Intelligent Packaging Film for the Detection of Lactic Acid Concentration During Fermentation in Durian

Suzihaque Maqsood Ul-Haque[1*], Nurfarah Nadhira Mohamad Bisri[1], Mohamad Hafiz Mamat[2], Nurfatin Amirah Mohd Jamil[1], Yang Lu[3]

[1] School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA, 40450, Shah Alam, Selangor

[2] School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450, Shah Alam, Selangor

[3] Tianjin University of Science and Technology, 1038 Dagu Nanlu, Hexi District, Tianjin, Republic of China

suzihaque@uitm.edu.my

Abstract. Intelligent packaging film is a biodegradable and environmentally safe alternative to traditional packaging materials. Made from starch and anthocyanin, it can detect food freshness by analyzing properties like pH and lactic acid concentration. This research focuses on monitoring the freshness of perishable fruits like durian, which are high in moisture and sugar content. The film is dipped into the durian that has been stored in an air-tight container and the analysis was done for 7 days. The film changes color influenced by pH, turning pinkish, indicating the durian's acidity. The lactic acid concentration is determined by comparing pH data and storage days. The lower the pH value, the higher the concentration of lactic acid in durian. The study also incorporates IR 4.0 technology, which uses a color detector mobile application on smartphones to ensure food safety. The technology could potentially improve the effectiveness of this innovative packaging method in monitoring and detecting spoilage in perishable fruits like durian.

Keywords: Intelligent film, Lactic Acid, Tempoyak, Durian.

1 Introduction

Food packaging has been widely used as a tool to control the freshness of the food. It plays a crucial role in ensuring the quality and safety of food, as consumers frequently express concerns about its freshness, which is the primary factor determining its safety [1]. Currently, there is a widespread development of intelligent packaging films that utilise pH-sensitive indicators to monitor food freshness in an efficient way [2].

The use of conventional food packaging made from non-biodegradable plastic can cause harm and be a threat to the environment's sustainability. It is hard to dispose of

N. A. S. Abdullah et al. (eds.), *Proceedings of the International Conference on Innovation & Entrepreneurship in Computing, Engineering & Science Education (InvENT 2024)*, Advances in Computer Science Research 117,
https://doi.org/10.2991/978-94-6463-589-8_11

and eliminate, thus polluting the ocean, as it is the last resort of improper waste management [3]. Therefore, one way to overcome the problem is to use other alternatives to produce the food packaging such as from polysaccharide. Starch is an example of polysaccharide which also known as a biodegradable polymer, is often used because of its availability, cost-effectiveness, and non-toxic [4]. The characteristics of the film that is produced from starch are that it contains no flavour, is transparent, and is resistant to gas flow. Nevertheless, it possesses stronger hydrogen bonds and elevated near-melting points, making it resistant to melting [5]. Commercial starch is typically derived from corn; however, it can also be obtained from potatoes, wheat, and tapioca [3]. In previous studies, variety of starch has been used to make food packaging film, including cassava starch [2], purple sweet potato starch [6] and yam [1]. Adding anthocyanin to the mixture of starch-based film can alter its physical (colour) and chemical properties, thus increasing the beneficial elements of the film.

Red cabbage anthocyanin [7], [8],[9], [10], [11], rose petals anthocyanin [10], [12] and purple cauliflower anthocyanin have been widely studied in the making of food packaging film. The incorporation of anthocyanin in the making of film makes it an intelligent film as it is a pH-sensitive compound and can be in various forms depending on the acidity and alkalinity of food products tested on the film, including fruits and vegetables.

Tempoyak is one of the products from the fermentation of durian. It is produced through spontaneous fermentation that involves the existence of microorganisms [13]. There are few species of lactic acid bacteria in tempoyak, including Pediococcus Acidilactici, Lactobacillus Plantarum, Lactobacillus Curvatus and Leuconostoc Mesentroides [14]. The fermentation process of durian is done to prolong the consumption of durian, which is thus utilised for food preservation, shelf-life extension, nutritional quality, aroma, and texture enhancement [15] [16].

The short shelf life of durian is due to the microbial activity in the durian by lactic acid bacteria (LAB). Sugar in durian is fermented by LAB, producing lactic acid. Lactic acid concentration is a measure of pH levels, microbial activity, safety, taste, and freshness of food products. Lactic acid is unquestionably highly beneficial for human health, yet too much of it can have a negative impact on humans and also on food [17]. In a more understandable phrase, the higher the concentration of lactic acid, the nearer the food reaches its end. Thus, it is important to know the level of lactic acid concentration, as it can affect the whole structure of food.

According to [1], intelligent packaging film has been proven to indicate the freshness of the meat as the film's colour changes to signify the meat has spoiled. It also proved the biodegradability and environmental benefits of using the starch-based film.

As a result, the objective of this study was to develop an intelligent packaging film using starch and red cabbage anthocyanins, which can be a pH and freshness indicator for durian. Thus, the study aimed to evaluate the film's effectiveness under real-world conditions, which included various stages of durian ripening and deterioration, as well as the lactic acid concentration of durian throughout the storage period. Lastly, to integrate the IR 4.0 element into the durian, lactic acid concentration detection process, utilizes a smartphone's colour detector mobile application.

2 Methodology

2.1 Material

The fresh durian was purchased from a roadside stall in Seksyen 7, Shah Alam. The type of durian is *'Tembaga Emas'*. 150 g of red cabbage (purple cabbage) and 70 ml of ethanol were used in the extraction of anthocyanin. Materials for the film included 4 g of potato-soluble starch, 1 g of glycerol, 20 ml of anthocyanin, and 80 ml of distilled water.

2.2 Methods

Preparation of 50g of Durian. 50 g of fresh durian was weighted on a weighing scale and kept in an air-tight container. The container was kept at room temperature for seven days.

Preparation of Red Cabbage Anthocyanin. Red cabbage was washed thoroughly with clean water to remove any dirt and impurities. Then, it was weighed on a weighing machine for 150 g. The weighed red cabbage was cut into smaller pieces and placed in a blender before it was crushed. 70 ml of ethanol was measured and poured into a beaker, and the crushed red cabbage was added. The mixture was stirred and left for 15 to 30 minutes. Lastly, the mixture was filtered using a cloth filter, and the anthocyanin from the red cabbage was obtained [10].

Preparation of Packaging Film. 4 g of potato-soluble starch, 1 g of glycerol, 80 ml of distilled water, and 20 ml of anthocyanin were added to a beaker. The mixture in the beaker was stirred and heated at 300 rpm and 85 °C on a hot plate for 30 minutes until a gelatinized mixture was obtained. The gelatinized mixture is then cooled down to 40 °C before being poured into a disposable petri dish. Finally, it was dried in an oven at 50 °C for 24 hours. After 24 hours, the dried film can be obtained by easily peeled off from the disposable petri dish [6].

Colour-Changing Film Analysis. The film was cut into strips, and each strip was used for the analysis. Half of the strip was dipped in the durian paste, and the changing of colour on that part of the strip was observed. The colour of the strip was then analysed using a Konica Minolta chroma metre CR-400. The equipment displayed the results in L*, which indicates lightness; a* indicates red to green; and b* indicates blue to yellow. This analysis was carried out everyday for 7 days.

pH Analysis. The pH of the durian paste was measured using a pH meter. Prior to measurement, a calibration was done using a buffer pH of 7.0 solution. This analysis was done everyday for 7 days.

Detection of Lactic Acid Concentration in Durian using Mobile Application. The intelligent film, which changes colour when dipped in the durian paste with a different pH, can estimate the lactic acid concentration produced in durian. A mobile application such as the "Color Identifier Colorimeter" was developed to detect the RGB value of colours and can monitor the colour changes of the intelligent film [18]. Initially, the application has to be installed in your smartphone. After launching the application, a picture of the film was captured, and it will display the RGB value. The value will then be compared with the concentration of lactic acid that has been generated in Microsoft Excel.

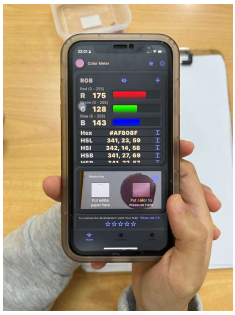


Fig. 1. Film Colour Detection using Mobile Application

3 Results and Discussions

3.1 Effect of Durian's pH on the Film Colour

The mechanism in the intelligent film detects the freshness of durian. The freshness of durian can be detected based on its acidity using pH value as it deteriorates.

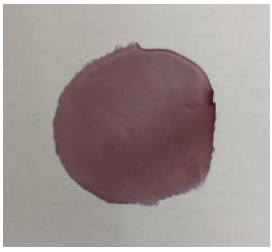


Fig. 2. Intelligent Film Produced Before Being Dipped in Durian

The value of L* a* b* of the original intelligent film before being dipped in the durian was 36.95, 2.25 and -0.19, respectively. After dipping the intelligent film into the durian and conducting the analysis for seven days, the Table 1 below displays the values of L*a*b*.

Table 1. Effect of Durian's pH on the Film Colour

Time (Day)	Film Colour after dipped into durian		L* a* b* value
1			L* = 24.75 a* = 5.49 b* = -2.72
2			L* = 37.26 a* = 2.22 b* = 0.15
3			L* = 22.17 a* = 4.68 b* = 2.17
4			L* = 28.14 a* = 3.83 b* = -1.94
5			L* = 39.53 a* = 3.55 b* = -1.46
6			L* = 22.52 a* = 4.42 b* = 1.80
7			L* = 28.45 a* = 13.12 b* = 4.04

L* represents lightness, a* represents red-green, and b* represents yellow-blue colour and the value of was obtained from the chromameter and the reading can be referred to the CIELAB Colour Chart as shown in figure below.

3.2 Detection of Lactic Acid Concentration in Durian

The concentration of lactic acid in durian was obtained from the fermented durian sample, involving sample preparation, lactic acid extraction, chromatography analysis, and the concentration calculation. Table 2 below shows the lactic acid concentration in the durian during fermentation for 7 days.

Table 2. Lactic Acid Concentration in comparison with pH

Time (Day)	Lactic Acid Concentration (ppm)	pH
1	2.86	7.30
2	2.91	7.15
3	2.93	6.96

4	2.98	5.12
5	2.99	4.92
6	3.02	4.84
7	3.07	4.68

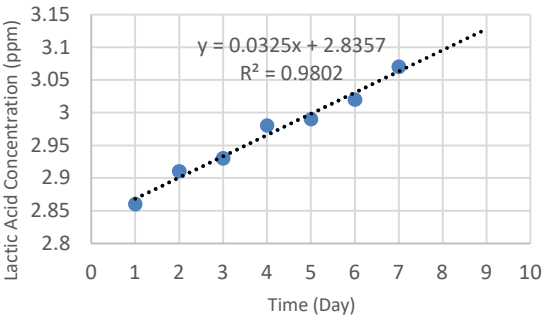


Fig. 3. Graph of Lactic Acid Concentration vs Day

According to the Figure 3 above, the concentration of lactic acid has increased over time. The graph's linear regression shows a positive correlation with the equation $y = 0.0325x + 2.8357$ and an R^2 value of 0.9802. The increasing concentration of lactic acid is due to the microbial activity that occurs during the 7-day storage period in an airtight container, which resulted from anaerobic fermentation. Anaerobic durian fermentation can influence the growth of lactic acid bacteria [19]. As a result, the longer the durian is stored, the higher the concentration of lactic acid is produced.

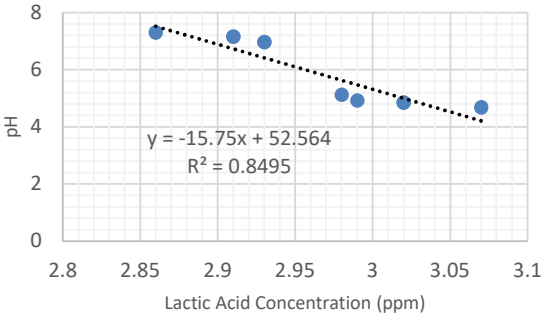


Fig. 4. Graph of pH vs Lactic Acid Concentration

The relationship between the lactic acid concentration and pH in durian is shown in Figure 4 above, which clearly shows a negative correlation. The pH of durian falls with

increasing lactic acid concentration, as indicated by the linear regression equation $y = -15.75x + 52.564$ with a high R^2 value of 0.8495.

This consistent linear relationship indicates that the concentration of lactic acid has played an important part in determining pH in durian, making up about 85% of pH changes. The lactic acid's acidic nature decreases pH as it's concentration increases, and is shown in the regression line's negative slope. Increased lactic acid makes the durian more acidic and possibly sour, therefore this inverse relationship has plays role in affecting the acidity and the taste of durian.

3.3 Mobile Application Aided in the Detection of Lactic Acid Concentration in Durian

Determining biochemical parameters, such as the concentration of lactic acid in durian, can be done easily and effectively by using a mobile application to capture and analyse RGB (Red, Green, Blue) colour intensity values of the intelligent film. The provided graphic below in Table 3 demonstrates how digital colour analysis can be used by showing various colour shades together with their RGB values as recorded by a smartphone application.

Table 3. RGB Value of the Intelligent Film obtained from Mobile Application

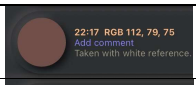
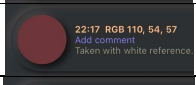
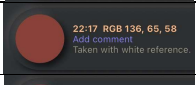
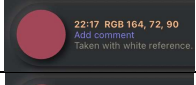
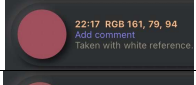
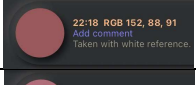
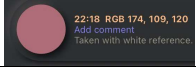
Time (Day)	Lactic Acid Concentration (ppm)	RGB value
1	2.86	
2	2.91	
3	2.93	
4	2.98	
5	2.99	
6	3.02	
7	3.07	

Table 3 shows the colours in the samples range from darker, more muted tones to lighter and more vibrant shades as the RGB values increases. For instance, the first sample has an RGB value of (112, 79, 75), representing a darker purple-brownish colour. As in the seventh day, the RGB values increase, and the colours shift to lighter and more intense

reds and pinks, with the last sample having an RGB value of (174, 109, 120). As discussed before, the lighter shade that appears on the film on the seventh day indicates that the durian has become more acidic and the has lower pH.

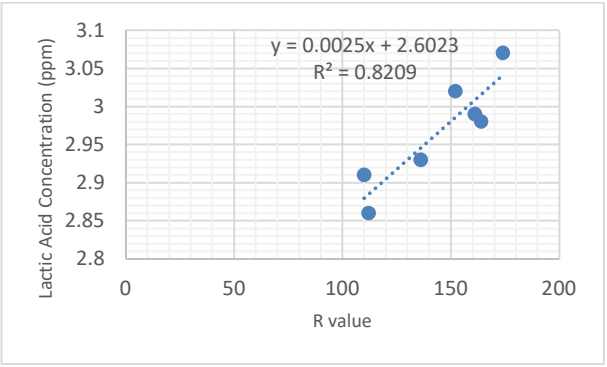


Fig. 5. Graph of Lactic Acid Concentration (ppm) vs R Value

Figure 5 shows the positive correlation between the lactic acid concentration and the R value of the film. This correlation suggests a significant linear relationship that can be useful for estimating the value of the lactic acid concentration, simply by determining the R value of the intelligent film using mobile applications on smartphones. Therefore, one can quickly and easy to determine the safety of consuming durian.

4 Conclusion

An intelligent food packaging film was successfully produced from starch and red cabbage anthocyanin. Data obtained show results for pH and lactic acid concentration in detecting freshness of durian. This film's development will benefit environment as it is biodegradable and can be used as an alternative to using conventional plastics. Over a seven-day period, the pH of durian decreases as it becomes more acidic, a trend that correlates with the concentration of lactic acid. The longer the storage period, the higher the production of lactic acid. The inclusion of IR 4.0 element in this research is through detection of unsafe food by using smartphone applications. This way, people can access innovation wherever and whenever they wanted. The incorporation of the estimated lactic acid concentration by the intelligent food packaging film with smartphone application provides a more accurate estimation, making this as a potential innovation device.

Acknowledgements. The second author would like to show her gratitude to Dr Suzihaque for her comments on an earlier version of the manuscript and she would like to thank Prof. Ir. Dr Mohamad Hafiz Mamat for his insights and expertise that greatly assisted the research. Finally, to her fellow research friend, Nurfatin Amirah who provided insights and expertise that has been assisted this research. Lastly, author would like to thank College of Engineering, School of

Chemical Engineering, Universiti Teknologi MARA for their financial support in completing this experiment and publishing this paper.

References

1. [1] L. Wang *et al.*, "A pH-sensitive intelligent packaging film harnessing Dioscorea zingiberensis starch and anthocyanin for meat freshness monitoring," *Int J Biol Macromol*, vol. 245, no. June, p. 125485, 2023, doi: 10.1016/j.ijbiomac.2023.125485.
2. [2] X. Wu, X. Yan, J. Zhang, X. Wu, M. Luan, and Q. Zhang, "Preparation and characterization of pH-sensitive intelligent packaging films based on cassava starch/polyvinyl alcohol matrices containing Aronia melanocarpa anthocyanins," *Lwt*, vol. 194, no. September 2023, p. 115818, 2024, doi: 10.1016/j.lwt.2024.115818.
3. [3] W. Zhang, M. Azizi-Lalabadi, S. Jafarzadeh, and S. M. Jafari, "Starch-gelatin blend films: A promising approach for high-performance degradable food packaging," *Carbohydr Polym*, vol. 320, no. August, p. 121266, 2023, doi: 10.1016/j.carbpol.2023.121266.
4. [4] H. L. Huang *et al.*, "Intelligent films of marine polysaccharides and purple cauliflower extract for food packaging and spoilage monitoring," *Carbohydr Polym*, vol. 299, no. September 2022, p. 120133, 2023, doi: 10.1016/j.carbpol.2022.120133.
5. [5] D. Dutta and N. Sit, "Comprehensive review on developments in starch-based films along with active ingredients for sustainable food packaging," *Sustain Chem Pharm*, vol. 39, no. October 2023, p. 101534, 2024, doi: 10.1016/j.scp.2024.101534.
6. [6] M. Sohany, I. S. M. A. Tawakkal, S. H. Ariffin, N. N. A. K. Shah, and Y. A. Yusof, "Characterization of anthocyanin associated purple sweet potato starch and peel-based ph indicator films," *Foods*, vol. 10, no. 9, 2021, doi: 10.3390/foods10092005.
7. [7] N. Ghareaghajlou, S. Hallaj-Nezhadi, and Z. Ghasempour, "Red cabbage anthocyanins: Stability, extraction, biological activities and applications in food systems," *Food Chem*, vol. 365, no. March, p. 130482, 2021, doi: 10.1016/j.foodchem.2021.130482.
8. [8] G. C. Vidana Gamage, J. K. Goh, and W. S. Choo, "Application of Anthocyanins from Blue Pea Flower in Yoghurt and Fermented Milk: An Alternate Natural Blue Colour to Spirulina," *Int J Gastron Food Sci*, vol. 37, no. October 2023, p. 100957, 2024, doi: 10.1016/j.ijgfs.2024.100957.
9. [9] D. S. B. Anugrah *et al.*, "Development of alginate-based film incorporated with anthocyanins of red cabbage and zinc oxide nanoparticles as freshness indicator for prawns," *Int J Biol Macromol*, vol. 251, no. August, p. 126203, 2023, doi: 10.1016/j.ijbiomac.2023.126203.
10. [10] S. Maqsood-ul-Haque and N. S. M. Shariffuddin, "Development of Biodegradable Food Packaging Incorporated with Pigment of Rose and Red Cabbage," *International Journal of Integrated Engineering*, vol. 14, no. 5, pp. 188–197, 2022, doi: 10.30880/ijie.2022.14.05.021.
11. [11] M. Faisal *et al.*, "Colorimetric pH indicators based on well-defined amylose and amylopectin matrices enriched with anthocyanins from red cabbage," *Int J Biol*

Macromol, vol. 250, no. August, p. 126250, 2023, doi: 10.1016/j.ijbiomac.2023.126250.

12. [12] R. V. Wagh, Z. Riahi, J. T. Kim, and J. W. Rhim, "Carrageenan-based functional films hybridized with carbon dots and anthocyanins from rose petals for smart food packaging applications," *Int J Biol Macromol*, vol. 272, no. P1, p. 132817, 2024, doi: 10.1016/j.ijbiomac.2024.132817.
13. [13] Y. R, Rosida, and N. M, "Fermentation Process Evaluationo on Tempoyak Quality," vol. 8, no. 1, pp. 84–103, 2014.
14. [14] Hasanuddin, "Mikroflora pada Tempoyak," *Agritech: Jurnal Fakultas Teknologi Pertanian UGM*, vol. 30, no. 4, pp. 218–222, 2012.
15. [15] C. L. Ramos, A. P. Bressani, N. N. Batista, S. J. Martinez, D. R. Dias, and R. F. Schwan, "Indigenous fermented foods: nutritional and safety aspects," *Curr Opin Food Sci*, vol. 53, p. 101075, Oct. 2023, doi: 10.1016/J.COFS.2023.101075.
16. [16] Y. V. Rajagukguk and M. Arnold, "Tempoyak: Fermented durian paste of Malay ethnic and its functional properties," *Int J Gastron Food Sci*, vol. 23, no. December 2020, p. 100297, 2021, doi: 10.1016/j.ijgfs.2020.100297.
17. [17] G. Rattu and P. Murali Krishna, "Enzyme-free colorimetric nanosensor for the rapid detection of lactic acid in food quality analysis," *J Agric Food Res*, vol. 7, p. 100268, 2022, doi: 10.1016/j.jafr.2022.100268.
18. [18] S. Gokul Eswaran *et al.*, "Preparation of a portable calorimetry kit and one-step spectrophotometric nanomolar level detection of L-Histidine in serum and urine samples using sebacic acid capped silver nanoparticles," *Journal of Science: Advanced Materials and Devices*, vol. 6, no. 1, pp. 100–107, 2021, doi: 10.1016/j.jsamd.2020.12.002.
19. [19] E. S. Khalil, M. Y. A. Manap, S. Mustafa, A. M. Alhelli, and P. Shokryazdan, "Probiotic properties of exopolysaccharide-producing lactobacillus strains isolated from tempoyak," *Molecules*, vol. 23, no. 2, pp. 1–20, 2018, doi: 10.3390/molecules23020398.