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Quality of Arumanis Mango Fruit Due To Heat Treatment and Waxing

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ABSTRACT

Production of Arumanis mango shows an increase, however to meet the needs of the export markets, quarantine regulations are hampered because mango is a host for fruit flies. The combination of hot water treatment (HWT) and waxing is an alternative for fruit fly disinfestation and maintaining quality. The purpose of this study was to determine the effect of HWT and waxing on the quality of Arumanis mango. Arumanis mangoes at 85% maturity were obtained from farmers in Cirebon having average weight of 400-450 g. The HWT was carried out at 47.0°C for 65 minutes and 75 minutes then waxing the fruit in: 1.5% chitosan (P1), 6% beeswax (P2) and a combination of beeswax 6% + chitosan 1.5% (P3). After the treatment, the fruit quality was analyzed every 4-day including hardness, weight loss, total soluble solids, color, respiration rate, total plate count, and organoleptic test. The best treatment was HWT at 47.0°C for 65 minutes and waxing using a combination of beeswax and chitosan. This combination treatment resulted in fruit quality with hardness was 1.72 kgf weight loss of 0.05%; total dissolved solids of 13.4°Brix; and color L a* b*, of respectively 43.9 ;16.7; 28.2, the respiration rate of 5.2 ml O2/ kg.h and CO2 production were of 7.1 ml CO2/kg.h and total plate count of 1.25 × 103 CFU/ml.*

1. INTRODUCTION

Mango (*Mangifera indica* L.) is one of Indonesia's export commodities. The most exported type of mango is Arumanis. Arumanis mango is ideal for export because it has thick flesh with thin seeds, along with the taste, aroma, texture that consumers prefer, and good shelf life (Rebin & Karsinah, 2012). Mango production in 2018 showed an increase in the demand for mangoes by 2,585,854 tons. This figure exceeds the target set at 1,991,004 tons (Direktorat Jenderal Hortikultura 2019). Then, according to the Kementerian Pertanian RI (2022), this figure increased by 2.86% in 2020 due to high market demand.

The high production of mango is not accompanied by the high shelf life of mangoes because they are easily damaged and susceptible to pests/diseases.

In general, fruits after harvesting still carry out metabolic activities which include respiration and transpiration. Mango fruit is classified as a climacteric fruit, where the respiration rate soars during the ripening period and then undergoes a wilting period which is indicated by a rapid rate of quality deterioration. An increase in respiration rate is usually followed by a decrease in texture, color change, an increase in sugar content, a decrease in acid content and an increase in ethylene gas production (Wills *et al.* 1998).

So far, postharvest activities for maintaining the quality and freshness of the fruit and controlling pests/diseases have been carried out using fumigation techniques, but chemical residues on fruits are feared to be harmful to consumer health. Therefore, one of the technology applications that are safe to use is heat treatment such as hot water treatment (HWT) or vapor heat treatment (VHT) as the main alternative for the disinfestation process. Hasbullah (2015) said that in supporting the export of horticultural products, especially mangoes, heat treatment is known to be able to kill insects or fruit flies and fungi (anthracnose and stem end rot) without damaging fruit quality. One of the heat treatments such as VHT can increase or decrease the respiration peak of climacteric fruits and maintain fruit firmness by inhibiting the hydrolysis of pectin. This also applies to HWT. In addition to the application of HWT, waxing is also one-way to maintain the quality and freshness of the fruit.

Waxing on the surface of the fruit can prevent excessive water evaporation and can change the internal atmospheric conditions (oxygen and carbon dioxide gas) of the fruit which can inhibit the rate of respiration and can slow down the withering of the fruit. The use of two coates on the fruit was reported to give better results. Research conducted by Nurrachman *et al.* (2006), sapodilla fruit coated with two coates of chitosan 1.5% and beeswax 6% showed a better tendency than single use, which was able to reduce ethylene production, lower weight loss and maintain fruit firmness. Based on this description, this research was conducted to evaluate the use of hot water treatment and waxing on the quality of mango Arumanis. It is expected that the method will produce mangoes of the best quality.

2. MATERIALS AND METHODS

Arumanis mango were received from the garden in Belawa Lemahabang, Cirebon. Arumanis mango was selected with maturity level of 85%, which was 110-120 days after the flowers bloomed, green with a yellowish base and soft with a fruit weight of 400-450 g. The fruits were packed in box containers. Fruit were then transported to Bogor by car (4 hours transport distance). The research process was conducted at Food and Agricultural Product Processing Engineering Laboratory (TPPHP), Siswadhi Soepardjo Laboratory and Bacterial Laboratory of the Bogor Agricultural University. The hot water treatment (HWT) process was carried out at Siswadhi Soepardjo Laboratory. The waxing process and quality observations (weight loss, hardness, total dissolved solids (TDS), color testing, hardness, respiration rate, organoleptic) were carried out at the TPPHP laboratory and total plate count testing was carried out at the Bogor Agro Industry Center.

2.1. Materials and Equipment

The materials used in this research were water bath, refrigerator, and incubator. The main ingredient used in this study was Arumanis mango, the types of waxing used in

this study were chitosan 1.5% and beeswax 6%. The chemicals used were acetic acid, starch, oleic acid, triethanolamine and water for hot water treatment, alcohol, PDA and distilled water.

2.2. Procedures

The sorted and cleaned mangoes were treated with hot water treatment. According to Kementrian Pertanian RI (2013), the duration of temperature and time of hot water treatment based on the size and shape of the fruit, which is at 46.1–47.2°C for 65 min and 75 min, then cooled using flowing water until the fruit temperature reached ambient temperature, then drained and continued with waxing treatment. After that, the mango Arumanis was coated by immersing it for 30 seconds in a single application using chitosan 1.5% (P1) and beeswax 6% (P2), and a combination application using beeswax 6%, then dried with a fan, then immersing it in chitosan 1.5% (P3). After immersion, dry the fruit with a fan for 5-10 minutes (Susanto *et al.* 2018). Then, Arumanis mango was stored at 13°C (optimum low temperature to store mango) for 24 days and quality was observed every 4 days. All parameters were observed using different fruits. Assessment of fruit quality was performed on the following parameters: hardness, weight loss, total dissolved solids, color, respiration rate, total plate count and organoleptic tests. For hardness was determined by measuring the maximum force required to penetrate 10 mm into the fruit, using a rheometer. Weight loss the fruit were weighed on a digital scale at the start and end of the experiment. Weight loss was determined using the formula $(W_0\text{-}W_1)/W_0$ x 100%= %WL. The total dissolved solids content was determined by the index of refraction using a refractometer and is referred to as degrees Brix. Brix is the percentage of sucrose (sugar) in the solution. The color was determined by measuring (*L** value) indicates brightness level, (*a** value) positive *a** denotes redness while negative *a** indicates greenness, (*b** value) positive *b** denotes yellowness while negative *b** indicates blueness of the fruit using chromameter. The respiration rate was determined by measuring the consentration of CO_2 and O_2 using a gas analyzer. Then total plate count was determined by measuring the number of microbes contained in mango during storage and organoleptic tests using the hedonic test with 20 panelists.

2.3. Data Analysis

Data analysis of research results was carried out with Microsoft Excel. The experimental design used was a factorial completely randomized design (CRD) with two treatment factors, namely hot water treatment (65 minutes and 75 minutes) and waxing (chitosan 1.5%, beeswax 6%, beeswax 6% + 1.5% chitosan and control), with two replications. If there is a significant effect between treatments, then it is further tested with DMRT (Duncan Multiple Range Test) at a 95% confidence interval (α = 0.05). Data analysis was carried out using IBM SPSS 25.

3. RESULTS AND DISCUSSION

3.1. Respiration Rate of Arumanis Mango

As it is known that respiration is a process that involves the absorption of O_2 gas and the production of CO_2 gas as well as energy used for further metabolic reactions and other reactions. The graph of the respiration rate of the Arumanis mango is presented in Figure 1.

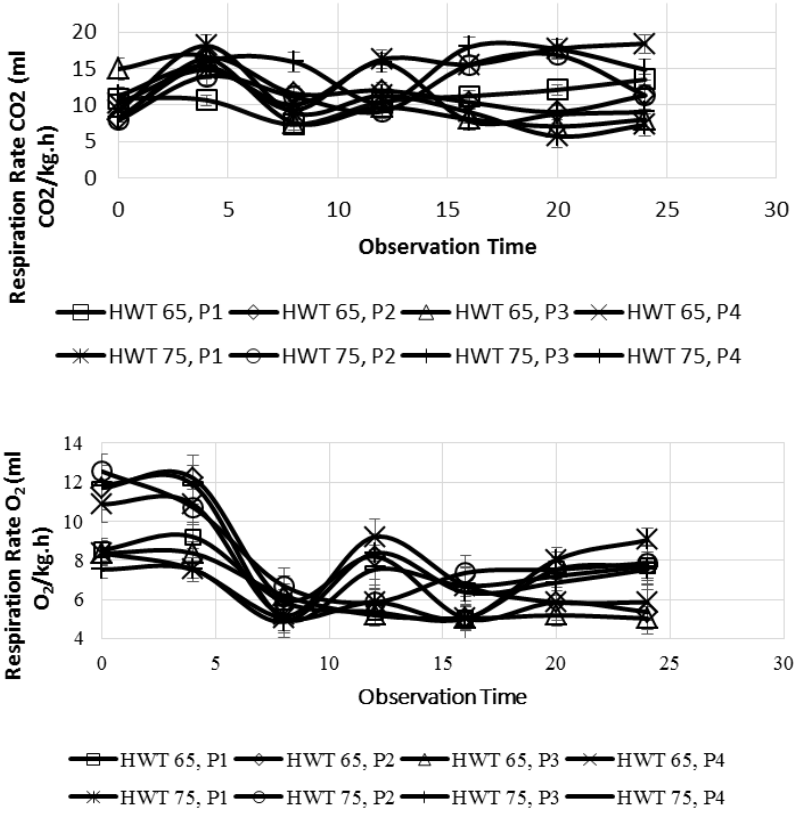

Figure 1. Respiration rate of CO_2 and O_2

In Figure 1, the Arumanis mango tends to show an increase in respiration rate although on certain days it has decreased. In this case, the Arumanis mango shows a climacteric pattern, where the Arumanis mango can still carry out the ripening process after passing the 24th day. This study is in line with Yassin *et al.* (2013), where during storage, the banana fruit has not reached decay because the respiration rate pattern still shows an increase. That is, the fruit is still in the process of ripening the fruit until it decays.

Table 1. DMRT results of CO_2 and O_2 respiration rates of Arumanis mango

HWT	Waxing	Respiration Rate	
		CO_2 (ml CO_2/kg.h)	O_2 (ml O_2/kg.h)
65 minutes	Chitosan 1,5%	12,10 ± 0,49^{b}	7,53 ± 0,71^{c}
	Beeswax 6%	9,09 ± 3,47^{ab}	5,86 ± 1,18^{ab}
	Beeswax 6% + Chitosan 1,5%	7,08 ± 0,49^{a}	5,19 ± 0,23^{a}
	Control	17,72 ± 1,20^{c}	5,86 ± 0,23^{ab}
75 minutes	Chitosan 1,5%	5,72 ± 0,71^{a}	8,04 ± 0,47^{c}
	Beeswax 6%	16,87 ± 0,71^{c}	7,53 ± 0,24^{c}
	Beeswax 6% + Chitosan 1,5%	8,74 ± 0,99^{ab}	6,87 ± 0,24^{bc}
	Control	17,67 ± 0,42^{c}	7,19 ± 0,71^{bc}

Numbers in the same column followed by the same letter are not significantly different based on Duncan test result α = 0,05

The ANOVA results showed that the HWT and waxing on Arumanis mango influenced the respiration rate of the Arumanis mango on day 20. This is based on the significance value < 0.05. Table 7 shows that Arumanis mangoes treated with 75 minutes of HWT had a higher respiration rate than 65 minutes of HWT, both with and without waxing. These results are in line with Hasbullah *et al.* (2001), where the HWT caused an increase in the respiration of Irwin mangoes. This is suspected there is a heat injury on the surface of the mango fruit. In addition, the CO_2 respiration rate in Arumanis mangoes without coating was higher than that in waxing. This is explained by Mudyantini *et al.* (2017), that the concentration of fruit waxing affects air exchange in fruit tissues.

3.2. Quality Changes of Arumanis Mangoes During Storage

3.2.1. Hardness

Mango fruit that had been treated with 65 minutes and 75 minutes of HWT and waxing experienced changes in fruit hardness during storage. The results of this study showed that the level of hardness of the Arumanis mango decreased in each type of waxing, both at 65 minutes and 75 minutes of HWT (Figure 2).

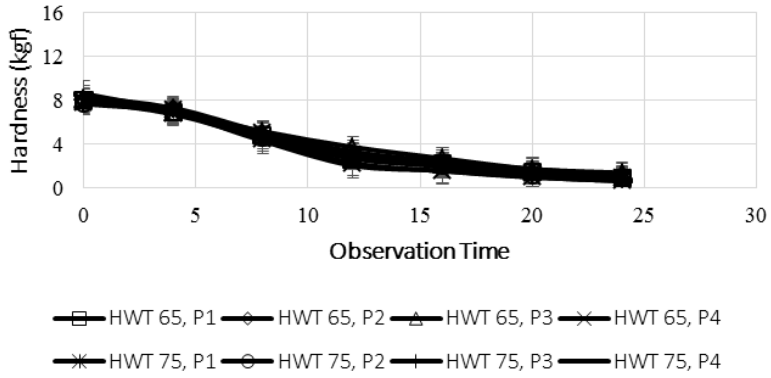

Figure 2. Hardness of Arumanis mango

Figure 2 shows that the decrease in the level of hardness of the Arumanis mango occurred along with the length of storage, both at 65 minutes and 75 minutes of HWT. According to Dhyan *et al.* (2014), fruit will continue to experience water loss because there is a difference in humidity between the storage space and the material.

Table 2. DMRT results of Arumanis mango hardness

HWT	Waxing	Hardness (kgf)
65 minutes	Chitosan 1,5%	$1,43 \pm 0,01^{bc}$
	Beeswax 6%	$1,23 \pm 0,16^{ab}$
	Beeswax 6% + Chitosan 1,5%	$1,73 \pm 0,40^{c}$
	Control	$0,97 \pm 0,01^{a}$
75 minutes	Chitosan 1,5%	$1,35 \pm 0,06^{ab}$
	Beeswax 6%	$1,18 \pm 0,04^{ab}$
	Beeswax 6% + Chitosan 1,5%	$1,72 \pm 0,28^{c}$
	Control	$1,00 \pm 0,14^{a}$

Numbers in the same column followed by the same letter are not significantly different based on Duncan test result α = 0,05

The ANOVA results showed that the type of waxing on the Arumanis mango influenced the hardness of the mango on day 20. This is based on the significance value < 0.05. In Table 2, the difference in the time duration of HWT gave different hardness values to Arumanis mangoes. Kim *et al.* (2007) explained that HWT can prevent the decaying of Arumanis mangoes caused by an increase in the ripening process. It can be seen in the hardness value of Arumanis mango with 6% beeswax + 1.5% chitosan waxing which had a higher hardness value than other types of waxing and without waxing (control).

3.2.2. Weight Loss

In this study, Arumanis mango experienced an increase in weight loss value (Figure 3). Figure 3 shows an increase in the value of weight loss in Arumanis mango during storage, both at 65 minutes and 75 minutes of HWT. However, there is a difference in the weight loss value of the Arumanis mango between the two. The difference was caused by the different time duration of the Arumanis mango.

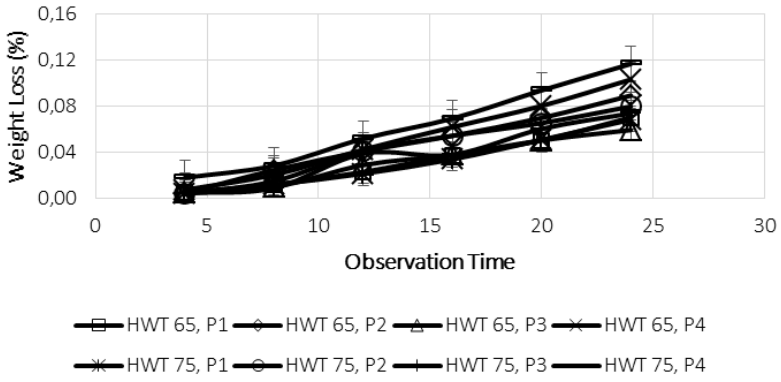

Figure 3. Weight loss of Arumanis mango

The increase in the weight loss value of Arumanis mangoes, both with and without waxing was caused by the high respiration rate of the fruit and evaporation of water through the skin of the Arumanis mango. Sudjatha & Wisaniyasa (2008) said that the increase in weight loss occurred due to the process of respiration and transpiration. The respiration process in fruit will result in the evaporation of water, gas, and energy, while the transpiration process results in the release of water components in the form of water vapor. The waxing treatment influenced the weight loss value of Arumanis mango on day 20. This is based on the significance value < 0.05. DMRT results are presented in Table 3.

In Table 3, the percentage value of weight loss of mango fruit with 65 minutes of HWT had a lower weight loss value than 75 minutes of HWT. This study is in line with Khan *et al.* (2016) said that HWT with high temperatures and long-time duration of soaking can cause cracking on fruit surface cells, resulting in an increase in fruit weight loss. In addition, there are significant differences in the types of waxing on the weight loss value of Arumanis mangoes. In this case, the 6% beeswax waxing had a higher weight loss value than 1.5% chitosan waxing and the combination of the two waxing (6% beeswax + 1.5%). The results of this study are similar to Mukdisari *et al.* (2016), where waxing on papaya fruit with chitosan was able to reduce the decrease in fruit weight loss.

Table 3. DMRT results of Arumanis mangoes weight loss

HWT	Waxing	Weight loss (%)
65 minutes	Chitosan 1,5%	0,05 ± 0,00[a]
	Beeswax 6%	0,07 ± 0,19[bc]
	Beeswax 6% + Chitosan 1,5%	0,05 ± 0,00[a]
	Control	0,08 ± 0,00[cd]
75 minutes	Chitosan 1,5%	0,05 ± 0,00[a]
	Beeswax 6%	0,07 ± 0,00[abc]
	Beeswax 6% + Chitosan 1,5%	0,06 ± 0,20[ab]
	Control	0,09 ± 0,10[d]

Numbers in the same column followed by the same letter are not significantly different based on Duncan test result α = 0,05

3.2.3. Total Dissolved Solid

The total dissolved solids in the fruit defines the total sugar contained. The sweetness value of the fruit depends on the total amount of sugar. The higher the total dissolved solids value, the sweeter the fruit taste. Based on Figure 4, the value of total dissolved solids in Arumanis mangoes increased during storage, both at 65 minutes and 75 minutes of HWT. Marlina *et al.* (2014) explained that the increase in total dissolved solids was caused by the fruit respiration process. During the respiration process, mangoes consume O_2 from the environment to break down carbohydrates into simple sugar compounds. Based on the results of ANOVA, the different types of waxing on the Arumanis mango on day 20 influenced the total dissolved solids value. This was caused by a significant value < 0.05.

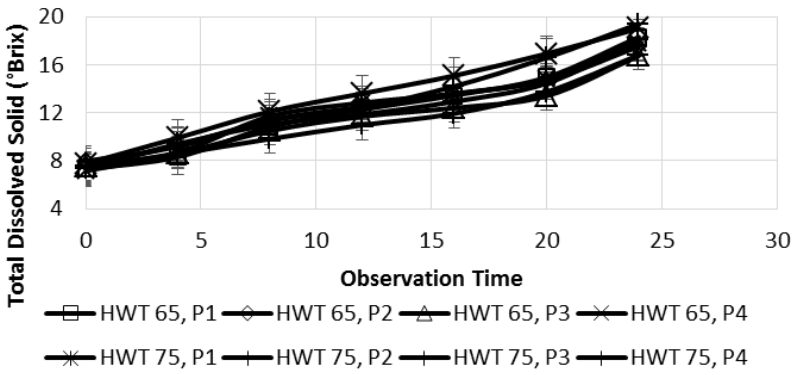

Figure 4. Total dissolved solids of Arumanis mango

In Table 4, the value of total dissolved solids in each type of waxing between HWT 65 minutes and 75 minutes was not significantly different even though the total value of dissolved solids at HWT 75 minutes was higher than HWT 65 minutes. Meikapasa & Seventilofa (2016) said that high temperatures in the soaking process can result the degradation of carbohydrate compound into water-soluble simple sugars. In addition, mango fruit coated with 6% beeswax + 1.5% chitosan had a lower total dissolved solids value than other waxing types. Darmajana *et al.* (2018) said that fruit weight loss can be prevented by waxing the fruit because it can slow down the penetration of O_2 and the formation of other simple compounds resulting from the overhaul of complex organic compounds.

Table 4. DMRT results of Arumanis mango total dissolved solids

HWT	Waxing	Total dissolved solids (°Brix)
65 minutes	Chitosan 1,5%	14,95 ± 0,45[c]
	Beeswax 6%	14,69 ± 0,73[bc]
	Beeswax 6% + Chitosan 1,5%	13,40 ± 0,66[a]
	Control	16,92 ± 0,16[d]
75 minutes	Chitosan 1,5%	14,77 ± 0,09[bc]
	Beeswax 6%	14,45 ± 0,40[bc]
	Beeswax 6% + Chitosan 1,5%	13,74 ± 0,09[ab]
	Control	16,58 ± 0,21[d]

Numbers in the same column followed by the same letter are not significantly different based on Duncan test result α = 0,05

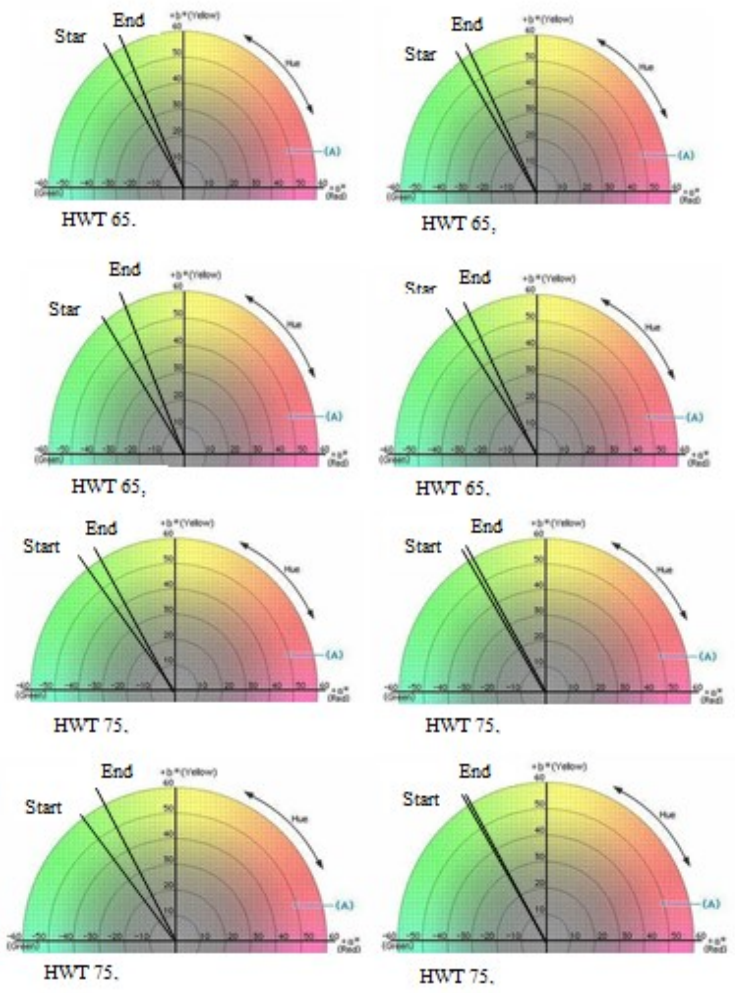

Figure 5. Colors of Arumanis mango

3.2.4. Color

Color is one of the parameters that greatly affects the consumer's desire to buy a product. In fruits, the color describes the level of maturity of the fruit. Generally, colors are graded based on brightness (*L**), green or red (*a**) and blue or yellow (*b**) as presented in Figure 5.

Based on Figure 5, the color of Arumanis mango with 1.5% chitosan waxing and a combination of 6% beeswax + 1.5% chitosan, both at 65 minutes and 75 minutes of HWT had a bright green color compared to mangoes with other types of waxing and without waxing. This is presumably because the combination of the two waxing was able to maintain the color quality of the Arumanis mango during storage. The results of this study are in line with the research of Khalil *et al.* (2022), Arumanis mango with waxing has a lower yellow color level value than control (without waxing). This means that the Arumanis mango with waxing has a high shelf life and has not led to decay. Based on the ANOVA results, the HWT and waxing treatment on Arumanis mango on day 20 influenced the color coordinate value of the Arumanis mango fruit. This was based on a significant value < 0.05.

Table 5. DMRT results of Arumanis mango color

HWT	Waxing	Coordinat		
		L*	a*	b*
65 min	Chitosan 1,5%	46,23 ± 0,74^{b}	-14,60 ± 0,28^{f}	22,15 ± 0,78^{b}
	Beeswax 6%	59,68 ± 0,64^{e}	-18,91 ± 0,50^{a}	36,43 ± 0,01^{e}
	Beeswax 6% + Chitosan 1,5%	43,96 ± 0,22^{a}	-16,70 ± 0,06^{d}	28,21 ± 0,66^{c}
	Control	61,36 ± 0,26^{f}	-18,18 ± 0,30^{b}	40,21 ± 0,11^{g}
75 min	Chitosan 1,5%	48,43 ± 0,35^{c}	-14,32 ± 0,26^{e}	21,21 ± 0,16^{a}
	Beeswax 6%	52,67 ± 0,56^{d}	-17,12 ± 0,15^{cd}	38,18 ± 0,71^{f}
	Beeswax 6% + Chitosan 1,5%	48,01 ± 0,25^{c}	-16,91 ± 0,23^{cd}	33,08 ± 0,22^{d}
	Control	62,32 ± 0,14^{f}	-17,51 ± 0,39^{bc}	40,42 ± 0,50^{g}

Numbers in the same column followed by the same letter are not significantly different based on Duncan test result α = 0,05

Based on Table 5, according to Anwar & Malik (2007), HWT can increase fruit skin color during the ripening process. HWT can cause gas exchange on the surface of the fruit skin, where there is a decrease in O_2 gas consumption, resulting in the biodegradation of chlorophyll a. With the combination of waxing treatments on Arumanis mangoes, the chlorophyll biodegradation process can be inhibited during storage.

3.3. Total Plate Count

The waxing on the Arumanis mango serves to slow the growth of microorganisms. As the growth of microorganisms increased during storage (Figure 6). Figure 6 shows that the growth of microorganisms increased on day 20. The increase in the number of microorganisms in the Arumanis mango is caused by the very high sugar content in the fruit during the fruit ripening process, where there is a reshuffle of complex organic compounds into simple sugar compounds and other compounds.

Based on the results of ANOVA, HWT and waxing on Arumanis mango on day 20 influenced the TPC value of Arumanis mango. This was caused by a significant value < 0.05. Based on Table 6, the difference of time duration in HWT gave a different number of microorganisms. Mangoes treated with 65 minutes of HWT had a higher TPC value than 75 minutes of HWT. This is because the long-time soaking in hot water, where HWT treatment for 10 minutes can suppress the growth of microorganisms greater

than HWT for 5 minutes. In addition, mango without waxing has a higher number of microorganisms than mango with waxing. Zong *et al.* (2010) said that the waxing acts as an antibacterial and antifungal because it can affect the growth activity of pathogens by damaging the plasma membrane of the spores and cytoplasm of fungi and inhibiting the growth of mycelia.

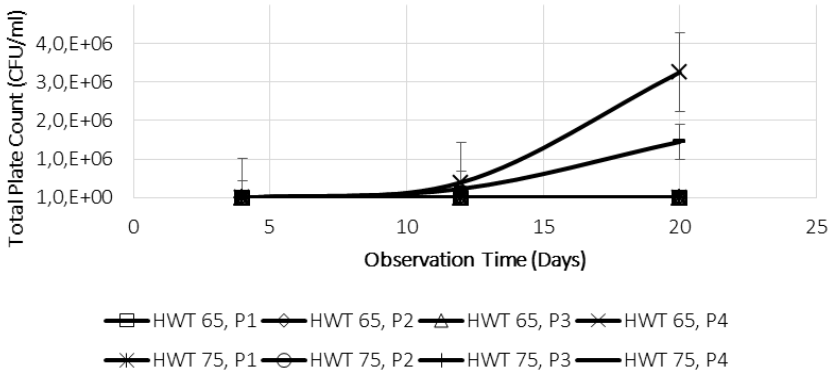

Figure 6. Total plate count of Arumanis mango

Table 6. DMRT results of Arumanis mangoes total plate count

HWT	Waxing	Total plate count (CFU/ml)
65 min	Chitosan 1,5%	$1{,}60x10^{3} \pm 1{,}41x10^{2}$ a
	Beeswax 6%	$3{,}10x10^{3} \pm 1{,}41x10^{2}$ a
	Beeswax 6% + Chitosan 1,5%	$1{,}25x10^{3} \pm 7{,}07x10^{1}$ a
	Control	$3{,}25x10^{6} \pm 2{,}12x10^{5}$ c
75 min	Chitosan 1,5%	$6{,}50x10^{2} \pm 2{,}12x10^{2}$ a
	Beeswax 6%	$1{,}45x10^{2} \pm 7{,}07x10^{0}$ a
	Beeswax 6% + Chitosan 1,5%	$1{,}25x10^{2} \pm 2{,}12x10^{1}$ a
	Control	$1{,}45x10^{6} \pm 2{,}12x10^{5}$ b

Numbers in the same column followed by the same letter are not significantly different based on Duncan test result α = 0,05

3.4. Organoleptic Test

Panelists preferred the color of mango fruit on day 16, both with and without waxing. However, on day 20, a score of 6 was given to Arumanis mangoes without waxing, both with 65 minutes and 75 minutes of HWT. The highest score was given for the aroma test on each waxing treatment and without waxing, both with 65 minutes and 75 minutes of HWT, located on day 20, which was 6.

In addition, the highest score was obtained at HWT 65, P1 and P4, and HWT 75 P4 with a score of 6 on day 16 for the texture test. This is because the Arumanis mango has reached its maturity phase. Finally, the panelists preferred the taste of Arumanis mango on day 20, both at 65 minutes and 75 minutes of HWT. This is due to the very sweet taste due to the high simple sugar compounds from the complex sugar compound reshuffle process. According to ANOVA analysis, HWT and waxing on Arumanis mangoes had no effect on the organoleptic test of Arumanis mangoes.

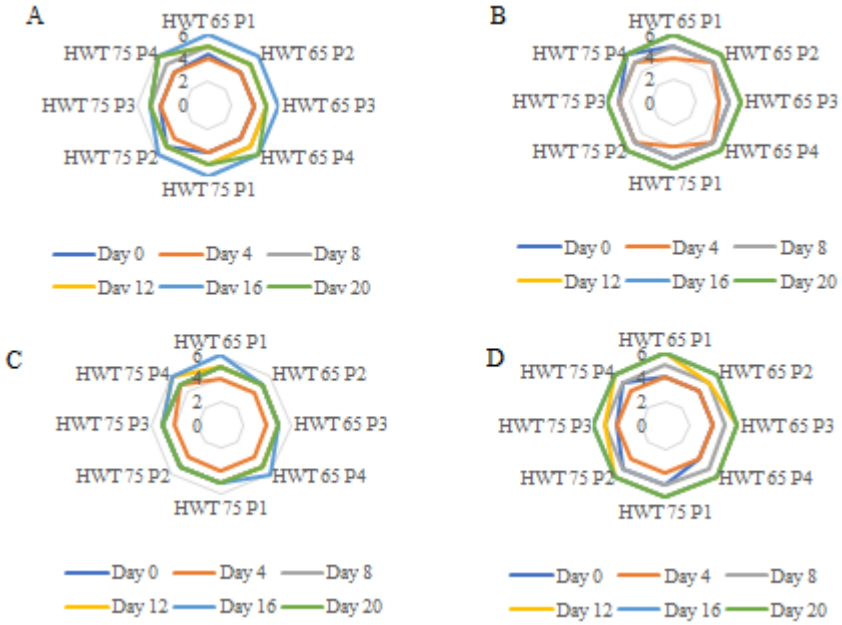

Figure 7. Organoleptic test of Arumanis mango: a) color, b) flavor, c) texture, d) taste

4. CONCLUSIONS

The results showed that the combination of HWT and waxing on the 20th observation had a significant effect on quality (hardness, weight loss, total dissolved solids, and color), respiration rate and total plate count of Arumanis mango. Based on the results, Arumanis mango with the combination of HWT 65 minutes and beeswax 6% + chitosan 1.5% has a good shelf life than other waxing treatments. HWT 65 minutes has a short-term process so that the fruit does not crack and leads to decay. It can be stored for up to 20 days at 13°C.

REFERENCES

Anwar, R., & Malik, A.U. (2007). Hot water treatment affects ripening quality and storage life of mango (*Mangifera indica* L.). *Pakistan Journal of Agricultural Researc*h. ***44***, 304-311.

Darmajana, D.A., Afifah, N., Sholichah, E., & Indriyani, N. (2018). The effect of combination plasticizer on characteristics edible film by carrageenan and beeswax. *Journal of Industry Biopropal*, ***9***(1), 49-60.

Direktorat Jenderal Hortikultura. (2019). Report. http://horticulture-ppid.pertanian.go.id/doc/15/LAPTAH-2018.pdf. May 16, 2022.

Dhyan, C., Sumarlan, H.D., & Bambang, S. (2014). Effect of beeswax coating and storage temperature on guava fruit quality (*Presidium guajava* L). *Jurnal Biopsi Komoditi Tropical*, ***2***, 79-90.

Hasbullah, R., Kawasaki, S., Kojima, T., Akinaga, T. (2001). Effect of heat treatments on respiration and quality of 'Irwin' mango. *Journal of The Society of Agricultural Structures Japan*, ***32***(2), 59-67.

Hasbullah, R. (2007). Technique of measuring respiration rate of horticultural products under controlled atmospheric conditions part 1: closed system method. *Journal of Agricultural Engineering*, ***21***(4), 419-427.

Hasbullah, R. (2015). *Quarantine Technology for Global Market*. Polimedia Publishing. ISBN: 979-979-9356-76-5.

Kementrian Pertanian RI. (2022). Demand for fruits and vegetables is high, the horticulture sub-sector grows positively 7.85 percent in the fourth quarter of 2020. https://www.pertanian.go.id/home/?show=news&act=view&id=4682. May16,2022.

Khan, S., Ullah, I., Khan, N., Iqbal, A., Shah, T., Shah, F., Islam, B., Ali, A., & Qadri, R.W.K. (2016). The role of ltst hot water immersion on quality of peach fruit during storage. *Madrigde Journal Food Technology*. ***1***(1), 31-36.

Khalil, H.A., Abdelkader, M.E.M., Lo'ay, A.A., El-Ansary, D.O., Shaaban, F.K.M., Osman, S.O., Shenawy, I.E., Osman, H.E.H., Limam, S.A., Abdein, M.A., & Abdelgawad, Z.A. (2022). The combined effect of hot water treatment and chitosan coating on mango (*Mangifera indica* L. cv. Kent) fruits to control postharvest deterioration and increase fruit quality. *Coatings*, ***12***, 83. https://doi.org/10.3390/coatings12010083

Kim, Y., Brecht, J.K., Talcott, S.T. (2007). Antioxidant phytochemical and fruit quality changes in mango (*Mangifera indica* L.) following hot water immersion and controlled atmosphere storage. *Food Chemistry*, ***105***, 1327-1334.

Marlina, L., Purwanto, Y.A., & Ahmad, U. (2014). Application of chitosan and beeswax coating to increase the shelf life of salak pondoh. *Jurnal Keteknikan Pertanian*, ***2***(1), 65-72.

Meikapasa, N.W.P., & Seventilofa, G,N,O. (2016). Characteristics of total dissolved solids, stability of lycopene and vitamin C in tomato sauce at various combination of temperature and cooking time. GaneC Swara, ***10***(1), 81-86.

Mudyantini, W., Anggarwulan, E., & Rahayu, P. (2015). Inhibition of ripening of sugar apple (*Annona squamosa* L.) with low temperature and chitosan coating. *AGRITECH*, ***27***(1), 23-29.

Mukdisari, Y., Suketi, K. & Widodo, W.D. (2016). Fruit coating with chitosan and beeswax to extend papaya shelf life. *Journal of Tropical Crop Science*, ***3***(3), 93-98.

Nurrachman, Prarudiyanto, A., Jayaputera, & Suryaningsih, L. (2006). Study of composite coatings (chitosan and beeswax) on postharvest physiology of

sapodilla fruit (*Archas zapota* L). *Competitive Grant Research Report*. Mataram University.

Rebin, R., & Karsinah, K. (2012). Improved management of mango trees. *Hortic Science*, ***8***, 1-7.

Sudjatha, W., & Wisamiyasa, N.W. (2008). Postharvest physiology and technology (fruits and vegetables). Udayana University Press. Bali

Susanto, S., Inkorisa, D., & Hermansyah, D. (2018). Wax effectively extends the shelf life of guava fruit (*Psidium guajava L.)* crystal. *Jurnal Hortikultura Indonesia.* ***9***(1), 19-26.

Wills, R.B.H, McGlasson, W.B., Graham, D., Lee, T.H., Hall, E.G. (1998). Postharvest: An introduction to the physiology and handling of fruit and vegetables. Avi Book, Van Nostrand Reindhold, New York: 164 pp.

Yassin, T., Hartanto, R., Haryanto, A., & Tamrin. (2013). The influence of gas composition on the respiration rate of banana (var. Janten) on modified atmosphere storage. *Jurnal Teknik Pertanian*, ***2***(3), 147-160.

Zong, Y., Liu, J., Li, B., Qin, G., & Tian, S. (2010). Effects of yeast antagonists in combination with hot water treatment on postharvest diseases of tomato fruit. *Biological Control*, ***54***(3), 316-321.