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Effects of Chitosan and 1-MCP on the Physical and Chemical Quality of Salak "Pondoh" (*Salacca edulis* REINW.) Fruits

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Abstract

Salak, or snake fruit, is a tropical fruit with a short shelf life when stored at room temperatures. The fruit's base, if injured or bruised, can serve as an entry point for microbes, leading to physical and chemical damage to the fruits. This research aims to determine if chitosan and 1-methylcyclopropene (1-MCP) treatment can prolong the shelf life of salak "Pondoh". The study tested two factors, chitosan (0%, 0.5%, 1.0%, 1.5%) and 1-MCP concentrations (0, 0.5, 1.0, 1.5 μL.L^{-1}). The findings indicate that the application of chitosan and 1-MCP treatments did not significantly extend the shelf life of the fruits on the 15th day of observation. However, 1.0% chitosan combined with 1.5 μL.L^{-1} 1-MCP and 1.5% chitosan combined with 0.5 μL.L^{-1} 1-MCP proved effective in enhancing the fruit's overall quality and maintained low ethylene production, high water content, and enhanced the organoleptic attributes including ease of peeling, fruit flesh color, texture, aroma, and taste. Top of Form

Keywords: coating, ease of peeling off, ethylene, CO_2 respiration, total dissolved solids

Introduction

Salak "Pondoh" is an Indonesian fruit variety that has high vulnerability to damages, resulting in a relatively short shelf life (5-7 days) at room temperatures (Atmaja et al., 2015; Wibowo et al., 2018). The susceptibility is attributed to the injured or bruised fruit base, acting as a point of entry for microbes that can inflict both physical and chemical damage to the fruits. This observation is corroborated by Siregar's research (2007), which highlights that the release of the fruit from bunches can lead to base injuries, such as peeling of the skin, accelerating the fruit's respiration (Trisnawati and Rubiyo, 2004). Adirahmanto et al. (2013) further note that salak kept in bunches can maintain freshness for 12 to 28 days, whereas peeled salak has a reduced shelf life of up to 6 days. In addition, the high content of water (78%) and carbohydrate (20.9%) in salak fruits contribute to the increased susceptibility of salak fruit to spoilage, particularly when stored at room temperature (26 °C) (Depkes RI, 2000).

Issues arising from microbial activity can significantly compromise the quality of stored fruit, leading to problems such as dry skin, browning, softening, and rotting, rendering the fruit unsuitable for consumption. Research by Al-Baarri et al. (2019) suggests that salak fruit browning is caused by the activity of the enzyme polyphenol oxidase (PPO), which reacts with oxygen to produce o-quinone, resulting in a brown coloration of the fruit. Sugianti et al. (2018) identified fruit rot caused by *Thielaviosis* sp. as one of the postharvest diseases affecting salak fruit, while Putra (2011) highlighted the involvement of mold types like *Fusarrium* sp., *Aspergillus* sp., *Penicillium* sp., and *Mucor* sp. in the rotting of salak fruit during storage. To address these challenges and extend the shelf life of the fresh fruits, the use of safe coating materials, such as chitosan and 1-methylcyclopropene (1-MCP), is recommended. Among natural polymers, chitosan stands out as a polysaccharide derived from crustacean shells or certain fungi cell walls. Chitosan exhibits excellent properties for film formation, biocompatibility, biosafety, antioxidant capabilities, and broad-spectrum antimicrobial activity (Kerch, 2015; Avelelas et al., 2019; Abd El-Hack et al., 2020). The application of chitosan coating has proven effective in preventing postharvest losses in litchi (Jiang et al., 2018; Lin et al., 2020) and pomelo oranges, owing to its beneficial biological activities (Chen et al., 2021).

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1-Methylcyclopropene (1-MCP, C_4H_6) is a volatile compound belonging to cyclopropane derivatives, specifically a cyclic olefin. The use of 1-MCP is regulated and legalized under the FFDCA (The Federal Food, Drug and Cosmetic Act, Sections 408 and 409), further amended by FQPA (Food Quality Protection Act, Public Law 104-170). According to these regulations, 1-MCP is categorized as low in toxicity, non-toxic, non-mutagenic, devoid of tissue effects, and non-irritating (EEG Classification). EPA concludes that 1-MCP is a non-toxic compound that is considered safe, even for infants and children (Sisler and Serek, 1997; Suprayatmi et al., 2005). As a novel ethylene receptor blocker, 1-MCP effectively inhibits the effects of ethylene in fruits and vegetables during storage, leading to delayed aging and extended shelf life (Hu et al., 2017). This compound has found widespread use in storage and preservation practices, including applications in litchi (Sivakumar and Lise, 2010), Mandarin orange (Qing et al., 2012), red and white dragon fruit (Tadeo et al., 2018), strawberry (Yang et al., 2018), and jujube (Cheng et al., 2020). The objective of this study is to investigate the impact of different concentrations of chitosan and 1-MCP treatments on the physical and chemical quality of salak "Pondoh" fruits.

Materials and Methods

The research was conducted between September - November 2021 at the Postharvest Center of the Agricultural Research and Development Agency, located in Cimanggu Central Bogor, Bogor City, West Java.

The materials utilized for the study included salak "Pondoh" fruits obtained from salak farm at the Salak Pondoh Production Center Mitra Turindo in Sleman, Yogyakarta, Central Java, Indonesia. Sleman Regency area, where the salak fruits were harvested, exhibits a varied topography with elevations ranging from <100 m to >1000 m above sea level. The land slope is > 40%, the total rainfall was 16.2 mm of rainfall during 20 days of study, with relative humidity ranging from 74% to 87%. The lowest air temperature recorded was 26.1-27.4 ºC.

The experimental design employed in this study was a factorial randomized group design with two factors and three replications, resulting in 48 experimental units. Each treatment group consisted of 16 fruits. The first factor is chitosan (C) concentrations: 0%, 0.5%, 1.0%, and 1.5%; the second factor is 1-MCP (M) concentrations: 0, 0.5, 1.0, and 1.5 $\mu L.L^{-1}$ of 1-MCP.

Fruit Preparation

The harvesting started at 6 months after pollination, focusing on plants that have developed a minimum of three bunches. Selection for sampling involves choosing ripe salak fruits characterized by a blackish-brown skin color. Ripe fruits are identified by their readiness to detach easily upon touch, and the fruit skin exhibits a lack of sharpness or smoothness. The selected fruits fall within a weight range of 75-85 g per fruit. Following harvest, the salak fruits were cleaned using a brush. Subsequently, the harvested fruits are carefully sorted to facilitate subsequent treatments and ensure the uniformity of the sample group.

Preparation of Chitosan and 1-Methylcyclopropene (1-MCP) *Solutions*

The preparation of the chitosan solution, as adapted from Rachmawati (2010), involves the following modified procedure. Initially, chitosan (0.5%, 1.0%, and 1.5%) is dissolved in 1% glacial acetic acid at 40ºC for 30 minutes using a magnetic stirrer (chitosan: glacial acetic acid = 1:100 w/v). Simultaneously, the 1-MCP solution is prepared by weighing 1 g of 1-MCP (SmartFresh), adding 1 ml of 0.1 N NaOH solution, and allowing it to stand for 30 minutes. An interject tube with a volume of 6 ml is used, resulting in an average 1-MCP gas concentration of 539.6 ppm. The application of chitosan, following the method outlined by Marlina (2015), commences with the spraying of the chitosan solution (0.5%, 1.0%, and 1.5%) on each salak fruit, using a sprayer at a rate of 250 ml^{-1} per 100 fruits. This process is conducted at room temperature (±30 ºC). Subsequently, the fruits are air-dried, and the samples are organized into fruit nets, 20 fruits per net.

Application of Chitosan and 1-Methylcyclopropene (1-MCP)

The application of the 1-MCP was based on Mubarok et al. (2019) study on bananas. The procedure involves placing fruits that have undergone chitosan treatment into individual glass boxes. A venoject tube containing 1-MCP was injected with a syringe into each glass box, with concentrations of 0.5, 1.0, and 1.5 ppm. Subsequently, the glass boxes are tightly closed and incubated for a period of 24 hours. Following the incubation period, the salak fruits are transferred into polyethylene (PE) plastic bags that are perforated and sealed using a sealer. The quality measurements encompass both physical and chemical attributes. Physical quality is assessed through the evaluation of skin color brightness (L*) and the progression of skin color changes from brown to black (a*). Chemical quality characteristics include total soluble solids

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(TSS), total titratable acidity (TTA), CO_2 respiration rate, and ethylene production rate. Additionally, organoleptic tests are conducted, focusing on the ease of peeling and overall acceptability of the salak fruits.

Fruit Storage After Chitosan and 1-MCP Application

Following the 24-hour incubation period, the fruit salak were carefully removed from the glass boxes. These samples are then individually separated and placed inside polyethylene (PE) plastic bags, which have been pre perforated and labelled based on the specific observation variables to be analyzed. Subsequently, the PE plastic bags are securely sealed using a sealer and arranged in baskets according to the designated observation times. The baskets are then stored in a cool storage facility at a temperature of 10 ºC. In a related study on salak "Pondoh" fruits (Adirahmanto et al., 2013), it was reported that the shelf life of salak "Pondoh" fruit can be extended when stored at cold temperatures (10 ºC), reaching up to 32 days. Another study by Widayanti et al. (2021) found that Nano-zeolite active packaging, combined with an antimicrobial solution, when stored at 10 °C, was effective in maintaining the shelf life of salak for up to 25 days, with damage levels remaining below 30%.
Measurements were conducted on the fruit color changes, total soluble solids, total titrated acid, fruit respiration rates and ethylene production. Fruit color changes during storage was conducted following Marpaung method (2015). For this analysis, an AMT501 colorimeter was employed to measure the color parameters on the outer side of the fruit skin.

The quantification of total dissolved solids followed the Sari method (2020) using a hand-held Atago 3810 refractometer. Initially, the fruit's flesh was mashed through grating, with the resulting juice serving as the test sample. Subsequently, the sample was carefully introduced into the refractometer prism. The outcomes were then visible on the device display, presented in °Brix, offering an accurate indication of the total dissolved solids content in the fruit juice.

The determination of total titratable acid was conducted following the method of Sadler and Murphy (1988). The flesh of the salak fruit was cut into small pieces of approximately ±5 g each and then crushed using a fruit crusher until it transformed into juice. The extracted juice was transferred into a 250 ml beaker and diluted with 250 ml^{-1} of distilled water. The mixture was then filtered using a specified mesh filter cloth to separate the residue from the filtrate. The filtrate was collected in a 100 ml volumetric flask and distilled up to the mark on the flask. For sample determination, 25 ml of the filtrate was collected and titrated with 0.1 N NaOH, using phenolphthalein as the indicator. The measurement results were expressed in ml of 0.1 N NaOH per 100 g of material.

$$\%\ \text{Total acid} = \frac{\text{mL NaOH} \times \text{N NaOH} \times 0.88 \times \text{DF}}{\text{sample weight}} \times 100\%$$

where: ml NaOH = NaOH (ml)
N NaOH = normality NaOH (0.01 N)
0.88 = 0.88 mg ascorbic acid is comparable to 1 ml solution of I2 0.01
DF = dilution factor

The determination of respiration rate and ethylene followed the method by Adirahmanto et al. (2013). The fruits were introduced into a Gas Analyzer Felix F-950. Air was circulated within a sealed glass bottle containing the fruits, directing it into the Gas Analyzer at a flow rate of 70 ml/minute for a duration of 30 minutes. This process facilitated the measurement of respiration rate and ethylene production by the fruits.

Organoleptic Test

The organoleptic test procedure followed the method described by Juliani et al. (2017), employing a sensory evaluation to assess product quality based on the five human senses. The specific parameters considered were the ease of peeling and overall acceptability, rated on a scale from 1 to 5. A rating of 1 indicated the highest difficulty or acceptability, while a rating of 5 signified the easiest peeling or unacceptability. A panel consisting of 20 individuals was engaged in expressing their judgments regarding the ease of peeling the salak fruit's skin and their overall preference for the fruit throughout the storage period following the treatment. The sensory evaluation allowed for a comprehensive understanding of the fruit's qualities as perceived by the human senses.

Data Analysis

Analysis of covariance using IBM SPSS Statistics 26 program was used to analyse the quantitative data. Treatments that exhibited significant differences were further analyzed using the Least Significant Difference test (LSD) with a 95% confidence interval (α = 0.05). For the organoleptic test results, the Kruskal-Wallis test was employed.

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Results and Discussion

Fruit Physical Quality

The evaluation of changes in the skin color of salak fruit, ranging from untreated to those treated with chitosan and 1-MCP, involved measuring brightness (L*) and a* value (brown to black) over a 12th day storage period. On the 6th day, the lightness value (L*) demonstrated that untreated salak fruit and those treated with 0.5% chitosan and 1.0 μL.L^{-1} 1-MCP were effective in maintaining the brightness of salak "Pondoh" skin. This preservation of lightness value was also observed on the 12th day with 0.5% chitosan treatment combined with 1.0 μL.L^{-1} 1-MCP (Table 1). In terms of the a* value, representing a dark brown color, it was found that 1.5% chitosan treatment with 0.5 μL.L^{-1} and 1.0 μL.L^{-1} could effectively maintain the skin color of the salak fruit on the 3rd and 12th days of observation. It is interesting to note that Nugraha (2019) reported no significant impact on the color changes of salak "pondoh" skin, including brightness values (L*) and a*, when using coatings with beeswax and liquid smoke. Similarly, in a study on salak "Madu" fruit by Sari et al. (2020), coating with *Aloe vera* and beeswax showed no significant effect on the a* value of the fruit skin.

Fruit Chemical Quality

Chitosan and 1-MCP treatment did not effectively inhibit the metabolic processes of the fruits (Table 2). The total soluble solids were nearly identical on the 3rd and 6th days, particularly evident in the 1.5% chitosan treatment combined with 1.0 μL.L^{-1} 1-MCP treatment. Similar findings were reported by Marlina et al. (2014), where the application of chitosan coating on salak "Pondoh" showed no significant difference in the total soluble solid. In contrast, Cheng et al. (2020) suggested that the combination of 1-MCP and chitosan proves effective in delaying the decrease in total soluble solids in jujube fruit. Regarding the changes in the total titratable acid values, it was observed that on the 3rd day, the 1.5% chitosan treatment with 1.0 μL.L^{-1} 1-MCP and 1.0% chitosan with 1.5 μL.L^{-1} 1-MCP could inhibit the reduction of total titratable acid. This aligns with findings from Marlina (2015), who reported that chitosan coating by immersing fruit bases and storage temperature did not significantly affect total acid during the observation period. However, when

Table 1. Effect of chitosan and 1-MCP on changes in skin color (L* and a*) of Salak "Pondoh"

Treatment	L*value				a*value			
	0	3	6	12	0	3	6	12
Without 1-MCP								
Without chitosan	25.91	23.01	23.83^{a}	20.59^{abc}	8.88	8.02^{ab}	10.13	7.85^{b}
0.5%	25.91	24.00	22.04^{ab}	21.45^{abc}	8.88	8.95^{ab}	11.05	7.37^{b}
1.0%	25.91	23.30	21.65^{ab}	19.85^{abc}	8.88	8.55^{ab}	9.77	7.88^{b}
1.5%	25.91	22.01	20.94^{abc}	21.18^{abc}	8.88	8.56^{ab}	11.96	8.33^{ab}
0.5 μL.L^{-1} 1 -MCP								
Without chitosan	25.91	22.39	20.56^{abc}	23.03^{ab}	8.88	8.10^{ab}	10.53	6.73^{b}
0.5%	25.91	23.62	17.77^{bc}	17.54^{c}	8.88	8.45^{ab}	11.62	5.83^{b}
1.0%	25.91	24.88	20.30^{abc}	21.42^{abc}	8.88	9.23^{ab}	12.68	6.88^{b}
1.5%	25.91	22.06	18.31^{abc}	20.01^{abc}	8.88	7.95^{ab}	10.06	4.92^{b}
1.0 μL.L^{-1} 1 -MCP								
Without chitosan	25.91	23.75	21.04^{abc}	19.78^{abc}	8.88	9.92^{ab}	11.07	7.09^{b}
0.5%	25.91	22.83	20.01^{abc}	24.17^{a}	8.88	9.30^{ab}	12.62	12.73^{a}
1.0%	25.91	21.33	17.68^{bc}	21.18^{abc}	8.88	7.80^{ab}	10.76	7.21^{b}
1.5%	25.91	20.85	15.70^{c}	19.61^{abc}	8.88	7.44^{b}	10.28	5.90^{b}
1.5 μL.L^{-1} 1 -MCP								
Without chitosan	25.91	22.84	22.28^{ab}	22.13^{abc}	8.88	9.84^{ab}	11.02	7.42^{b}
0.5%	25.91	21.68	19.32^{abc}	20.36^{abc}	8.88	9.76^{ab}	10.97	8.22^{ab}
1.0%	25.91	20.94	20.10^{abc}	18.88^{bc}	8.88	10.66^{a}	11.82	7.45^{b}
1.5%	25.91	23.87	21.87^{ab}	21.36^{abc}	8.88	10.50^{ab}	13.72	9.32^{ab}

Note: values followed by the same letter in the same column are not significantly different based on the HSD test at α=0.05.

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Table 2. Effect of chitosan and 1-MCP on the total soluble solid and total titrated acid of Salak "Pondoh"

Treatment	Total soluble solid (°Brix)				Total titrated acid (%)			
	0	3	6	12	0	3	6	12
Without 1-MCP								
Without chitosan	18.80	18.60ab	17.93abc	18.27	0.36	0.30bc	0.35	0.34
0.5%	18.80	18.40ab	17.70b	18.23	0.36	0.33abc	0.34	0.35
1.0%	18.80	17.67a	18.17abc	17.73	0.36	0.36abc	0.37	0.32
1.5%	18.80	18.67ab	17.77abc	18.73	0.36	0.33abc	0.33	0.36
0.5 µL.L^{-1} 1 -MCP								
Without chitosan	18.80	17.87b	17.23bc	18.77	0.36	0.31bc	0.34	0.30
0.5%	18.80	17.77ab	18.03abc	18.90	0.36	0.36abc	0.45	0.37
1.0%	18.80	17.63b	18.17bc	18.63	0.36	0.29bc	0.36	0.32
1.5%	18.80	18.63ab	17.87ab	18.40	0.36	0.27c	0.32	0.38
1.0 µL.L^{-1} 1 -MCP								
Without chitosan	18.80	18.30ab	18.03abc	18.83	0.36	0.32abc	0.35	0.34
0.5%	18.80	17.97ab	18.30a	18.50	0.36	0.30bc	0.33	0.34
1.0%	18.80	18.47ab	17.63abc	17.90	0.36	0.37abc	0.43	0.36
1.5%	18.80	18.10ab	17.73abc	18.20	0.36	0.43a	0.33	0.31
1.5 µL.L^{-1} 1 -MCP								
Without chitosan	18.80	17.30ab	17.80abc	18.63	0.36	0.39ab	0.35	0.35
0.5%	18.80	17.93ab	17.83abc	18.27	0.36	0.36abc	0.40	0.25
1.0%	18.80	17.70ab	17.53abc	18.87	0.36	0.34abc	0.38	0.39
1.5%	18.80	17.90ab	17.53abc	18.28	0.36	0.39ab	0.35	0.26

Note: values followed by the same letter in the same column are not significantly different based on the HSD test at α=0.05.

applied through spraying on the entire surface of the fruit, the concentration of chitosan had a significant effect on total acid.

The interaction between chitosan and 1-MCP (Table 3) indicates that there is a higher respiration rate on the 6th and 12th days. This suggests that coating can inhibit the respiration rate on the 6th day; however, on the 12th day, even without administration-coating, it can still inhibit the respiration rate of the fruit. The lack of a significant difference may be attributed to the thin layers formed by the coating, which could be insufficient to inhibit the gas transmission rate. According to Sari et al. (2020), a given coating can maintain the respiration rate of salak "Madu" fruits until the 14th day of observation. Lin et al. (2020) reported that chitosan treatment reduced the respiration rate of longan fruits, decreased the permeability of pericarp cell membranes, and slow down the aging of longan during postharvest storage.

The CO_2 respiration rate correlated with the rate of ethylene production, demonstrating similar trends during storage (Table 4). Both coated fruit and the control group showed no significant effect. The peak rate of ethylene production started to increase on the 3rd day of observation and reached its highest peak on the 12th day, for both chitosan and 1-MCP treatments. Interestingly, without coating, it was observed that ethylene production was inhibited on day three. This might be attributed to the high concentration of 1-MCP used, which could be excessive for non-climatic fruits, including in salak "Pondoh". Setyadjit et al. (2012) reported that the use of 1-MCP on fruits, vegetables, and ornamental plants is recommended to be as minimal as possible, preferably combined with an extended duration and modified atmosphere packaging (MAP).

Organoleptic Test

Values (1) in the radar diagram means that salak fruits are hard to peel, whereas a larger value (4) means easier. The assessment by the panellists showed that 1.5% chitosan combined with 0.5 µL.L^{-1} 1-MCP effectively altered the ease of peeling the fruit skin. Consequently, salak fruit skin quality can be maintained with this treatment, preventing it from becoming dry and sharp, thereby reducing the likelihood of causing wounds on the fingers.

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Table 3. Effect of the interaction of chitosan and 1-MCP on the respiration rate of $C0_2$ Salak "Pondoh"

Treatment	The respiration rate of CO_2 (ml.kg^{-1} per hour)			
	0	3	6	12
Without 1-MCP				
Without chitosan	21551.78	8139.09^{de}	12970.31^{ab}	12389.38^{c}
0.5%	21551.78	9734.47^{a}	13371.88^{ab}	16295.23^{abc}
1.0%	21551.78	9076.46^{abc}	11620.85^{b}	14615.71^{abc}
1.5%	21551.78	9326.19^{ab}	12992.38^{ab}	15556.40^{abc}
0.5 µL.L^{-1} 1 -MCP				
Without chitosan	21551.78	8929.26^{abcd}	15626.90^{a}	17923.57^{ab}
0.5%	21551.78	7997.28^{e}	13461.07^{ab}	15600.66^{abc}
1.0%	21551.78	8373.95^{cde}	14134.98^{ab}	14451.59^{abc}
1.5%	21551.78	8813.99^{bcde}	13375.92^{ab}	14638.47^{abc}
1.0 µL.L^{-1} 1 -MCP				
Without chitosan	21551.78	9287.12^{ab}	13823.44^{ab}	12880.04^{bc}
0.5%	21551.78	9239.80^{abc}	12803.19^{ab}	15228.12^{abc}
1.0%	21551.78	9217.34^{abc}	13597.91^{ab}	16242.89^{abc}
1.5%	21551.78	9673.77^{ab}	13538.06^{ab}	15249.48^{abc}
1.5 µL.L^{-1} 1 -MCP				
Without chitosan	21551.78	9006.41^{abcd}	12981.67^{ab}	18426.96^{a}
0.5%	21551.78	8940.91^{abcd}	11367.00^{b}	15246.87^{abc}
1.0%	21551.78	8167.10^{de}	11233.15^{b}	15119.01^{abc}
1.5%	21551.78	9018.38^{abcd}	11763.93^{b}	13630.16^{abc}

Note: values followed by the same letter in the same column are not significantly different based on the BNJ follow-up test at the 5% level

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Table 4. Interaction of chitosan and 1-MCP in affecting ethylene production rate of Salak "Pondoh"

Treatment	The ethylene production rate (ml.kg^{-1} per hour)			
	0	3	6	12
Without 1-MCP				
Without chitosan	0.06	0.21^{b}	0.97	3.60
0.5%	0.06	0.27^{b}	1.01	3.50
1.0%	0.06	0.30^{ab}	1.00	3.69
1.5%	0.06	0.28^{ab}	0.88	3.24
0.5 µL.L^{-1} 1 -MCP				
Without chitosan	0.06	0.28^{b}	1.07	3.64
0.5%	0.06	0.30^{ab}	1.06	3.05
1.0%	0.06	0.29^{ab}	0.97	3.32
1.5%	0.06	0.24^{b}	0.88	3.18
1.0 µL.L^{-1} 1 -MCP				
Without chitosan	0.06	0.24^{b}	0.89	3.45
0.5%	0.06	0.29^{ab}	1.11	3.86
1.0%	0.06	0.25^{b}	1.07	3.62
1.5%	0.06	0.24^{b}	1.02	3.29
1.5 µL.L^{-1} 1 -MCP				
Without chitosan	0.06	0.26^{b}	1.06	3.52
0.5%	0.06	0.34^{ab}	1.12	3.34
1.0%	0.06	0.42^{a}	1.05	3.37
1.5%	0.06	0.35^{ab}	1.00	3.30

Note: values followed by the same letter in the same column are not significantly different based on the HSD test at α=0.05.

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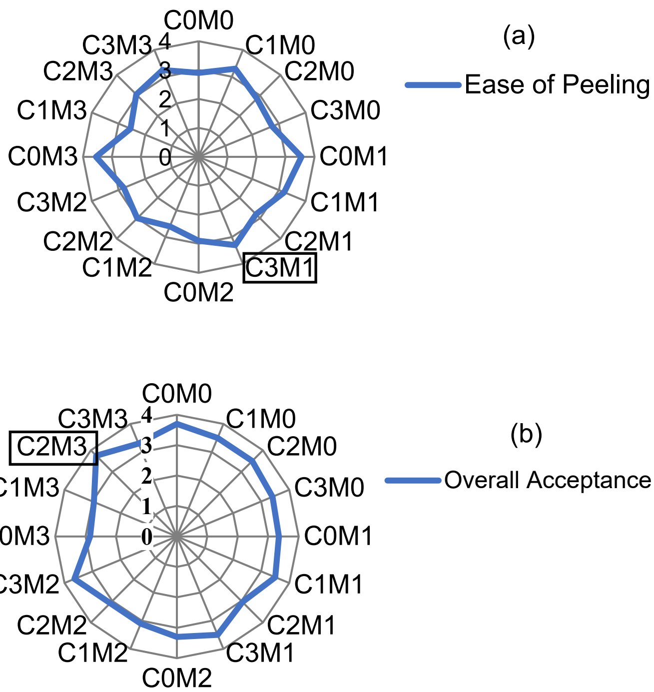

Figure 1. Organoleptic test net diagram of (a) ease of peeling and (b) overall acceptance of salak "Pondoh" treated with chitosan and 1-MCP on the 15th day of observation. C0, C1, C2 and C3 are chitosan at 0, 0.5%, 1%, 1.5%, respectively. M0, M1, M2 and M3 are 1-MCP at 0, 0.5, 1, and 1.5 μL.L^{-1}, respectively. The ease of peeling and overall acceptability was based on scale 1 to 5; 1 being the hardest to peel or unacceptable, 5 being the easiest to peel or acceptable.

The radar diagram demonstrates that a smaller value (1) indicates lower overall acceptance by the panelists in organoleptic testing, encompassing factors such as ease of peeling fruit skin, color of fruit flesh, texture of fruit flesh, fruit aroma, and taste of Pondoh salak fruit flesh. Conversely, a larger value (4) signifies that the treatment involving 1.0% chitosan combined with 1.5 μL.L^{-1} 1-MCP was deemed overall acceptable by the panelists (Figure 2). According to Marpaung (2015), edible coatings can be complementary to the food additives and other substances to preserve the color, aroma, and texture of the product. In addition, this treatment can control microbial growth and enhance the overall appearance of the product.

Conclusion

Application of chitosan at 0%, 0.5%, 1.0%, and 1.5%, and 1-MCP at 0, 0.5, 1.0, and 1.5 μL.L^{-1} did not lead to an increase in the shelf life of salak "Pondoh" fruits at day 15. However, combination of 1.0% chitosan + 1.5 μL.L^{-1} 1-MCP and 1.5% chitosan + 0.5 μL.L^{-1} 1-MCP can maintain low ethylene production rates, high water content, and positive outcomes in the organoleptic test results including ease of peeling, fruit flesh color, fruit flesh texture, fruit aroma, fruit flesh taste, and the fruits' overall acceptability.

References

Abd El-Hack, El-Saadony, M.E., Shafi, M.T., Zabermawi, M.E., Arif, N.M., Batiha, M., Al-Sagheer, G.E.A.A. (2020). Antimicrobial and antioxidant properties of chitosan and its derivatives and their applications: A review. *International Journal of Biological Macromolecules* **164**, 2726–2744.

Adirahmanto, K.A., Hartanto, R., Novita, D.D. (2013). Chemical changes and storage time of salak pondoh (*Salacca edulis* Reinw) in CO_2 air dynamic storage. *Jurnal Keteknikan Pertanian* **2**, 123–132.

Al-Baarri, A.N., Rizqiatia, H., Zulkharisma, M.D., Legowo, A.M., Mawarid, A.A., Pangestika, W., Hadipernata, M., Broto, W. (2019). Application of Olive Leaf Extract (*Olea europaea* L.) in vacuum packaging to prevent browning of the salak fruit. *Jurnal Penelitian Pascapanen Pertanian* **16**, 129–136.

Atmaja, I.B.W.M., Gunam, I.B.W., Wrasiati, L.P. (2015). Coating applications with oleic acid, stearic acid, and emulsions palmitic acid in the preservation of fresh balinese salak fruit. *Jurnal Rekayasa dan Manajemen Agroindustri* **3**,113–118.

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https://doi.org/10.29244/jtcs.11.01.39-48

Avelelas, F., Horta, A., Pinto, L.F.V., Cotrim, M.S., Marques, N.P., Pedrosa, R., Leandro, S.M. (2019). Antifungal and antioxidant properties of chitosan polymers obtained from nontraditional polybius henslowii Sources. *Marine Drugs* **17**, 239.

Chen, C., Peng, X., Chen, J., Gan, Z., Wan, C. (2021). Mitigating effects of chitosan coating on postharvest senescence and energy depletion of harvested pummelo fruit response to granulation stress. *Food Chemistry* **348**, 129–113.

Cheng, S., Yu, Y., Guo, J., Chen, G., Guo, M. (2020). Effect of 1-methylcyclopropene and chitosan treatment on the storage quality of jujube fruit and its related enzyme activities. *Scientia Horticulturae* **265**,1–7.

[Depkes RI] Departemen Kesehatan RI. (2000). "List of Food Ingredients". Badan Penelitian dan Pengembangan Kesehatan Kementerian Kesehatan RI.

Hu, Z.J., Tang, C.X., He, Z.B., Lin, J., Ni, Y.H. (2017). 1-methylcyclopropene (MCP) containing cellulose paper packaging for fresh fruit and vegetable preservation: a review. *Bioresources* **12**, 2234–2248.

Jiang, X., Lin, H., Shi, J., Neethirajan, S., Lin, Y., Chen, Y., Lin, Y. (2018). Effects of a novel chitosan formulation treatment on quality attributes and storage behavior of harvested litchi fruit. *Food Chemistry* **252**,134–141.

Juliani, N.K., Utama, I.M.S., and Aviantara, I.G.N. A. (2017). Effect of ethanol vapor and beeswax emulsion on the quality and shelf life of sugar salak fruit (*Salacca zalacca* var. amboinensis). *Jurnal Biosistem dan Teknik Pertanian* **5**, 59–67.

Kerch, G. (2015). Chitosan films and coatings prevent losses of fresh fruit nutritional quality: A review. *Trends in Food Science and Technology* **46**,159–166.

Lin, Y., Li, N., Lin, H., Lin, M., Chen, Y., Wang, H., Lin, Y. (2020). Effects of chitosan treatment on the storability and quality properties of longan fruit during storage. *Food Chemistry* **306**,125–627.

Marlina, L., Purwanto, Y.A., Ahmad, U. (2014). Coating application of chitosan and beeswax to increase the shelf life of salak Pondoh. *Jurnal Keteknikan Pertanian* **2**, 65–72.

Marlina, L. (2015). "Application of Chitosan Coating to Maintain the Quality of Salak Pondoh (*Salacca edulis* Reinw) During Storage" [Thesis]. Institut Pertanian Bogor.

Marpaung M. (2015). Pelapis nanokomposit untuk pengawetan salak pondoh terolah minimal. *Jurnal Keteknikan Pertanian* **3**, 73–80.

Mubarok, S.N.S., Suminar. E., Kamaluddin, N.N. (2019). 1-methylcyclopropene as an effective ethylene inhibitor to extend *Musa acuminata* "Cola Muli" postharvest quality. *IOP Conference Series: Earth and Environmental Science* **334**, 12–51.

Nugraha BE. (2019). Kajian efikasi asap cair dan karakterisasi film lilin lebah dan asap cair untuk mencegah serangan cendawan pada buah salak Pondoh. *Jurnal Keteknikan Pertanian* **6**, 287–294.

Putra, B.S. (2011). "Study of Coating and Storage Temperature to Prevent Fruit Rot in Salak Pondoh (Salacca edulis Reinw.)" [Thesis]. Institut Pertanian Bogor.

Qing, Li., Fuwang, W., Taotao, L., Xinguo, S., Guoqiang, J., Hongxia, Q., Yueming, J., Xuewu, D. (2012). 1-methylcyclopropene extends the shelf-life of 'Shatangju' mandarin (*Citrus reticulate* Blanco) fruit with attached leaves. *Postharvest Biology and Technology* **67**, 92–95.

Rachmawati, M. (2010). Chitosan coating salak pondoh snake fruit (*Salacca edulis* Reinw.) to extend the shelf-life and its physical characteristics study during storage. *Jurnal Teknologi Pertanian*. **6**, 45–49.

Sadler, G.D and Murphy, P.A. (1998). ph and titrable acidity *In* "Food Analysis" 2nd ed. (S.S. Nielsen, editor). Kluwer Academic, Plenum Publishers, USA.

Sari, P.R.P., Darmawat, E., Ahmad, U. (2020). *Aloe vera* and bee-wax based coating to maintain shelf life salak cv. madu. *IOP Conf. Series: Earth and Environmetal Science* **542**, 1–6.

Setyadjit., Sukasih, E., Asep, W.P. (2012). Application of 1-MCP can extend the fresh life of horticultural commodities. *Buletin Teknologi Pascananen Pertanian* **8**, 27–34.

Received 113/03/2024; Revised 09/12/2023; Accepted 19/01/2024
https://doi.org/10.29244/jtcs.11.01.39-48

Siregar, W.L.S. (2007). “Salak Fruit Transportation Packaging Design (*Salacca edulis*) Made from Bark” [Thesis]. Institut Pertanian Bogor.

Sisler, E.C. and Serek, M. (1997). Inhibitors of ethylene responses in plants at the receptor level: recent developments. *Physiologia Plantarum* **100**, 577–582.

Sivakumar, D., and Lise. (2010). Korsten fruit quality and physiological responses of litchi cultivar McLean’s Red to 1-methylcyclopropene pre-treatment and controlled atmosphere storage conditions. *LWT Food Science and Technology* **43**, 942–948.

Sugianti C, Tamrin, and Pakpahan EF. (2018). Effect of hot water treatment on fruit rot and content of pondoh salak fruit *In* Proceedings of National Seminar PERTETA 2018: “Mekanisasi, Otomasi dan Aplikasi ICT dalam Mendukung Bioindustri danIndustri Kelapa Sawit Berkelanjutan” pp. 344-353. [February 28, 2023]. http://journal.instiperjogja.ac.id/index.php/PTT/article/viewFile/204/196.

Suprayatmi, M., Hariyadi, P., Hasbullah, R., Andarwulan, N., and Kusbiantoro, B. (2005). Application of 1-methylcyclopropene (1-MCP) and ethylene to control Ambon banana ripeness at room temperature *In* Proceeding of National Seminar “Teknologi Inovatif Pascapanen untuk Pengembangan Industri Berbasis Pertanian” pp. 253–263 [September 20, 2022]. https://repository.ipb.ac.id/jspui/bitstream/123456789/26014/1/prosiding_seminar_teknologi_inovatif_pascapanen-26.pdf.

Tadeo, P.R.M., Castillo-Israel, K.A.T., Serrano, E.P., Gandia, J.B.L., and Absulio, W.L. (2018). Physiological responses and storage quality of fresh cut red and white dragon fruit (*Hylocereus spp.*) treated with 1-methylcyclopropene (1-MCP). *International Food Research Journal* **25**, 2090–2098.

Trisnawati, W., and Rubiyo. (2004). The effect of the use of packaging and storage time on the quality of salak Bali. *Jurnal Pengkajian dan Pengembangan Teknologi Pertanian* **7**, 76–82.

Wibowo, D.N., Wicaksono, R., and Naufalin, R. (2018). Increasing the storage of fresh salak fruit in Prigi village, Banjarnegara, through the application kecombrang flower extract *In* “Proceeding of National Seminar ”Pengembangan Sumber Daya Perdesaan dan Kearifan Lokal Berkelanjutan VIII”. 14-15 November 2018 Purwokerto pp 106-109; [November 11, 2021]. http://www. jurnal. lppm. unsoed.ac.id/ojs/index.php/Prosiding/article/viewFile/705/643.

Yang, X., Zhang, X., Fu, M., Chen, Q., and Muzammil, J.M. (2018). Chlorine dioxide fumigation generated by a solid-releasing agent enhanced the efficiency of 1-MCP treatment on the storage quality of strawberries. *Journal Food Science and Technol*ogy **6**, 2003–2010.