https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)

ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

Effects of Storage Temperature on Shelf-Life of Mango Coated with Zinc Oxide Nanoparticles

Nur Syazwani Abdul Malek[1,2*], Nurfarhana Rosman[1,2], Mohamad Rusop Mahmood[2,3], Zuraida Khusaimi[1.2], Noor Asnida Asli[1,2*]

[1]*Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM) Selangor, Shah Alam Campus, 40450 Shah Alam.*

[2]*NANO-SciTech Centre, Institute of Science, Universiti Teknologi MARA (UiTM) Selangor, Shah Alam Campus, 40450 Shah Alam.*

[3]*Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM) Selangor, Shah Alam Campus, 40450 Shah Alam.*

Corresponding authors: nsyazwanimalek@gmail.com and nasnidaasli@gmail.com

Received: 17 December 2019; Accepted: 28 February 2020; Published: 1 June 2020

ABSTRACT

Effect of different storage temperatures on physical and physiological changes of Golden Lily mango was investigated. Zinc oxide (ZnO) nanoparticles edible coating was prepared by sol-gel method and Golden Lily mangoes were dipped in the solution and stored at different (32 ℃, 27 ℃ and 5 ℃) temperatures for 7 days. The mangoes were characterized by Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive X-ray Spectroscopy (EDX), Fourier-transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD) after 7 days of storage. Both the analysis of FESEM and EDX revealed the highest volume ratio of ZnO nanoparticles with a homogeneous dispersion throughout the mango peel surface is at 5 ℃. FTIR spectra revealed the absence of Zn–O bonding as metal oxides absorption is expected to be in the region below 700 cm^{-1}. The mangoes stored at 5 ℃ delayed ripening, slowed down weight loss and found to be firmer than mangoes stored at 32 ℃ and 27 ℃.

Keywords: *Zinc oxide nanoparticles; Edible coating; shelf-life; Field Emission Scanning Electron Microscopy (FESEM); Fourier-transform Infrared Spectroscopy (FTIR)*

INTRODUCTION

Mango (*Mangifera indica* L.) is a climacteric fruit that ripens rapidly after harvest. It is crucial to preserve post-harvested mangoes as it has a short shelf-life and high susceptibility to disease. Temperature is the most important environmental factor that will influence the deterioration of harvested fruit [3]. A proper storage temperature has great impact on reducing extension of postharvest life and retaining quality of

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

mango fruits [18]. Postharvest fungal diseases of mango fruit such as anthracnose disease caused by *Colletotrichum gloeosporioides* [2], appear as rounded brown to black lesions on fruit surface [6] can reduce fruit quality and cause postharvest losses [3]. Control of this fungal disease in a prolonged period at an optimum temperature is essential in extending the storage life and marketing period of mango fruit in both domestic and export markets.

Previously, fungicides were used to control this disease [27]. A variety of physical and chemical approaches have been tested to preserve mangoes, such as wax coating [21, 22], controlled modified atmosphere packaging [21], application of bio-agents [22] and preparation of edible coatings [26]. Among them, edible coating is an ideal approach to prolong the shelf life of mango and inhibit microbial growth [22]. Studies reported that the reparation of edible films and composite coating formulations can be made from various biopolymers such as cellulose, chitosan and proteins [27].

Zinc oxide (ZnO) is less toxic and considered safe materials which widely applied in the food industry and has generally recognized as a safe substance by the US Food and Drug Administration (FDA) 2016 [6]. ZnO nanoparticle is an excellent antibacterial agent [23] and has been one of the most promising coating materials due to its relatively high antimicrobial agent with high stability as a comparison to natural-based coating [2]. Studies reported that starch-based films have good mechanical properties with comparable tensile strength and elongation at break at ambient humidity compared to films made with synthetic polymers [24]. Recent study revealed that an edible film made from tapioca flour can produce transparent clear films [20] and high tensile values. Exhibiting a good film-forming property [24], the incorporation of ZnO and tapioca starch resulted in an excellent coating property which is particularly effective for inhibiting respiration rate, maintaining hardness and extending shelf-life of fruits.
Thus, the main objectives of this study were to find the effect of different storage temperature on extending the shelf life of mango fruit and to determine the optimum temperature on control of anthracnose diseases, weight loss and firmness in mango fruit to ensure better quality for fresh consumption and long storage of post-harvested mangoes.

EXPERIMENTAL

Edible coating solution was prepared by sol-gel method using ZnO powder, tapioca starch, and distilled water. ZnO powder was milled prior to mixing for 15 minutes. The solution was stirred for 2 hours using a hot plate stirrer at 100 ℃. Fresh Golden Lily mangoes were dipped into the solution for 10 minutes, allowed dry and placed at different storage temperatures (32 ℃, 27 ℃ and 5 ℃) for 7 days. After a week, the skin of the mangoes was peeled and left to dry for 24 hours while the remaining mango flesh was chopped into smaller pieces to prepare juice extract. The weight loss and firmness of mangoes were done at every 2-day intervals from the 0^{th} day until the 7^{th} day of the storage period while the firmness of mangoes was subjected to a texture profile analysis (TPA). In this study, the morphology, the phase composition and the absorption of functional group present on the mango surface were investigated by using Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive X-ray Spectroscopy (EDX), Fourier-transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD).

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

RESULTS AND DISCUSSION

Figure 1 illustrates the mass reduction (g) over storage period (days) of individual mangoes at 2-days intervals whereas Table 1 shows the percentage of weight loss of the individual mangoes. At 32 ℃, the recorded percentage is the highest with 19.25% which would express that there is a maximum dryness that occurred during the storage period. This result was due to the decreasing in the driving force of water movement as rehydration progressed until the system reached equilibrium [8]. The process of degradation in the structural compounds becomes greater at higher temperature [28], thus accelerating the reduction in the firmness of fruit. Low storage temperature delayed fruit softening and affected the activities of fruit softening enzymes in the flesh thus sowing down its textural deterioration [19].

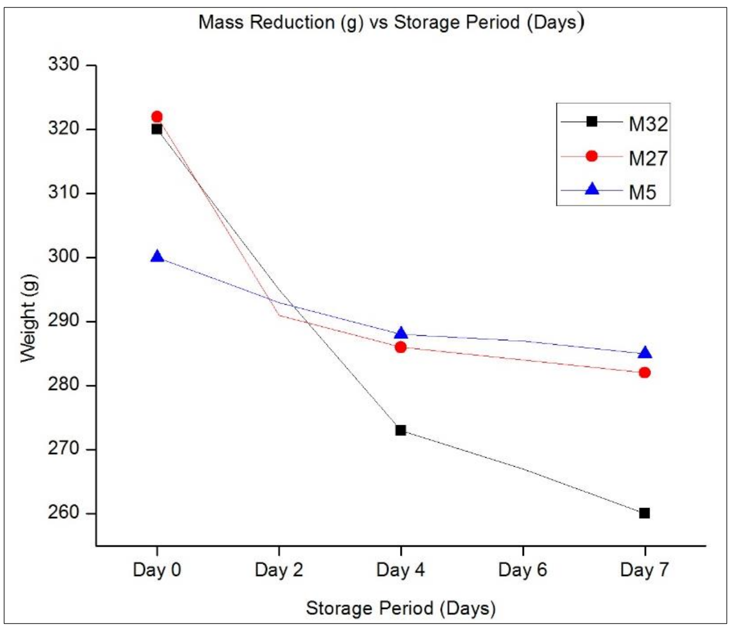

Figure 1: Graph of mass reduction of Golden Lily mangoes during storage period.

Table 1: Physical changes of Golden Lily mangoes after 7 days of storage.

Mango	Day 0 (g)	Day 7 (g)	Percentage (%) weight loss
M32	341	90	73.61
M27	340	90	73.53
M5	363	123	66.11

ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

The loss of weight in fruits would probably as in the loss of moisture through transpiration and during the respiration process. It was also stated that a lower physiological loss in weight at a lower storage temperature might possibly of lesser water vapor inadequacy compared to at ambient conditions which have slowed down the metabolic activities of the fruits. A detailed examination of physiological weight loss in fruits was possibly on account of the loss of moisture through transpiration and utilization in respiration process [7]. Agustini [9] also stated that a higher percentage of moisture content loss will affect storage quality as there will inhibit the growth of mold and agglomeration.

Figure 2 shows M5 mango has greater firmness with 2110.6 N while M32 and M25 with only 872 N and 857 N respectively. The variation of hardness was from textural alteration due to loss of fracture strength. As expected, the strength of internal bounds in the fruit was highest when stored at a 5℃ than at 32℃. The firmness of fruits is related to the cell wall structure and architectural changes [10] occurred during fruit development and ripening. During maturation, the tissue changes within the fruit increase fruit softening at a higher temperature. It is the result of an increase in the enzymatic activity of fruit which provokes changes in its structural cell wall during the ripening process and thus reduced its firmness [10].

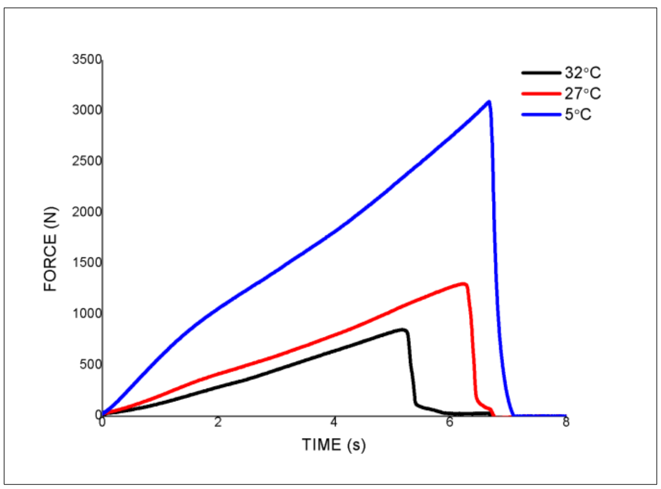

Figure 2: The comparison of compression force in Texture Profile Analysis (TPA).

Mangoes reported to be technically less acidic and estimated to have a pH value ranging from 5.8-6.0 [8], however, as tabulated in Table 2, only mango M5 was recorded to obtain a pH value nearest to the estimated value. A possible explanation for these results may be due to oxidation of acid [17] and the acidic composition of the mango pulp during storage. Mangoes vary in their acidity depending on how ripe and how they were ripened [9]. An increment in pH value would be caused by the breakup of acids with respiration during storage period [12]. It was also stated that the changes are significantly affected by the rate of metabolism especially respiration, thus declining the acidity. In accordance with the results, Appiah *et al.* [13] stated that the declining could be due to the susceptibility of citric acid to oxidative destruction as impacted by the ripening process. The decreases in acidity were due to the reduction in sourness with the potential of improving the sweet taste during the storage period [13]. Lower temperature storage has

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

allowed mango to ripen at a slower rate thus attributed to the increased activity of enzymes responsible for the hydrolysis of starch into soluble sugars [12].

Table 2: pH value and Total Soluble Slid (TSS) of mango juices at three different temperatures.

Mango	Temperature (°C)	pH Value	Sugar Content (◦ Brix)
M32	32	4.80	2%
M27	Room Temperature	4.98	2%
M5	5	5.33	3%

Figure 3 (a,b,c) shows that ZnO nanoparticles were found to be in an agglomerated smooth spherical shape. This could be explained as a result of the preparation conditions and physical structure. Agglomeration in the result obtained was due to the presence of tapioca starch that was used as a binding agent. A possible account for this outcome could also due to the hydrophobic and electrostatic interactions between ZnO nanoparticles and derived calcium of the tapioca starch which leads to a strong binding [11].

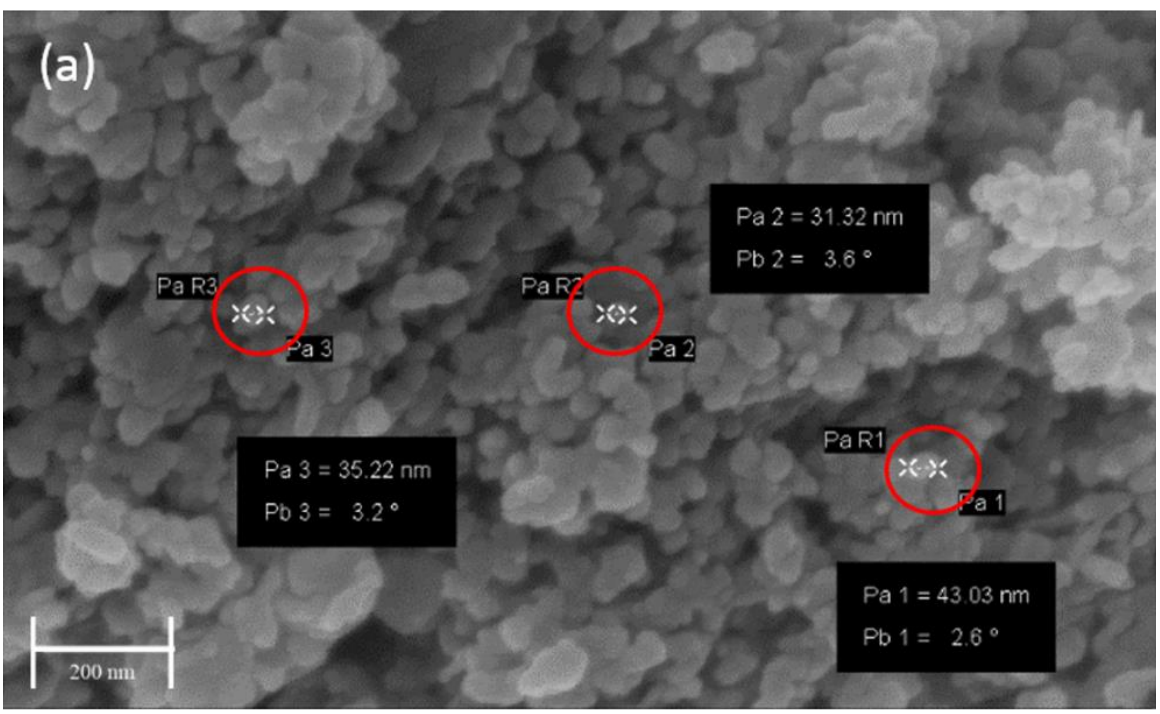

Figure 3(a): FESEM micrograph of ZnO nanoparticles at different storage temperature at 32 ℃.

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)

ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

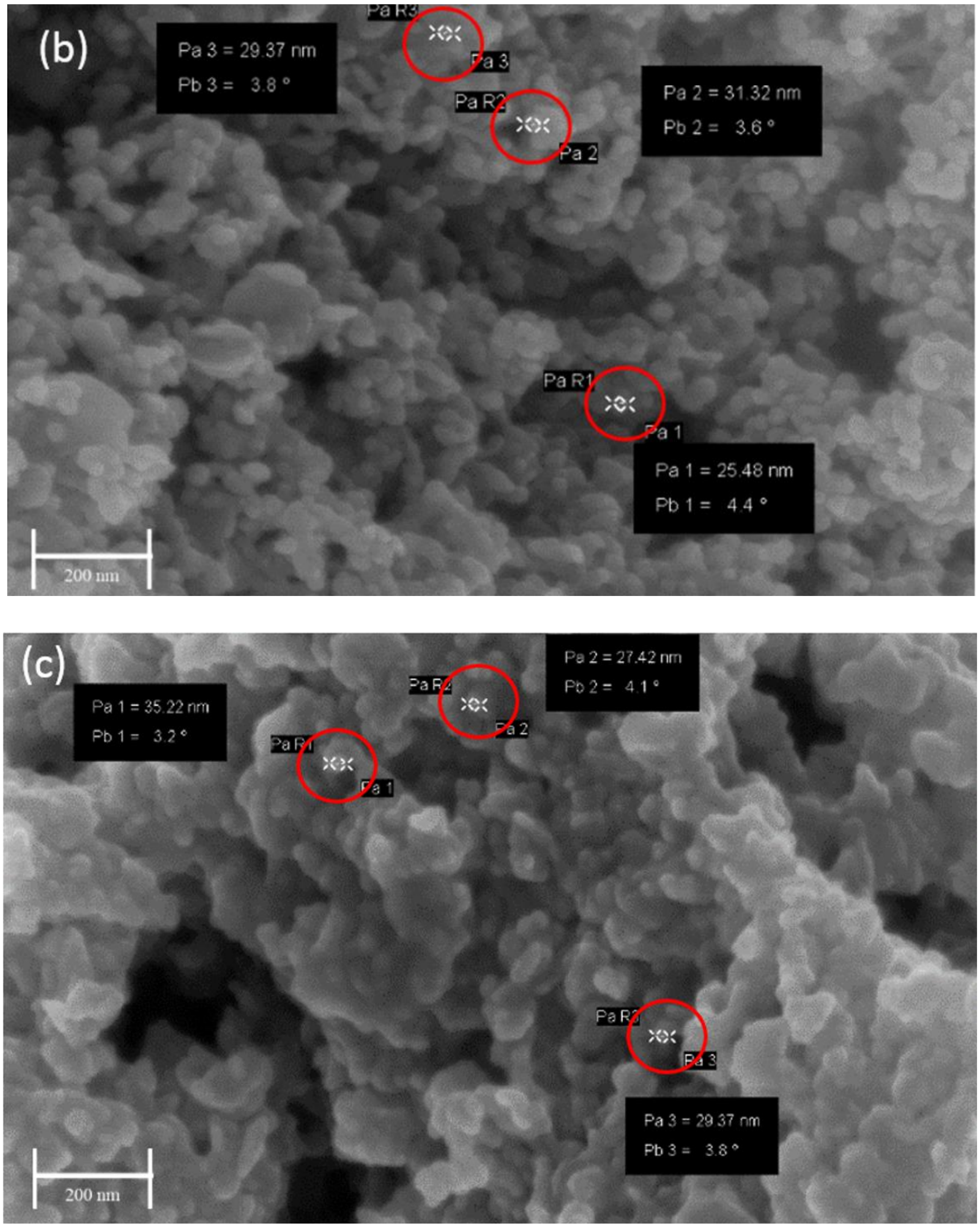

Figure 3(b&c): FESEM micrograph of ZnO nanoparticles at different storage temperature: (b) 27 ℃ and (c) 5 ℃.

ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

Also, in Figure 4, the EDX spectrum displays known peaks of elements that were present on the mango peel which is zinc (Zn), oxygen (O) and carbon (C). Strong signals were observed at 1 keV and 0.5 keV, which correspond to the presence of Zn and O respectively. The highest amount of Zn was found on the mango peel stored at 32 ℃ (Figure 4a) whereas the lowest was found on the mango peel stored at 5 ℃ (Figure 4c). A high sintering temperature is known to provide a larger driving force for internal atomic diffusion which responsible for grain growth of metal oxides [25].

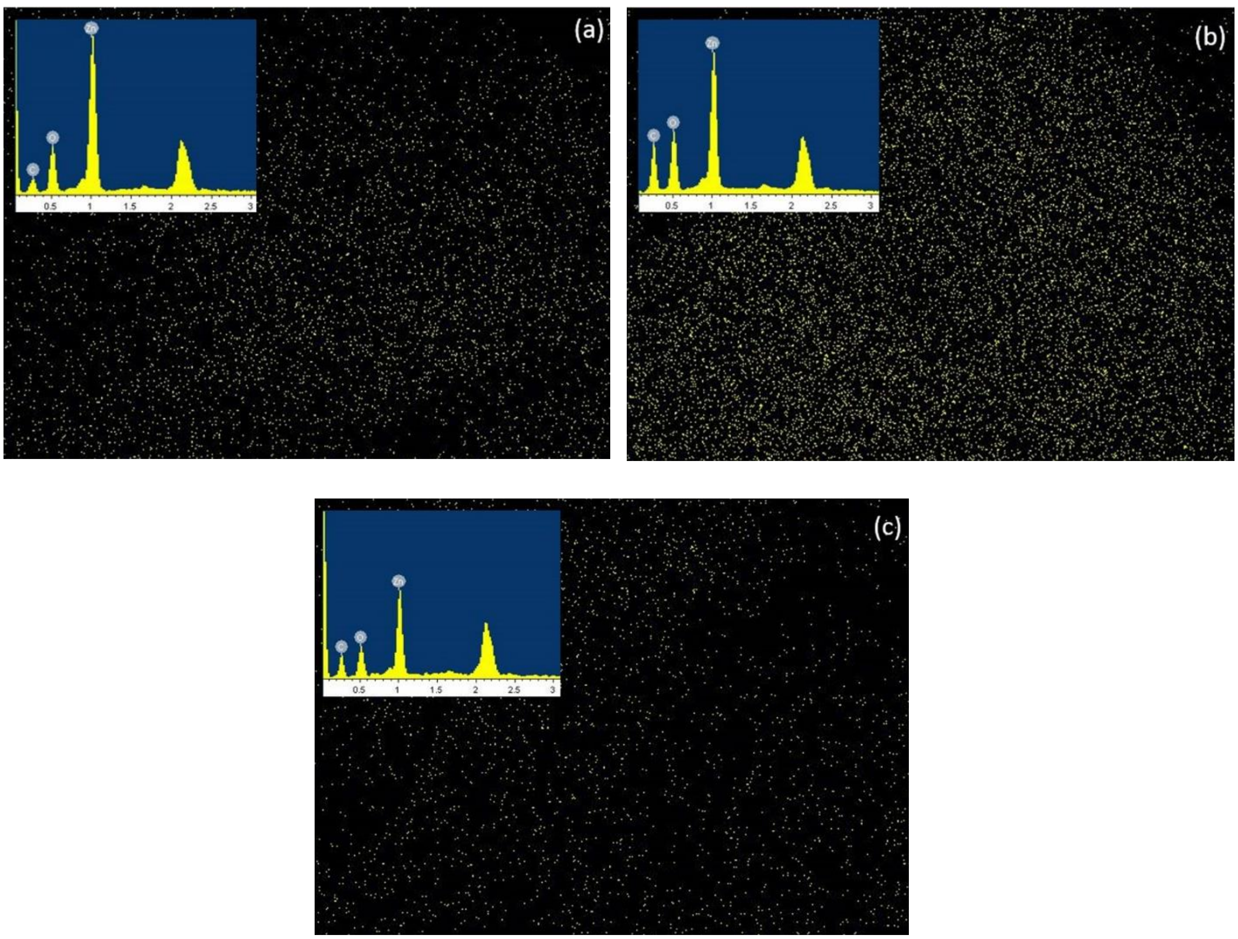

Figure 4: EDX analysis and mapping of ZnO nanoparticles at different storage temperature: (a) 32 ℃, (b) 27 ℃ and (c) 5 ℃.

ZnO nanoparticles have been dispersed randomly on the surface of mango peel in Figure 5. The overall average particle size ranging from 21–44 nm. This could also correlate with the agglomeration of ZnO and tapioca starch. The agglomeration may have influenced the size distribution which leads to different grain sizes [11]. The diameter represents the maximum penetration depth of the primary electron from the effect of the backscattered electrons (BSE) and secondary electron (SE).

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

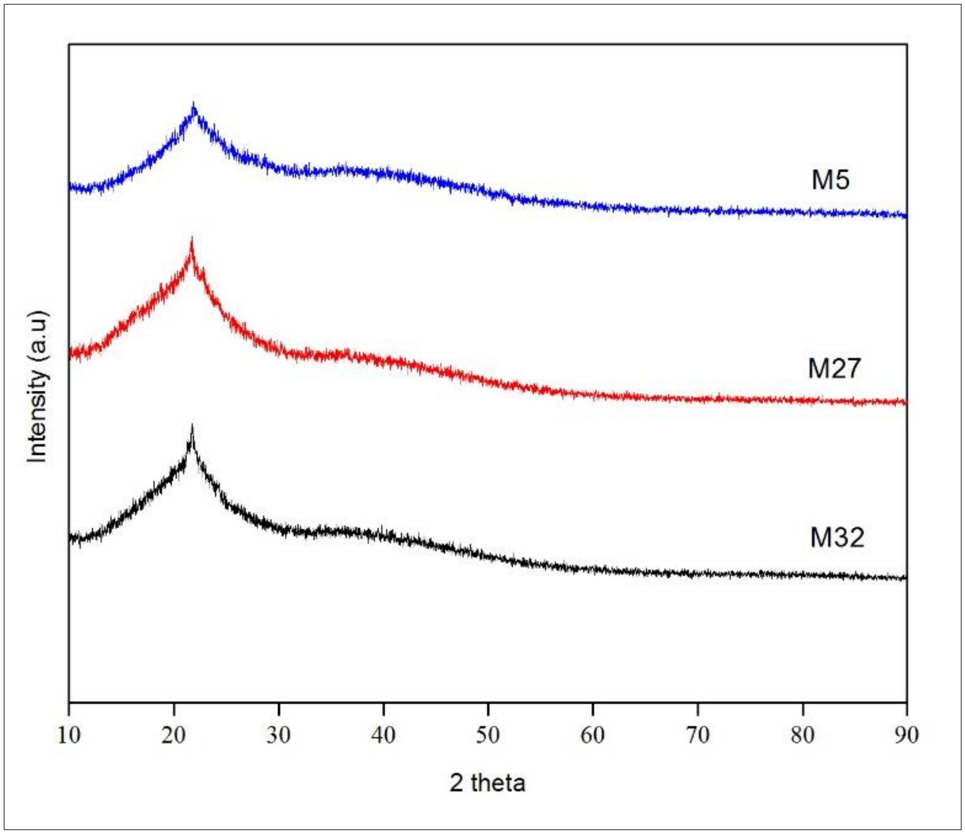

Figure 5: X-ray diffraction profiles of ZnO nanoparticles at 32 ℃, 27 ℃ and 5 ℃ storage temperature.

A broad and wide peak which indicates an amorphous pattern graph was observed on all mango samples. Aside from Zn, there were also no peaks from other phases that were found which also suggests that there are no other products were obtained on the mango peel. A possible explanation for these results may be due to crystallite size and instrumental profile. The broadening of a single diffraction peak could also arise due to the lower intensity of metal oxides than the instrumental detection limit and thus was not able to be detected [16].

The absorption peaks observed at 3253 and 3688 cm^{-1} were due to O–H stretching [2, 15, 16]. These peaks can be attributed to the characteristic absorption of the hydroxyl group [15]. A strong and sharp peak ranged between 2849 to 2915 cm^{-1} corresponds to C–H stretching of an aldehyde (Figure 6). The weak and broad peak observed at 722 to 727 cm^{-1} identified the absorption bands of Zn–O bond. Metal oxides such as ZnO commonly give absorption bands in the region below 800 cm^{-1} arising from inter-atomic vibrations [2]. The spectrum of Zn–O might be shifted to lower wavenumber due to the stress acting on ZnO nanoparticles and variation in morphology which might due to deterioration of peaks with the increase of temperature during storage period [14].

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

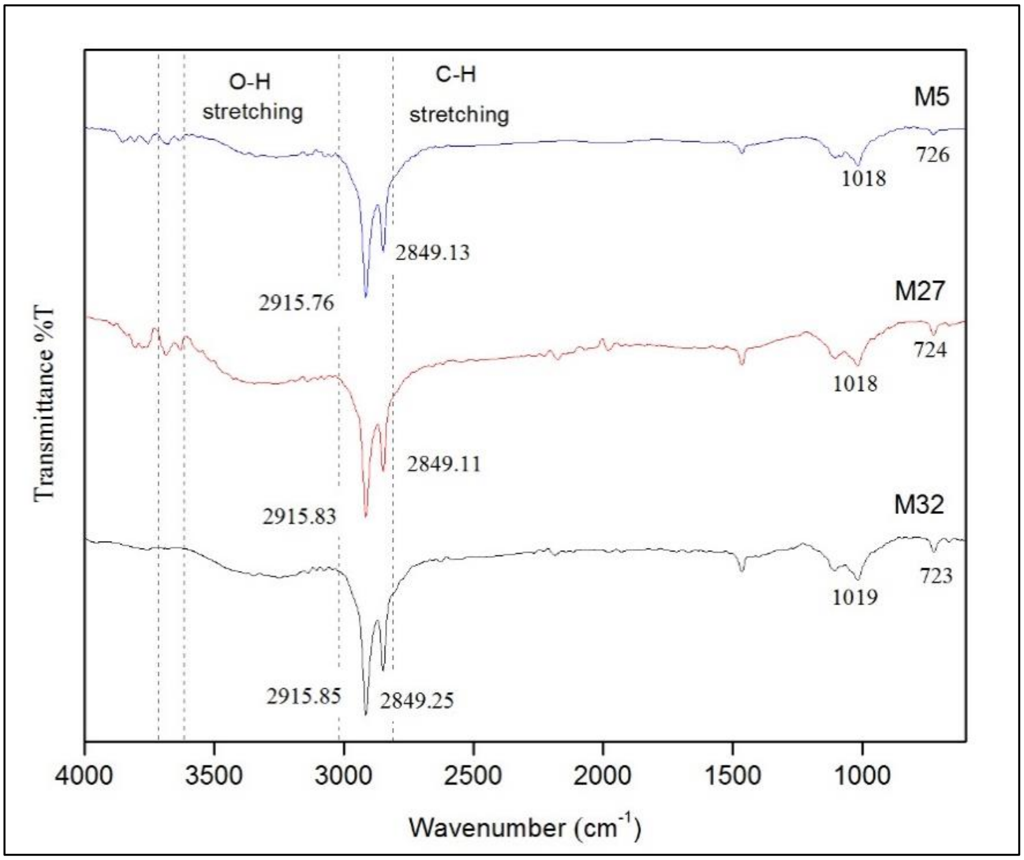

Figure 6: FTIR spectrum of ZnO nanoparticles at 32 ℃, 27 ℃ and 5 ℃ storage temperature.

CONCLUSIONS

The effect of different (32 ℃, 27 ℃ and 5 ℃) storage temperature on extending the shelf life and controlling of anthracnose diseases, weight loss and firmness on Golden Lily mango fruit was done in this study. Each storage temperature affected the mango qualities differently. This study showed that the storage temperature of 32 °C resulted in an accelerated decrease in fruit firmness, cohesiveness, and resilience. A maximum shelf-life of 7 days for mangoes stored at 5 ℃ while a maximum of 2 days for mangoes stored at 32 ℃ and 27℃. The most obvious finding emerged from this study is that the ability of ZnO-Starch coating in minimizing the growth of anthracnose disease increases at lower temperature storage. According to the result obtained, the ability of ZnO in prolonging the shelf-life of Golden Lily mango is found below 5 ℃. Storage temperature of 5 °C is found to be favourable for delaying textural changes and maintaining the shelf life of the Golden Lily mangoes. Therefore, the results could provide some insights into the postharvest storage temperature of Golden Lily mango in markets and households.

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

ACKNOWLEDGMENTS

Greatest gratitude to Ministry of Higher Education Malaysia, Nano SciTech Centre (NST), Faculty of Applied Sciences UiTM Shah Alam, Institute of Science (IOS) UiTM Shah Alam for the technical support and Research Management Institute, UiTM Shah Alam for financial support under grant number 600-IRMI/FRGS/5/3.(415/2019).

REFERENCES

[1] Baloch, M. K., and Bibi, F, Effect of harvesting and storage conditions on the post-harvest quality and shelf life of mango (*Mangifera indica* L.) fruit, South African Journal of Botany, 83:109–116 (2012).

[2] Kalpana, V. N., Kataru, B. A. S., Sravani, N., Vigneshwari, T., Panneerselvam, A., and Devi Rajeswari, V, Biosynthesis of Zinc oxide nanoparticles using culture filtrates of Aspergillus niger: Antimicrobial textiles and dye degradation studies, OpenNano, 3(6): 48–55 (2018).

[3] Kanade, N. M., Pawar, C. D., Ghule, V. S., Gajbhiye, R. C., and Salvi, B. R., Effect of Different Precooling and Storage Temperatures on Shelf Life of Mango cv. Alphonso, International Journal of Current Microbiology and Applied Sciences, 6(11):845–855 (2017).

[4] Lakshmi, S. J., and Sharanagouda, H., Effect of biosynthesized zinc oxide nanoparticles coating on quality parameters of fig (*Ficus carica* L.) fruit, Journal of Pharmacgnosy and Phytochemistry. 7(3):10–14 (2018).

[5] Misra, A. K., Post-harvest diseases of mango and their management. Global Conference on Augmentating Production and Utilization of Mango: Biotic and Abiotic Stresse, Uttar Pradesh, India, Central Institue of Subtropical Horticulture. 137-144 (2016).

[6] Sothornvit, R., and Klangmuang, P., Active Edible Coating to Maintain The Quality of Fresh Mango. Acta Horticulturae, 1079:473–480 (2015).

[7] Yadav, M. K., Singh, P., and Singh, P., Irradiation and Storage Temperature Influence the Physiological Changes and Shelf Life of Mango (*Mangifera indica* L.), American Journal of Plant Biology, 2(1):5–10 (2017).

[8] Ansari, S., Farahnaky, A., Hosseini, E., and Badii, F., Effect of moisture content on textural attributes of dried figs. International Agrophysics, 28(4):403–412 (2014).

[9] Agustini, S., The Characterization of Mango (*Mangifera indica* L.) Powder of Various Drying Temperature, Journal of Physics: Conference Series, 1095 (2018).

[10] Nyorere, O., and Uguru, H., Instrumental Texture Profile Analysis (TPA) of Cucumber Fruit as Influenced by Its Part and Maturity Stage, American Journal of Engineering and Technology Management, 3(4):54–60 (2018).

[11] Kiranda, H. K., Mahmud, R., Abubakar, D., and Zakaria, Z. A., Fabrication, characterization and cytotoxicity of spherical-shaped conjugated gold-cockle shell derived calcium carbonate nanoparticles for biomedical applications, Nanoscale Research Letters, 13(1) (2018). 2018 Jan 2;13(1):1

[12] Zakir, H. M., Fardush, J., Hossain, M. S., Islam, M. Z., Shariar, S. M. S., Rokshana, K., and Hossian, M., Effects of Storage Temperatures on different Biochemical Characteristics of 1-Methylcyclopropene Treated Mango (*Mangifera Indica* L.)Variety Khirshapat, American Journal of Food Science and Technology, 6(2):76–82 (2018).

[13] Appiah, F., Kumah, P., and Idun, I., Effect of Ripening Stage on Composition, Sensory Qualities and Acceptability of Keitt Mango (*Mangifera indica* L.) Chips, African Journal of Food, Agriculture, Nutrition and Development, 11(5):5096–5109 (2011).

[14] Sowri Babu, K., Ramachandra Reddy, A., Sujatha, C., Venugopal Reddy, K., and Mallika, A. N., Synthesis and optical characterization of porous ZnO. Journal of Advanced Ceramics, 2(3):260–265 (2013).

[15] Khan, M., Naqvi, A. H., and Ahmad, M., Comparative Study of The Cytotoxic and Genotoxic Potentials of Zinc Oxide and Titanium Dioxide Nanoparticles, Toxicology Reports, 8 (2015).

https://scilett-fsg.uitm.edu.my/
Science Letters, **14**(2): 47-57 (2020)
ISSN: 1675-7785
eISSN: 2682-8626
DOI: 10.24191/sl.v14i2.9542

[16] Parthasarathy G, Saroja M, and Venkatachalam M., Bio-Synthesized Nano-Formulation of Zinc Oxide-Aloe Vera and to Study Their Characterization and Antibacterial Activities Against Multiple Pathogens, International Journal of Pharmaceutical Sciences and Research, 8(2):900–907 (2017).

[17] Islam, M. K., Khan, M. Z. H., Yeasmin, S., Ali, M. K., and Uddin, M. H., Postharvest quality of mango (*Mangifera indica* L.) fruit affected by different levels of gibberellic acid during storage, Malaysian Journal of Analytical Sciences, 17(3):499–509 (2013).

[18] Patel, B. B., Roy, F. S., Saiyad, M. J. S., & Joshi, D. C., Respiration behaviour and heat of respiration of mango (*cv*. Langdo) under different storage conditions, International Journal of Agriculture, Environment and Biotechnology, 9(5):855 (2016).

[19] Noiwan, D., Suppakul, P., Joomwong, A., Uthaibutra, J., & Rachtanapun, P., Kinetics of Mango Fruits (*Mangifera indica* cv. 'Nam Dok Mai Si Thong') Quality Changes during Storage at Various Temperatures, Journal of Agricultural Science, 9(6):199 (2017).

[20] Rostini, I., Pratama, R. I., & Rochima, E., Characterization of Bioplastic Packaging from Tapioca Flour Modified with the Addition of Chitosan and Fish Bone Gelatin, 85–98 (2019).

[21] Meindrawan, B., Suyatma, N. E., Wardana, A. A., & Pamela, V. Y., Nanocomposite coating based on carrageenan and ZnO nanoparticles to maintain the storage quality of mango, Food Packaging and Shelf Life, 18(October), 140–146 (2018).

[22] Li, J., Sun, Q., Sun, Y., Chen, B., Wu, X., & Le, T., Improvement of banana postharvest quality using a novel soybean protein isolate/cinnamaldehyde/zinc oxide bionanocomposite coating strategy, Scientia Horticulturae, 258 (2019).

[23] Yusof, N. A. A., & Zain, N. M., The effect of ZnO nanoparticles on the physical, mechanical, and antibacterial properties of chitosan/gelatin hydrogel films, Jurnal Teknologi, 81(2):21–26 (2019).

[24] Kim, S. R. B., Choi, Y. G., Kim, J. Y., & Lim, S. T., Improvement of water solubility and humidity stability of tapioca starch film by incorporating various gums, LWT - Food Science and Technology, 64(1):475–482 (2015).

[25] Sendi, R. K., & Mahmud, S., Effect of Temperature Treatment on the Properties of ZnO Nanoparticle-Bi_2O_3-Mn_2O_3 Varistor Ceramics. 2012 10th IEEE International Conference on Semiconductor Electronics, ICSE 2012 - Proceedings, 163–167 (2012).

[26] Dubey, P. K., Shukla, R. N., Srivastava, G., Mishra, A. A., & Pandey, A., Study on Quality Parameters and Storage Stability of Mango Coated with Developed Nanocomposite Edible Film, International Journal of Current Microbiology and Applied Sciences, 8(04):2899–2935 (2019).

[27] Srinivasa, P. C., Baskaran, R., Ramesh, M. N., Harish Prashanth, K. V., & Tharanathan, R. N., Storage studies of mango packed using biodegradable chitosan film, European Food Research and Technology, 215(6):504–508 (2012).

[28] Sierra, N. M., Londoño, A., Gómez, J. M., Herrera, A. O., & Castellanos, D. A., Evaluation and modeling of changes in shelf life, firmness and color of 'Hass' avocado depending on storage temperature, Food Science and Technology International, 25(5):370–384 (2019).