Fish products perish easily due to microbial contamination. Uncontrolled thawing will increase the rate of microbial activity at every 10°C increase in temperature. One of the indicators that can detect food quality is the time-temperature indicator (TTI) with changes in pH. However, these indicators are generally made of synthetic chemicals which tend to pollute the environment. This study aimed to summarize various studies on anthocyanins from agro-waste as time-temperature indicator to monitor freshness of fish products. This research used systematic literature review (SLR) from various relevant research and resources. The SLR process includes practical screening, quality appraisal, synthesizing, and reviewing. Anthocyanins derived from agro-waste than can be developed into TTI are purple yam peel, black plums peel, blueberries peel, rambutan peel, sweet potato peel, dragon fruit peel. The TTI from agro-waste anthocyanins can be developed to monitor freshness of fish products.
1. INTRODUCTION

Fish products perish easily due to microbial contamination (Rawat, 2016). About 6-10% of the world's total fish production is inedible due to rot during improper storage and distribution processes (Arvanitoyannis and Kassaveti, 2008). Uncontrolled thawing will increase the rate of microbial activity at every 10°C increase in temperature (Roiha et al., 2018). Spoilage bacteria degrade fish protein into alkaline compounds which increase the acidity (pH) of fish, making it inedible (Omafuvbe et al., 2000). Therefore, it is necessary to conduct a study to maintain quality of fish products by developing indicators.

One indicator that can detect food quality is the temperature time indicator or TTI with changes in pH (Zhai et al., 2018; Shi et al., 2021a; Shi et al., 2021b). Fish protein decomposition in fish will release volatile compounds such as trimethylamine which is reactive to natural pH indicators (Kang et al., 2018). The main principle of acid-based TTI is to detect changes in pH by displaying a gradual color change because of an irreversible chemical reaction (Bobelyn et al., 2006). However, these indicators are generally made of synthetic chemicals which tend to pollute the environment (Syahirah et al., 2018).

Current research has proven that natural anthocyanin pigments can be used as pH indicators since their sensitivity to pH changes that lead to color changes (Pakolpakçıl et al., 2021). However, the anthocyanins used usually come from staple foods such as sweet potatoes, dragon fruit, and red cabbage. Therefore, this study aimed to summarize various studies on anthocyanins from agro-waste as time-temperature indicator to monitor freshness of fish products.

2. METHODS

This research used systematic literature review (SLR) from various relevant research and resources. The SLR process includes practical screening, quality appraisal, synthesizing, and reviewing (Peffers et al., 2007). Figure 1 describing the method of collecting data research from google scholar.

![Figure 1. Method and process of SLR used.](image-url)
3. RESULTS AND DISCUSSION

3.1. ANTHOCYANINS FROM AGRO-WASTE

Anthocyanins are naturally found in plants, fruits, and vegetables in the form of water-soluble pigments (Arruda et al., 2021). Anthocyanins consist of several conjugated phenolic rings. When the pH changes, the protonation and deprotonation of the hydroxyl groups along the phenolic rings of the anthocyanin molecule change the conjugation pattern across the molecule causing the color change (Khoo et al., 2017). In general, anthocyanins can give a blue, red, or purple color. Therefore, anthocyanins may also be found in parts that are not eaten, such as fruit skins.

3.2. ANTHOCYANINS FROM AGRO-WASTE AS TIME-TEMPERATURE INDICATORS TO MONITOR FRESHNESS OF FISH PRODUCT

Fish products potentially contaminated at temperatures above 10°C by the bacteria Vibrio Parahaemolyticus, Escherichia coli, Aeromonas, Salmonella, Staphylococcus, Clostridium botulinum, and others (Novotny et al., 2004). Damage to fish is characterized by the formation of trimethylamine (TMA) from the reduction of trimethylamine oxide (TMAO). The breakdown of protein by bacteria will release volatile compounds such as trimethylamine. pH <7.6 indicates fresh quality, pH 7.6 - 7.9 indicates edible but not number one quality, and pH > 7.9 indicates rotten value.

By knowing these parameters, anthocyanins can act as a Time-Temperature Indicator to detect changes in pH by displaying a gradual color change because of an irreversible chemical reaction (Bobelyn et al., 2006). Table 1 summarizes some agricultural limes that contain anthocyanins and have the potential to be used as indicators of fish freshness.

Table 1. Response of anthocyanins from agro-waste to different pH condition.

| No. | Source of Anthocyanin | Type of Anthocyanin | Total Anthocyanin Content |
|-----|------------------------|---------------------|---------------------------|
| 1   | Purple yam peel (Dioscorea alata L) | cyanidin-3-glucoside | 155 mg/L |
| 2   | Black plums peel (Syzygium cumini) | cyanidin-3-glucoside | 23.3g/100g fresh weight |
| 3   | Blueberries peel (Cyanococcus) | cyanidin-3-glucoside | 300 mg/L |
| 4   | Rambutan peel (Nephelium lappaceum L.) | cyaniding-3-glucoside | 39.27 mg/L |
| 5   | Sweet potato peel (Ipomoea batatas L.) | peonidin-3-glucoside | 6.93 mg/L |
| 6   | Dragon fruit peel (Selenicereus undatus) | betacyanin | 0.85 mg/100 g fresh weight |
| 7   | No Data                |                     | No Data |
| 8   | No Data                |                     | No Data |
Source of Anthocyanin

| No. | 1. Purple yam peel (Dioscorea alata L.) | 2. Black plums peel (Syzygium cumini) | 3. Blueberries peel (Cyanococcus) | 4. Rambutan Peel (Nephelium lappaceum L.) | 5. Sweet potato peel (Ipomoea batatas L.) | 6. Dragon fruit peel (Selenicereus undatus) |
|-----|---------------------------------------|--------------------------------------|----------------------------------|----------------------------------------|----------------------------------------|-------------------------------------------|
| 9   | No Data                               | No Data                               | No Data                          | No Data                                | No Data                                | No Data                                    |
| 10  | No Data                               | No Data                               | No Data                          | No Data                                | No Data                                | No Data                                    |
| 11  | No Data                               | No Data                               | No Data                          | No Data                                | No Data                                | No Data                                    |
| 12  | No Data                               | No Data                               | No Data                          | No Data                                | No Data                                | No Data                                    |
| 13  | No Data                               | No Data                               | No Data                          | No Data                                | No Data                                | No Data                                    |
| 14  | No Data                               | No Data                               | No Data                          | No Data                                | No Data                                | No Data                                    |

| Reference | (Aquino & Morales, 2021) | (Sun et al., 2021) | (Bilgiç et al., 2019) | (Jing et al., 2012) | (Capello et al., 2020) | (Apriliyanti et al., 2018) |

### 4. CONCLUSION

Time-Temperature Indicator (TTI) can be made from agro-waste anthocyanins. Agro-waste than can be developed into TTI are purple yam peel, black plums peel, blueberries peel, rambutan peel, sweet potato peel, dragon fruit peel. The TTI from agro-waste anthocyanins can be developed to monitor freshness of fish products.

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### 5. AUTHORS’ NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

### 6. REFERENCES

Apriliyanti, M. W., Wahyono, A., Fatoni, M., Poerwanto, B., and Suryaningsih, W. (2018). The Potency of betacyanins extract from a peel of dragon fruits as a source of colourimetric indicator to develop intelligent packaging for fish freshness monitoring. *IOP conference series: Earth and environmental science, 207*(1), 012038.

Aquino, A. M., and Morales, D. B. (2021). Development and characterization of cassava starch films incorporated with purple yam (Dioscorea alata L.) peel anthocyanins. *Food Research, 5*(1), 108-113.

Arruda, H. S., Silva, E. K., Peixoto Araujo, N. M., Pereira, G. A., Pastore, G. M., and Marostica Junior, M. R. (2021). Anthocyanins Recovered from Agri-Food By-Products Using Innovative Processes: Trends, Challenges, and Perspectives for Their Application in Food Systems. *Molecules, 26*(9), 2632.
Arvanitoyannis, I. S., and Kassaveti, A. (2008). Fish industry waste: treatments, environmental impacts, current and potential uses. International journal of food science & technology, 43(4), 726-745.

Bilgiç, S., Söğüt, E., and Seydim, A. C. (2019). Chitosan and starch based intelligent films with anthocyanins from eggplant to monitor pH variations. Turkish Journal of Agriculture-Food Science and Technology, 7(sp1), 61-66.

Bobelyn, E., Hertog, M. L., and Nicolaï, B. M. (2006). Applicability of an enzymatic time temperature integrator as a quality indicator for mushrooms in the distribution chain. Postharvest Biology and Technology, 42(1), 104-114.

Capello, C., Trevisol, T. C., Pelicioli, J., Terrazas, M. B., Monteiro, A. R., and Valencia, G. A. (2021). Preparation and characterization of colorimetric indicator films based on chitosan/polyvinyl alcohol and anthocyanins from agri-food wastes. Journal of Polyomers and the Environment, 29(5), 1616-1629.

Jing, P., Zhao, S. J., Ruan, S. Y., Xie, Z. H., Dong, Y., and Yu, L. L. (2012). Anthocyanin and glucosinolate occurrences in the roots of Chinese red radish (Raphanus sativus L.), and their stability to heat and pH. Food chemistry, 133(4), 1569-1576.

Kang, S., Wang, H., Guo, M., Zhang, L., Chen, M., Jiang, S., ... and Jiang, S. (2018). Ethylene-vinyl alcohol copolymer—montmorillonite multilayer barrier film coated with mulberry anthocyanin for freshness monitoring. Journal of agricultural and food chemistry, 66(50), 13268-13276.

Khoo, H. E., Azlan, A., Tang, S. T., & Lim, S. M. (2017). Anthocyanidins and anthocyanins: Colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food & nutrition research, 61(1), 1361779.

Novotny, L., Dvorska, L., Lorencova, A., Beran, V., and Pavlik, I. (2004). Fish: a potential source of bacterial pathogens for human beings. Veterinarni Medicina, 49(9), 343.

Omafuvbe, B. O., Shonukan, O. O., and Abiose, S. H. (2000). Microbiological and biochemical changes in the traditional fermentation of soybean for ‘soy-daddawa’—Nigerian food condiment. Food Microbiology, 17(5), 469-474.

Pakolpakçıl, A., Osman, B., Göktalay, G., Özer, E. T., Şahan, Y., Becerir, B., and Karaca, E. (2021). Design and in vivo evaluation of alginate-based pH-sensing electrospun wound dressing containing anthocyanins. Journal of Polymer Research, 28(2), 1-13.

Peffers, K., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of management information systems, 24(3), 45-77.

Rawat, S. (2015). Food Spoilage: Microorganisms and their prevention. Asian Journal of Plant Science and Research, 5(4), 47-56.

Roiha, I. S., Jónsson, Á., Backi, C. J., Lunestad, B. T., and Karlsdóttir, M. G. (2018). A comparative study of quality and safety of Atlantic cod (Gadus morhua) fillets during cold storage, as affected by different thawing methods of pre-rigor frozen headed and gutted fish. Journal of the Science of Food and Agriculture, 98(1), 400-409.

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Shi, C., Zhang, J., Jia, Z., Yang, X., and Zhou, Z. (2021a). Intelligent pH indicator films containing anthocyanins extracted from blueberry peel for monitoring tilapia fillet freshness. Journal of the Science of Food and Agriculture, 101(5), 1800-1811.

Shi, C., Zhang, J., Jia, Z., Yang, X., and Zhou, Z. (2021b). Intelligent pH indicator films containing anthocyanins extracted from blueberry peel for monitoring tilapia fillet freshness. Journal of the Science of Food and Agriculture, 101(5), 1800-1811.

Sun, W., Liu, Y., Jia, L., Saldaña, M. D., Dong, T., Jin, Y., and Sun, W. (2021). A smart nanofibre sensor based on anthocyanin/poly-l-lactic acid for mutton freshness monitoring. International Journal of Food Science & Technology, 56(1), 342-351.

Syahirah N. M, Luthfi M. U, Atika, A. Hafiz, M., Zulhelmi, M., Adzhan, M. A., and Khor.P. Y (2018). A Comparative Analysis of Clitoria ternatea Linn. (Butterfly Pea) Flower Extract as Natural Liquid pH Indicator and Natural pH Paper. Dhaka University Journal of Pharmaceutical Sciences, 17(1), 97-103.

Zhai, X., Li, Z., Zhang, J., Shi, J., Zou, X., Huang, X., and Povey, M. (2018). Natural biomaterial-based edible and pH-sensitive films combined with electrochemical writing for intelligent food packaging. Journal of agricultural and food chemistry, 66(48), 12836-12846.