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Effect of Bio-Based Protein Coating on the Quality and Shelf Life of Fig Fruit (*Ficus Carica* L.)

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ABSTRACT

Fruit coatings are an appropriate method to preserve quality and extend the shelf life of fruit. This study focused on the impact of coating fig fruit with bio-based proteins (sunflower seeds, whey, and caseins). The fruits were dipped into the coating solution and dried. Then, the fruits were stored in the refrigerator at 5°C with 85–90% relative humidity. Fruit quality was higher by using the coating method, and the fruits showed significantly higher sensory evaluation scores (color, texture, brightness, and overall acceptability) compared to the control, while the highest score was in the whey protein coating treatment. The weight loss and total soluble solids (TSS) in all coated fruits were significantly lower compared to the control. In particular, sunflower seeds protein had the highest titratable acidity (TA), and whey protein reduced polyphenol oxidase activity than the other treatments. However, a prolonged storage period substantially increased weight loss, TSS, TA, total sugar, and total phenol, as well as reduced all sensory evaluation scores. Therefore, the data of this study help to prolong the fig fruit shelf life and the period of display in the market. Especially, all bio-based protein coating significantly reduced fresh weight loss and preserved the fruit quality than the control throughout the post-harvest.

Keywords: Bio-based coating, Ficus Carica, polyphenol oxidase, postharvest periods.

1. Introduction

Approximately 30% of fruits and vegetables are impacted/damaged before and after the harvest. Therefore, fruit and vegetable preservation is a big challenge, because of the horticultural product's short shelf life, transportation, and storage. The current postharvest techniques need improvement, be more environmentally friendly, and be cost-effective. Fruit coating is an efficient way to preserve fresh fruits, the uses are increasing due to the impact and environmental concerns[1,2]. For instance, coatings with whey protein isolate (WPI) can regulate the atmosphere of the product and slow down fruit softening by inhibiting metabolic processes[3] or reducing the loss of weight[4]. Coating materials are made from synthetic or natural polymers with film-forming properties such as polysaccharides, proteins, and lipids[5]. The physical and chemical characteristics of coating materials are different; therefore, they might make different changes to the product. Materials from natural plant or animal origins are the potential ones to use, in particular from plants such as protein (from soybean, wheat gluten, corn zein, sunflower, gelatin, whey, casein, and keratin) and polysaccharides (cellulose derivatives, starches), gums[6,7]. In particular, the casein-based coating is used as a barrier to reduce weight loss and control the moisture in the fruit[8,9].

Fig (*Ficus Carica* L.) belongs to the Moraceae family and is considered one of the ancient fruit trees[10]. Fresh fig fruits have a unique taste and are rich in phytochemicals that have antioxidant activity, such as phenolic compounds and carotenoids[11]. The fruit's nutritional values are varied with the fruit type, cultivar (variety), and ripening stage. Fig fruits have a high number of soft and juicy tissues, which makes them susceptible to rapid damage by pathogens when the fruit is not harvested or after the harvest[12]. Fig fruits are usually very sensitive to physiological and pathological e.g, softening and cracking of the skin. The edible coatings (EC) were used in some fruit crops to lessen post-harvest fruit transpiration and preserve the visual quality of the fruit[13]. The casein-based coating is used to preserve the quality of fruits and extend their shelf life. Based on thorough research, casein was selected for maintenance the freshness fruits because of its availability, safety, and versatility as a shell-forming proteinaceous substance[9]. The coated casein

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protein is the barrier to weight loss and helps control the moisture remaining in the fruit for a prolonged time during storage[8]. The edible coating is based on a whey protein concentrate which was used to preserve the quality of the fruit. Coating with whey protein concentrate lessens the fresh weight loss in kiwi fruit compared with uncoated fruits during the storage time[14]. Therefore, the aim of this study is to evaluate the impact of bio-based protein coating materials (sunflower seeds protein, whey, and casein) on the quality of fig fruit during the postharvest periods.

2. Material and Methods

2.1 Materials

Whey protein was purchased from Velcos (Greece), which contained 80.7% protein. Casein protein was obtained from Alfasol (Turkey), which consists of 86.50% casein protein. Sunflower seeds protein was prepared according to the method described in [15] Sunflower seeds were finely ground and the lipid fraction was extracted with hexane at a 1:5 (v:v) ratio for one hour at room temperature with constant stirring. The hexane phase was removed and the partially defatted flour was allowed to dry overnight. After additional grinding, the defatting process was repeated. The final defatted Sunflower seeds flour samples were dried using a freeze dryer instrument) and stored at -20 ºC until use. The sunflower protein concentrate was prepared according to the process described by Wolf[16] with minor modifications. Defatted sunflower flour was mixed with 95% aqueous alcohol (1:20, w/v) and stirred for 1h at ambient temperature (about 25 °C). The suspension was filtered and the residues were air-dried in a fume hood. Residues were dispersed in cold acetone (1:9, w/v) at filtered, and protein concentrate residues were air dried.

2.2 Preparation of coating solutions

Coating solutions were prepared by dissolving 50 g of the bio-based protein (whey proteins, casein, and sunflower seeds protein) in 920 mL of distilled water. The pH of the protein solution was adjusted to 8 to make sure the proteins dissolved. After the proteins were dissolved completely, the pH was adjusted to 7. After that, 30 mL of glycerol was added as a plasticizer, and the volume of solution was completed to 1L. The solutions were kept in a water bath for 30 minutes at 90 ºC. Finally, the solutions were homogenized in a blender for 5 min. and degassed as described in[17].

2.3 Harvesting Fig fruits

Fig fruits were harvested manually at the ripening stage from 4-year-old trees from Zamaqi, Halabja, in Iraqi Kurdistan Region. During the harvest, uniform fruits were selected in terms of size, color, maturity, and free from phenotypic defects.

2.4 Coating fig fruits

Harvested fig fruits were dipped into the coating solutions for one minute for all treatments, while for control the fruits were dipped in distillate water. After that, the fruits were dried on a flat surface at room temperature, then the fruits were stored in a polyethylene plastic container (1kg capacity, and with 8 holes with 1cm diameter). The containers and fruits were stored at 5°C and 85–90% RH, according to storage periods. Four different treatments were investigated: Control (fruits were immersed in distilled water), sunflower seeds protein (5%), whey protein (5%), and casein protein (5%). Fruits were stored for 7, 14, and 21 days after the storage periods the fruits were characterized.

2.5 Fruit phytochemical properties

The fig fruit was characterized to determine the fruit quality after storage periods. Fresh weight loss (%) was measured by recording the initial and final fruit weights during storage periods.

Total soluble solids (TSS)% was measured by a hand refractometer using an ATAGO refractometer, as described in [18]. Titratable acidity (TA) % was measured as the methods described by[19].

Total Sugars (%) were calculated in the juice by using phenol (5%) and concentrated sulfuric acid (97%) as the reagent, as described by[20]. Total phenol (mg/100 ml) was extracted from the juice using alcoholic hydrochloric acid consisting of 95% ethyl alcohol and (1.5 N) HCl, and total phenol was measured as reported in[21]. Carotene content (mg/100 ml) was measured according to the method[22]. Polyphenol oxidase (PPO) activity (unit/ml) was measured as the method reported by[23]. In addition, sensory evaluation of the fruit was done by five specific panelists after each storage period. Major sensory properties were selected, such as; fruit color, texture, taste, and brightness (25 scores for each property), and finally (100 scores) for overall acceptability as the method described by[24, 25].

2.6 Statistical Analysis

To find statistical differences between the treatments, complete randomized design (CRD) within a factorial experiment two factors were performed, using XLSTAT Software and Duncan's test at 5% level (three replicates, n=3).

3. Results and discussion

All coating treatments impacted fig fruit quality. Fig fruit fresh weight loss was reduced significantly, when coated with bio-based protein, compared with control, where distilled water was used.

The lowest weight loss was observed in fruits coated with casein and whey, Figure 1. The fruit weight loss increased gradually with a prolonged storage period. In the first 7 days of storage, the weight loss reached 8.41% and gradually increased to 14.15 % at 21 days. Weight loss occurs based on the water vapor pressure gradient between the fruit and the environmental air[26]. The coatings improve the atmosphere around the surface of the fruit and reduce fruit weight loss by the transpiration of the surroundings[27]. The epidermal and cuticle layers help reduce transpiration[28]. Furthermore, the fruit coatings decrease transpiration due to surface coating completely or partially covers the stomata, lenticels, and micropores, and the formation of a semipermeable barrier prevents gas exchange and ultimately reduces transpiration[29]. The result is in agreement with the study when guava (*Psidium guajava*) and fig were coated with 5% and 10% composite casein protein[8,24,30,31] Perez-Gago et al., (2006) reported that the whey protein and bee wax reduced weight loss in the apple (*Malus domestica*) fresh-cut coated fruits.

The TSS showed a significant decrease in all of the coated fruits compared to the control fruits. The lowest TSS value (20.27%) was observed in the fruits coated with whey protein, Figure 1. The TSS significantly increment during the storage period, at the seven days of storage the TSS was 21.28%, and it increased gradually to 22.33% at the end of the storage period. This results in agreement with what was reported by[24,8]. This decrease in TSS may be achieved by slowing/inhibiting the generation of ethylene within the tissues of fruit[32,33]. On the other hand, the highest value of TSS in control treatment is due to the increment amount of weight loss (Figure 1). TSS increasing with the storage period might be due to the nutritional breakdown, for example, breaking down starch into simple saccharide components (sugars), as they are major compounds of TSS. Alternatively, this might be the result of transpiration and water loss[34].

TA was changed significantly in coated treatments compared with control. The fruits coated with sunflower protein had the highest TA% content, while the lowest value was found in fruits coated with whey protein. In addition, significant differences were found in TA% during the storage periods. The lowest TA was recorded in the fruits that were stored for 14 days (0.51%), but the highest TA% was recorded at 21 days of storage (1.05%). It is proven that TA% content is impacted by the cultivars, kind of coating, and storage conditions[35]. Previous studies reported that casein coating helped the strawberry fruit to retain the acidity, although the acidity alteration was not substantially different from the control. Explained[17] that the casein coatings can delay fruit development and ripening, which is important to preserve fruits during storage. In addition, found by[30] that TA% increased at the end of storage. The changes in TA% may be due to the changes in nutritional values in the fruits during the respiration process, for instance, converting the carbohydrate compounds to organic acids or to phenolic compounds and vice versa.

Overall, total sugars, total phenol, and carotene contents in the coated fruits were not changed significantly compared with the control treatment, Figure 1. However, total sugars, total phenol, and carotene contents were changed significantly in the coated fruits when stored for the longest period. As appeared by [24, 30] that the total sugar contents increased during the storage period. The total sugar content increased due to the change in water loss during storage periods, which resulted in the fruit juice concentration and increase in the TSS (Figure 1).

The fruits coated with whey protein were significantly superior to the other treatments (including control) in minimizing PPO activity, Figure 1. The decrease in enzyme activity might be due to the reduction of the total phenol contents, despite the highest total phenol being measured in the fruits coated with casein protein. Significant differences in PPO activity were also noticed during the storage periods. The lowest activity was found in the fruits stored for 21 days, whilst the highest activity was found in fruits stored for 14 days. Indicated[29] that the PPO decreased toward the end of storage.

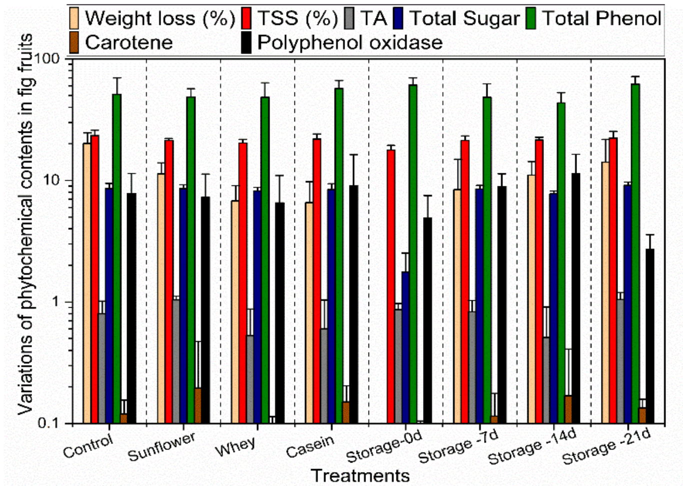

Figure 1: Phytochemical contents of fig fruits when coated with a bio-based protein solution and storage periods. Data are given as the average (n=3), and error bars indicate standard deviations. (TSS)= Total soluble solids, (TA)= Titratable acidity.

Integrating the treatments of coating and storage period caused significant differences in the weight loss and phytochemical content of the fruits Table 1. The highest weight loss, TSS, TA, total sugars, and total phenol were observed in control treatment fruits that were stored for 21 days. Carotene content was the highest in coated fruits with sunflower protein after 14 days, whereas the lowest value was found in coated fruits with whey protein after 14 days. The lowest polyphenol oxidase activity was found in coated fruits with sunflower protein after 21 days, whereas the highest activity was observed in coated fruits with casein protein after 14 days.

Table 1: The interaction effect of biobased-protein coating and storage period on phytochemical contents of fig fruit.

Treatments	Storage Periods	Weight loss (%)	TSS (%)	TA (%)	Total Sugar (%)	Total Phenol (mg/100g)	Carotene (mg/100g)	polyphenol oxidase (unit/ml)
Control	7	18.42^{b}	21.73^{cd}	0.77^{d}	8.25^{bc}	39.80^{e}	0.09^{b}	7.60^{d}
	14	15.99^{c}	21.60^{cd}	0.77^{d}	7.85^{cd}	38.62^{e}	0.11^{b}	12.00^{b}
	21	25.94^{a}	26.73^{a}	1.15^{a}	9.64^{a}	74.91^{a}	0.16^{ab}	3.80^{fg}
Sunflower	7	8.62^{ef}	20.47^{de}	1.02^{abc}	8.78^{abc}	48.08^{cde}	0.08^{b}	9.60^{c}
	14	10.69^{d}	21.87^{cd}	0.99^{bc}	7.88^{cd}	44.64^{de}	0.39^{a}	10.20^{c}
	21	14.64^{c}	21.53^{cd}	1.11^{ab}	8.99^{abc}	52.83^{b-e}	0.13^{b}	2.00^{h}
Whey	7	3.94^{g}	19.00^{e}	0.56^{e}	8.11^{bcd}	39.08^{e}	0.09^{b}	12.20^{b}
	14	7.70^{f}	19.80^{e}	0.13^{f}	7.99^{bcd}	42.18^{de}	0.08^{b}	5.00^{ef}

	21	8.76^ef^	22.00^cd^	0.90^cd^	8.81^abc^	63.52^abc^	0.11^b^	2.40^h^
Casein	7	2.64^g^	23.93^b^	0.94^c^	8.80^abc^	66.03^ab^	0.21^ab^	6.20^e^
	14	9.82^de^	22.53^bc^	0.13^f^	7.38^d^	48.29^cde^	0.10^b^	18.40^a^
	21	7.26^f^	19.07^e^	1.03^abc^	9.05^ab^	56.65^bcd^	0.14^ab^	2.60^gh^

Different letters in the column indicate a statistical difference (5%) between the treatments using Duncan's multiple ranges. (TSS)= Total soluble solids, (TA)= Titratable acidity.

Fig fruits from all treatments were subjected to sensory analysis; color, taste, texture, brightness, and overall acceptability. Fig fruits were positively affected when coated with a bio-based protein solution, Figure 2, meaning the coating improved significantly the sensory evaluation of the fruits. While the lowest scores of sensory evaluations were recorded in control treatment fruits. The taste is the balance between sweet flavor and acidity at the ripening, while TA was the taste desired by the panelist evaluation, Figure 1. Furthermore, the brightness and texture were influenced by weight loss, which has a role in the panelist's decision (Figure 1). All characteristics have an effect on overall fruit acceptability; thus, the coated fruits were more acceptable than the control fruits. In addition, the storage period had a significant impact on the taste, brightness, and overall acceptability of fruits. The highest taste score, brightness, and overall acceptability were found in fruits that were stored for 7 and 14 days, which were significantly different from the fruits that were stored for 21 days. However, the color and texture did not change significantly during storage periods. This could be due to the increase in weight loss, TSS, TA, and total sugar content in the fruits during the storage period.

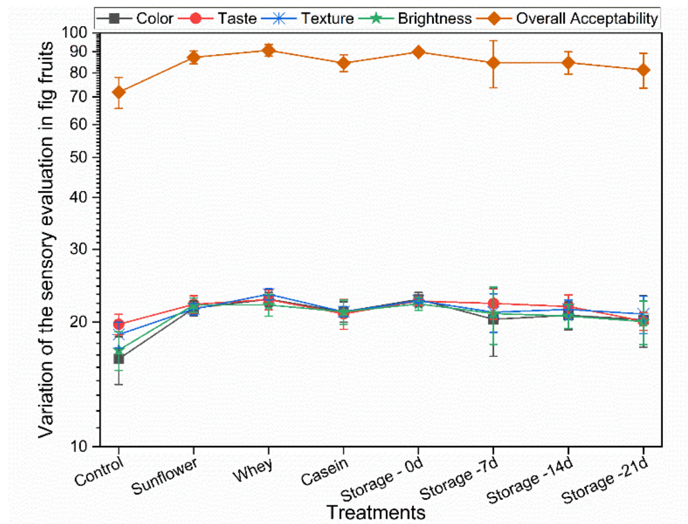

Figure 2: The effect of bio-based protein coating and storage periods on the sensory evaluation of the fig fruits. Data are given as the average (n=3), and error bars indicate standard deviations.

Integrating the treatments of bio-based protein fruit coating and storage period caused significant changes sensory evaluation of fig fruits, Table 2. The highest color score, texture, brightness, and overall acceptability were observed in the fruits coated with whey proteins and stored for seven days, compared with all treatments. However, uncoated fig fruits from the control experiment had the lowest color score, texture, brightness, and overall acceptability after seven days of storage. As expected the lowest taste score was in control fig fruits that were stored for 21 days.

Table 2: The interaction effect of biobased-protein coating and storage period on the sensory evaluation of fig fruits.

Treatments	Storage Periods	Color (25)	Taste (25)	Texture (25)	Brightness (25)	Overall Acceptability (100)
Control	7	14.27^f^	19.27^cd^	17.73^f^	15.67^f^	66.93^g^
	14	18.73^d^	21.13^b^	20.33^e^	19.40^e^	79.60^f^
	21	15.93^e^	18.93^d^	17.93^f^	16.33^f^	69.13^g^
Sunflower	7	22.27^ab^	23.07^a^	21.73^bcd^	23.07^ab^	90.13^ab^
	14	21.87^ab^	22.47^a^	22.13^bc^	21.60^c^	88.07^bc^
	21	20.73^bc^	20.73^b^	20.73^de^	21.40^cd^	83.60^de^
Whey	7	22.87^a^	23.40^a^	23.60^a^	23.33^a^	93.20^a^
	14	22.47^ab^	23.47^a^	22.87^ab^	22.27^abc^	91.07^ab^
	21	22.87^a^	21.20^b^	23.60^a^	20.47^de^	88.13^bc^
Casein	7	21.93^ab^	23.07^a^	21.53^cde^	21.93^bc^	88.47^bc^
	14	20.07^cd^	20.20^bc^	20.60^de^	19.53^e^	80.40^ef^
	21	21.60^abc^	19.60^cd^	21.47^cde^	22.13^bc^	84.80^cd^

Different letters in the same column indicate the presence of statistical differences at the level of 5%.

Conclusions

This study showed that coating fig fruits with a bio-based protein solution could impact the quality and sensory evaluation of fig fruits by testing the fruits during the different storage periods (7, 14, and 21 days). The phytochemical contents of the fig fruits were also affected by coating. In particular, whey protein coating reduced polyphenol oxidase activity significantly more than control and other treatments. Integrating the treatments of coating and storage period caused significant differences in the physical properties and phytochemical content of fruits. The fruit coating treatments reduced the weight loss significantly and preserved the quality, compared with control fig fruits. In addition, all the coating treatments had higher scores in all sensory evaluations: color, texture, brightness, and overall acceptability compared with the control treatment. Further research studies on coating are needed especially using other fruits and using different bio-based protein solutions to find the optimum coating solution so we can extend the fruit shelf-life after harvest.

Author’s contribution

All of them contributed to all parts of this article.

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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