Characteristics and postharvest life of snake fruit (*Salacca edulis* Reinw) during storage as influenced by application of activated nanostructured natural zeolites

Widayanti, S M¹, Hoerudin¹, and Ismayana Andes²

¹Indonesian Center for Agricultural Postharvest Research and Development, Indonesian Agency for Agricultural Research and Development, Jl. Tentara Pelajar No. 12, Bogor 16114, Indonesia
²Department of Agroindustrial Technology, Bogor Agricultural University, Jl. Raya Darmaga Kampus IPB Darmaga, Bogor 16680, Indonesia

E-mail: sm.widayanti@gmail.com

Abstract. *Salacca edulis* Reinw Cv. Pondoh or “Salak Pondoh” is an important exported fruit native to Indonesia. The fruit is highly perishable and hence has a very limited postharvest life for export. This study aimed to investigate effects of activated nano-zeolites application on physico-chemical properties and postharvest life of “Salak Pondoh” during storage. Mordenite and mordenite-clinoptilolite types of nano-zeolites (sized 395–400nm) were prepared by ball-milling method, activated in alkaline conditions, and finally calcinated. Sacheted nano-zeolites and bio-disinfected fresh “Salak Pondoh” were packed in perforated LDPE bags, stored at 10±2°C for 25d. Results showed that the fruits packed without nano-zeolites started to show quality damages on their flesh after 15d of storage, although their skin remained intact. Meanwhile, the skin and flesh of fruits packed with activated nano-zeolites remained intact and fresh after 25d of storage. This was confirmed by their physico-chemical properties comparable to those of “Salak Pondoh” for fresh consumption. The presence of activated nano-zeolites (regardless of their types) gave 10-20% lowered RH values that may retard decaying process. These results suggest the potential use of activated nano-zeolites as atmosphere-modifying agents in food packaging for extending the postharvest life of “Salak Pondoh” and other related fresh fruits.

1. Introduction

Snake fruit is one of Indonesia’s native tropical fruits [1] as well as a leading export commodity that has high economic value and have competitive power both in national and international markets. One of the agricultural development strategies 2015-2019 is to increase the competitiveness of agricultural products through standardization of products and processes, improving supply chains, quality and food safety [2]. This is in accordance with the policies and commitments of the Minister of Agriculture to increase Indonesian Snake fruit export [3].

After harvested, Snake fruit will still have a metabolic process. One of the metabolic processes in fresh fruit is the respiration process [4]. In the respiration process, carbon dioxide (CO₂) and moisture will be produced. In a certain amount, the two gases can cause a decrease in fruit quality. Snake fruit will rot quickly due to the presence of water which support the microorganisms growth [5]. According to Supriadi [6], the shelf life of fresh Snake fruit in natural conditions (temperature 29 oC and relative humidity 71%) varies between 5-10 days. Therefore, controlling CO₂ and moisture during storage is expected able to extend their shelf life.

The control of atmospheric conditions for fresh horticultural products storage has encouraged the development of various packaging technologies, including active packaging. In the active packaging, a substances that have certain functional properties are added to modify the environmental conditions in the packaging during storage, such as CO₂ gas adsorber and moisture [7]. Recently, the use of zeolites in industry and agriculture is growing because it has functional properties that act as cation exchangers, molecular filters, catalysts, and gas adsorber [8,9,10,11,12,13].
This study aimed to investigate effects of application of activated nano-zeolites on physico-chemical properties and postharvest life of “Salak Pondoh” during storage. It is expected able to extend the shelf life and at the same time reduce the loss of production of fresh horticultural products (Snake fruit).

2. Material and methods
2.1 Research Site
The research was carried out in testing and development laboratory, Bogor Agricultural Postharvest Center in 2016.

2.2 Materials and tools
Salak Pondoh originated from Sleman, Yogyakarta is harvested at a maturity level 60% -70% and zeolite is taken from Tasikmalaya. The tools used are refractometer, chromameter, texture analyzer.

2.3 Preparation of activated nano zeolites
The zeolite obtained from Tasikmalaya, West Java. The first step was reducing the size of the zeolite particles to less than 1 micron (1000 nm) using planetary ball milling. Furthermore, zeolite was physically activated (by heating in the furnace at 400 °C for 6 hours) and chemically activated by soaking in NaOH 1 N solution for 24 hours. The zeolite was then neutralized by using distilled water and centrifuged with a rotating speed of 8000 rpm [14]. The activated zeolite was then dried using an oven at 80°C for 12 hours or until the zeolite became dry. The zeolite was then packed using cellulose paper, each package contained approximately 5g of activated zeolite. Nano-zeolite as CO₂ and moisture absorber was ready to use. Whereas in the combination of activated-nano-zeolite and KMnO₄ nano zeolite, the weight ratio was 3.5:1.5 grams. Treatment application to snake fruits:

a. Snake fruit with a weight of 0.5 kg each (for 1 treatment) was treated by soaking in galangal extract solution as antimicrobial (1) and not soaked in galangal extract (NL). Then, the Snake fruit was packed with LDPE plastic with 0.04 mm of thickness and 72 holes. Nano-zeolite was put into the package with (a) activated zeolite + KMnO₄; (b) activated zeolite (CO₂ and H₂O absorber) and (c) control (without activated zeolite)

b. The packed Snake fruit was then stored at a temperature of 10°C (T1) and room temperature (T0)

c. The study was using a completely randomized design (CRD) with 2 replications. Observations were made on the packaging condition of Snake fruit (CO₂ and H₂O absorber), physical quality (color, texture, weight loss), chemical quality (pH, water content, total soluble solids), sensory quality and Moisture absorption test which is tested by re-measuring the amount of aquadest (25 ml) poured into the pieces of snake fruit peel after 24 hours of treatment. The reduced amount of aquadest is used as the basis for determining the ability of the snake fruit peel to hold water.

d. Observations were made until the fruit’s condition wasn’t consumable physically and sensory.

3. Result and Discussion
3.1 Temperature and Relative Humidity (RH) in the package
The recorded temperature and relative humidity (RH) conditions in the packages with and without zeolite during storage was performed to determine the effect of nano-zeolite application on the packaging atmospheric conditions, and then compared to the temperature of cold room. The results of the recorded temperature and RH conditions are presented in Figures 1 and 2.

From the e-button data inserted in several Snake fruit packages, it is known that the RH value was smaller for 30 days of storage compared to the control. The ideal RH in the packaging of horticultural product such as fruit is around 85%. The RH will maintain the freshness of the product by reducing its evapotranspiration rate. RH values above 95% are also undesirable for a packaging environment because will cause the product to decay quickly. Humid environment will trigger the growth of
unwanted microorganisms, which causes the packaged products to be damaged more quickly [15]. This happened in the control treatment where the RH in the package reached 100%.

![RH conditions](image1)

**Figure 1.** RH conditions

Figure 1 shows that there are differences in RH conditions between inside and outside packages, as well as between packages with and without nano-zeolite. During storage, RH in the package was higher than the outside of the package. This might be related to the presence of moisture from Snake fruit respiration in the packaging. The relative humidity in activated nano-zeolite package (average 85-95%) was lower than without activated nano zeolite (average 98-100%). This shows that the activated nano-zeolite was able to absorb moisture in the packaging. The ideal RH in the packaging of horticultural products such as fruit ranges from 85 to 95%. With such RH, it is hoped that it will maintain product freshness by reducing its evapotranspiration rate.

![Temperature conditions](image2)

**Figure 2.** Temperature conditions in the package

Figure 2 shows a temperature graph recorded by the e-button during the storage process. Moisture production creates cooler air conditions and thus lowering the temperature. Conversely, CO₂ production creates hot air conditions and thus increasing temperatures. This observation indicates that the production of moisture from snake fruit respiration was higher than the CO₂ gas production. Meanwhile, the temperature conditions inside the Snake fruit packaging with and without nano-zeolite during storage was not different too much. According to Paul [16], cold temperature storage conditions for tropical fruits provide additional advantages, especially on non-physical parameters such as fruit texture and aroma. Thus, the quality of the fruits will be maintained longer at cold storage than at room temperature.
3.2 Moisture content

3.2.1 Peel moisture content

The initial skin moisture content of the control and the treated ranged between 77.20 - 78.22% thus there was no significant difference between the raw materials of Snake fruit. From observations, the storage temperature affected the moisture content of the fruit skin. The control which is packaged and stored in cold storage at 10°C can be stored for 25 days with a skin moisture content of around 72%. For the control without packaging, skin moisture content was very low, around 13-14%, because the RH in the cooled room was low enough so that the skin had very high evapotranspiration, it made the skin very dry and difficult to peel. This was slightly different to the controls stored at room temperature. Storage time was up to 10 days but with slightly higher moisture content, ranging from 15% - 20%. From these findings, it can be seen that the temperature and packaging affect the shelf life of the Snake fruit. The shelf life of control which was packaged and stored at 10 °C was longer than controls which was stored at room temperature. One indicator of fruit damage is the skin moisture content. Dry snake fruit skin makes it difficult to remove the skin from the pulp. In such conditions the fruit is unfit for consumption.

The use of LDPE plastic packaging affects the moisture content of the fruit. Packaging can maintain the evapotranspiration rate so that the packaged fruit has a higher moisture content than without packaging. Soaking of control fruit in galangal extract solution, which acts as an anti-fungal, gave a significant effect. Non-soaking control treatment lasted for about 15 days, while the soaked control lasted up to 25 days at 10°C of temperature. Snake fruit control and treatment which stored at room temperature only lasted up to 10 days.

The treatment combination between activated zeolite as CO₂ and moisture absorber and nano zeolite-KMnO₄ as ethylene absorber was also studied to see the effect of the combination to maintain the quality of Snake fruit during storage. Although the fruit is a non-climacteric, it still produces ethylene in the ripening process even though in very small quantity[17].

Figure 3 shows that at application of nano zeolite-KMnO₄, the skin moisture content is higher than without KMnO₄. This is presumably because the amount of zeolite used as CO₂ and moisture absorber is become low, namely 3.5 g, compared to those without nano zeolite-KMnO₄, which is 5 g.

![Figure 3. Snake fruit skin moisture content during storage](image-url)

3.2.2 Fruit flesh moisture content

The initial moisture content of the fruit flesh used in this study was 77.4%. Observations show that control treatment stored at 10 °C for 25 days had average flesh moisture content around 79 -82%, while the treatment had a longer shelf life, namely up to 30 days, with a moisture content ranged from 79.04% -81.95%. Control and treatment fruit stored at room temperature is only lasted for 10 days with a moisture content around 80%.

Galangal extract effected on the snake fruit flesh moisture content. The shelf life of 5 days longer than control without soaked at galangal extract. Application of zeolite as CO₂ and moisture absorber
did not affect the moisture content of the fruit flesh. This proves that the bark can properly protect the flesh from evapotranspiration.

3.3 Weight Loss
Weight loss is one of the parameters observed during fruit storage. Fruits with high weight loss have been damaged or not suitable for consumption because the physical condition has changed to wrinkles or its freshness has decreased[9]. The shelf life of control and treated fruits which were stored at room temperature was only lasted up to 9 days. This is consistent with several studies on the shelf life of Snake fruit. Weight loss during storage was relatively small.

The weight loss of control which was stored at 10 °C for 25 days and treatment for 30 days was measured based on the initial weight minus the final weight. The data obtained has a standard deviation between 0.5-1.5. From the data, on the day 25th, control and treatment had a damage level less than 30%. Weight loss in control snake fruit was higher than treated snake fruit, as well as fruit without packaging (K3, K4, K7 and K8 at cold temperatures and K1, K2, K15 and K16 at room temperature). As shown in the graph, the weight loss value of the 8 treatments ranged from 50-75 g. This indicates that without packaging, the evapotranspiration process of the fruit will be higher, especially with the low RH environmental conditions.

The graph also shows that treatment with perforated plastic, soaked in galangal solution, application of CO₂ and moisture absorber and keeping it at cold temperatures, gave the best results.
with weight loss values ranging from 2-15 g per treatment. Snake fruit can be stored at 25 °C for 25 days with damage rate less than 30%.

3.4 Total Soluble Solids
Total soluble solids (TSS) are defined as the amount of organic (including organic acids) and inorganic matter contained in the fruit [17]. In general, raw fruit has a lower TDS than ripe fruit, because during storage, the metabolic process of the fruit continues, which causes chemical and physical changes in fruit such as changing starch to simple sugars, decreasing organic acids, and decreasing fruit hardness due to degraded pectin.

Observations on TSS showed that during storage, the TSS value did not change significantly, even some of the treatments had decreased. Snake fruit harvested at 70% maturity level had a TDS value ranging from 16.6-20.0 with a pH of 4.3 - 4.7. At the end of the 30-day storage period, the average TDS of Snake fruit was 17.4-21.0 and pH 4.6 - 5.5. The standard deviation of the data obtained ranged from 0.1 to 1.0. This is because the snake fruit is non-climacteric fruits. Non-climacteric fruits are fruits that do not have peak respiration. Lacking a climacteric peak causes the fruit not to have enough energy for metabolic processes which can change the chemical and physical content of the fruit. This is the reason why the quality of non-climacteric fruit will be largely determined by the harvesting age. Non-climacteric fruit does not undergo a “ripening” process.

3.5 Color
3.5.1. Peel Color
Skin color of the Snake fruit during storage changed, although it was not significant. This can be seen from the L (light) value which initially 27.0 changed to 28.0-29 after 25 to 30 days of storage. Snake fruit harvested at optimum aging will have darker and brighter color during storage. Meanwhile, from the degree of hue, the control was brighter (hue value between 57 – 63) than the treatment (hue value around 60). The color change of the fruits is because of ripening process and also caused by soaking the fruit in the galangal extract solution which functions as an antimicrobial. Soaking time will greatly affect the color of the fruit. Snake fruit will be darker if soaked too long.

Graph in Figure 5 shows that the Hue value of the treated fruit skin was darker than the control. Visually, it can be seen in Figure 6.

![Figure 5. Skin Color of Snake fruit (°Hue)](image-url)
3.5.2 Flesh of snake fruit

Pondoh Snake fruit has white flesh when harvested at its optimum age. Storage time will cause the flesh fruit color gradually change to creamy-white, then beige, brownish cream and brown, which indicates that there has been damage. In this study, flesh fruit color at \( H_0 \) was generally ranged from 80.0-87.0 (L). On the day 30\(^{th}\) of storage, there had been a decrease in the brightness of the flesh, with an average L value 77.0 - 83.0. This was might due to oxidation reaction (maillard) in the flesh during storage. Meanwhile, from the hue value, as in Figure 7, it can be seen that the longer storage time, the degree of flesh hue did not experience a significant decrease. The value of the hue degree ranged from 80 to 83. The insignificant color change indicated that the treatment succeeded in maintaining one of the physical qualities of the fruit, namely the color of the flesh.

Figure 6. Appearance of skin color during storage

Color of Snake fruit flesh at day 0
3.6 Texture of Snake fruit flesh
Snake fruit hardness value for 30 days of storage was around 488.33 g, decreasing from the initial average values ranging from 600-720 g. The texture or hardness of the snake fruit flesh are influenced by several factors, including the decrease in cell turgor pressure caused by the metabolic process during storage\cite{18}. Although Snake fruit is classified as a non-climacteric, the process of breaking down carbohydrates into sugars continues even in small amounts. These processes cause the fruit texture become softer when stored for a long time.

3.7 Moisture absorption test
The test was carried out to determine snake fruit skin ability to control fruit flesh evapotranspiration to the outside environment. Figure 8 shows that the snake fruit skin was able to hold moisture for a certain time (Cobb method modification). Therefore, the skin was able to control the evapotranspiration rate for a certain time. This was showed from the value of the flesh moisture content stored for 30 days was not decreased, but increased. The average of initial flesh moisture content increased from 78% to 80% on average. This was might be due to the metabolic results of the fruit causing the juicy taste during the storage process.
4. Conclusion

Active packaging of Nano-zeolite (CO₂ and moisture adsorber) combined with antimicrobial solutions and storage at 10 °C was able to maintain the snake fruit shelf life up to 25 days with a damage rate less than 30%.

Acknowledgments

The authors express appreciation for the support from Indonesian Center for Agricultural Postharvest Research and Development (ICAPRD) and Indonesian Agency of Agricultural Research and Development (IAARD) for funding the research.

References

[1] Adirahmanto K A, Hartanto R, and Novita D D. 2013. Perubahan kimia dan lama simpan buah salak Pondoh (Salacca edulis Reinw) dalam penyimpanan dinamis udara CO₂. J. Teknik Pertanian Lampung 2(3) pp 123-132.
[2] Kementan 2014. Kebijakan pembangunan pertanian 2015-2019 Bahan Presentasi Biro Perencanaan Kementerian Pertanian Republik Indonesia Diakses pada tanggal 20 Februari 2015. Tersedia di http://deptan.go.id/ep1/planning/tinymcpuk/ gambar/ file/ Kebijakan_pemangun_pertanian_2015-2019.pdf
[3] Beritasatu.com 2015. Mentan bertekad tingkatkan ekspor buah salak pondoh. Tersedia di http://www.beritasatu.com/ekonomi/319879-mentan-bertekad-tingkatkan-ekspor-buah-Snake fruit.html diakses pada tanggal 24 Februari 2016.
[4] Sampaio S A, Bora P S, Holschuh H J, Silva S M 2007 Postharvest respiratory activity and changes in some chemical constituents during maturation of yellow mombin (Spindias mombin) fruit. Cienc. Tecnol. Aliment 27(3) pp 511-515.
[5] Wills R, McGlasson B, Graham D and Joyce D 1998 Postharvest: An introduction to the physiology & handling of fruit, vegetables & ornamentals 4th edn, Wallingford: CAB International.
[6] Supriyadi S, Suhardi M, Suzuki M Yoshida K, Muto T, et al. (2002), ‘Changes in the volatile compounds and in the chemical and physical properties of snake fruit (Salacca edulis Reinw) cv. Pondoh during maturation’, J Agri Food Chem, 50, 7627 – 7633 .
[7] Suppakul P, Joseph M, Kees S and Stephen W B 2006 Characterization of antimicrobial films containing basil extracts Packag. Technol. Sci. 19 pp 259–268
[8] Lestari Y 2010 Kajian modifikasi dan karakterisasi zeolit alam dari berbagai negara Prosiding seminar nasional Kimia dan Pendidikan Kimia 2010 ISBN: 978-xxx-xxxx-x-x www.kimia.uny.ac.id
[9] Pawlesa J, Arnost Z and Jiri J 2007 Synthesis and adsorption investigations of zeolites MCM-22 and MCM-49 modified by alkali. Spinger
[10] Harlick P J E and Tezel F H 2004 An experimental adsorbent screening study for CO2 removal from N2 Microporous and Mesoporous Materials vol. 76, no. 1–3 pp. 71-9.
[11] Rini D. Kususma, F Lingga 2010. Optimasi aktivasi zeolit alam untuk dehumidifikasi Skripsi Undip.
[12] Xu, X, Song, C, Andréson, JM, Miller, BG & Scaroni, AW 2003, ‘Preparation and characterization of novel CO₂ “molecular basket” adsorbents based on polymer-modified mesoporous molecular sieve MCM-41’, Microporous and Mesoporous Materials, vol. 62, no. 1–2, pp. 29-45.
[13] Yuliusman, Purwanto W W, Nugroho Y S 2013 Pemilihan adsorben untuk penjerapan karbon monoksida menggunakan model Adsorpsi isotermin Isingmuir. Reaktor 14 (3) pp 225-233.
[14] Widayanti, 2016. Desain kemasan aktif penyerap etilen berbahan nano zeolit-KMnO₄ untuk penyimpanan buah klimakterik Disertasi IPB
[15] Widodo W D, Sukety K and Sabrina B 2011 Effectiveness of packaging materials for ethylene oxidators to extend raja bulu banana self-life Proceeding of the PERAGI-PERHORTI-PERIPI-HIGI pp 449-57
[16] Paul R E 1999 Effect of temperature and relative humidity on fresh commodity Quality J. Postharvest Biology and Technology 15 (1999) pp 263–277
[17] Kader AA 2002 Postharvest Technology of Horticultural Crops 3rd Edition University of California Agricultural and Natural Resources 3529
[18] Pech J C, Purgatto E, Bouzayen, Latche 2012 Ethylene and fruit ripening Annual Plant Review 44 pp 275-304