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The Utilization of Red Cabbage Extract (*Brassica oleracea*) in the Production of Avocado (*Persea americana Mill*) Freshness Indicator as Smart Packaging Element

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Abstract: This research aimed to study and produce smart packaging indicator by utilizing red cabbage extract which could be applied to avocados. The research was conducted in a laboratory with the following stages; making red cabbage extract, preparing color indicator and applying it to smart packaging. The results showed that the soaking time and pH of the red cabbage extract solution as an indicator solution which was suitable for making freshness indicator of avocado were 15 h with the temperature of 28±2°C and pH 7. The color indicator that had been applied to the packaging had a color change from light purple to red that visible with the naked eye. The color change of the indicator reflected the freshness level of packaged avocado, in which the purple color showed mature, yellowish blue showed the optimal ripe fruit while the red color indicated the fruit rotten during storage. Indicator changes also had a similar tendency towards changes in several parameters such as increasing pH, total acid, vitamin C, hardness and total dissolved solids which are usually used to characterize the freshness of avocados. Organoleptic tests namely color, aroma, texture and taste showed that the panelists preferred the avocado on day 4. In general, this indicator could be used as smart packaging.

Keywords: Shelf Life**,** Fruit, Food Quality

Introduction

Avocado is a type of climacteric fruit. Climacteric fruit is a fruit that has increased respiration and ethylene during the fruit ripening (Cherian *et al*., 2014). Based on the data of the Directorate General of Indonesia Horticulture in 2015, avocado is classified as one of the fresh fruit commodities with a high level of production targets. The target of avocado production in 2015-2019 is around 300,780 - 325,561 tons. However, avocados are very susceptible to damage either due to microbiological disturbances, environmental temperature or mechanical damage. Mechanical damage is caused by transportation with a very long distance. This is due to the tendency of the fruit that does not have a uniform shape and size causes susceptibility to experience friction. Consequently, avocados have a relatively short shelf life.

One way to minimize damage to avocados is by using smart packaging (Hong and Park, 1999; Yam *et al*., 2005; Kuswandi *et al*., 2011; Andi Dirpan *et al*., 2018). Smart packaging is a package equipped with indicators to monitor the quality and safety of food products during storage, transportation and marketing (Kuswandi *et al*., 2012; Siracusa *et al*., 2008; Hidayat *et al*., 2019; Dirpan *et al*., 2019; Julyaningsih *et al*., 2020; Yolanda *et al*., 2020). Several studies about smart packaging in the form of indicator labels have been carried out. Dirpan *et al*. (2018) has been researching smart packaging color indicator to detect the quality of mango (Andi Dirpan *et al*. 2018) Besides that, previous studies have implemented smart packaging in beef, milk (Cavallo *et al*., 2014), shrimp (Kuswandi *et al*., 2012), kimchi (fermented vegetable product) (Hong and Park, 2000; 1999) and guava (Kuswandi *et al*., 2013).

One source of natural dyes can be obtained from the commodity of red cabbage. Red cabbage is a plant that contains a lot of anthocyanins. Anthocyanin is a pigment that can dissolve in water. Chemically anthocyanins can be grouped into flavonoids and phenolics. These substances play a role in the coloration of red cabbage (Harborne *et al*., 2006). So that in this research red cabbage was utilized as a natural indicator that was immobilized into paper Whatman no. 1.

The application of smart packaging with the use of red cabbage extract as an indicator of avocados' freshness has not been applied. Therefore, this study aimed to understand:

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How to make smart packaging elements as an indicator of fruit freshness in avocado (*Persea americana* mill) with the utilization of red cabbage extract (*Brassica oleracea*)? how to apply smart packaging to avocados? and What is the color change profile on the freshness indicator of the avocado (*Persea americana* mill)?.

Research Methods

Time and Place

This research was conducted on April-June 2018 in the Laboratory of Food Microbiology and Biotechnology, Laboratory of Chemistry Analysis and Food Quality Control and Laboratory of Food Processing, Program Study Food Science and Technology, Department of Agricultural Technology, Hasan Uddin University, Makassar.

Equipment and Materials

Equipment used in this experiment were hair dryer (Philips), Erlenmeyer 300 mL, drop pipette, hot plate, penetrometer, pH meter, knife, basin, mortar and pestle, stirrer, analytical balance, funnel, blender, centrifuge, volumetric flask, bulb, volume pipette, hand refractometer, beaker glass, digital microscope (model: Digital microscope 5-500 x) and titration set manual.

Materials used in this experiment were: Avocados and red cabbage (purchased in fresh condition from the supermarket), NaOH solution (Merck), HCl solution (Rofa), styrofoam, Whatman paper No. 1 (Whatman), ethanol, demineralized water, amylum solution, phenolphthalein solution (Merck), iodine solution (Merck), polyethylene plastic, aluminum foil, tissue and label.

Research Procedure

The research conducted consisted of two stages, namely, preliminary and main research.

Preliminary Research

Red Cabbage Extract Making

We cut red cabbage into small pieces and then weighed an amount of 600 grams. After that, the cabbage was mashed with a blender and macerated with 160 mL ethanol-distilled water (ratio 7:3). We adjusted the pH of the sample to 2.0 with HCl (1 mol/L). Then, the material was stored at 10°C in the refrigerator for 24 h. We then centrifuged the cabbage solution at 5000 rpm for 20 min. The centrifugation resulted cabbage extract. We filtered the cabbage extract using Whatman paper No. 1 to obtain clear cabbage extract. We then adjusted the pH of extract to alkaline condition (pH 7, 9 and 11) Modified from Silva-Pereira *et al*. (2015).

Preparation of the Color Indicator Label

We cut the Whatman no 1 paper sheets in size 2×4 cm then we soaked it in 10 mL of red cabbage indicator solution at room temperature (28±2ºC) for 5, 15 and 30 h. The treatment was carried out to obtain the best treatment in producing color changes. If the indicator solution succeeded in reacting with Whatman paper, it would give light purple on Whatman No. 1 which was white. Next, Whatman paper 1 dried with an electric dryer.

Main Research

Smart Packaging Application on Avocado Fruit

We weighed around 500 grams of Avocado by two pieces (each packaging container), then placed it on a styrofoam tray. Then the indicator paper was affixed to the packaging label and placed in the packaging, by attaching the packaging indicator label to the polyethylene plastic as a styrofoam cover (Fig. 1). Samples were stored in room conditions (28±2°C) with normal light exposure. Triple packages of avocado products taken at the right time interval (every 1 day for 7 days) for analysis of pH, total vitamin C, Total Dissolved Solids (TDS), total acid, fruit hardness and color index on packaging indicator paper of avocado.

Research Design

The research design that was carried out for preliminary research was the determination of the pH of the indicator solution and the determining of the best soaking time. The type of pH of the indicator solution and soaking time were:

A1: Red cabbage extract solution pH 7
A2: Red cabbage extract solution pH 9
A3: Red cabbage extract solution pH 11
B1: Soaking for 5 h
B2: Soaking for 15 h
B3: Soaking for 30 h

The best treatment from each of the mentioned steps was then used in the primary research for making smart packaging indicators for avocados. Then, the indicator label was applied to the packaging of avocados with a storage time of 7 days in a room temperature (28±2°C).

Observation Parameters

The observation parameters were carried out by several tests, namely pH measurement method (AOAC, 1995), total acid titration method (Retnowati and Kusnadi 2013) total dissolved solids (hand refractometer) (Hurriyah and Pratoko, 2017), Vitamin C (Helmiyesi *et al*., 2008), organoleptic in the form of texture, taste, color and aroma (Setyaningsih *et al*., 2010) and quantification of indicator color measurement (Francis 1994; Gunasekaran 1996; Yam and Papadakis, 2004).

Fig. 1: Smart packaging application on Avocado fruit

Statistical Analysis

One-way Analysis of Variance (ANOVA) applied to analyze the pH, total acid, Total Dissolved Solid (TDS), vitamin C and hardness, while the significant differences among means were determined using Tukey's test with a level of significance of $p<0.05$. SPSS software for Windows version 16.0 (SPSS Inc., IL, USA) and Microsoft Excel 2010 was used to analyze the data

Results and Discussion

Based on the results of preliminary research conducted, it was known that the soaking time and pH of the red cabbage extract solution as an indicator solution suitable for making indicators of avocado freshness were 15 h with the temperature of 28±2°C and pH 7. It can be seen through the significant color change of the indicator label that was applied to the avocado. The use of red cabbage extract as a natural solution immobilized to What man paper number 1 which produced an indicator label that was applied to avocados could change in color due to the release of volatile acids such as acetic acid in avocados during storage which is directly bound to the indicator. The color purple indicated that the fruit is highly fresh, then experiencing a change in color to yellowish blue showed fresh fruit and turning to red indicated that the fruit is experiencing the beginning of decay.

pH

Based on the pH measurement of packaged avocados using pH meters' in Fig. 2, it showed that there was an increase in pH every day during storage. The results of the analysis of variance showed that the pH value on day 0 was significantly different from day 4, 5, 6 and day 7 and not significantly different from day 1, 2 and day 3. The measurement results of the pH value of avocados on day 0 was around 6.8 while the day 7 showed a pH value of 7.3. The increase in pH is thought to have occurred due to the climacteric properties of avocado, in which the ripening process continues during storage, resulting in a drop in fruit acidity and an increase in pH. This is in accordance with (Muchtadi *et al.,* 2010) which state that young fruit contains a lot of organic acids that will decrease during the fruit ripening process and is supported by a statement (Kuswandi *et al*., 2012) that pH changes can significantly be known because of the formation of acetic acid during the ripening process.

Total Acid

Here we commence our discussion of the total acid in Fig. 3. The results of variance analysis showed that total acid on day 0 was significantly different from total acid on day 6 and 7 and was not significantly different from day 1, 2, 3, 4 and 5. The total acid value on day 0 is around 7.7×10-3% and has decreased to 3.4×10-3% on day 7. The reduction in the total acidity of avocado packaged during storage is caused by the use of organic acids in avocados during the respiration process which requires energy during storage, the energy needed is obtained by overhauling nutrients contained in food. Also supported by (Tranggono and Sutardi, 1989) stated that the total content of acid would decrease during the maturation period and together with the decrease in total acid, a reduction in starch content occurs.

Total Dissolved Solids (TDS)

Figure 4 provides a quantitative analysis of the TDS. Based on analysis of variance, avocados stored for seven days showed that the TDS on day 0 was significantly different from the TDS on other days from day 1 to day 7. While the TDS on the first day was significantly different from day 0, 5, 6 and 7 and not significantly different from day 2, 3 and 4. The test results for total dissolved solids on day 0 showed a value that was equal to 1.23°Brix and experienced an increase on day 7 which was 7.60 °Brix. Based on these results it was known that during the storage, total dissolved solids on avocados increased. The step up in total dissolved solids is caused by the breakdown of carbohydrate polymers, especially starch in avocados, into sugar resulted in an increase in sugar content in general. This result is consistent with (Buckle and Edward, 2013) statement that the higher the concentration of sucrose contained in a ripe fruit will produce a high total dissolved solid.

Vitamin C

The results of vitamin c are summarised in Fig. 5. The results of variance analysis showed that the vitamin C content on day 0 was significantly different from the day 3, 4, 5, 6 and 7 and was not significantly different from the day 1 and 2.

The results of vitamin C measurement on the day 0 showed a value that was equal to 2.4×10^{-3}% and continuously increased until day 7 which reached 12.7×10^{-3}%. The increase of vitamin C content is because generally in fruits contain vitamin C, the vitamin C increase is in accordance with the development of fruit. When the fruit is still in a young state the content of vitamin C is very low while when the size of fruit reaches the maximum level, same goes to the vitamin C. This is in accordance with (Pantastico, 1975) which state that the content of vitamin C in fruit is usually in accordance with the development of fruit. Young fruit contain low level of vitamin C while when the fruit size reaches the maximum level, the vitamin C is also maximum.

Hardness

Let's turn to the results of hardness in Fig. 6. The results of analysis of variance showed that the hardness level of avocados on day 0 was significantly different from day 3, 4, 5, 6 and day 7 and not significantly different from the day 1 and 2. The value of the hardness level of avocados showed that on the first day was 56.6 N and decreased gradually up to 7.6 N on day 7. Decrease in the hardness of avocados during storage due to the hydrolysis of cell wall composition during the ripening process. This result was supported by (Nelson *et al*., 2006) that during the ripening process of fruit, the hydrolysis of pectin and hemicellulose which is a component that forms cell walls occurs and causes fruit softening.

Color Change Index

The results of these observations indicated that there was a color level change of the indicator (the intensity of purple that changes) to various levels of freshness during storage. In Fig. 7, the color change response decreased continuously (the change became red), in which on day 0, the intensity of the light purple color is 189 AU. While on day 7, it decreased to 121 AU. Color changes that occur are due to the release of volatile acids such as acetic acid in avocados during storage which is directly bound to the indicator. The purple color indicated mature fruit (in this condition the fruit has physical characteristics if observed in a visual way, in which the surface of the fruit skin looked like there is a layer of wax, fresh dark green, had a solid and filled shape, had a hard texture and a bit bitter taste). Indicator color changes to yellowish blue indicated that the fruit ripens optimally (this condition the fruit experiences a decrease in hardness or softening fruit, green fruit flesh color, green fruit skin color is less fresh and sweet taste). Changing the color of the indicator from yellowish blue to red indicates that the packaged fruit has been decayed (in this condition the texture of the fruit is getting softer, the taste of the fruit is sweet and somewhat bitter, the skin color of the fruit is not fresh and runny). The result obtained was inconsistent with (Kuswandi *et al*., 2012) that all color indicators placed in the packaging are used to detect changes in pH as a result of the biosynthesis of volatile acids which come out gradually in the packaging during the ripening process.

Organoleptic Color

The panelists' assessment of the color of avocados in Fig. 8 showed that the color of the fruit preferred by the panelists was fruit at the day 4 of storage with an average value of 3.70. The color Avocado had on day 4 were green color and flesh with yellowish green color. This change is due to the drastic degradation of the chlorophyll pigment during the cooking stage which coincides with the rate of reduction of reducing sugars. The result was in accordance with (Winarno, 2008) who stated that color changing in food can be caused by several sources and one of the most important sources is pigments contained in vegetable and animal ingredients.

Aroma

The panelists' assessment of the aroma of avocados in Fig. 9 showed that the fruit aroma preferred by panelists was on day 4 of storage with an average value of 3.74. The aroma produced on day 4 is a distinctive aroma of avocado. This aroma occurred because the fruit has undergone optimal maturation and the release of ethylene or esters during ripening takes place. This result was supported by the opinion of (Pantastico, 1975), who states that a typical odor arises around a ripe fruit which is usually produced when entering the climatic form of aliphatic alcohol esters and short chain fatty acids.

Texture

The panelists' assessment of the texture of avocados in Fig. 10 showed that the fruit texture preferred by panelists was at day 4 of storage with an average value of 3.84. The texture avocado had on day 4 was the overall texture of the base of the fruit which was still rather hard, but the flesh of the fruit has a soft and not too hard texture. The texture indicated that on the day 4 of storage, avocado experienced the optimal ripening. The occurrence of softening of avocados during storage is caused by hydrolysis of the fruit cell wall component during the ripening process so that the cell component became soft. Texture softening involved enzymes. The enzyme is an enzyme called polygalacturonase that generally found in avocados. This explanation was supported by (Barbut, 2014), stating that the fruit ripening process occurs hydrolysis of the components forming the cell wall which causes the fruit to become soft during the ripening process.

Taste

The panelists' assessment of avocado flavor in Fig. 11 showed that the fruit flavor favored by panelists was at day 4 of storage with an average value of 3.84. The taste produced on day 4 is sweet and slightly bitter. This taste indicated that avocados had undergone optimal maturation. This change in taste occurs because of the hydrolysis of starch into simpler sugars, as a result of the breakdown of starch which causes an increase in fruit reducing sugar levels which can cause sweetness and is accompanied by a decrease in levels of organic acids and phenolic substances which is usually related to a sour taste. This explanation was in accordance with the statement of Winarno (2008) that when the fruit is ripe the sugar content increases and the organic acid content decreases, as a result the sugar and acid ratio will change so that the fruit tastes better. This also supported by Tranggono and Sutardi (1989), who states that the total acid content will decrease during the ripening period and together with the decrease in total (1) acid, the starch content decreases, while the sugar content as a determinant of fruit sweetness increases.

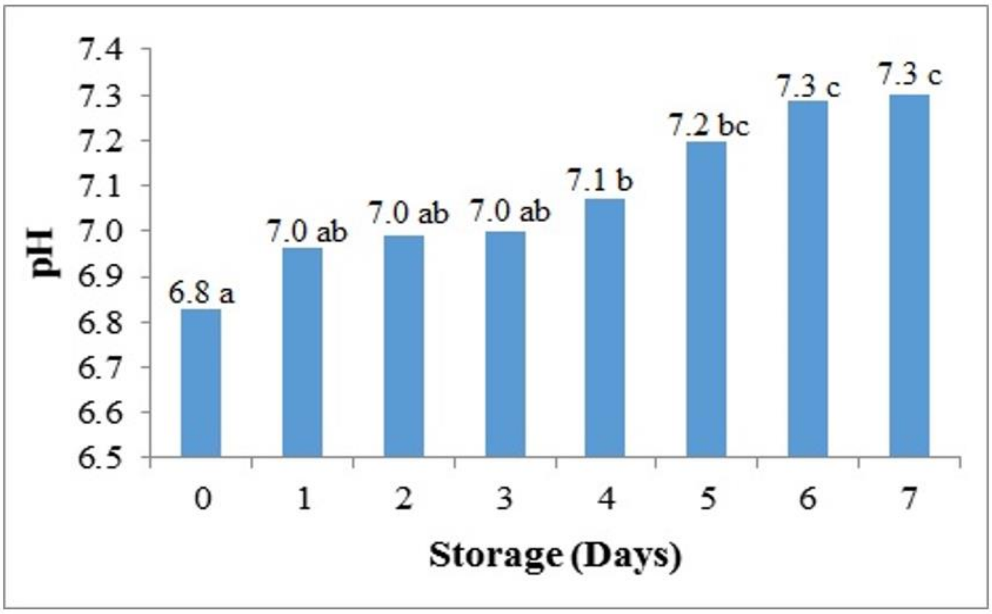

Fig. 2: The results of pH measurement on avocados during storage. Mean values (N = 3) within the bars with different letters indicate significant difference (p<0.05) of pH of avocado fruit during storage

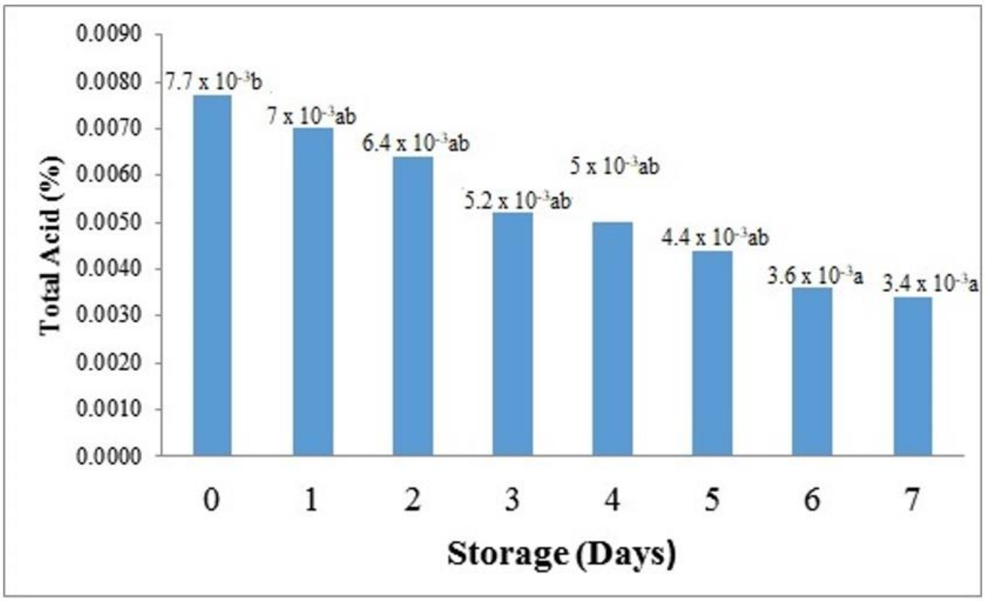

Fig. 3: Total acid measurement results on avocado fruit during storage. Mean values (N = 3) within the bars with different letters indicate significant difference (p<0.05) of total acid content of avocado fruit during storage

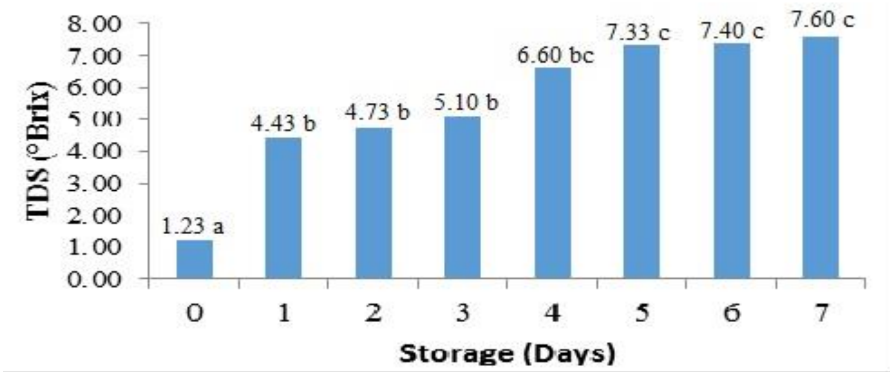

Fig. 4: Total dissolved solids of avocado fruit during storage. Mean values (N = 3) within the bars with different letters indicate significant difference ($p<0.05$) of TDS of avocado fruit during storage

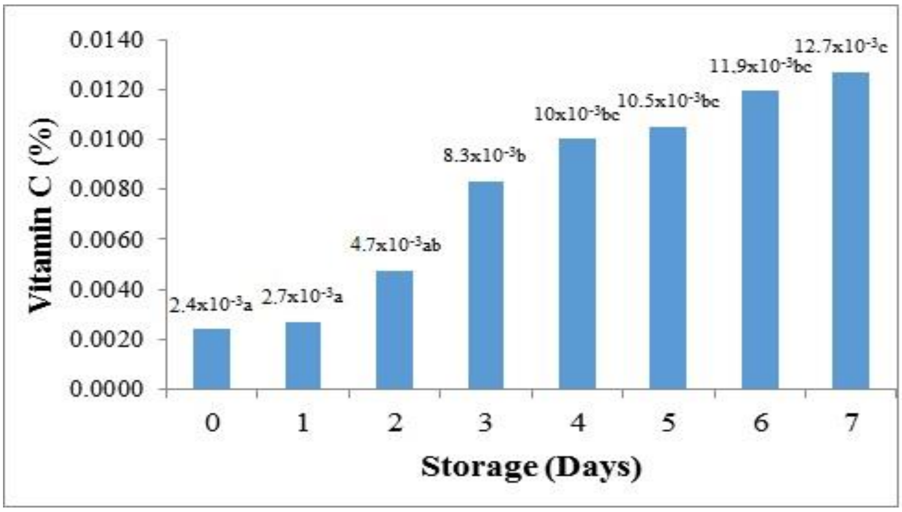

Fig. 5: Vitamin C measurement results of on avocado fruit during storage. Mean values (N = 3) within the bars with different letters indicate significant difference ($p<0.05$) of vitamin C content of avocado fruit during storage

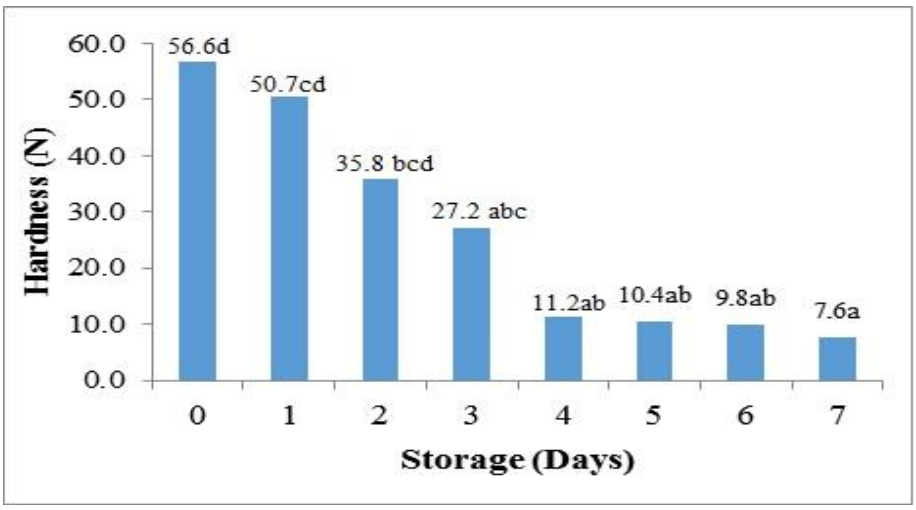

Fig. 6: Measurement results of hardness level on avocado fruit during storage. Mean values (N = 3) within the bars with different letters indicate significant difference ($p<0.05$) of hardness of avocado fruit during storage

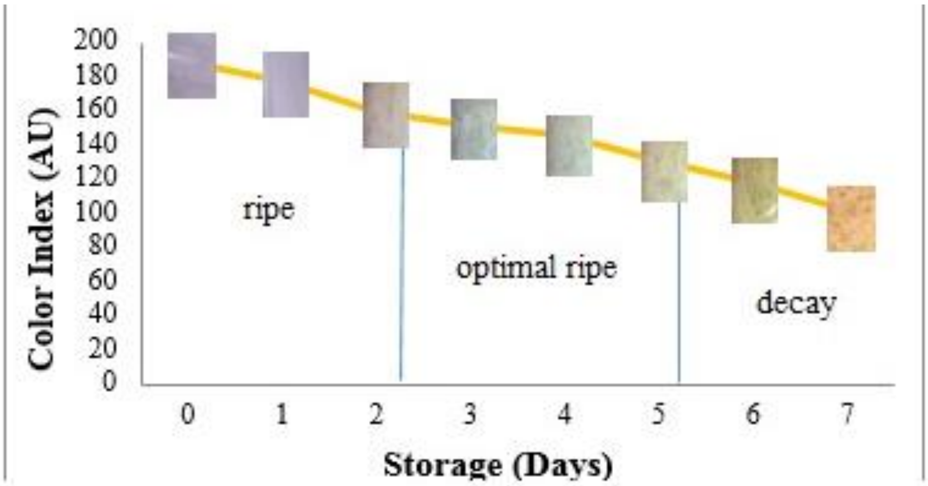

Fig. 7: Color change profile on the indicator of avocado freshness

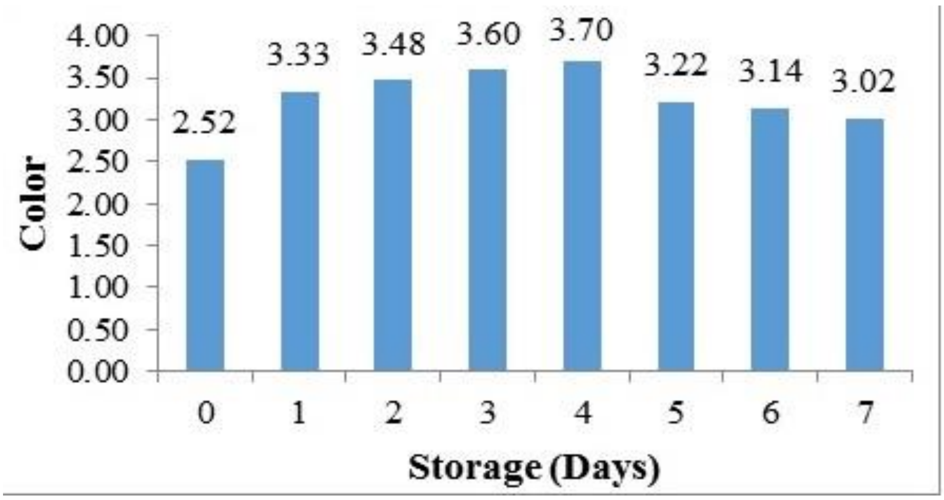

Fig. 8: Organoleptic test for color in avocado fruit during storage

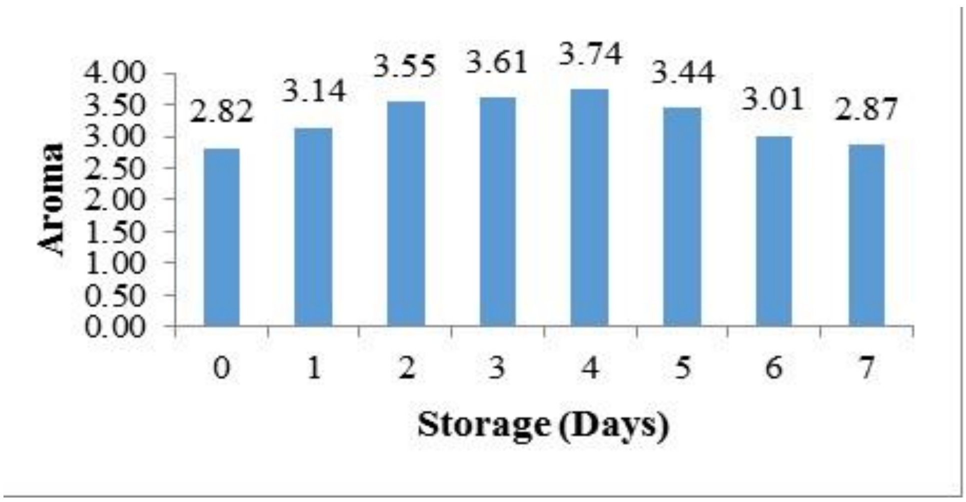

Fig. 9: Organoleptic test of aroma on avocado fruit during storage

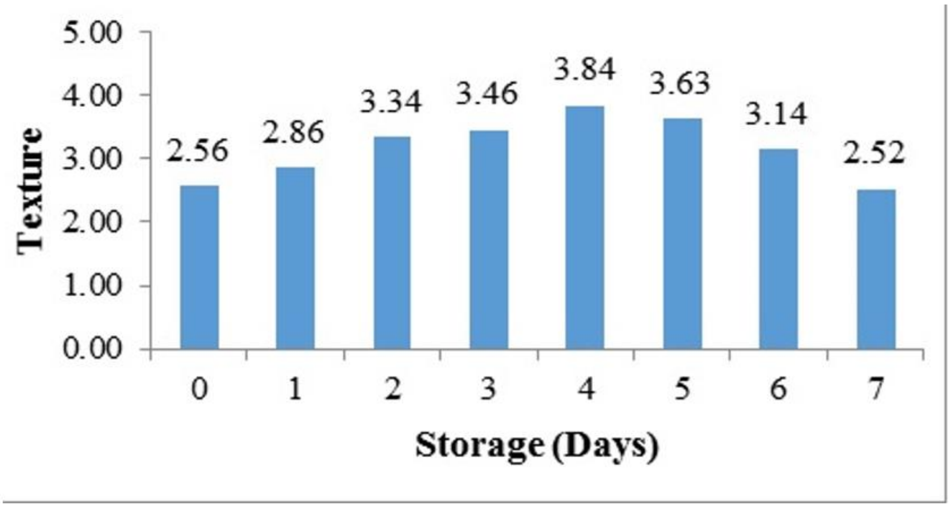

Fig. 10: Organoleptic texture test on avocado fruit during storage

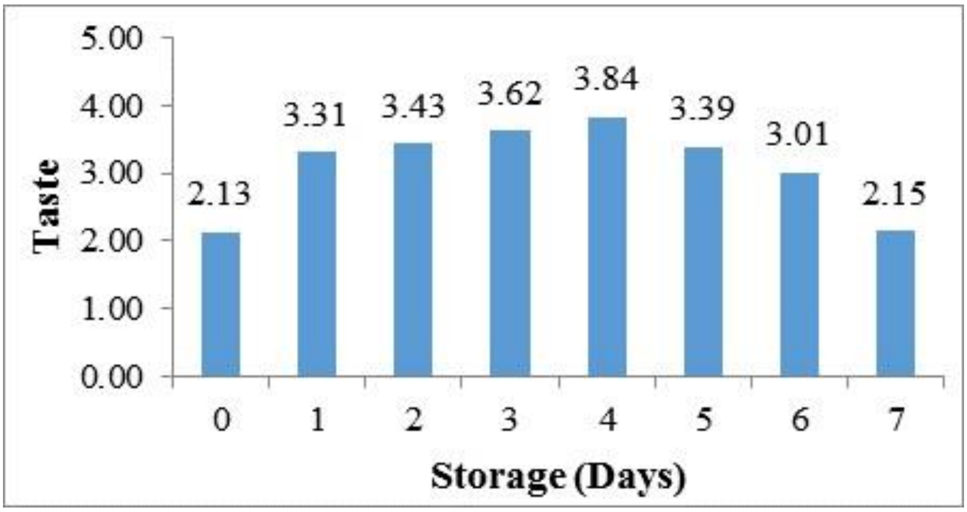

Fig. 11: Organoleptic test on taste of avocado fruit during storage

Conclusion

The conclusions of this research were:

1. 1.The freshness indicator of avocados can be made by using red cabbage as a natural solution and using 2. What man filter paper number 1 as an absorbent material for red cabbage extract with the paper size of ±2 × 4 cm.
2. Application of smart packaging on avocados could be done by placing indicators in the packaging with a distance of ±2 cm from the avocado.

Authors and Contribution

Andi Dirpan: Conceptualization, Methodology, Validation.

Muspirah Djalal: Writing - Original Draft, Validation.

Riskawanti Rahman: Data Curation.

Jalil Genisa: Supervision.

Ethics

References

AOAC. (1995). Official Methods of Analysis of The Association of Analytical Chemists. Washington D.C.

Barbut, S. (2014). Texture. Handbook of Fermented Meat and Poultry, 207-215. doi.org/10.1002/9781118522653.ch24

Buckle. & Edward. (2013). Ilmu Pangan. Terjemahan Purnomo Dan Adiono. Jakarta: Universitas Indonesia Press.

Cavallo, J. A., Strumia, M. C., & Gomez, C. G. (2014). Preparation of a milk spoilage indicator adsorbed to a modified polypropylene film as an attempt to build a smart packaging. Journal of Food Engineering, 136, 48-55. doi.org/10.1016/j.jfoodeng.2014.03.021

Cherian, S., Figueroa, C. R., & Nair, H. (2014). 'Movers and shakers' in the regulation of fruit ripening: a cross-dissection of climacteric versus non-climacteric fruit. Journal of Experimental Botany, 65(17), 4705-4722. doi.org/10.1093/jxb/eru280

Dirpan, A., Kamaruddin, I., Syarifuddin, A., Rahman, A. N. F., Latief, R., & Prahesti, K. I. (2019, November). Characteristics of bacterial cellulose derived from two nitrogen sources: Ammonium sulphate and yeast extract as an indicator of smart packaging on fresh meat. In IOP Conference Series: Earth and Environmental Science (Vol. 355, No. 1, p. 012040). https://iopscience.iop.org/article/10.1088/1755-1315/355/1/012040/meta

Dirpan, A., Latief, R., Syarifuddin, A., Rahman, A. N. F., Putra, R. P., & Hidayat, S. H. (2018, May). The use of colour indicator as a smart packaging system for evaluating mangoes Arummanis (Mangifera indica L. var. Arummanisa) freshness. In IOP Conference Series: Earth and Environmental Science (Vol. 157, No. 1, p. 012031). IOP Publishing. 3 https://iopscience.iop.org/article/10.1088/1755-1315/157/1/012031/meta

Setyaningsih, A., & Sari. (2010). Analisa Sensori Untuk Industri Pangan Dan Agro. Bogor: IPB.Bogor.

Francis, F. J. (2014). Colorimetric properties of foods. In Engineering properties of foods (pp. 725-754). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9781420028805-20/colorimetric-properties-foods-francis

Gunasekaran, S. (1996). Computer vision technology for food quality assurance. Trends in Food Science & Technology, 7(8), 245-256. doi.org/10.1016/0924-2244(96)10028-5

Harborne, A. R., Mumby, P. J., ZŻychaluk, K., Hedley, J. D., & Blackwell, P. G. (2006). Modeling the beta diversity of coral reefs. Ecology, 87(11), 2871-2881. doi.org/10.1890/0012-9658(2006)87[2871:MTBDOC]2.0.CO;2

Helmiyesi, H., Hastuti, R. B., & Prihastanti, E. (2008). Pengaruh lama penyimpanan terhadap kadar gula dan vitamin C pada buah jeruk siam (Citrus nobilis var. microcarpa). Anatomi Fisiologi, 16(2), 33-37. http://eprints.undip.ac.id/6197/

Hidayat, S. H., Dirpan, A., Djalal, M., Rahman, A. N. F., & Ainani, A. F. (2019, October). Sensitivity determination of indicator paper as smart packaging elements in monitoring meat freshness in cold temperature. In IOP Conference Series: Earth and Environmental Science (Vol. 343, No. 1, p. 012076). IOP Publishing. https://iopscience.iop.org/article/10.1088/1755-1315/343/1/012076/meta

Hong, S. I., & Park, W. S. (1999). Development of color indicators for kimchi packaging. Journal of food science, 64(2), 255-257. doi.org/10.1111/j.1365-2621.1999.tb15877.x

Hong, S. I., & Park, W. S. (2000). Use of color indicators as an active packaging system for evaluating kimchi fermentation. Journal of Food Engineering, 46(1), 67-72. doi.org/10.1016/S0308-8146(00)00141-2

Hurriyah, B. K., & Pratoko. (2017). ""Simple Digital Imaging Method for Measuring and Analyzing Color of Food Surfaces." Pustaka Kesehatan 5 (3), 406-12. doi.org/10.19184/pk.v5i3.5890

Julyaningsih, A. H., Latief, R., & Dirpan, A. (2020, April). The making of smart and active packaging on tuna fillet. In IOP Conference Series: Earth and Environmental Science (Vol. 486, No. 1, p. 012053). IOP Publishing.

Kuswandi, B., & Nurfawaidi, A. (2017). On-package dual sensors label based on pH indicators for real-time monitoring of beef freshness. Food Control, 82, 91-100. doi.org/10.1016/j.foodcont.2017.06.028

Kuswandi, B., Larasati, T. S., Abdullah, A., & Heng, L. Y. (2012). Real-time monitoring of shrimp spoilage using on-package sticker sensor based on natural dye of curcumin. Food Analytical Methods, 5(4), 881-889. doi.org/10.1007/s12161-011-9326-x

Kuswandi, B., Maryska, C., Abdullah, A., & Heng, L. Y. (2013). Real time on-package freshness indicator for guavas packaging. Journal of Food Measurement and Characterization, 7(1), 29-39. doi.org/10.1007/s11694-013-9136-5

Kuswandi, B., Wicaksono, Y., Abdullah, A., & Jayus, H. LY, & Ahmad, M. (2011). Smart packaging: sensors for monitoring of food quality and safety. Sensing anda Instrumentation for Food Quality and Safety, 5, 137-146.

Muchtadi, T. R., & Ayustaningwarno, F. (2010). Teknologi proses pengolahan pangan. Alfabeta. Bandung, 246.

Nelson, Scot C, Randy C Ploetz and Angela Kay Kepler. 2006. "Species Profiles for Pacific Island Agroforestry: Musa Species (Banana and Plantain)." Permanent Agriculture Resources (PAR), 2006.

Pantastico, E. B. (1975). Postharvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. https://agris.fao.org/agris-search/search.do?recordID=US201300517356

Retnowati, P. A., & Kusnadi, J. (2013). Pembuatan Minuman Probiotik Sari Buah Kurma (Phoenix Dactylifera) Dengan Isolat Lactobacillus Casei Dan Lactobacillus Plantarum [In Press April 2014]. Jurnal Pangan dan Agroindustri, 2(2), 70-81.

Silva-Pereira, M. C., Teixeira, J. A., Pereira-Júnior, V. A., & Stefani, R. (2015). Chitosan/corn starch blend films with extract from Brassica oleraceae (red cabbage) as a Visual Indicator of Fish Deterioration." LWT - Food Science and Technology 61 (1), 258-62. doi.org/10.1016/j.lwt.2014.11.041

Siracusa, V., Rocculi, P., Romani, S., & Dalla Rosa, M. (2008). Biodegradable polymers for food packaging: a review. Trends in Food Science & Technology, 19(12), 634-643. doi.org/10.1016/j.tifs.2008.07.003

Tranggono, & Sutardi. 1989. Biokimia Dan Teknologi Pasca Panen. Pusat Antar Universitas Pangan Dan Gizi,. Yogyakarta.

Winarno. (2008). *Kimia Pangan Dan Gizi*. Bogor: M-Bio:Press,.

Yam, K., Takhistov, P., & Miltz, J. (2005). "R : Concise Reviews/Hypotheses in Food Science Intelligent Packaging : T Package Devices." Journal of Food Science 70 (1), 1–10. doi.org/10.1111/j.1365-2621.2001.tb16112.x

Yam, K. L., & Papadakis, S. E. A. (2004). "Simple Digital Imaging Method for Measuring and Analyzing Color of Food Surfaces. J. Food Eng. 61,."

Yolanda, D. S., Dirpan, A., Rahman, A. N. F., Kamaruddin, I., & Ainani, A. F. (2020, October). Determination the best concentration of antimicrobial ingredients with a mixture of paper to create active paper packaging. In IOP Conference Series: Earth and Environmental Science (Vol. 575, No. 1, p. 012019). IOP Publishing. https://iopscience.iop.org/article/10.1088/1755-1315/575/1/012019/meta