Review Article
Open Access CrossMark

Potency of betacyanin from beetroot (Beta vulgaris) peel waste as chicken meat freshness indicator in sago starch-based biodegradable smart packaging

Abstract

High usage of synthetic plastic will harm the environment due to its difficulties in degrading and harming the environment. Environmentally friendly plastic packaging that can be used is active and intelligent packaging made from starch as one of the innovations in food packaging. The starch extracted from the sago (*Metroxylon sagu*) fruit can form a thin layer for biodegradable plastic packaging. Addition material such as natural pigment will enhance the biodegradable packaging ability to be active and intelligent. As a natural pigment, betacyanin can be collected from beetroot peel waste, which is rarely utilized. This review aimed to explore the potency of sago starch with betacyanin pigment addition from beetroot peel waste as an active and intelligent packaging plastic material. Sago starch mixed with a plasticizer can form a flexible thin layer (film) and be used as a packaging material. The addition of betacyanin to beetroot peel on sago starch biofilm plays an important role as a sensor through colour change due to its sensitivity to pH changes in spoiled chicken meat products. Sago starch and beetroot peel have excellent potential to be applied as smart packaging innovations.

Keywords: beet root, betacyanin, chicken, sago starch, smart packaging

Volume 8 Issue 5 - 2023

Esa Ghanim Fadhallah,[1] Sangiang Eka Ria Rinjani,[2] Angelika Katartizo Sant Anantasya,[2] Ari Pranata,[2] Rahmat Triharto,[2] Amarilia Harsanti Dameswary[3]

[1] Lecturer at Department of Agricultural Product Technology, Faculty of Agriculture, Universitas Lampung, Indonesia
[2]Student at Agricultural Product Technology Study Programme, Faculty of Agriculture, Universitas Lampung, Indonesia
[3]Center for Food Technology and Processing Research, National Research and Innovation Agency, Yogyakarta, Indonesia

Correspondence: Esa Ghanim Fadhallah, Department of Agricultural Product Technology, Faculty of Agriculture, Universitas Lampung, Indonesia, Jl. Prof. Dr. Soemantri Brojonegoro No. 1, Bandar Lampung, Lampung, 35145, Indonesia, Tel +62 721 701609, Fax +62 721 702767, Email esa.ghanim@fp.unila.ac.id

Received: September 21, 2023 | **Published:** October 16, 2023

Introduction

Plastic waste pollution has been a global issue for a long time. Currently, communities worldwide focus on disseminating plastic waste into the environment and its detrimental impact on the surrounding ecosystems. Plastic waste will harm the ecosystems inhabiting these environments. However, the demand for plastic continues to rise with technological advancements. Data from the Indonesian Central Statistics Agency[1] reported that the import value of plastic goods in 2013 reached US$ 4.5 billion, showing an increase of 9.7% compared to the previous year. This will also lead to an increase in the quantity of plastic waste disposed of, coinciding with the rise in plastic imports. Consequently, plastic usage and the volume of plastic waste are also increasing. According to data from Ritchie & Roser,[2] global plastic waste production has steadily increased from 1950 to 2015. By 2050, global plastic waste volume will be predicted to reach 2 million tons per year.

Based on the 2016 World Bank report, plastic waste contributes to approximately 12% of overall environmental pollution. If this trend continues, it is projected that by 2050, environmental pollution levels will reach 70%. Additionally, the issue of marine litter is of serious concern. Research conducted by Jenna Jambeck, a researcher from the University of Georgia, reveals that Indonesia is a coastal country that disposes 12.7 million tons of waste into the sea.[3]

The extensive use of plastic has the potential to harm the environment. This is attributed to the inherent characteristics of plastic, which make it highly resistant to degradation, leading to the accumulation of plastic waste that pollutes the environment.[4] Plastic properties such as non-biodegradability, resistance to natural degradation, impermeability to water, and corrosion resistance pose significant environmental challenges.

Furthermore, plastic waste also has a big potential to harm aquatic ecosystems. For instance, plastic waste can harm coral reefs and mangrove forests.[3] Therefore, an alternative in the form of environmentally friendly plastic materials is needed. Scientists and researchers are continuously striving to find eco-friendly plastic packaging materials. One solution to this issue is using biodegradable plastic or bioplastic made from natural materials that can degrade quickly. Biodegradable plastic is typically crafted from natural polymers like starch.[5]

Biodegradable plastic, or eco-friendly plastic packaging, is described as a type of plastic that can be naturally degraded and can be made from renewable natural resources such as oils, fats, biomass, and starch.[6–8] Kharb & Saharan[9] explain that biodegradable plastic has been applied in various sectors, including textiles, consumer goods, coatings and adhesives, and food packaging. Starch is the most popular material for biodegradable food packaging since it is non-toxic, widely and easily available, and low-cost compared to protein and lipids-based materials.[10] However, Young et al.[11] reported that in this 21st century, the demands for food packaging with the ability to monitor the food during storage are increasing in line with consumers' awareness. Based on this situation, it is important to innovate biodegradable food packaging with this ability, leading to the concept of smart packaging. Smart packaging, known as informative packaging provides real-time quality and freshness level to the consumers, which is indicated by a color change using an additional pH indicator from chemicals or natural pigments.[12–14]

Beet root peel is a source of natural colorant widely used as a natural dye[15] and food packaging freshness indicator.[16] It contains pigments sensitive to pH changes,[17] indicating the level of food freshness by different colors. Betalain consists of two different pigments, i.e. betacyanin with red-violent color and betaxanthin with yellow-orange color.[18] Zin et al.[19] and Silva et al.[20] reported that betalain extracted from beet root peel contains a higher level of betacyanin than betaxanthin. This explains betacyanin's major role in smart food packaging applications. However, beet root peel was also known as a by-product[21] generated from beetroot processing industries. The utilization of beet root peel waste is important to minimize waste generation and will be valuable since it contains important compounds.

Incorporation of betacyanin from beet root peel waste to a starch-based bioplastic as the active and intelligent packaging for food packaging will be potential. Active packaging enhances the quality and extends the shelf life of packaged food products, while intelligent packaging monitors and provides information about the quality of the packaged products. Using sago starch in producing such packaging is anticipated to increase the utilization of sago and beetroot while reducing reliance on plastic imports.[22,23] This paper explores the potential of using beetroot to produce active and intelligent packaging plastics.

Methods

The method used is an effective literature review following the topic. The method of discussion is based on the research results found by previous researchers, which are then integrated with other researchers to get strong results and conclusions.

Smart packaging

Packaging is the first thing one observes when considering a product purchase since it relates to the packaging's role as a silent salesman selling the product based on the information displayed on the packaging. Packaging not only serves as a means of marketing the product within but also functions to protect the packaged product. The term "smart packaging" may still be unfamiliar to some in the Indonesian community. According to Rahimah et al.,[24] smart packaging is a system embedded with sensors or indicator technologies that provide information about the quality of products, especially perishable foods. Smart packaging comprises two types of packaging: active packaging and intelligent packaging, emphasizing that packaging not only preserves the product but also provides information about the product's condition.

In research conducted by Qin et al.,[17] the creation of active and intelligent packaging using betalain pigments extracted from the red dragon fruit peel was described. These pigments were mixed with starch-based biofilm or PVA. Betalain is a natural pigment that is an antioxidant and antimicrobial agent in the biofilm produced. Furthermore, betalain demonstrates stability within a specific pH range of approximately 3-7 but exhibits various color variations in an alkaline environment. This rationale led to the selection of betalain for monitoring pH changes in the packaged products as an indicator. In this study, the packaging's ability was tested for the freshness of stored shrimp, resulting in satisfactory outcomes, making this biofilm suitable for monitoring the freshness of other protein-rich animal products. Qin et al.[25] also employed extracts from Chinese goji berries and red dragon fruit peel to obtain betacyanin, which was then tested for pH sensitivity in various pH solutions. Betacyanin from red dragon fruit peel (B) would fade to a yellowish hue as the pH value increased and darken to a deeper red with decreasing pH.

A study by Setiawan et al.[26] explored betacyanin pigments obtained from beetroot tubers for use as a natural dye. Beetroot tuber peel contains 82.85% water, 5.95% fiber, 1.33% ash, and 0.31% lipids. The optimal method for extracting betacyanin from beetroot peel involved using ethanol as a solvent with HCl added during a 40-minute extraction process, resulting in 2.4535 mg/100 g of betacyanin. Ethanol acted as a solvent to extract betacyanin pigment from beetroot peel. Hydrochloric acid can be corrosive to samples, thus necessitating the substitution of hydrochloric acid with citric acid, a weak acid that still effectively correlates with ethanol to extract betacyanin. Betacyanin imparts shades of red to reddish-violet, with maximum absorbance measured at 534-535 nm.

In research by Silviana et al.,[27] the production of bioplastics made from sago starch was influenced by keratin from chicken feathers, glycerol as a plasticizer, and lime juice extract. The production process involved mixing 4% sago starch with water for hydration and heating to facilitate starch gelatinization. Before heating, lime juice extract (5% v/v) and glycerol (20% w/w) were added to the mixture and heated to 90°C. Subsequently, the resulting paste or gel was molded using acrylic molds and underwent air-drying at room temperature for 1-2 days.

Application of smart packaging for agricultural products

Agricultural produce is known for its perishable nature, indicating a very short shelf life for these products, such as fruits, vegetables, and animal products.[28] Sometimes, these changes are not visually perceptible, making detecting alterations in agricultural products difficult. Hence, a system that can be implemented from the production process to the distribution of agricultural products to maintain quality in line with consumer expectations is required. One solution that can be applied is smart packaging, allowing producers to communicate with consumers to monitor the quality of packaged products. Smart packaging typically incorporates sensors, including detectors, recorders, trackers, communication devices, and the application of scientific logic to facilitate decision-making, enhance safety, improve quality, and provide information and potential issue alerts.[29] One type of smart packaging that can be utilized involves biofilm layers made from sago starch.

Sago starch (*Metroxylon sagu*) is an abundant starch variety in Indonesia, yet its utilization has yet to receive sufficient attention from major industries. According to Wong et al.,[30] unmodified sago starch contains 70-80% amylopectin and 15-30% amylose fractions. Ahmad et al.[31] reported that biofilm derived from sago starch is a potential biofilm for application in the smart packaging concept. In the production of bioplastics or biofilm, additional compounds are needed to provide suitable characteristics for use as a biofilm. Bhasney et al.[32] explained that plasticizers aim to enhance bond mobility and reduce pressure between polymer chains, thus making the matrix softer and more elastic. This concept proposes glycerol and sorbitol as plasticizers for biofilm production. This choice was made because the glycerol-sorbitol mixture is considered a natural plasticizer with favorable characteristics for biofilm, such as providing better texture and superior mechanical properties compared to other plasticizers.[33]

pH changes are one indicator of the freshness of agricultural products. This freshness indicates its quality, including microbial growth or chemical changes in the agricultural produce. The reaction between microbial growth metabolites and the indicator results in visual changes in microbial quality in the product due to pH alterations.[29] Efforts to make biofilm from sago starch as a smart packaging concept involve the addition of betacyanin extract from beetroot as an indicator. This natural pigment is highly sensitive to changes in the material's pH, causing a colour change when the pH of the material changes. Although anthocyanin pigments are more pH-sensitive than betacyanin, the addition of betacyanin enhances the compactness of the biofilm. It strengthens the hydrogen bond interactions within the film matrix compared to anthocyanin. Therefore, we consider it suitable for application as smart packaging for animal-sourced products such as meats and horticultural products like fruits and vegetables. In addition to serving as a sensitive pH indicator, this biofilm remains robust as a product packaging material.

The design for the implementation of active and intelligent packaging involves a biofilm that covers the entire packaging of poultry products, specifically targeting cut chicken meat. Cut chicken meat is a common commodity sold in supermarkets. However, in the current condition, only some packaging solutions have provided real-time information directly to consumers about product spoilage. The growth of microbes on animal proteins can generate a substantial amount of volatile nitrogen compounds, such as ammonia, dimethylamine, and trimethylamine, which can influence the food's pH.[34] Chicken is chosen as the animal product due to its protein content, which is not significantly different from beef and fish. According to the Directorate of Nutrition, Ministry of Health (2010), as cited in Wijayanti et al.,[35] chicken meat contains 18.20 grams of protein, 25 grams of fat, and 404 Kcal per 100 grams of chicken meat. Meanwhile, beef's protein and fat content per 100 grams is 18.8 grams of protein and 14 grams of fat, according to Micinski et al.[36]

Chicken meat deteriorates rapidly if not stored and packaged according to applicable standards. Research by Poyatos-Racionero et al.[37] shows that microbial growth on meat products can produce volatile biogenic amine compounds. These volatile compounds can react with pH indicators in the designed packaging. The pigment used in this concept is betacyanin, extracted from beetroot peel. Besides being a sensitive pH indicator, betacyanin also possesses high antioxidant and antimicrobial properties, thus maintaining the quality of bell peppers during storage, both in the store and after consumer purchase. Labels containing pH change indicators on the packaging of cut chicken meat will be printed and affixed to the top layer of the chicken meat packaging, with a gradient of colors indicating product quality.

The above Figure 1 is an indicator that provides information to consumers about the quality of the packaged product, particularly cut chicken meat. The color produced by the biofilm with the betacyanin indicator illustrates the interaction of the betacyanin pigment, which is sensitive to changes in pH due to microbial metabolites. The deep red indicates that the chicken product is still in optimal condition, with a pH of around 6. Many protein-rich animal foods are generally susceptible to spoilage due to microbial contamination.

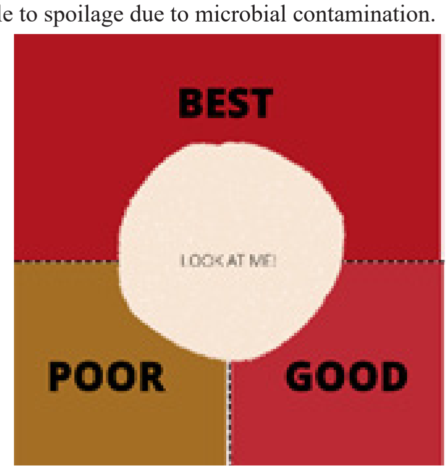

Figure 1 Illustration of product quality indicator on smart packaging.

The principle of intelligent packaging using sago-based material modified with betacyanin indicators from beetroot is based on pH changes resulting from the chemical processes generated by microorganisms in the product. The color change in betacyanin is a response to these pH changes. This concept refers to research by Qin et al.,[25] which revealed that betacyanin in the extract interacts with starch and glycerol (plasticizer) through hydrogen bonding. These hydrogen bonds enhance the film's water vapor barrier and mechanical properties. Furthermore, betacyanin derived from beetroot peel extract functions as a light barrier and antioxidant and possesses antimicrobial properties.

Beetroot peel waste as an indicator

Based on the research conducted by Qin et al.,[25] betalains are natural pigments produced by certain plants, such as red spinach and dragon fruit. Betalains can be categorized into two groups based on their chemical structures: betacyanin and betaxanthin. Beetroot peel has been selected as the source of betacyanin, serving as a natural pigment for a pH change detection sensor that indicates product spoilage. This choice is justified because the pigment derived from beetroot peel remains stable within the pH range of 3 to 7 but undergoes a color change from reddish-purple (under acidic conditions) to yellow (under alkaline conditions). Additionally, according to Gengatharan et al.,[38] there were observed color changes and the application of UV-Vis spectroscopy (Figure 2), resulting in a red-colored RPP (red-purple pigment) solution with a single absorption peak of betalains, which remains stable at pH levels ranging from 3 to 7, with betacyanin as the primary component.

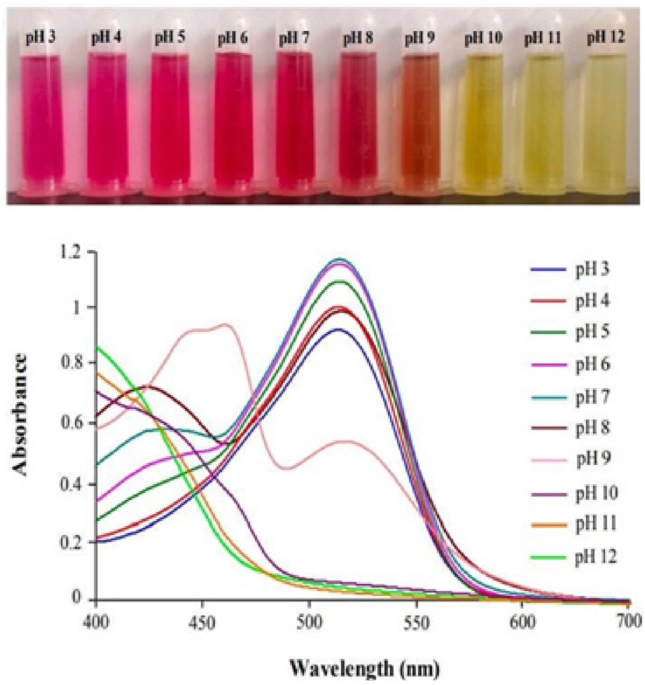

Figure 2 Color changes and UV-vis spectra of betalain at various pH.[28]

The development of intelligent packaging, using a base material of sago modified with a betacyanin indicator from beetroot peel, introduces innovation in packaging, enabling the detection of meat product spoilage. This packaging detects product spoilage using a colorimetric sensor that utilizes betacyanin pigment from beetroot peel. The sensor displays a reddish-purple color when the product is in good or fresh condition and shifts to a yellowish hue if the product experiences spoilage.

Strategic action for future implementation

Stabilizing beetroot production

Beetroot is one of the tuber crops gaining popularity due to its numerous benefits. Cultivating beetroot does not require special treatment but is generally grown in highland areas, resulting in moderate productivity. A strategy to stabilize red beetroot productivity can be achieved by improving the cultivation system, particularly by managing highland or limited-space areas using hydroponic systems. According to the research conducted by Jannah & Murdono,[39] hydroponic raft systems using rice husk charcoal as a medium yield positive results regarding beetroot diameter and sugar content. This presents an opportunity and foundation for cultivation, ensuring stable beetroot productivity.

Supporting semi-finished material industries for sago starch and beetroot extract production

Starch derived from Indonesia's native sago plant has numerous benefits and can serve as an alternative national food source and raw material for intelligent packaging. Sago plant cultivation is commonly known in the Eastern Indonesian region. However, according to the Indonesian Ministry of Agriculture,[40] it is produced in other regions such as Aceh, Riau, and South Kalimantan. The harvested sago is typically processed into semi-finished products, mainly sago starch, requiring support from various parties to boost sago cultivation and production. Meanwhile, beetroot harvests have been exported abroad and to various regions. Beetroot extract and peel are essential for packaging development and natural coloring, presenting an opportunity to establish a red beetroot extract processing industry.

Research and development

Research is necessary to realize smart packaging made from sago starch and beetroot peel betacyanin indicators. This research will analyze the color changes that occur in beetroot peel betacyanin. Furthermore, Dirpan et al.[41] explain that the research trends over the last 25 years and the future aim to determine the appropriate proportions of materials to create smart packaging with desirable film characteristics, including thickness, moisture content, mechanical properties, antioxidant activity, and antimicrobial activity.

Support from other parties

The increasing use of conventional plastics has led to environmental pollution. The development of smart packaging made from sago starch and beetroot peel betacyanin indicators is expected to minimize environmental damage caused by plastic waste. Schaefer & Cheung[42] explain that the future challenges of developing such packaging require support from various parties, including the community and the government. This can be achieved by reducing synthetic plastics and promoting awareness of the use of smart packaging in agricultural products, especially horticultural ones.

Conclusion

Incorporating betacyanin collected from beet root peel waste into sago starch biodegradable film emerges as a potential material for application in smart packaging. In the production of bioplastics, adding a compound, specifically betacyanin pigments, a pH indicator extracted from beetroot peel, which exhibits sensitivity to pH changes, is required. Innovating sago starch biodegradable films with the addition of betacyanin from beet root peel waste as intelligent packaging not only enhances the value of sago-based products and underutilized beetroot peel but also contributes to environmental sustainability by reducing the use of synthetic plastic waste.

Acknowledgments

None.

Funding

None.

Conflicts of interest

The authors declare that there are no conflict of interest in writing the manuscript.

References

1. Indonesian Central Statistics Agency. Data ekspor dan impor tahun 2013. 2013.
2. Ritchie H, Roser M. Plastic pollution. 2018.
3. Asia Arifin MZ. Dampak sampah plastik bagi ekosistem laut. *Buletin Matric*. 2017;14(1):44–48.
4. Astrianti W. Upaya Indonesia menanggulangi limbah sampah plastik dari Belanda. *JOM FISIP*. 2019;6(1):1–12.
5. Kamsiati E, Herawati H, Purwani EY. The development potential of sago and cassava starch-based biodegradable plastic in Indonesia. *Jurnal Litbang Pertanian*. 2017;36(2):67–76.
6. Babu RP, O'Connor K, Seeram R. Current progress on bio-based polymers and their future trends. *Progress in Biomaterials*. 2013;2(1):8.
7. Stephen EC, Temitope DF. Trends on bio-synthesis of plastics. *Advances in Biotechnology & Microbiology*. 2018;10(5):555797.
8. Chong TY, Law MC, Chan YS. The potentials of corn waste lignocellulosic fibre as an improved reinforced bioplastic composites. *Journal of Polymers and the Environment*. 2021;29:363–381.
9. Kharb J, Saharan R. Sustainable biodegradable plastics and their applications: a mini review. *IOP Conference Series: Materials Science and Engineering*. 2022;1248:1–16.
10. Zahid A, Khedkar R. Biobased packaging from food industry waste. In: Thakur, editor. *Sustainable Food Waste Management*. 2020;14:241–265.
11. Young E, Mirosa M, Bremer P. A systematic review of consumer perceptions of smart packaging technologies for food. *Frontiers in Sustainable Food Systems*. 2020;4:1–20.
12. Wells N, Yusufu D, Mills A. Colourimetric plastic film indicator for the detection of the volatile basic nitrogen compounds associated with fish spoilage. *Talanta*. 2019;194:830–836.
13. Albrecht A, Ibald R, Raab V, et al. Implementation of time temperature indicators to improve temperature monitoring and support dynamic shelf life in meat supply chains. *Journal of Packaging Technology and Research*. 2020;4:23–32.
14. Ningtyas R, Jayarachman MN, Imam S, et al. The use of colour indicator as a smart packaging for monitoring spoilage fillet catin fish (Pangasius sp.) in room temperature. *IOP Conference Series: Earth and Environmental Science*. 2023;117(012045=8):1–9.
15. Popescu V, Blaga AC, Cașcaval D, et al. *Beta vulgaris* L. A source with a great potential in the extraction of natural dyes intended for the sustainable dyeing of wool. *Plants*. 2023;12(10):1933.
16. Guo Z, Ge X, Li W, et al. Active-intelligent film based on pectin from watermelon peel containing beetroot extract to monitor the freshness of packaged chilled beef. *Food Hydrocolloids*. 2021;119:106751.
17. Qin Y, Liu Y, Zhang X, et al. Development of active and intelligent packaging by incorporating betalains from red pitaya (Hylocereus polyrhizus) peel into starch/polyvinyl alcohol films. *Food Hydrocolloids*. 2020;100:1–10.

18. Calva-Estrada SJ, Jimenez-Fernandez M, Lugo-Cervantes E. Betalains and their applications in food: The current state of processing, stability and future opportunities in the industry. *Food Chemistry: Molecular Sciences.* 2022;4:100089.
19. Zin MM, Marki E, Banvolgyi S. Conventional extraction of betalain compounds from beetroot peels with aqueous etanol solvent. *Acta Alimentaria.* 2020;49(2):163–169.
20. Silva JPP, Bolanho BC, Stevanato N, et al. Ultrasound-assisted extraction of red beet pigments (Beta vulgaris L.): Influence of operational parameters and kinetic modeling. *Journal of Food Processing and Preservation*. 2020;00:e14762.
21. Lazăr S, Constantin OE, Horincar G, et al. Beetroot by-product as a functional ingredient for obtaining value-added mayonnaise. *Processes*. 2022;10(2):227.
22. Bhat R, Abdullah N, Din RH, et al. Producing novel sago starch based food packaging films by incorporating lignin isolated from oil palm black liquor waste. *Journal of Food Engineering.* 2013;119(4):707–713.
23. Agustina S, Wardhono EY, Namiroh N, et al. Synthesis of chitosan nanoprticle through simultaneous emulsification technique and self-assembly of nanoparticles as an active packaging material. *Jurnal Integrasi Proses*. 2019;8(2):70–75.
24. Rahimah S, Malinda W, Zaida, et al. Betacyanin as bioindicator using time-temperature integrator for smart packaging of fresh goat milk. *The Scientific World Journal*. 2020;2020:1–9.
25. Qin Y, Xu F, Yuan L, et al. Comparison of the physical and functional properties of starch/polyvinyl alcohol films containing anthocyanins and/or betacyanins. *International Journal of Biological Macromolecules*. 2020;163:898-909.
26. Setiawan MAW, Nugroho EK, Lestario LN. Extraction of betacyanin from beet (Beta vulgaris) peel for natural dyes. *AGRIC Journal of Agricultural Science*. 2015;27(1):38–43.
27. Silviana, Zuhri LA, Muzakki MM, et al. Utilization of lime juice to enhance mechanical performance of sago-starch based biofilm reinforced chicken feather keratin. *Advanced Science Letters.* 2017;23:5739–5741.
28. Nadhori IS, Ahsan AS. An automatic scheduling system for perishable product's supply chain. *JAICT Journal of Applied Information and Communication Technologies*. 2016;1(2):1–4.
29. Alfaro EB, Craveiro DV, Lima KO, et al. Intelligent packaging with pH indicator potential. *Food Engineering Reviews*. 2019;11:235–244.
30. Wong CW, Muhammad SKS, Dzulkifly MH, et al. Enzymatic production of linier long-chain dextrin from sago (Metroxylon sagu). *Chemistry*. 2007;100:774–780.
31. Ahmad AN, Lim SA, Navaranjan N. Development of sago (Metroxylon sagu)-based colorimetric indicator incorporated with butterfly pea (Clitoria ternatea) anthocyanin for intelligent food packaging. *Journal of Food Safety*. 2020;40(4):e12807.
32. Bhasney SM, Patwa R, Kumar A, et al. Plasticizing effect of coconut oil on morphological, mechanical, thermal, rheological, barrier, and optical properties of poly (lactic acid): A promising candidate for food packaging. *Journal of Applied Polymer Science*. 2017;45390:1–12.
33. Jun ECH, Hanry EL, Surugau N. Effects of different plasticizer concentration on characteristics of biofilms made from semi-refined carrageenan (Kappaphycus alvarezii). *Transactions on Science and Technology*. 2020;7(3-2):113–120.
34. Liu J, Wang H, Wang P, et al. Films based on κ-carrageenan incorporated with curcumin for freshness monitoring. *Food Hydrocolloids*. 2018;83:134–142.
35. Wijayanti DA, Hintono A, Pramono YB. The protein content and tenderness of chicken nuggets with various level of broiler livers substitution. *Animal Agriculture Journal*. 2013;2(1):295–300.
36. Micinski J, Zwierzchowski G, Kowalski IM, et al. Health-supporting properties of beef. *Journal of Elementology*. 2012;17(1):149–157.
37. Poyatos-Racionero E, Ros-Lis JV, Vivancos JL, et al. Recent advances on intelligent packaging as tools to reduce food waste. *Journal of Cleaner Production*. 2018;172:3398–3409.
38. Gengatharan A, Dykes GA, Choo WS. Betalains: Natural plant pigments with potential application in functional foods. *LWT-Food Science and Technology*. 2015;64:645–649.
39. Jannah A, Murdono D. Effect of harvesting age on quantity and quality of red beet varieties ayumi 04 with hydroponic floating raft system. *Proceedings of the National Seminar of Universitas Sebelas Maret*; 2020;4(1):89–94.
40. Indonesian Ministry of Agriculture. Sago production by province in Indonesia (2017-2021). 2017.
41. Dirpan A, Hidayat SH, Djalal M, et al. Trends over the last 25 years and future research into smart packaging for food: A review. *Future Foods*. 2023;8:100252.
42. Schaefer D, Cheung WM. Smart packaging: opportunities and challenges. *Procedia CIRP 72*. 2018:1022–1027.