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Impact of Edible Coating Films on some Physiological, Physicochemical and Microbiological Properties of some Vegetable and Fruits

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ABSTRACT

Edible coatings improve the mechanical handling properties of fruits and vegetables by acting as a barrier to respiratory gases and water vapor. They have emerged as a solution to extend the shelf life of fruits and vegetables after harvest. The objective of the current study was to look at the effect of some edible coating treatments pectin, gum Arabic and beeswax on some physiological, physiochemical, and microbiological properties of tangerine (*Citrus reticulata* L.), guava (*Psidium guajava*) and green bell pepper (*Capsicum annuum* L.) during postharvest storage at ambient temperature for six weeks. The results showed that the coating process affected the percentage of water loss from the fruits, reduced the concentration of total soluble solids (%), and increased the percentage of acidity measured as citric acid, the pH values were slightly affected by the coating process, with overall increases in pH during storage. A clear effect of the coating process was observed in reducing the microbial load of treated fruits compared to uncoated fruits, the results indicated a decrease in yeast and mold counts in tangerines, guavas, and green bell peppers after storage at ambient temperature, all coated and uncoated fruits were free of coliform microbes during the storage period. At the same time all investigated fruits treated with beeswax have longer shelf life at ambient temperature reached to six weeks compared to uncoated and other treated fruits with pectin and gum Arabic.

Keywords: Edible coating, postharvest storage, tangerine, guava, green bell pepper.

INTRODUCTION

Quality is one of the most important factors in the selection of products. Fruits and vegetables by providing vital nutrients for health and maintenance of the body contribute to any healthy diet in food production chains. However, the perishability of these food categories is their main drawback in the development of food industries. Hence, significant amounts of work have been carried out to explore various solutions to maintaining the postharvest quality of fruits and vegetables (Porat *et al.,* 2018).

Due to pathological deterioration, rapid water loss, sagging and exposure to cold, the storage life of fruits and vegetables is reduced. (Fallik *et al.*, 2009).

Edible coatings improve the mechanical handling properties of fruits and vegetables by acting as a barrier to respiratory gases and water vapor. They have emerged as a solution to extend the shelf life of fruits and vegetables after harvest. (Khushi *et al.*, 2024).

Edible coating films prepared from natural substances like pectin, Arabic gum and beeswax are gaining increasing attention due to their ability to prolong the fruit and vegetables shelf life and maintain their quality. These coatings form a thin, biodegradable barrier that regulates gas exchange, moisture loss, and microbial growth, thus protecting the produce during storage. The effectiveness of these coatings in improving the physicochemical, physiological, and microbiological characteristics of various vegetables and fruits, including bell peppers, guava, and tangerines. For instance, pectin-based coatings have been found to reduce weight loss, delay ripening, and maintain firmness in bell peppers by minimizing water loss and oxidative damage during storage (Sundararaman *et al*., 2023).

Edible coverings based on pectin have been demonstrated to minimize bell pepper bacteria loads, hence reducing the risk of foodborne disease and spoiling while in storage (Kaur *et al*., 2022). Similar to this, beeswax coatings on guava have demonstrated benefits in maintaining the fruit's nutritional value, texture, and color while lowering chilling damage during cold storage (González-Rios *et al*., 2023; Sharma *et al*., 2022). On the surface of fruits and vegetables, pectin edible films or coatings provide a barrier that improves moisture and water retention. By boosting gas accumulation and postponing the ripening process, it produces a good barrier. Efforts were made to improve food firms by adding polysaccharides and essential oils (Rohasmizaha and. Azizah, 2022).

Research conducted on fruits such as tangerines and guavas show that these coatings contribute to the color retention, improved flavor stability, and nutritional content retention during storage (Moreno *et al*., 2023) Gum Arabic has also demonstrated efficacy in prolonging the shelf life of tangerines, postponing senescence, and preventing microbial growth, especially in reducing the likelihood of fungal contamination (Lopez-Martinez *et al*., 2023 and Majeed *et al*., 2021). One potential advantage of using beeswax as part of a food coating material is its antimicrobial properties (Wilson *et al*., 2015). The antimicrobial activity of beeswax is due to its content of propolis. its sticky material used by bees to seal holes and cracks in beehives. The major constituents of propolis are resins derived from the plants that the bees visit while collecting pollen .These results demonstrate how

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natural edible coatings can match customer desires for minimally processed and sustainable food preservation methods by enhancing the overall quality and safety of fresh fruits and vegetables.

MATERIALS AND METHODS

Materials

Raw Materials and Treatment.

Tangerine (*Citrus reticulata* L.), guava (*Psidium guajava*), and green bell pepper (*Capsicum annuum* L.) fruits. The fruits were picked for maturity, ripeness, uniform size, shape, and color, with no signs of mechanical injury or fungal degeneration. The fruits were acquired at a local market in Fayoum governorate during the February 2022 season. Immediately delivered to the Faculty of Agriculture's Food Science and Technology Labratory at Fayoum University in Egypt. After washing with tap water to remove dust, they were gently dried with paper towels and left at room temperature until covered (Hosseini, 2009 and Restrepo, 2010).

Apple pectin

Apple pectin type VP was purchased from Pektin-Fabrik, Herbstreith, USA.

Gum Arabic powders

Were bought in Fayoum City, Egypt's Fayoum Governorate, from the local market.

Beeswax

Beeswax was purchased from the apiary in the Faculty of Agriculture's experimental farm at Fayoum University in Fayoum, Egypt.

Chemicals

All chemicals used in coatings films preparation were parched from El- Gomhoria Chemical Co., Egypt.

Coating treatments:

Preparation of apple pectin coating.

Apple pectin solution was prepared at a concentration of 2% and dissolved in distilled water by heating at 60°C after complete dissolution, 1% glycerin (w/v) was added as a plasticizer (Silva, *et al.*, 2019).

Preparation of gum Arabic.

One liter of distilled water was used to dissolve 100 grams of gum arabic powder to create a 10% (w/v) gum Arabic solution. A hot plate (Model: Gesellschaft fur Labortechnik m.b.H D 3006 Burgwedel) and magnetic stirrer (model: Fisher Scientific Company U.S.A 220 P) were used to agitate the gum Arabic solution at 40 °C for 60 minutes. The mixture was then filtered through a muslin cloth to exclude contaminants and unidentified items. To increase the density and flexibility of the coating solution, 1% glycerin (w/v) was added as a plasticizer after the solution had been chilled to 20 °C. Using a digital pH meter, the solution's pH was brought to 5.6 by adding 1 N NaOH (Krishnadev and Gunasekaran, 2017).

Preparation of beeswax coating

The beeswax was melted in a water bath at a temperature of 60 ºC.

The fruits were divided into four groups of (25 fruits for each) as follow: -

1- The first group of fruits was washed with purified water. (Control).
2- The 2nd group was immersed in a 2% apple pectin solution for 1-2 minutes.
3- The third batch was immersed in 10% gum Arabic solution for 1-2 minutes.
4- The fourth batch was soaked in beeswax at 60 °C for 5 seconds.

After air drying, all of the fruits were kept at room temperature for 42 days. The initial physiochemical parameters of five fruits were established, and the changes were tracked at 7day intervals during the storage period.

Methods of analysis:

Physiological analysis

Weight Loss Percentage

Five labeled treated fruits were preserved at room temperature for seven days after harvest, and the weight loss was measured by weighing the fruits every seven days. The percentage of weight loss was calculated using the formula below:

Weight loss %=(The initial weight−fruit weight at examination date)/the initial weight.

Maturity Index (MI)

Determined by dividing the titratable acidity by the total soluble solids using the following equation: MI = TSS/TA (Mohammed *et al*., 2021).

Physiochemical analysis

Determination of pH value

Five grams of sample were blended in 50 ml of distilled water for two minutes then filtered through glass wool. The pH was measured by pH meter (Model WTW PH320) at ambient temperature (Pennisi *et al.*, 2020).

Determination of Total Soluble Solids Content (TSS)

Four samples of fruit pulp were squeezed out for each treatment, and the TSS % was measured from the resultant juice. (Brix) using a Carl Zeiss refractometer (Mohammed *et al*., 2021).

Determination of Titratable acidity (TA)

To measure (TA), 10 ml of flesh juice was titrated with sodium hydroxide (0.1 N), and the findings were represented as mg citric acid per 100g (AOAC, 2008).

Determination of total Carbohydrates content

The phenol-sulforic acid technique was used to calculate the total amount of carbs. (A.O.A.C., 2008).

Microbiological analysis

It was performed according to the guidelines recommended by ISO 4833-1:2013

Total viable counts (TVC)

TVC of samples were enumerated with nutrient agar medium. The plates were incubated at 35ºC for 48 hrs.

Coliform bacteria group

Coliform bacteria group were detected using MacConkey agar medium. From each of the previously prepared sterile dilutions, 1ml aliquots were delivered into duplicate sets of Petri dishes, previously inoculated with 10ml of sterile MacConkey agar after solidification, inoculated as well as control plates were incubated at an inverted position at 37ºC for 24 – 48 hrs.

Mold and yeasts

From each of the previously prepared sterile dilutions, 1ml aliquots were delivered into duplicate sets of Petri dishes, previously inoculated with 10ml of sterile potato dextrose agar medium after solidification, inoculated as well as control plates were incubated at an inverted position at 25ºC for 5 days.

Statistical analysis:

Version 30.0 of SPSS was used to perform statistical analysis. The standard deviation ± mean is used to express all data. A p-value of less than 0.05 was used to determine the significance of mean differences.

RESULTS AND DISCUSSION

Vegetables and fruits have a shorted shelf life. since they are perishing. The length and quality of storage could be reduced by environmental variables, transportation, and postharvest preservation conditions. Thus, by using safer postharvest treatments to extend the shelf life of fruits and vegetables, edible coatings are the focus of preservation techniques. To improve fruit and vegetable quality, safety, and shelf life during storage, active edible coatings containing various kinds of functional substances can be employed as a preservation technique Davis *et al.,* (2006).

Weight loss (%):

One of the primary physiological factors is water loss. that degrade the quality of fruits and vegetables during transportation, storage, and later marketing. Smith *et. al.,* (2006). With only a slight weight loss (3% to 10%), most fruits and vegetables deteriorate in quality, potentially rendering them unfit for sale (Robinson *et al*., 1975).). Effect of some edible coating treatments (pectin, gum Arabic and beeswax) on the weight loss (%) of tangerine, guava and green bell pepper fruits during postharvest storage for six weeks at ambient temperature compared to the same uncoated fruits were studied and the outcomes that were attained are shown in Table (1).

It was evident from the tabulated data in Table (1) that fruits lost weight as their storage duration increased and the rate of decrease was affected by coating treatments. In all the investigated fruits coated with beeswax showed the lowest weight loss meanwhile, the rest of treatments nearly had the same effect compared to the uncoated fruits (Control).

Table 1. Effect of edible coating treatments on weight loss (%) of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Uncoated	Pectin	Gum Arabic	Beeswax
Tangerine	0	0.00±0.00			
	7	10.70±0.61	5.80±0.72	6.40±0.53	0.40±٠.01
	14	28.50±1.04	23.12±0.81	26.80±1.11	3.80±0.26
	21	31.70±1.13	28.10±0.85	33.40±1.44	8.50±0.50
	42	S*	S*	S*	14.10±0.85
Guava	0	0.00±٠.00			
	7	8.70±٠.61	8.10±1.01	8.20±0.72	0.30±٠.02
	14	71.90±1.15	45.90±٠.85	44.00±2.00	14.10±٠.85
	21	S*	54.90±٠.85	46.00±1.00	20.10±1.15
	42	S*	S*	S*	29.40±0.79
Green Bell pepper	0	0.00±0.00			
	7	17.60±1.22	15.70±1.53	13.40±1.64	0.60±٠.02
	14	44.22±٠.72	54.10±1.15	56.70±٠.60	2.10±٠.36
	21	71.30±٠.61	71.80±1.59	84.40±1.51	5.10±0.66
	42	S*	S*	S*	15.70±1.47

S*= Spoiled

According to Yaman and Bayoindirli (2002), vapor pressure at different locations is the main cause of weight loss from fresh fruit and vegetables; however, respiration also contributes to weight loss (Pan and Bhowmilk, 1992). Due to the coating's functions the fruits coated in beeswax exhibited the least reduction in weight loss because the coating serves as a semi-permeable barrier

that prevents the transport of solutes, moisture, CO2, and O2., which reduces respiration, water loss, and oxidation reaction rates (Baldwin *et al.,* 1999 and Park, 1999).

The outcomes are consistent with Banks' (1984) findings that covering banana fruit with sucrose ester-based materials extended its shelf life by decreasing water loss and changing the internal environment. The same results showed that the green bell pepper coated with 10% gum Arabic lost a significant amount of weight compared to the uncoated fruits. The fundamental cause of this rise may be the thickly covered fruits, which generate heat and produce end products from anaerobic fermentation.

Total Soluble Solids (TSS):

One of the important elements affecting how tasty a fruit is depending on its total soluble solids (TSS), which rises as the fruit ripens and serves as a reliable indication of when a fruit is ready. Table (2) presents the findings of a study on the impact of several edible coatings, including pectin, gum Arabic, and beeswax, on the Total Soluble Solids (Brix) of tangerine, guava, and green bell pepper fruits after six weeks of postharvest storage at room temperature. It is evident from the tabulated data in Table (2) that all fruits under investigation had a rise in total soluble solids over the storage period, with the coating method having an impact on the rate of growth. In contrast to the fruits coated with beeswax, which had the lowest rates of total soluble solids, the uncoated fruits displayed the greatest rates. Because of the concentration of sugars in the fruit, an increase in moisture loss may also lead to an increase in total soluble solids; however, starch breakdown often has a bigger impact on changes in total soluble solids (Andrade *et al.*, 2017).

Table 2. Effect of edible coating treatments on Total Soluble Solids (Brix) of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Uncoated	Pectin	Gum Arabic	Beeswax
Tangerine	0	10.50±0.70			
	7	11.20±0.1031	11.10±0.85	11.15±0.33	10.70±o.89
	14	13.50±1.32	13.00±0.90	13.20±1.47	11.20±1.31
	21	12.20±0.72	12.90±0.85	12.90±0.36	11.70±,44
	42	S*	S*	S*	1,13 ±١٠,٣٠
Guava	0	9.20±0.72			
	7	10.90±1.15	10.90±o.53	11.00±1.00	9.50±0.50
	14	12.80±0.763	13.90±1.153256	13.40±0.65	10.20±0.72
	21	S*	12.10±0.85	12.70±0.72	11.40±0.85
	42	S*	S*	S*	0.85 ±٩,١٠
Green bell pepper	0	4.20±0.72			
	7	5.10±0.85	5.30±0.61	4.80±0.26	4.00±0.50
	14	6.50±0.50	5.80±0.26	6.40±0.53	4.40±0.79
	21	6.30±0.61	5.20±0.72	5. 10±0.85	4.90±0.60
	42	S*	S*	S*	3.50±0.50

S*= Spoiled

A decrease in respiration rate and the conversion of sugars to carbon dioxide and H_2o at later stages of storage, as well as a hydrolytic change in starch and the conversion of starch to sugar which is a significant indicator of the ripening process in fruits are known to be the causes of the increase in total soluble solids contents (Arthey and Philip, 2005). Increased conversion of sucrose, a non-reducing sugar, to monomeric sugars like glucose, a reducing sugar, and a larger accumulation of free sugar are common causes of total soluble solids rising. The breakdown of starch into soluble sugars can also cause an increase in the concentration of total soluble solids (Ali *et al*., 2010). Total soluble solids rise in response to an increase in the concentration of free sugars. During storage, the concentration of total soluble solids rises in response to an increase in the free sugar content (Cheour *et al*., 1990; Parven *et al*., 2020). Reduced respiration and metabolic activity, such as the conversion of sugars into Co_2 and H_2o, may be caused by changes in the internal atmosphere of the fruit, as evidenced by the low increase in Total Soluble Solids values for beeswax-coated fruits and the depletion of Total Soluble Solids values of fruits under investigation during the later stages of storage Ghasemnezhad (2011).

Titratable acidity (TA):

Since the balance of soluble sugars and organic acids greatly affects the flavor of the fruit flesh, the organic acid composition of fruits is fascinating (Karadeniz, 2004). The titratable acidity (TA) of fruit is a further important factor that influences how good it is for eating. Since organic acids are used as main substrates for respiration and other metabolic processes, total acidity (TA), which measures the overall acidity of a solution, is often lowered during postharvest storage (Mahfoudhi and Hamdi, 2015). The study measured the titratable acidity of three fruits tangerine, guava, and green bell pepper that were coated and uncoated. The fruits were stored for six weeks at room temperature after harvest, and the results are displayed in Table (3).

The findings shown in Table (3) indicate that, when it comes to coating treatments, beeswax coated fruits exhibited the highest titratable acidity during the postharvest storage period, whereas uncoated fruits had the lowest acidity. The ripening process may be the cause of the low titratable values for uncoated fruits. The use of organic acids as substrates for respiratory metabolism or sugar conversion because of enzymatic activity during microbial respiration are the reasons for the decrease in this parameter, which increases with pH.

Table 3. Effect of edible coating treatments on Treatable Acidity (TA) mg citric acid/١٠٠ g) of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Control	Pectin	Gum Arabic	Beeswax
Tangerine	0	4.82±٠.26			
	7	3.80±0.20	4.30±٠.61	4. 50±0.50	4.27±٠.25
	14	3.15±٠.10	2.95±٠.21	3.90±٠.60	3.90±٠.36
	21	2.35±0.40	2.32±٠.49	3.17±٠.76	2.75±٠.32
	42	S*	S*	S*	2.20±٠.26
Guava	0	3.91±٠.10			
	7	2.24±0.15	3.50±٠.44	3.70±٠.30	3.85±0.15
	14	1.65±٠.42	2.75±٠.25	3.10±٠.36	3.70±٠.30
	21	S*	2.33±٠.15	2.50±٠.15	3.49±٠.50
	42	S*	S*	S*	2.25±٠.25
Green bell pepper	0	2.75±٠.31			
	7	1.52±٠.15	2.53±٠.42	2.21±٠.21	2.45±٠.15
	14	1.83±٠.21	1.42±٠.21	1.01±٠.06	2.08±٠.12
	21	0.60±٠.02	0.70±٠.04	0.94±٠.01	1.60±٠.20
	42	S*	S*	S*	0.89±٠.03

S*= Spoiled

The data showed that there were variations in the treatments under study during the postharvest storage period, and that the coatings produced a good semi-permeable film around the fruit, altering the internal atmosphere by raising Co_2 and/or decreasing O_2, as well as reducing the production of ethylene. Lower respiration rates also result in lower metabolite synthesis and utilization, which lowers SSC (Yaman and Bayoindirli, 2002). The gum Arabic and beeswax coating films delayed ripening by generating a semi-permeable barrier surrounding the fruit, as indicated by the lower TA level in the coated fruit as compared to the control fruit. Fruit that respires strongly should have a lower acidity since organic acids, such citric acid, are important substrates for respiration (El-Anany *et al*., 2009). According to Yaman and Bayoindirli (2002), coatings are also believed to decrease respiration, which may postpone the utilization of organic acids. Additionally, it was found by Khaliq *et al*. (2019) and Ali *et al*. (2010) that coatings such gum Arabic and *aloe vera* diminish organic acid oxidation and reduce O_2 availability, which in turn conserves more TA in the treated product.

Maturity Index (MI):

The most essential measure in evaluating fruit quality is the TSS/TA ratio, which impacts fruit taste harmony and customer acceptance. Gum Arabic and beeswax coated fruits displayed a lesser rise in the TSS/TA ratio, implying reduced ripening compared to untreated and other coated (pectin, gum Arabic and beeswax) fruits during postharvest storage at ambient temperature for six weeks,

The results shown in Table (4) it could be noticed the maturity index (MI) it was affected by the coating treatments especially in case of guava fruits. When compared to the other treatment, the uncoated fruits had the greatest values, while the beeswax-coated fruits displayed the lowest values. The rise in fruit sugar content may be the cause of the maturity index increase. Because starch is converted into simple sugars by catabolic processes such respiration, it is known to rise during ripening (Mahfoudhi and Hamdi, 2015). Subsequently cause the total soluble solids to rise.

Table 4. Effect of edible coating treatments on maturity index (MI) of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Uncoated	Pectin	Gum Arabic	Beeswax
Tangerine	0	2.18±0.25			
	7	2.95±0.25	2.58±0.21	2.48±0.21	2.51±0.30
	14	4.29±0.31	4.41±0.60	3.38±0.32	2.87±0.42
	21	6.04±0.50	5.99±0.31	4.70±0.61	4.25±0.25
	42	S*	S*	S*	5.59±0.40
Guava	0	2.55±0.25			
	7	4.87±0.15	3.11±0.36	2.97±0.21	2.47±0.21
	14	8.97±1.05	5.05±0.40	4.32±0.40	2.76±0.25
	21	S*	5.62±0.47	5.08±0.31	3.27±0.25
	42	S*	S*	S*	5.38±0.21
Green Bell pepper	0	1.53±0.32			
	7	3.36±0.40	2.09±0.15	2.17±0.21	1.63±0.25
	14	3.55±0.45	4.08±0.45	6.34±0.76	2.12±0.15
	21	10.50±1.00	8.86±0.81	6.70±0.44	3.06±0.40
	42	S*	S*	S*	6.52±0.50

S*= Spoiled

The ripening process causes a reduction in the fruits' titratable acidity at the same time. This viewpoint was corroborated by Gol *et al*. (2013), who reported that changes in TA during storage were largely brought on by living tissues' metabolic processes, which deplete organic acids (such as citric and malic).

pH value:

Table (5) presents the findings of a study conducted on the impact of coating treatments on the pH value of tangerine, guava, and green bell pepper fruits during the postharvest storage period at room temperature.

From the results tabulated in Table (5) it could be noticed the pH values of investigated fruits it was affected by the type of coating form both of gum Arabic and beeswax coatings have the lowest pH values compared to uncoated (Control) and the rest of coating forms which showed relatively high pH values. Consequently, it could be shows that gum Arabic and beeswax coatings slowed creating a semi-permeable shield around the fruit to aid in its ripening. Since organic acids, such citric or malic acid, are essential substrates for respiration, it is expected that fruit that is respiring vigorously would have less acidity, which will raise the pH of the fruit. According to Yaman and Bayoindirli (2002), coatings are also believed to decrease respiration, which may postpone the utilization of organic acids. Prior studies have demonstrated that many fruits treated with edible coatings and films maintain their titratable acidity (Yaman and Bayoindirli, 2002; Tanada-Palmu and Grosso, 2005). The oxidation of organic acids results in the lowering of TA. Previous studies have postulated that the increased reduction in acidity observed in uncoated fruits results from the preservation process's usage of organic acids as substrates for respiratory metabolism.

Table 5. Effect of edible coating treatments on pH value of tangerine, guava and green bell pepper during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Uncoated	Pectin	Gum Arabic	Beeswax
Tangerine	0	3.57±0.31			
	7	3.65±0.15	3.78±0.15	3.82±0.15	3.10±0.10
	14	3.75±0.25	3.85±0.15	3.72±0.15	3.35±0.15
	21	4.22±0.15	4.28±0.15	3.39±0.15	3.52±0.21
	42	S*	S*	S*	3.61±0.10
Guava	0	3.83±0.15			
	7	4.11±0.36	4.45±0.15	3.47±0.25	3.82±0.40
	14	4.65±0.40	4.91±0.36	3.62±0.32	3.75±0.25
	21	S*	4.46±0.50	3.51±0.20	3.59±0.40
	42	S*	S*	S*	3.63±0.32
Green bell pepper	0	5.36±0.45			
	7	6.46±0.25	6.74±0.31	6.90±0.20	5.73±0.25
	14	6.53±0.25	6.90±0.15	6.13±0.21	6.28±0.25
	21	7.10±0.31	7.23±0.25	6.28±0.31	6.50±0.50
	42	S*	S*	S*	±0.10٦,٩٠

S*= Spoiled

Total carbohydrates Content:

The study examined the impact of several edible coatings, including pectin, gum Arabic, and beeswax, on the overall sugar content (%) of tangerine, guava, and green bell pepper fruits after six weeks of storage at room temperature. The findings are displayed in Table (6).

From the presented data in Table (٦) it could be noticed that at the first stages of storage period the total carbohydrates content (%) it was increased in all investigated fruits and the rate of increasing it was affected by the type of coating form then, a depletion of the total carbohydrates contents at the late stages from storage period it was noticed. From other hand, uncoated fruits showed the highest rates of total sugar content (%) meanwhile, the fruits coated with beeswax showed the lowest rates of total sugars contents.

The apparent increase in total carbohydrates contents may be attributed to the loss of water content during storage period which lead to concentration of the sager contents. Ullah *et al.*, (2017) they concluded that the Sugar content increases with fruit ripening and senescence. Similarly, the conversion of starch may contribute to increased sugar concentration. Meanwhile, the coating treatments prevent ripening, following senescence, and starch conversion into sugar contents.

When fruits coated with beeswax were stored, this value went up a little bit. This was probably because there was less water loss, less activity from hydrolytic enzymes, or less respiration rate and sugar conversion into Co_2 and H_2o throughout the storage time. Lastly, as previously reported by Arthey and Philip (2005) and Mahfoudhi and Hamdi (2015), the increase and decrease in total carbohydrates contents during ripening may be caused by a hydrolytic change in starch and the conversion of starch to simple sugars by catabolic processes such as respiration, which is an important indicator of the ripening process in fruits. There may also be a decrease in respiration rate and sugar conversion to Co_2 and H_2o at later stages of storage.

Table 6. Effect of edible coating treatments on Total Carbohydrates Contents (%) of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Control	Pectin	Gum Arabic	Beeswax
Tangerine	0	9.25±٠.72			
	7	10.10±٠.85	9.80±1.03	9.60±o.53	9.40±0.56
	14	11.90±1.15	11.20±٠.72	11.40±o.96	9.60±٠.36
	21	11.20±٠.72	10.90±0.85	10.50±0.50	10.20±٠.72
	42	S*	S*	S*	9.40±٠.66
Guava	0	7.37±٠.60			
	7	8.70±0.36	8.30±0.61	8.50±٠.50	7.60±0.60
	14	10.30±٠.61	9.70±٠.26	10.05±٠.90	8.30±٠.61
	21	S*	8.50±٠.50	9.60±٠.53	9.10±٠.85
	42	S*	S*	S*	7.20±٠.72
Green bell pepper	0	2.65±٠.49			
	7	2.70±٠.44	2.80±٠.26	3.40±0.56	2.80±٠.35
	14	2.90±٠.20	3.10±٠.36	4.20±٠.72	2.90±٠.20
	21	3.10±٠.36	2.40±٠.53	3.00±٠.45	3.10±٠.36
	42	S*	S*	S*	2.30±0.30

S*= Spoiled

Microbial Examination:

Total viable count (TVC), total mold and yeasts and Coliform group counts were examined for all fruits and vegetables samples during storage for six weeks at ambient temperature as mentioned in Tables (7, 8).

Total viable count in different treated fruits and vegetables storaed at ambient temperature.

High water activity in fruits can encourage the growth of pathogens such as *Salmonella Typhimurium* and *Escherichia coli*, as well as rotting organisms like *Penicillium expansum* and *Rhizopus stolonifer* (Andrade *et al.*, 2017). Furthermore, it has been demonstrated that edible coatings possess antibacterial qualities, which might mean that they take the place of synthetic fungicides in postharvest management (Bal, 2013 and Andrade *et al*., 2017). The amount of viable microorganisms in a sample is indicated by the total viable count.

The table shows the impact of various edible coatings on the overall viable count of different fruits across varying storage durations (0, 21, and 42 days). Fruits coated with beeswax, pectin, gum Arabic, and untreated (Control) were the treatments. Table (7) presents the findings of a study conducted on the effect of edible coatings on the total viable count (log cfu/g) of tangerine, guava, and green bell pepper fruits after storage for six weeks at room temperature.

Tangerine fruits:

As a result, presented in Table (7) it could be noticed that the uncoated fruits (Control group) showed a gradual increase in the total viable count over time. This indicates that without any treatment or coating, the microbial growth on the fruits naturally increased during storage, and the total viable count was 2.5 at zero time, which increased to 4.4 (log cfu/g) by day 21, after which the fruits became spoiled and were not fit for consumption by day 42.

The use of pectin as an edible coating seemed to have a positive effect on reducing the total viable count compared to that of the control group. On day 21, there was a significant decrease in the microbial count compared to control group. At no growth, the count was 2.8 (log cfu/g) on day 21, after which the plants became spoiled by day 42.

Gum Arabic also shows some effectiveness in controlling microbial growth on fruits. The total viable counts were lower than those in both the control and pectin treatments at certain time points. The count was 2.8 on day 21, after which the fruits became spoiled and were not fit for consumption by day 42.

Beeswax treatment appears to be quite effective at reducing microbial growth on fruits throughout most of the storage period. This treatment consistently maintained lower total viable counts than did the other treatments. The count was 2.3 (log cfu/g) on day 21, and by day 42, the fruits had spoiled.

Table 7. Effect of edible coatings on total viable count of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature

Fruits	Storage Time (day)	Treatments			
		Uncoated	Pectin	Gum Arabic	Beeswax
Tangerine	0	2.5			
	21	4.4	2.8	2.8	2.3
	42	S*	S*	S*	4.5
Guava	0	2.0			
	21	S*	2.0	2.5	2.7
	42	S*	S*	S*	4.4
Green bell pepper	0	1.8			
	21	4.2	2.9	2.8	2.1
	42	S*	S*	S*	4.3

S*= Spoiled

Beeswax appears to be the most effective treatment for reducing microbial growth on Tangerine fruits. Pectin also shows promise in controlling microbial counts. Arabic gum is somewhat effective but less effective than pectin and beeswax. The antimicrobial activity of beeswax is due to its content of propolis. its sticky material used by bees to seal holes and cracks in beehives. The major constituents of propolis are resins derived from the plants that the bees visit while collecting pollen (Wilson *et al.*, 2015).

Guava fruits:

The total viable count in the control group increased over time. For example, in guava fruits, the count was 0.2 (log cfu/g) on day zero, after which the fruits became spoiled and were not suitable for consumption by day 42.

The use of pectin as an edible coating seemed to have a varying effect on the total viable count depending on the fruit type and storage time. In guava fruits, for instance, the count was 2.0 (log cfu/g) on day 21, and by day 42; the fruits were not fit for consumption.

Gum Arabic also showed mixed results across different fruits and storage times. In guava fruits, the total viability was 2.5 (log cfu/g) on day 21, after which the fruits became spoiled by day 42.

Beeswax as a coating exhibited some effectiveness in reducing the total viable count in certain cases. In guava fruits, there was an increase from 2.7 (log cfu/g) on day 0 to 4.4 (log cfu/g) on day 42. Edible coatings such as pectin, Arabic gum, bee wax, and emulsion bee wax can play a significant role in controlling the total viable count of guava fruits during storage. Further research could delve deeper into optimizing these coatings for specific fruit types and storage conditions.

Bell pepper samples:

At zero time, all coated samples showed no detectable viable counts, indicating an initial reduction in microbial load compared to that of the control, which had a count of 1.8 (log cfu/g). By day 21, all coatings maintained lower viable counts than did the control, with emulsion bee wax showing the highest viable count among the other coatings. The viable counts were 4.2, 2.9, 2.8, 3.3 and 2.1 (log cfu/g) for the control, pectin, Arabic gum and beeswax bell pepper treatments, respectively. By day 42, all the coated samples had spoiled except for the beeswax coated peppers, which still had a viable count of 4.3 (log cfu/g). The results suggest that while all coatings initially reduced microbial counts compared to those of the control, their effectiveness decreased over time. Beeswax showed better preservation effects up to day 42 than the other coatings. Gum Arabic has garnered significant attention as a postharvest edible covering because of its ability to preserve fresh produce's quality and lengthen its shelf life. Because of its advantageous emulsifying, stabilizing, binding, and shelf-life-extending properties, it is a successful food preservative (Quazeem *et al.*, 2023).

Total yeast and mold:

Results in Table (8) shows the effect of different edible coatings on total yeast and mold count in investigated samples at various storage times. The fruits studied included Tangerine, Guava, and Bell Pepper. The treatments applied to these fruits were uncoated (Control), Pectin, Arabic Gum, and Beeswax.

Effect of edible coatings on total yeast and mold count (log cfu/g) of tangerine, guava and green bell pepper during storage for six weeks at ambient temperature was studied and the results are shown in Table (8).

Tangerine fruits:

From the results presented in Table (13) it could be noticed that at zero time, all treatments showed no detectable (ND) yeast or mold counts. By day 21, the control, pectin, gum Arabic and beeswax treatments had counts of 3.2, 2.0, 2.3, and 2.6 log cfu/g and ND, respectively. By day 42, all treatments except beeswax had spoiled with varying counts.

Guava fruits:

Only the control treatment had a count of 1.6 log cfu/g at zero time. By day 21, the counts for the control treatment, pectin treatment, gum Arabic treatment, and beeswax treatment had grown to 3.2 log cfu/g, 2.6 log cfu/g, and 3.0 log cfu/g, respectively. Except for beeswax, all treatments had deteriorated by day 42, with counts rising to 3.6 (log cfu/g).

Green bell pepper samples:

At zero time, only the control treatment had a count of 2.0 log cfu/g. By day 21, the counts increased to 3.4, 3.3 and 3.1 log cfu/g for the green bell pepper control, pectin and gum arabic treatments, respectively; however, no discernible (ND) yeast or molds were observed on the green bell peppers covered in beeswax. Bell pepper samples treated with various coatings exhibited deterioration by day 42, except for beeswax, which continued to have a lower count of mold and yeast than the other coatings. Using edible coatings such as pectin, Arabic gum, and emulsion bee wax seemed to delay spoilage compared to that in the control group in most cases. The Beeswax coating appeared to be more effective at inhibiting yeast and mold growth than the other coatings across the different fruits studied. Gum Arabic has been well studied in the literature with promises of superior microbial activity inhibition when coupled with essential oils and seed extracts. For example, adding ginger and black pepper essential oils to Gum Arabic composite films dramatically decreased the growth of Bacillus cereus, Staphylococcus aureus, Escherichia coli, and Salmonella typhimurium (Amalraj *et al.*, 2020).

Table 8. Effect of edible coatings on total yeast and mold count of tangerine, guava and green bell pepper fruits during storage for six weeks at ambient temperature.

Fruits	Storage Time (day)	Treatments			
		Uncoated	Pectin	Gum Arabic	Beeswax
Tangerine	0	ND			
	21	3.2	2.0	2.3	ND
	42	spoil	Spoil	spoil	3.3
Guava	0	1.6			
	21	spoil	2.6	2.8	ND
	42	spoil	Spoil	spoil	3.6
Green bell pepper	0	2.0			
	21	3.4	3.3	3.1	ND
	42	spoil	Spoil	spoil	3.5

S*= Spoiled

Coliform group counts:

The impact of various food coatings on the overall numbers of coliform groups in various fruits (Tangerine, Guava and green bell pepper) over different storage times (0, 21, and 42 days) were studied. The data shows that the application of edible coatings such as pectin, gum Arabic and beeswax appears to have effectively reduced or inhibited the growth of total coliform group counts in the tested fruits. Across all fruits tested (Tangerine, Guava and green bell pepper) and different storage times (0, 21, 42 days), the coatings seemed to be successful in maintaining low or undetectable levels of coliform bacteria. Our results agreement with the previous study which carried by Kim *et al.* (2013) found that applying a coating on plums was efficient in preventing cell development both before and after coating, indicating Such coatings might be useful in preventing the development of microorganisms at any time after an infection. Guar gum, according to Dong *and* Wang (2018), decreased fruit deterioration from 43% in the control group to 26% in the coated fruit after eight days of storage at 20 °C and 70–75% relative humidity. Fruit perishing was decreased to just 13% when ginseng extract was added to the coating, significantly reducing the frequency of decay.

The experiment's findings demonstrated that applying beeswax as an antimicrobial coating is a workable substitute for limiting the microbiological growth found in fruits with minimal coating because it significantly slowed the growth of yeasts, molds, and total coliforms.

CONCLUSION

Based on the current study's findings, it is recommended to use beeswax as a coating for various veggies and fruits to increase their shelf life. The beeswax coating slows down the respiration rate, reduces oxygen availability, and minimizes the oxidation of organic acids, thereby preserving ascorbic acid (vitamin C) and bioactive compounds. Additionally, the coating reduces water loss, weight loss, and microbial load. An important development in active food packaging technology has been the incorporation of antimicrobial agents into edible films made of biopolymers. It is very effective at preventing or eliminating the spoilage or pathogenic microorganisms that contaminate food. It can lessen the possible unwanted flavors that result from the direct addition of active ingredients to food.

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تأثير عملية الطلاء بالأغلفة القابلة للأكل على بعض الخصائص الفسيولوجية والفيزيوكيميائية والميكروبيولوجية لبعض ثمار الخضر والفاكهه

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الملخص

تعتبر الطلاءات الصالحة للأكل حل لإطالة العمر الافتراضي للفواكه والخضروات بعد الحصاد، حيث تعزز الخصائص الميكانيكية للثمار وتعمل كحاجز للغازات وبخار الماء. أجريت الدراسة الحالية لدراسة تأثير بعض معاملات التغطية بالأغلفة الصالحة للأكل المصنعة من (البكتين والصمغ العربي وشمع العسل) على بعض الخصائص الفسيولوجية والكيميائية والفيزيائية والمكروبيولوجية لبعض أصناف الفاكهة والخضر مثل البرتقال اليوسفي (*Citrus reticulata* L.) والجوافة (*Psidium guajava*) والفلفل الأخضر (*Capsicum annuum* L.) أثناء التخزين بعد الحصاد في درجة حرارة الغرفة لمدة ستة أسابيع. أظهرت النتائج أن عملية التغطية أثرت على نسبة فقدان الماء من الثمار، وخفضت من تركيز المواد الصلبة الذائبة الكلية TSS، وزادت نسبة الحموضة مقدرة كحامض الستريك، وتأثرت قيم درجات الأس الهيدروجيني بشكل طفيف بعملية الطلاء، مع زيادة إجمالية في الأس الهيدروجيني أثناء التخزين. لوحظ وجود تأثير واضح لعملية التغطية في تقليل الحمل الميكروبي للثمار المعاملة مقارنة بالثمار غير المغلفة، وأشارت النتائج إلى انخفاض في أعداد الخميرة والأعفان في اليوسفي والجوافة والفلفل الأخضر الحلو بعد التخزين على درجة حرارة الغرفة، وكانت جميع العينات المغلفة وغير المغلفة خالية من وجود ميكروبات القولون خلال فترة التخزين. وفي نفس الوقت فإن جميع الثمار محل الدراسة المعاملة بشمع العسل أظهرت فترات تخزين أطول على درجة حرارة الغرفة وصلت إلى ستة أسابيع مقارنة بمثيلاتها من الثمار غير المغلفة والمعالجة الأخرى بالبكتين والصمغ العربي.

الكلمات الافتتاحية: الأغلفة القابلة للأكل، معاملات ما بعد الحصاد، البرتقال اليوسفي، الفلفل الأخضر، الجوافة.