Effect of edible beeswax coating on tomato (*Solanum lycopersicum*) postharvest quality

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Abstract. Beeswax, known for its beneficial composition, has found wide application in various industries, including pharmacy, and medicine. The purpose of this study was to determine the efficacy of beeswax as a covering for preserving tomato postharvest quality. Beeswax was applied to tomato fruits in three different dosages (5, 15, and 25 g) and stored for 30 days at 10 °C. The results revealed that uncoated fruits exhibited a higher percentage of weight loss and firmness compared to coated fruits during storage. Coating treatments demonstrated the ability to delay the decline in weight loss, firmness, TSS and the preservation of bioactive compounds such as lycopene. Notably, the fruits coated with 25 g beeswax displayed significantly lower weight loss percentages than the other treatments. These findings suggest that the postharvest application of beeswax has the potential to extend the storage life of tomato fruits by maintaining fruit quality.

1 Introduction

Tomato is one of the most widely cultivated and consumed vegetables worldwide. Typically, the produce is sold as fresh fruit or used in the food industry. As a climacteric fruit, tomatoes keep getting riper even after being harvested. Carotenoids are produced as the green pigment chlorophyll breaks down during ripening [1]. For buyers and customers, the texture and skin color of fresh tomatoes are the two most crucial quality characteristics. The firmness of the flesh and strength of the skin have an impact on texture. After harvesting, softness and ripening were the primary issues since they could increase the tomatoes' susceptibility to damage. [2]. In tropical regions, tomato losses across the stages of distribution from harvest to consumption ranged up to 50 % [3]. This is consistent with [4] estimations that, of all agricultural goods, between 49 and 80% are consumed while the remaining 20% are lost.

The idea of employing edible coatings is to preserve fresh and minimally processed produce for longer periods of time and shield it from adverse environmental effects. Based on the necessity for excellent quality and the demand for minimal food processing and storage methods, these have been highlighted [5]. The use of edible films and coatings on food inventions has increased within the industry. There are several different kinds of edible coatings, including emulsion films, composite bilayers, and monolayers [6]. These films can contain lipids that span from animal and plant waxes to vegetable oils and fatty acids.

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Carnauba wax and beeswax are among the natural waxes that have been studied and proven can increase the shelf life of many vegetables and fruits [8].

Beeswax is a natural wax produced by honeybees (*Cera alba*) and consists of long-chain fatty acids and fatty alcohols [9]. The addition of beeswax to the edible film's formulation potentially can improve the moisture barrier, mechanical properties and the appearance of fresh produce [10, 11]. The application of beeswax as a coating can lower the respiration rate of strawberries [12] and reduce the senescence of eggplants [13]. Due to this reason, this study was conducted to assess the potential for employing beeswax as an edible coating on tomatoes.

2 Materials and methods

2.1 Tomato samples

Fresh tomatoes were bought from the Fertigation House at the Department of Agriculture, Kuala Terengganu, Terengganu, Malaysia. The tomatoes were carefully selected to obtain uniform weight, size, colour and free from injuries. The fruits were transported to Postharvest Laboratory, Universiti Malaysia Terengganu. Before treatment application, all tomatoes were washed under running tap water and air-dried at ambient temperature. Beeswax homogenous solution was prepared based on the method by [14]. Each of the tomato fruits was coated with beeswax solution using a clean brush and then stored at 10 °C storage temperature for thirty days.

2.2 Postharvest quality evaluation

The weight of tomatoes was measured using an analytical balance. By calculating the difference between the starting weight and the final weight, the percentage of weight reduction was determined. The firmness was measured using a Texture analyzer (TA-TX) Plus (Texture Technologies Corp, USA). The firmness of the tomatoes was accessed via non-destructive compression and the force per unit deformation was taken as a measure of hardness [15].

Total Soluble Solid (TSS) was analyzed using a hand-held refractometer (Atago Co. Ltd). Two longitudinal slices were made from the stem end to the calyx end of the tomato fruit. In order to extract juice from all areas of the slice, it was compressed longitudinally. On the prism of the refractometer, two to three drops of the fruit juice were applied. The instrument was held up to the light and the reading was taken by looking through the lens. The TSS data was expressed as °Brix value.

The pH value of the tomato juice was determined by immersing the electrode into the juice until the reading of the pH meter was stable. Then, the reading was recorded from the pH meter.

A titration method was performed to analyze tomato fruit titratable acidity (TA) [16]. The distilled water was used to dilute 10 mL of tomato juice to 50 mL volumes. With the addition of a couple of drops of phenolphthalein, a 10 mL sample aliquot was titrated against 0.1 N NaOH. The titration was repeated until the solution's color changed from colorless to slightly pink.

Determination of lycopene was carried out using [17] method. A total of 750 mg of finely diced tomato was weighed and put into a mortar and one g of magnesium oxide powder and 20 mL of acetone were added. Samples were ground with a pestle until no intact tomato tissues were observed. The majority of the solid magnesium oxide was left in the mortar after extracting it into a 50 ml falcon centrifuge tube, and 20 ml more of 100% acetone was used to rinse the mortar and pestle. After that, the extract was centrifuged for 5 minutes at 2000 ppm. In a 50 mL volumetric flask, pour the supernatant and fill to volume with 100% acetone. Clear particles should make up the extract. The absorption of each tomato extract was determined using a UV-Vis spectrophotometer at 503 nm wavelength.

The samples in the experiment were arranged in Complete Randomized Design (CRD). The treatments tested were T0 (control): Uncoated tomatoes, T1: 5g beeswax, T2: 15 g beeswax and T3: 25 g beeswax. Three replicates of each sample were used for every treatment. All parameters were evaluated at every three days intervals using destructive and non-destructive methods, depending on the analysis. Collected data were analyzed based on One Way Analysis of Variance (ANOVA) using Statistical Package for the Social Sciences (SPSS) software version 20.0. Tukey (LSD) was used to distinguish treatments with the least significance at $p<0.05$.

3 Results and discussion

3.1 Fruit weight loss and firmness analysis

The results of the weight loss and firmness analysis were presented in Figure 1. Data from Figure 1 (A) demonstrated increasing trends of weight loss in both uncoated and coated tomatoes throughout the storage period. Untreated tomatoes had higher weight loss compared to fruits coated with beeswax coatings. Specifically, the weight loss percentages of the coated fruits with 15 g and 25 g of beeswax were significantly lower than those of the other treatments. These outcomes align with previous findings in crops, as similar benefits were observed when applying beeswax coatings to vegetables like cucumber [18] and eggplants [13]. Additionally, a similar pattern was noticed in other fruit qualities, such as strawberries and apricot [14] and mango [19]. The reduced weight loss resulting from the application of edible coatings can be attributed to their ability to create an extra barrier that minimizes the transpiration process [20, 21]. Moreover, based on the observations made, preserving weight loss was accompanied by an increase in shine and an improvement in the texture of the tomato fruit (unpublished data).

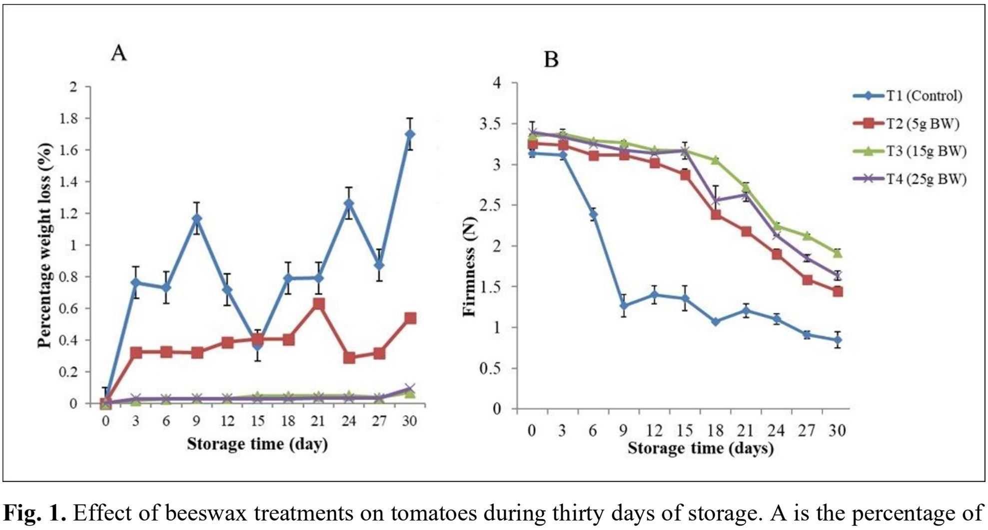

Fig. 1. Effect of beeswax treatments on tomatoes during thirty days of storage. A is the percentage of weight loss; B is firmness evaluation.

Figure 1 (B) demonstrated that fruit firmness reduced gradually during storage for both control and coated tomatoes. All coating treatments (T2 – T4) can delay the decline of firmness compared to the uncoated fruits (control). After the third day of storage, the uncoated fruits started to show a significant reduction in firmness when compared to the treated tomatoes. The reduction of firmness in the uncoated sample was 72%, compared to 46% in the coated tomatoes after 30 days of storage. This finding is in agreement with the review by [22], where the author found that various edible coatings such as peach gum polysaccharides and chitosan can maintain the firmness of tomatoes. During fruit ripening, a loss of water can occur through transpiration and respiration, leading to a decrease in cell turgor pressure [23]. Active compounds in the edible coating can also prevent the activity of the enzyme that causes the tissues of tomato fruits to soften and can reduce the loss of firmness [24].

3.2 Phytochemical analysis

Table 1. Effect of beeswax coatings on total soluble solid (TSS), pH of the fruit juice, titratable acidity (TA) and lycopene contents of tomatoes during storage,

Treatments/ Phytochemical analysis	Storage period (day)					
	0	6	12	18	24	30
Total soluble solid (TSS) (°Brix value)						
T1 (Control)	2.86±0.12	3.86±0.83	3.66±0.31	3.67±0.76	3.60±0.35	3.43±0.40
T2 (5 g beeswax)	3.66±0.61	3.60±0.35	3.73±0.23	3.93±0.31	3.53±0.42	4.20±1.11
T3 (15 g beeswax)	3.00±0.20	3.66±0.58	3.93±0.81	4.13±1.03	3.80±0.53	4.33±0.46
T3 (25 g beeswax)	2.86±0.31	3.93±0.23	4.00±0.87	4.00±1.06	4.60±0.40	5.27±0.31
pH						
T1 (Control)	4.21±0.03	4.19±0.02	4.15±0.04	4.17±0.03	4.11±0.02	4.10±0.01
T2 (5 g beeswax)	4.18±0.01	4.19±0.02	4.15±0.01	4.14±0.02	4.13±0.01	4.15±0.03
T3 (15 g beeswax)	4.19±0.01	4.19±0.03	4.13±0.04	4.17±0.03	4.15±0.02	4.14±0.037
T3 (25 g beeswax)	4.19±0.02	4.17±0.06	4.14±0.01	4.18±0.04	4.13±0.02	4.15±0.04
Titratable acidity (TA)						
T1 (Control)	0.32±0.03	0.42±0.06	0.38±0.05	0.36±0.06	0.47±0.09	0.45±0.07
T2 (5 g beeswax)	0.29±0.02	0.45±0.18	0.38±0.02	0.39±0.04	0.36±0.04	0.56±0.03
T3 (15 g beeswax)	0.26±0.05	0.41±0.10	0.38±0.04	0.36±0.10	0.37±0.14	0.49±0.02
T3 (25 g beeswax)	0.29±0.05	0.45±0.11	0.35±0.03	0.36±0.04	0.45±0.11	0.50±0.04
Lycopene content						
T1 (Control)	0.00±0.00	0.79±0.58	0.99±0.01	1.19±0.12	1.66±0.09	1.92±0.08
T2 (5 g beeswax)	0.00±0.00	1.09±0.01	1.44±0.09	1.75±0.07	2.16±0.03	2.78±0.11
T3 (15 g beeswax)	0.00±0.00	0.91±0.11	1.89±0.11	2.40±0.43	3.49±0.23	4.44±0.26
T3 (25 g beeswax)	0.00±0.00	0.89±0.10	1.16±0.14	2.06±0.05	2.40±0.34	3.18±0.16
The data value indicates the mean and standard error						

Total soluble solids serve as a general indicator of the sugar content in fruits. As fruits ripen, complex polysaccharides break down into simple sugars, leading to an increase in total soluble solids (TSS). Based on the data from Table 1, there was a marginal increase in the coated tomatoes compared to the uncoated control fruits. The highest °Brix value (5.27±0.31) was achieved with treatment T3 (25 g beeswax) after a 30-day storage period. The result of the study is consistent with the outcome of the application of candelilla wax edible coating with *Flourensia cernua* bioactive ([25]. This finding, however, contrasts with a [26] study in 2021, where they found that coated tomatoes with a composite bi-layer coating (whey protein isolate, xanthan gum, and clove oil) had a lower TSS value compared to uncoated fruit. Similarly, chitosan and aloe vera gel-coated tomatoes retained the TSS value compared to untreated tomatoes having the maximum value of TSS [27]. After the 24th day, the TSS of the uncoated tomatoes gradually decreased. This could be as a result of the breakdown of pectin and carbohydrates during respiration, as well as the partial hydrolysis of proteins and the subunitization of glycosides. [28].

At the end of the storage period, uncoated and coated tomatoes showed no significant differences in the pH value and titratable acidity measurement. The pH and TA values remained constant throughout the study. This observation however does not corroborate with findings by [29] and [30]. Reference [29] reported that they observed a high pH value on coated tomatoes with aloe vera, meanwhile, [30] found that oligosaccharides produced from *Laminaria japonica*-incorporated pullulan coatings had lower TA.

Throughout the storage period, the lycopene content in all tomato treatments exhibited a consistent ascendant trend, indicating a progressive increase in lycopene accumulation over time. Table 1 shows the lycopene content was the lowest in untreated tomatoes (1.92±0.08) and the highest in treatment T3 (4.44±0.26). This highest value was observed during the 30 days of cold storage. The increasing trend of lycopene contents in the treated tomatoes was not observed when applying aloe vera gel-based edible coating [29]. However, 80% of aloe vera gel-treated tomatoes still can retain the lycopene contents stable compared to control and other treatments.

4 Conclusion

The potential of applying beeswax edible coating was evaluated in this study. Tomato fruits treated with different amounts of beeswax showed reduced weight and firmness loss during 30 days of storage at 10 °C. Despite the pH and TA values remaining constant across all samples, the edible coating successfully increased the TSS value and preserved lycopene content. Consequently, the findings indicate that the beeswax edible coating provides significant benefits, making it a promising method to extend the shelf-life of tomato fruits. Further evaluation of disease incidents and different storage conditions of beeswax coating may provide new insights into the postharvest treatment of tomatoes.

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