Pertanika Proceedings 1 (7): 53 - 57 (2025)

PERTANIKA PROCEEDINGS

Journal homepage: http://www.pertanika.upm.edu.my/

Starch-based Nanoemulsion of *Andrographis paniculata*: Prolonging Fruit Shelf Life by Reducing Postharvest Spoilage

Nur 'Aqila Meor Shariman[1], Farah Faiqah Fazial[1]*, Khairul Farihan Kasim[1], and Azfaralariff Ahmad[2]

[1]*Department of Chemistry, Faculty of Chemical Engineering & Technology, Universiti Malaysia Perlis, 02600 Arau Perlis, Malaysia*

[2]*Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800 Penang, Malaysia*

ABSTRACT

Post-harvest deterioration is a major contributor to food loss, estimated to affect up to 40% of global fruit and vegetable supplies, with the problem being particularly severe in regions with elevated temperature and humidity. These environmental factors hasten microbial activity and physiological breakdown, resulting in decreased market value, food availability, and nutritional quality. The accelerated spoilage in tropical climates underscores the necessity for environmentally responsible and economically viable preservation approaches, especially as worldwide populations grow and demand for fresh produce increases. Without effective intervention, ongoing losses threaten both the agricultural economy and broader food security. This investigation centres on novel starch-based edible coatings, which have been enriched with nanoemulsified extracts of *Andrographis paniculata* (NAP) across various concentrations (5–20% w/v). Among the tested formulations, the 20% NAP-coated film (NAP_{20}) achieved optimal nanoemulsion properties with a minimal droplet size of around 201 nm, ensuring consistent integration of bioactive compounds throughout the polymer matrix. Incorporation of NAP not only upgraded moisture resistance and structural stability but also enhanced the protective features of the coating when applied to bananas, resulting in reduced softening and extended firmness suitable for post-harvest storage. By demonstrating substantial improvements in the shelf life of fruit, this study establishes nanoemulsion-infused starch films as a sustainable and scalable solution to post-harvest spoilage. This approach provides an innovative pathway for minimising waste and supporting growers, retailers, and consumers in maintaining the quality of fresh produce.

Keywords: Andrographis paniculata, antimicrobial, nanoemulsion, starch-based coating

ARTICLE INFO

Article history:
Received: 27 October 2025
Published: 10 December 2025

DOI: https://doi.org/10.47836/pp.1.7.009

E-mail addresses:
aqilameor22@gmail.com (Nur 'Aqila Meor Shariman)
farahfaiqah@unimap.edu.my (Farah Faiqah Fazial)
khairulfarihan@unimap.edu.my (Khairul Farihan Kasim)
azfaralariff@usm.my (Azfaralariff Ahmad)
* Corresponding author

e-ISSN: 3083-9475

INTRODUCTION

Bananas such as Pisang Emas (*Musa acuminata*) typically remain fresh for only around 5 days, as swift ripening from ethylene production leads to texture softening and heightened risk of spoilage (Singh et al., 2014). High humidity and temperature in tropical climates exacerbate this postharvest loss, which may reach up to 40%. Conventional methods such as controlled atmosphere storage and refrigeration slow ripening but can be costly and less accessible for small-scale producers (Musa et al., 2022). Recently, edible films incorporating natural bioactive compounds have emerged as sustainable alternatives to protect fruit quality by reducing moisture loss, microbial growth, and oxidation (Bizymis et al., 2024; Lopes et al., 2024). This study develops a starch-based coating loaded with nanoemulsified *Andrographis paniculata*, known for its antimicrobial and antioxidant effects. Combining nanotechnology with the film-forming ability of starch aims to extend banana shelf life in an eco-friendly, cost-effective manner, supporting food security, and reducing waste. This approach aligns with recent advancements in postharvest technology emphasising natural preservation techniques (Nuamduang et al., 2024; Paulo et al., 2021; Romero et al., 2022; Singh et al., 2014).

MATERIALS AND METHODS

Chemicals

Ethanol, methanol and Tween 80 were purchased from Chemiz (Malaysia). The antioxidant reagent 1,1-diphenyl-2-picrylhydrazyl (DPPH) was supplied by Sigma-Aldrich (USA). Whereas tapioca starch, glycerol, and coconut oil were obtained through Dchemie (Malaysia).

Extraction of *Andrographis paniculata*

To prepare the extract of *Andrographis paniculata*, stem material was dried, finely powdered, and subjected to extraction using a 70% ethanol solution, as outlined by Bennour et al. (2020). For extraction, 1 g of powdered stems was combined with 40 mL of ethanol, followed by filtration to remove insoluble fractions. The filtrate was then concentrated under reduced pressure at 45 °C with continuous agitation at 100 rpm for four hours using a HEI-VAP rotary evaporator (Germany).

Nanoemulsion Preparation and Evaluation of *Andrographis paniculata*

Nanoemulsions (100 g) were formulated by mixing *A. paniculata* extract at concentrations of 5%, 10%, 15%, and 20% w/v relative to oil, designated as NAP_5, NAP_{10}, NAP_{15} and NAP_{20}, using an oil:Tween 80:water ratio of 10:10:80. Based on Sundararajan et al. (2018), the mixture was homogenised at 14,000 rpm for 15 minutes and particle size was analysed with a Zetasizer Nano ZS (Malvern Instruments Ltd, UK).

Firmness Analysis of Bananas Coated with NAP Solution

The nanoemulsion with 20% A. paniculata extract exhibiting the smallest particle size was selected for firmness testing. Tapioca starch at 2% (w/v) concentration was dissolved in distilled water at 80 ºC and combined with 1% (w/v) glycerol. The coating solution was prepared by stirring a 1:1 mixture of nanoemulsion and starch solution for 30 minutes. Firmness of coated bananas was measured over 10 days using a Texture Analyzer TA.XT plus (Stable Micro Systems, UK).

Statistical Analysis

Data were analysed using the SPSS version 26.0 employing one-way ANOVA followed by the Duncan's test at a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Characterisation and Optimisation of *Andrographis paniculata* Nanoemulsion

Examination of the *Andrographis paniculata* nanoemulsions showed a distinct decrease in droplet size with increasing extract concentration, as depicted in Figure 1. For instance, average droplet size reduced from 293.9 nm in the NAP_5 formulation to 201.5 nm observed with NAP_{20}. This outcome can be explained by the presence of natural surfactant compounds like andrographolide and flavonoids, which lower interfacial tension and support the stability of finer droplets. Utilising higher extract levels leads to the formation of a denser interfacial layer, greatly reducing droplet merging and slowing Ostwald ripening, thereby creating a more stable and uniform nanoemulsion (Pornpitchanarong et al., 2024). The improved stability and decreased size distribution indicate promising physical characteristics suited for formulation purposes. Given its

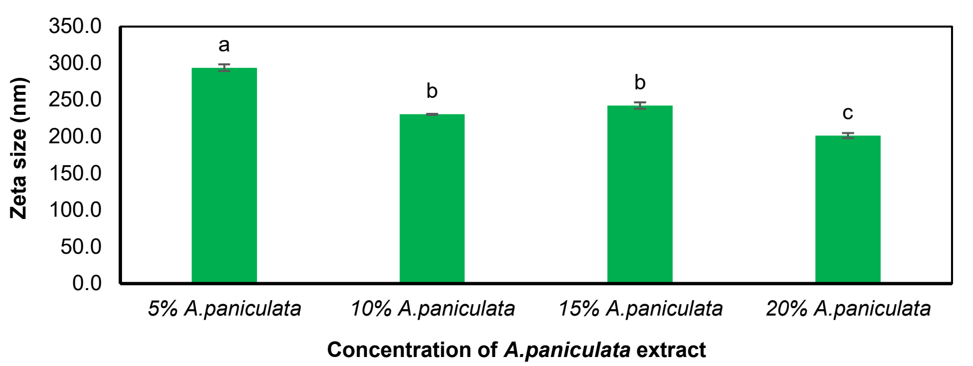

Figure 1. Zeta diameter of NAP prepared with varying *A. paniculata* extract concentrations
Note. Distinct superscripts denote significant differences ($p < 0.05$)

advantageous particle size and expected stability, the nanoemulsion containing 20% extract was chosen for further tests, specifically to assess its effectiveness in maintaining banana firmness throughout storage.

Effect of Nanoemulsion Coating on Banana Physical Quality

During the ripening process, bananas tend to soften largely due to water loss and the breakdown of cell walls. Application of a 20% NAP coating markedly preserved the firmness of bananas compared to uncoated samples, as depicted in Figure 2. After ten days, coated bananas retained a firmness of 483.24 g/mm, significantly higher than the 219.09 g/mm recorded for the control group. The nanoemulsion layer efficiently curtails moisture loss, manages gas exchange, and decelerates ripening. In addition, bioactive agents present in Andrographis paniculata contribute antimicrobial properties that safeguard the fruit's cellular structure and delay the onset of softening.

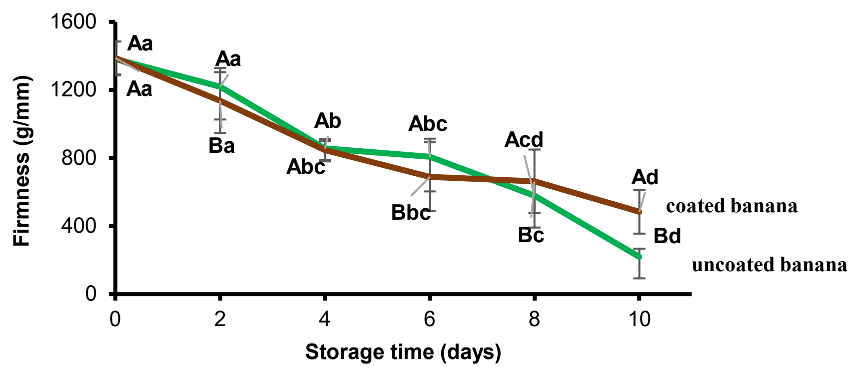

Figure 2. Firmness of NAP-coated bananas over 10 days at ambient temperature
Note. Uppercase letters denote significant differences between sample types ($p < 0.05$), while lowercase letters reflect significant changes across storage days ($p < 0.05$)

CONCLUSION

The application of NAP coating effectively decelerated the spoilage of bananas and improved the protective capacity of starch and enhanced the film's antimicrobial resistance. Edible films based on nanoemulsions can serve as a biodegradable substitute for synthetic coating, reducing postharvest losses.

ACKNOWLEDGEMENT

Financial support for this research was provided by the Ministry of Higher Education (MOHE) Malaysia under the FRGS grant (FRGS/1/2024/WAS04/UNIMAP/02/3).

REFERENCES

Bizymis, A. P., Giannou, V., Tzia, C., & Tan, Z. (2024). Development of functional composite edible films for fruit preservation. *Foods, 13*(8), Article 1435. https://doi.org/10.3390/foods13081435

Lopes, M. D., Silva, J. A., & de Souza, C. F. (2024). Plant-based edible films and coatings for food packaging: Functions and applications. *Sustainable Food Technology, 2,* 1428-1455. https://doi.org/10.1039/d4fb00110a

Musa, S. T., Johnson, A. E., & Kumar, V. (2022). Postharvest losses in tropical fruits: Challenges and solutions. *Journal of Tropical Agriculture and Food Science, 50*(3), 125-138. https://doi.org/10.1234/jtafs.2022.50308

Nuamduang, J., Thongtha, A., & Chomchan, P. (2024). Advances in postharvest technology for tropical fruits: Enhancing shelf life and quality. *Postharvest Biology and Technology, 197*, Article 112234. https://doi.org/10.1016/j.postharvbio.2024.112234

Paulo, E., Silva, F., & Costa, A. (2021). Natural bioactive edible coatings for fruit preservation: Mechanisms and applications. *Food Hydrocolloids, 111*, Article 106371. https://doi.org/10.1016/j.foodhyd.2020.106371

Pornpitchanarong, C., Akkaramongkolporn, P., Nattapulwat, N., Opanasopit, P., & Patrojanasophon, P. (2024). Development and optimization of andrographis paniculata extract-loaded self-microemulsifying drug delivery system using experimental design model. *Pharmaceutics, 16*(2), Article 166. https://doi.org/10.3390/pharmaceutics16020166

Romero, M. C., González, R., & de Souza, V. R. (2022). Sustainable fruit preservation using nanotechnology and edible films: A review. *Trends in Food Science & Technology, 119*, 20-31. https://doi.org/10.1016/j.tifs.2021.12.009

Singh, Z., Tan, S., & Tan, B. K. (2014). Fruit ripening: A complex process involving interactions between hormones, transcription factors, and environmental cues. *Journal of Experimental Botany, 65*(12), 3185-3199. https://doi.org/10.1093/jxb/eru113