes the fruits stay hard. The alginate-based edible coating is effective in controlling water content loss and is also a good calcium chloride carrier as a hardening agent on fruit flesh [22]. Calcium Ion interacts with pectin polymers (alginate) to create a cross-tissue which increases mechanical strength, delaying aging and controlling physiological damage on fruits and vegetables [9].

On day 9 to 15, the level of hardness on minimum-processed red pitaya fruit has declined. This is caused by the damage in cell walls which has an impact on pectin degradation. During the storage, pectin essences undergo depolymerization and de-esterification which softens the previously insoluble pectin soluble and softens the fruit texture [23]. Prasana et al. [24] added that the softening of fruit during storage is caused by the activity of poly-galacturonate enzymes which turns protopectine with poly-
galacturonate acids into galacturonate acids. Fruit will become soft if the polygalacturonate activity is high. Picture 2 shows the histogram of minimum processing red pitaya fruit during storage.

![Figure 2](image_url)

**Figure 2.** Firmness level of fresh-cut red pitaya fruit during storage.

### 3.3. Titrable acidity.

According to the experiment’s results, the application of vanilla essential oil on alginate-based edible coating show a visible difference (p<0.05) on the total acid content on day 9 and 12, with non-significant differences showing in observations on day 3, 6, and 15. Table 3 shows the best results were shown by the treatment with 0.6 vanilla essential oil treatment (P4) on day 9, while the control group (P1) shows the highest level of titrated acids. The average results of acid content are shown in table 3.

| Treatment                  | Total titrable acidity (%) | Days 0 | Days 3 | Days 6 | Days 9 | Days 12 | Days 15 |
|----------------------------|----------------------------|--------|--------|--------|--------|---------|---------|
| Control                    |                            | 2.05 a | 1.25 a | 3.57 a | 0.63 a | 0.80 b  | 1.07 a  |
| EOs vanilla (0.1%)         |                            | 2.05 a | 1.43 a | 3.66 a | 0.54 ab| 1.07 a  | 0.98 a  |
| EOs vanilla (0.3%)         |                            | 2.05 a | 0.98 a | 4.02 a | 0.36 bc| 0.80 b  | 0.89 a  |
| EOs vanilla (0.6%)         |                            | 2.05 a | 1.07 a | 4.02 a | 0.27 c | 0.80 b  | 0.89 a  |

Numbers followed by the same letters in the same column showed insignificant differences based on 5% DMRT tests.

Total titrable acidity during storage experience fluctuations. The total acid content on day 0 to 3 tends to decline. The decline of acid percentage on fresh-cut red pitaya fruit on day 3 was caused by the respiration process, which used the organic acids. While on day 6, the total acid content experienced a high increase. This increase is due to the high production of organic acid on the respiration process during the Krebs cycle. In addition, this increase in total acid content is suspected to be caused by microbial and fungal activities to adapt before entering the exponential log phase by producing acids as its metabolic function. This is in line with the microbial data which shows an increase on day 6 of the storage. After adapting, microbes and fungi will enter an exponential log phase which causes a high increase in fungi population. This Aspergillus activity increases the acid content on minimum-processed red pitaya fruit on day 6. The histogram of total titrated acid levels can be seen in picture 3.
Figure 3. Total titrable acidity of fresh-cut red pitaya fruit during storage.

On day 9, total titrable acidity content experienced a decrease. This decrease is because of vanilla essential oil inhibiting the activity of microbes. On day 9, the essential oil functions to inhibit acid level-increasing microbial growth. The treatment of 0.6% vanilla essential oil shows the best result, which lowers the acid contents to 0.27%. On day 12 and 15, vanilla essential oil did not show a significant effect on titrated acid levels. This is because the fruit has passed its senescence phase shown by the increase of total acid levels.

3.4. Total Soluble Solids.

Based on the results of the experiment, alginate-based edible coating with vanilla essential oil has a significant difference (p<0.05) to the total number of soluble solids on storage day 3, 9, 12, and 15. On day 3, the treatment of edible coating with 0.3% essential oil shows the best result in inhibiting respiration compared to other treatment with 14.93% Brix soluble solids. The following table shows the total number of soluble solids.

| Treatment          | Total titrable acidity (%) | Days |
|--------------------|----------------------------|------|
| Control            | 16.10 a                    | 14.06 c       | 10.67 a | 12.57 a | 13.43 a | 13.97 a |
| EOs vanilla (0.1%) | 16.10 a                    | 14.57 b       | 9.87 a  | 11.60 b | 13.33 a | 13.93 a |
| EOs vanilla (0.3%) | 16.10 a                    | 14.93 a       | 11.03 a | 11.03 c | 12.30 c | 12.80 b |
| EOs vanilla (0.6%) | 16.10 a                    | 14.23 c       | 11.77 a | 11.77 b | 12.83 b | 12.90 b |

The average number followed by the same letter in one column shows no visible differences based on 5% DMRT tests.

The change in total soluble solids of fresh-cut red pitaya fruits from each treatment shows a decrease shown in the histogram (figure 4). This is caused by the sugars formed from the starch, which was used as a respiration substrate to create energy. The increase in respiration is caused by the stress in the fruits due to the minimum processing.

On day 9 to 15, the total number of soluble solids increased. This accumulation of sugars is an indication that the fruit experienced an increase in senescence pace. This senescence is caused by the damage caused by microbial activity. On this pace, the fruit undergoes changes inside the cell, one of which is the damaging of mitochondria, where respiration takes place. According to Perotti [25], the damage in mitochondria causes the decrease of respiration and photosynthesis. If the respiration flow
decreases, there will be an accumulation of simple sugars on fruit. The increase of sugar on storage day 9 to 15 is also caused by the availability of starch, which could be turned into sugar. It is assumed that microbes turned the complex essences like carbohydrate into simple sugars in the senescence phase. This supports the increase of total soluble solids on treatments without vanilla essential oil on day 9 to 15. The following is the histogram of total soluble solids during storage.

![Histogram of total soluble solids during storage.](image)

**Figure 4.** Total soluble solids on fresh-cut red pitaya fruits during storage.

3.5. **Vitamin C content.**

According to the experiment, the vanilla essential oil has no significant effect (p>0.05) on vitamin C content of fresh-cut red pitaya fruit from the beginning of storage until the end of the storage at day 15. This shows that vanilla essential oils have no effect on the change of vitamin C content on minimum-processed red pitaya fruits. The Histogram of vitamin C content can be seen in figure 5.

![Histogram of vitamin C content during storage.](image)

**Figure 5.** Vitamin C content of fresh-cut red pitaya fruits during storage.

The Vitamin C content of minimum-processed red pitaya fruit tends to be stable with an increase on day 15 of storage. The alginate edible coating layer is suspected to withhold oxidation of ascorbic acid and respiration during storage, which maintains the number of ascorbic acids.

On day 15 of storage, vitamin C content on all treatment underwent a significant increase. This is suspected to come from the synthesis of ascorbic acid from the accumulation of sugars at the end of the storage. According to Helmiyesi [26], the increase in vitamin C content is possibly from the biosynthesis
process of Vitamin C from UDP Glucoronate into ascorbic acid. This synthesis is spurred by the increase of ascorbic acid’s oxidation pace because ascorbic acid is often used to trap oxidants such as H2O2. Because of the high ace of oxidation, Glutathione was reduced into ascorbic acid. This high pace of oxidation is suspected to be the results of damage caused by senescence on minimum processed red pitaya fruit. According to Setiawan [27], the oxidation of ascorbic acid is related to its role as antioxidants on fruit and vegetables. Ascorbic acid binds reactive oxygen (ROS) of H2O2 which is the byproduct of photosynthesis. ROS is also one of the free radicals. The behavior of free radical can trigger the creation of other free radicals which creates a chain reaction. Because of that property, free radicals is often linked to cell damage, tissue damage, and aging process.

3.6. Microbiology Test.
After an observation through a microscope with 40x10 magnification, it is suspected that the dominant fungi in the decomposition of fresh-cut red pitaya fruit in one of the fungi under Aspergillus sp. Genus. This is seen from the yellowish-green hypha with white mycelia at the beginning of the growth. The images of decomposition-causing fungi can be seen at the images below.

![Figure 6. Microscopic view of fungal conidia (left) and spore (right) found on fresh-cut pitaya.](image)

Characteristics of Aspergillus is the fibred colony, flat-convex surface, and the green-gray, yellowish-green, and white colony. The color of the colony is influenced by the color of conidia, with conidia resulting in a green colony, with the white colony not visible in the petri dish [28].

![Figure 7. Fungal growth on fresh-cut red pitaya fruit during storage from day 9 to 10 (4 CFU/ml).](image)
The histogram on figure 7 shows an increase in microbes/fungi population on fresh-cut red pitaya fruit during storage. The longer the storage, the higher the increase of fungi population in fresh-cut red pitaya fruit. Microbes cause wounds which will impact the respiration pace of fresh-cut pitaya fruit during storage.

The addition of vanilla essential oil as antimicrobial agent shows a positive influence in inhibiting fungal growth on fresh-cut pitaya fruit. Treatment with alginate edible coating and 0.6% vanilla essential oil shows the lowest fungi growth compared to other treatments at the end of the storage. This is shown by the lowest microbe/fungi population on 123.5x10^4 CFU/ml followed by 0.3% essential oil which shows 200x10^4 CFU/ml on storage day 9, where microbes are at the exponential log phase. The inhibition of microbial growth is caused by the eugenol essences functioning as antimicrobial agents in vanilla essential oil. This is in line with Rialita [29] which stated that antibacterial essences in an essential oil such as thymol, eugenol, and carvacrol can cause damage in cellular membranes, releasing intercellular ATP and other microbial components. The higher concentration of vanilla essential oil, the stronger its inhibitory properties on fungi.

3.7. Color.
Figure 8 shows an increase of color interest/appearance of fresh-cut red pitaya fruit on storage day. The interest level of minimum-processed red pitaya fruit with edible coating on all four treatments underwent a decline. The longer the fruit is stored, the worse the consumer’s color interest will be. Until storage day 15, treatment of edible coating with 0.6% vanilla essential oil (P4) could maintain the best color score compared to other treatments on 2.2 Panelists could still tolerate the color of minimum-processed red pitaya fruit until day 9 on treatment with alginate edible coating and 0.3 vanilla essential oil. According to panelists, the bright red fruit is more desirable than the dark purple fruit.

3.8. Taste.
The histogram on figure 9 shows the panelists’ favorite taste level fluctuated during storage. From the taste organoleptic scoring on day 15, the best score given to panelists is 3 on day 15 for the treatment with edible coating and 0.6% vanilla edible coating (P4). This is linked to the change in total soluble solids which affects the panelist’s scores on the sweetness of the fruit. The lower organic acid levels and high sugar levels cause a higher taste score. On day 15, a degradation on cannot be seen and the red pitaya fruits are still acceptable since it still contains some sweetness.
3.9. Flavor.
The organoleptic scoring on flavor gave until day 15 is 3.0 3.2 is “favorable” on fresh-cut red pitaya fruit. This is because vanilla essential oil did not influence the panelists’ favorability on flavor. However, it can be said that the panelists favored the aroma of red pitaya fruit with or without the treatment. This is because the flavor of essential oil did not contaminate the flavor of the fruit. In addition, the presence of alginate edible coating can inhibit the vaporization of volatile essences which causes the stench in fruit. The flavor of vanilla essential oil declines the longer the fruit is stored.

From sensory tests towards color, taste, and flavor, the panelists’ most favored treatment is the alginate edible coating with added 0.6% vanilla essential oil.

4. Conclusion
Edible coating with vanilla essential oil as an antimicrobial agent can maintain the quality of fresh-cut red pitaya fruit. The concentration of 0.6% essential oil performed better in preserving the physical qualities (firmness, weight loss) and the taste and aromatic qualities of fruit, as well as inhibiting fungal growth during storage. Meanwhile, the concentration of 0.3% vanilla essential oil performed better in preserving the chemical parameters (acid content, soluble solids total). Treatment of alginate edible coating with vanilla essential oil can prolong the storage life of fresh-cut pitaya fruit up to 9 days.
References

[1] Ahmed J, Lobo M G and Ozadali F 2012 Tropical and subtropical fruits Postharvest physiology, processing and packaging (Hoboken, NJ: John Wiley & Sons).
[2] Nurul S and Asmamah R 2014 Int. Food Res. J. 21 1689-1697.
[3] Ilvira R F, Suryantini A and Darwanto D 2015 Agro Ekonomi 25 185-94.
[4] Siddiqui M W and Rahman M S 2014 Minimally Processed Foods: Technologies for Safety, Quality, and Convenience (Switzerland: Springer) p 297.
[5] Goldman M, Vinokur Y, Horev B, Lurie S, Rodov V and Liguori G 2004 Proc. V Int. Postharvest Symp. 682 1961-6
[6] Guo M, Yadav M P and Jin T Z 2017 Int. J. Food Microbiol. 263 9-16.
[7] Guerreiro A C, Gago C M L, Faleiro M L, Miguel M G C and Antunes M D C 2015 Postharvest Biol. Technol. 100 226-33.
[8] Cagri A, Ustunol Z and Ryser E T 2004 J. Food Protect. 67 833-48.
[9] Rojas-Grü M A, Raybaudi-Massilia R M, Soliva-Fortuny R C, Avena-Bustillos R J, McHugh T H and Martin-Bellos O 2007 Postharvest Biol. Technol. 45 254-64.
[10] Parreidt T, Müller K and Schmid M 2018 Foods 7 170.
[11] Pereira R, Tojeira A, Vaz D C, Mendes A and Bártolo P J 2011 Int. J. Polym. Anal. Charact. 16 449-64.
[12] Raybaudi-Massilia R M, Mosqueda-Melgar J and Martin-Bellos O 2008 Int. J. Food Microbiol. 121 313-27.
[13] Embuscado M E and Huber K C 2009 Edible films and coatings for food applications (London, UK: Springer).
[14] Lisin G, Safliyev S and Craker L 1997 II WOCMAP Congress Medicinal and Aromatic Plants p 283-8.
[15] Shaabani H A, El-Ghorab A H and Shibamoto T 2012 J. Essen. Oil Res. 24 203-12.
[16] Walton N J, Mayer M J and Narbad A 2003 Phytochemistry 63 505-15.
[17] Cava-Roda R M, Taboada-Rodriguez A, Valverde-Franco M T and Marin-Iniesta F J F 2012 Food Bioproc. Technol. 5 2120-31.
[18] Konuk Takma D and Korel F 2017 Food Chem. 221 187-95.
[19] Ngarmsak M, Delaquis P, Toivonen P, Ngarmsak T, Ooraikut B and Mazza G 2006 J. Food Protect. 69 1724-7.
[20] Fennema O, Donhowe I G and Kester J 1994 Lipid type and location of the relative humidity gradient influence on the barrier properties of lipids to water vapor Water in Foods (Amsterdam, The Netherlands: Elsevier) 225-39.
[21] Miksusanti 2008 Kajian aktivitas antibakteri minyak atsiri temu kunci dan aplikasinya dalam film edibel antibakteri Doctoral Dissertation (Bogor: Institut Pertanian Bogor)
[22] Azarakhsh N, Osman A, Ghazali H, Tan C and Mohd Adzahan N 2012 Int. Food Res. J. 19 2144-51.
[23] Prabasari I 2001 Pemanasan dan pelapisan alginit sebagai upaya mempertahankan kualitas sawo yang diolah minimal (Yogyakarta, Indonesia: Universitas Gadjah Mada)
[24] Prasanna V, Prabha T and Tharanathan R J C 2007 Nutrition 47 1-19.
[25] Perotti V E, Moreno A S and Podestá F E 2014 Mitochondrion 17 1-6.
[26] Helmiyies H, Hastuti R B and Prihastani E 2008 Buletin Anotomi dan Fisiologi 16 33-7.
[27] Setiawan C K 2013 Efek Warna Light Emitting Diode terhadap Ekspresi Gen yang terlibat dalam Metabolisme dan Biosintesis Asam Askorbat pada Bunga Brokoli Master Thesis (Yogyakarta, Indonesia: Universitas Gadjah Mada)
[28] Pitt J I and Hocking A D 1997 Fungi and food spoilage (Heidelberg, Germany: Springer)
[29] Rialita T, Rahayu W P, Nuraida L and Nurtama B J A 2015 Agritech 35 43-52.