

The performance of beeswax coating containing vegetable oil-based lecithin as an emulsifier on weight loss and shelf life estimation of mango

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Abstract. Fruits are one of the agricultural commodities grown in Indonesia and mango constitutes the third largest. One of the disadvantages in transporting mangoes to long distant markets is the short shelf life when fruits are stored at the room temperature. Some efforts to maintain quality and freshness have been coating the fruits with natural wax/beeswax. This study aimed to determine the effects of beeswax coating containing vegetable oil-based lecithin on physical and weight loss in mango, as well as estimate the shelf life using the Accelerated Shelf-Life Testing (ASLT) method. The coating formulation consisted of beeswax, triethanolamine, stearic acid, vegetable lecithin (soybean: rice bran), and water. Mango coated with beeswax coating with a concentration of vegetable lecithin emulsifier were varied at 0.25, 0.5, 0.75, 1%, and control (without beeswax coating) stored at room temperature 301°K and cooler temperature 286°K. Samples were monitored for five weeks and evaluated periodically for physical change and weight loss. Beeswax coated mango exhibited slower rate of ripening than the control stored in both room and cooler temperatures. The lowest total weight loss of mangoes at both temperatures for 5 weeks with beeswax coating at 0.25% vegetable lecithin emulsifier was 7.25%. The estimation of shelf life using ASLT method and Arrhenius model to mango fruit coated with beeswax coating at 0.25% vegetable lecithin concentration as emulsifier was 36.91 days.

Keywords: beeswax, coating, emulsifier, rice bran lecithin, mango

INTRODUCTION

Fruits contribute significantly to horticulture in Indonesia. According to the Government reports released by the Central Bureau of Statistics (BPS), mango production ranked third at 2.2 million tons in 2017[10]. Mango has a good market potential as well as a promising export commodity [5].

The biggest disadvantage of long-distance markets of mango is the short shelf life when stored at room temperature. Mango experiences full ripening within two to three days post-harvest [13]. The most common method to increase shelf life in fruits has been lowering the storage temperature. However, this method does not apply optimally on mango because of it requires very low temperatures of 10-13°C

[7,9]. In addition to lowering the storage temperature, another common method to increase shelf life in fruits is by employing food-grade wax/beeswax as coating. By coating the surface of fruits with wax, water evaporation can be reduced and freshness can be maintained longer [13].

One of the main ingredients in the wax coating is an emulsifier that functions to form the product. Lecithin is widely used as the emulsifier in food-grade wax and is obtained by extracting oil from animal and vegetable oil sources. Rice bran oil can be used in a lecithin mixture because it contains 1.0-2.0% of phosphatide gum [11].

In previous research, pineapple, papaya and cempedak are horticultural commodities that are perishable. Based on that, technologies are required for processing them, and one alternative is juice technology. To ensure that the juice is still suitable for consumption and unspoiled, information on shelf life is necessary. Method of estimating shelf life used

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is ASLT (Accelerated Shelf Life Test). The estimated shelf life of pineapple-cempedak juice at a temperature of -5 °C was 197.85 days [1]. Further research use fruit leather technology on manalagi apples, Fruit leather is a thin sheet-shaped slurry product with 2-3 mm in thickness. To ensure that the fruit leather is still suitable for consumption, information on shelf life is necessary. Method of estimating shelf life used is ASLT. Shelf life calculation result of manalagi apples fruit leather based on sensory colour parameter values through the Arrhenius approach on the storage temperature of 30°C is 33.11 days [8].

The objectives of this study were to determine the effects of beeswax containing vegetable oil-based lecithin, at several concentrations, on the quality and weight loss in mango. The vegetable oil-based lecithin was a mixture of lecithin extracted from rice bran oil and soy oils. The determination on shelf-life estimation was also conducted using the Accelerated Shelf-Life Testing (ASLT) method.

METHODOLOGY

Preparation and application of beeswax coating

In the preparations of beeswax coating, the concentrations of vegetable oil-based lecithin, (rice bran and soybean) with ratio 1:6, were varied at 0.25, 0.5, 0.75, and 1%. Beeswax (12 g) and water (82 g) were heated at the same time in different containers to temperature of 90-95°C. Stearic acid (1.75, 1.5, 1.25, 1) g and lecithin (0.25, 0.5, 0.75, 1) g were added into the beeswax, while triethanolamine (4 g) was added into water. The two solutions were thoroughly mixed, and the temperature was lowered to 80°C under constant stirring. The water-TEA mixture was added into the beeswax solution and mixed thoroughly. The final mixture was cool down to the room temperature for 30 minutes and filtered for a cleaner result [4].

Two layers of the beeswax coating was applied to mangoes with a brush and air dried for two hours. The coated mangoes were stored either at room temperature 301°K and cooler temperature at 286°K. The control mangoes were uncoated and placed on a tray without any cover to simulate a market display. One mango for each sample was sampled for analyses every week for five weeks.

Weight loss [13]

Weight loss is calculated based on the difference in initial weight and weight at the time of measurement during the fruit storage

period expressed in percent as shown in the following formula.

$$\text{Weight Loss} = \frac{W_2 - W_1}{W_1} \times 100\% \dots\dots\dots (1)$$

Where, W_1 is the initial weight (g); W_2 is the final weight (g).

Analyses for the prediction of shelf-life using Accelerated Shelf-Life Testing (ASLT) method, Arrhenius Equation

Quality Change (A) Vs. Time (t) Curves [2]

The change of product quality during storage was measured with physical analyses. At this stage, data were plotted into the A (y axis) versus t (x axis) curve, and ln (A) versus (t) curve to obtain two linear formulas representing two storage temperatures from each curve with the equation of $y = a + bx$, in which b was the slope and k was a constant.

Determining the Reaction Order [2]

Reaction orders were determined from the curve formula with the highest correlation coefficient (R^2). Zero order was chosen when the R^2 for A vs t curve was greater than the R^2 ln A vs t curve. Whereas first order was chosen when the R^2 for ln A vs t was greater than the R^2 for A vs t curve.

(ln k) vs temperature (1/T in K) [2]

The value of b slope used was based on the reaction order that had been determined. A linear formula of $y = a + bx$ or $\ln k = \ln k_0 - (E_a/R) (1/T)$, which is called Arrhenius equation, in which ln k_0 was the intercept, E_a/R was the slope, E_a was activation energy, and R was the ideal gas constant (1.986 cal/mol K).

Calculating the Activation Energy [2]

The activation energy (cal/mol) was calculated from the b value from the Arrhenius equation multiplied with R.

Predicting Shelf Life [2]

Reaction rate (k) at certain temperature was determined by the Arrhenius Equation. The prediction of shelf life was obtained from the difference the quality changes after and before storage. The formula to determine the shelf life is:

$$t = (A_0 - A_t)/k \text{ (Zero Order Formula)} \dots\dots\dots (2)$$

$$t = \ln (A_0 - A_t)/k \text{ (First Order Formula)} \dots\dots\dots (3)$$

Note:

t = Shelf life

A_0 = Initial Quality Attributed Value (day 0)

A_t = Final Quality Attributed Value (day t)

k = Quality Reduction Constant

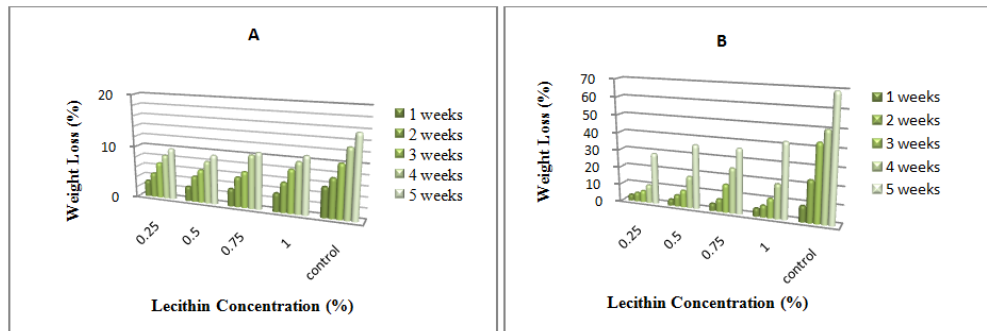


Figure 1. Weight Loss in Mango Stored at Two Storage Temperatures, (A) Cooler Temperature 286°K

RESULT AND DISCUSSION

The effects of lecithin concentration and storage length of mango on the weight loss

In post-harvest processing of mango, coating fruits with wax, or waxing, can reduce the respiration rate, and therefore, this treatment can be a good option to prolong the shelf life. Waxing can decrease the respiration process in harvested fruits, which in turn suppresses the chemical changes. The slow down on the respiration rate can therefore delay the fruit ripening process [3].

Weight loss is one of the perimeters to measure the degree of freshness in fruits. This phenomenon is a manifestation of the respiratory processes taking place in the harvested fruits. Weight loss is the result of water evaporation and glucose breakdown into CO₂ and water. In addition, weight loss is also related to the reduction of firmness, in which connections among cells in the fruit have been weakened by the loss of water [12].

The results showed that the smallest weight loss was achieved from samples treated with beeswax coating containing 0.25% vegetable oil-based lecithin was 7.25%. Whereas the highest weight loss took place in uncoated or control mangoes at 20.62%. Figure 1 shows that cooling reduced weight loss. This result corresponds to other study [7]. The largest weight loss occurred in mangoes stored at room temperature. In this condition, fruits undergo active respiration and transpiration processes in the fruits. Cooling can reduce those processes and therefore decrease the rate of weight loss [7].

Table 1 shows changes in the the quality of mangoes for 5 weeks at room and cooler temperature. In most fruits, the first sign of ripening is the loss of green coloration caused by the reduction of chlorophyll contents. Table 1 demonstrates that mangoes without coating stored at room temperature underwent ripening in the first week and rotted completely in the second week. Whereas the beeswax-coated

Table 1. The Changes in Quality of Mango throughout Five-Week Experiment

	0 Weeks		1 Weeks		2 Weeks		3 Weeks		4 Weeks		5 Weeks	
	301°K	286°K	301°K	286°K	301°K	286°K	301°K	286°K	301°K	286°K	301°K	286°K
Control												
0.25												
0.5												
0.75												
1												

mangoes exhibited partial rots in the fourth week.

The color change on coated mangoes stored in the cooler was more stable. Mangoes remained green with a little browning. No rotting was observed throughout the five-week trial period.

Analyses on the Shelf Life Prediction using ASLT method, Arrhenius equation

The length of shelf life can be predicted using weight loss curves. The data on weight loss on mangoes during this five-week trial are presented on Table 2.

Each treatment in this trial exhibited a different pattern of weight changes from others. If the rate of changes is constants, the reaction can be categorized into zero order. However, if the rate is not constant, logarithmic, or exponential, the reaction can be categorized into first order. Determining the reaction order is the method for predicting the shelf life [1].

For zero order, the formula is obtained by plotting the data on to a curve with y axis representing mango weight and x axis representing length of storage. Whereas the formula for first order reaction is obtained by plotting the data on a curve with ln mango weight on y axis and length of storage on x axis.

The reaction order is determined based on the greater value of R² of the corresponding curves [1]. The determining values (R²) on weight loss on mangoes obtained in this trial were higher in

zero order reaction than those in first order (Table 3). It can be concluded that the kinetic reaction in weight loss on mango in storage follows a zero-order reaction.

The gradient or slope value (k) describes the relation between change of quality/weight and length of storage. Negative values of k indicate that there were weight reductions during storage was shown on Table 3.

By calculating the slope of the regression formula for ln mango weight and length of trial at two storage temperatures, the quality change value (k) could be determined. These values are presented in Table 5. In summary, k at each storage temperature could be calculated using the resulting Arrhenius Equations for each beeswax coating [1].

For example, using the Arrhenius equation for 0.25% lecithin of $\ln k = -5613 \cdot x(1/T) + 19.25$ (Table 5), the shelf life for mangoes stored at 286oK would yield $\ln k = -0.395$ or $k = 0.673$. This means that there is 0.673 gram weight reduction per day.

The plot of the values of ln k and 1/T in the changes in mango fruit weight were shown in Figure 2.

The results presented in Table 5 show that the smallest k value occurred in mangoes coated with 0.25% lecithin. The control mangoes exhibited the highest k value, which meant that this sample lost the most weight during storage.

Table 2. The Weights of Uncoated and Coated Mangoes Stored at Two Temperatures During a Five-Week Storage

Day	Weight of The Mango (g)									
	Concentration 0.25%		Concentration 0.5%		Concentration 0.75%		Concentration 1%		Control	
	Temp 286 K	Temp 301 K	Temp 286 K	Temp 301 K	Temp 286 K	Temp 301 K	Temp 286 K	Temp 301 K	Temp 286 K	Temp 301 K
0	247.25	276.93	272.34	326.41	259.53	230.33	313.25	259.65	269.57	318.85
7	239.60	267.70	264.75	314.95	250.85	220.95	302.30	248.50	255.70	290.05
14	236.00	263.55	259.06	305.00	244.72	214.16	296.09	243.69	251.28	252.77
21	229.45	259.25	254.95	293.30	241.65	193.78	287.40	232.95	243.75	200.92
28	226.50	249.00	249.85	264.00	233.35	171.80	282.50	211.70	236.00	180.15
35	222.75	199.45	246.85	204.68	231.80	145.91	279.70	141.85	229.20	113.28

Table 3. The Changes of Weight on Beeswax-Coated Mangoes During Storage Analyzed in Zero and First Order Reactions.

Vegetable Oil-Based Lecithin Concentration	Temperature (K)	1/T	Order 0		Order 1	
			Formula	R ²	Formula	R ²
0.25%	286	0.0035	-0.687x+245.6	0.979	-0.002x+5.504	0.982
	301	0.0033	-1.827x+284.6	0.749	-0.007x+5.660	0.715
	average			0.864		0.8485
0.50%	286	0.0035	-0.719x+270.5	0.981	-0.002x+5.600	0.984
	301	0.0033	-3.155x+339.9	0.856	-0.011x+5.847	0.811
	average			0.9185		0.8975
0.75%	286	0.0035	-0.792x+257.5	0.969	-0.003x+5.551	0.972
	301	0.0033	-2.407x+238.3	0.95	-0.012x+5.490	0.924
	average			0.9595		0.948
1%	286	0.0035	-0.962x+310.3	0.965	-0.003x+5.738	0.97
	301	0.0033	-2.898x+273.7	0.78	-0.014x+5.642	0.719
	average			0.8725		0.8445
Control	286	0.0035	-1.095x+266.7	0.982	-0.027x+5.853	0.929
	301	0.0033	-5.752x+326.7	0.98	-0.004x+5.587	0.985
	average			0.981		0.957

Table 4. The Constant Values of Reaction Rate (k) and ln k of Beeswax-Coated Mango Weight

Vegetable Oil-Based Lecithin Concentration	Temp. (K)	1/T	k	ln k
0.25%	286	0.0035	0.687	-0.37542
	301	0.0033	1.827	0.602675
0.50%	286	0.0035	0.719	-0.32989
	301	0.0033	3.155	1.148988
0.75%	286	0.0035	0.792	-0.23319
	301	0.0033	2.407	0.878381
1%	286	0.0035	0.962	-0.03874
	301	0.0033	2.898	1.064021
Control	286	0.0035	1.095	0.090754
	301	0.0033	5.752	1.749548

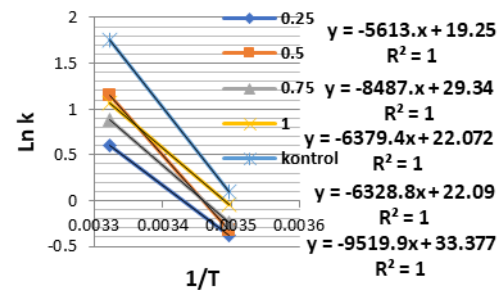


Figure 2. Arrhenius Equation for ln k and Inversed Storage Temperatures (1/T) of Beeswax-Coated Mangoes.

Table 5. Predicted Shelf Life of Beeswax-Coated Mangoes Based on Weight Loss During Storage at The Temperatures of 286°K and 301°K

Temp. (K)	Vegetable Oil-Based Lecithin Concentration (%)	Initial Weight (gr)	Final Weight (gr)	Arrhenius Equation	Activation Energy (Ea)	ln k	k	Shelf Life (days)
286	0.25	247.25	222.75	-5613.x+19.25	-11147.418	-0.395	0.673	36.378
301		276.93	199.45			0.727	2.069	37.446
							Average	36.912
286	0.5	272.34	246.85	-8487.x+29.34	-16855.182	-0.364	0.694	36.700
301		326.41	204.68			1.332	3.792	32.101
							Average	34.400
286	0.75	259.53	231.80	-6379.x+22.07	-12668.694	-0.256	0.773	35.838
301		230.33	145.91			1.019	2.771	30.464
							Average	33.151
286	1	313.25	279.70	-6328.x+22.09	-12567.408	-0.058	0.943	35.558
301		259.65	141.85			1.207	3.345	35.213
							Average	35.386
286	Control	269.57	229.20	-9519.x+33.37	-18904.734	0.053	1.054	38.266
301		318.85	113.28			1.980	7.245	28.371
							Average	33.319

The parameter that can be used to detect sensitivity to temperature changes is the activation energy (Ea). Lower Ea indicates higher weight-change stability [6]. In this trial, mangoes coated with beeswax containing 0.25% plant-based lecithin exhibited the lowest Ea at 11147.4 cal/mol (Table 5).

The analyses for predicting the shelf life using ASLT method and Arrhenius Equation are presented in Table 5. Mangoes treated with beeswax coating containing 0.25% plant-based lecithin exhibited the longest shelf life an average of 36.91 days or 1.23 month for both storage temperatures, derived from the Arrhenius Equation for this treatment of $y = -5613.x + 19.25$.

CONCLUSIONS

The conclusions that can be drawn from these results are mango fruits coated with beeswax containing plant-based lecithin exhibited smaller weight loss than the uncoated fruits stored in both room 301°K and cooler temperatures 286°K; the smallest weight losses occurred in mangoes coated with beeswax containing 0.25% plant-based lecithin at the value of 7.25%; and the prediction of shelf life for mangoes coated with 0.25% plant-based lecithin using the Arrhenius equation yielded 36.91 days.

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