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Research Article

Effect of Biofilm Application Regimes on Fruit Quality Properties of Blueberry (*Vaccinium corymbosum* L.)

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Abstract: In this study, the effects on quality characteristics such as mass, length, width and color (L*, a* and b*) in blueberry (*Vaccinium corymbosum* L. cv. 'Bluecrop') fruit of biofilm (Parka^{TM}) sprayed in pre-harvest different regimes were investigated. The highest fruit mass was measured in T1, T3, T4 and T8 treatments at harvest, whereas all treatments at harvest +7 were similar. At harvest and harvest +7, the highest fruit length was obtained in T1 and T1 and T4 treatments, respectively. Fruit width was similar in all treatments at harvest and harvest +7 (except for T8). L* value of T3, T4, T5, T6 and T9 treatments was higher from T1 at harvest. On the contrary, it was similar in all treatments at harvest +7. It was observed that the a* and b* values of all treatments were similar. When harvesting periods are compared, fruit mass in T3 and T8; T3, T6, T7, T8, T9 and T10 in fruit length; fruit width in T3, T5, T6, T8 and T9; T5, T6 and T7 treatments in b* values was higher at harvest than at harvest +7. As a result, it was revealed that the biofilm could be a significant effect on the physical and color properties of the blueberry fruit.

Maviyemişin (*Vaccinium corymbosum* L.) Meyve Kalite Özellikleri Üzerine Biyofilm Uygulama Rejimlerinin Etkisi

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Anahtar Kelimeler
Biyofilm,
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Meyve ağırlığı,
Hasat dönemi,
Vaccinium corymbosum L.

Öz: Bu çalışmada, hasat öncesi farklı uygulama sıklığında püskürtülen biyofilmin (Parka^{TM}) maviyemişte (*Vaccinium corymbosum* L. cv. 'Bluecrop') ağırlık, boy, en ve renk (L*, a* ve b*) gibi meyve kalite özellikleri üzerine olan etkileri incelenmiştir. En yüksek meyve ağırlığı hasatta T1, T3, T4 ve T8 uygulamalarında ölçülürken, hasat+7'de tüm uygulamaların ağırlığı benzer bulunmuştur. Hasat ve hasat+7'de en yüksek meyve boyu sırasıyla T1 ve T1 ve T4 uygulamalarında elde edilmiştir. Hasat ve hasat+7'de (T8 hariç), tüm uygulamalarda meyve genişliği benzer düzeyde olmuştur. T3, T4, T5, T6 ve T9 uygulamalarının L* değeri hasatta T1'den daha yüksek olmuştur. Aksine hasat+7'de tüm uygulamalarda benzer olmuştur. Tüm uygulamaların a* ve b* değerlerinin benzer olduğu gözlenmiştir. Hasat dönemleri karşılaştırıldığında, hasatta T3 ve T8'de meyve ağırlığı; T3, T6, T7, T8, T9 ve T10'da meyve boyu; T3, T5, T6, T8 ve T9'da meyve eni; T5, T6 ve T7 uygulamalarında b* değerleri hasat+7'de ölçülen değerlere kıyasla hasatta daha yüksek olmuştur. Sonuç olarak, biyofilmin maviyemiş meyvesinin fiziksel ve renk özellikleri üzerine önemli bir etkisinin olabileceği ortaya konmuştur.

1. Introduction

Blueberry (*Vaccinium corymbosum* L.), which is naturally distributed worldwide, was first cultivated in the USA in the 1960s. Soils with acidic character, rich in organic matter and mild climate conditions are ideal for cultivation. In our country, it is cultivated in orchards and soilless conditions in the Marmara, Mediterranean and Aegean regions, especially in the Black Sea (Çelik & Ağaoğlu, 2013). Its popularity is increasing day by day due to its rich vitamin and nutrient content, high antioxidant activity, and high yield per unit area (Çelik, 2009; Wang et al., 2012; Özgen et al., 2014). However, consumers demand large and high-quality fruit that have completed their color development in the market.

In addition to cultural treatments such as irrigation, fertilization and pruning, biofilm and growth regulator treatments are used as tools to increase fruit quality (NeSmith, 2002; Vance & Strik, 2018; Ates et al., 2022). Coating treatments made with biofilm have positive effects against diseases and pests, delaying cracking in fruits due to precipitation, maintaining fruit flesh firmness, increasing fruit size by delaying maturity and promoting color development (Ozturk et al., 2018; Baswal et al., 2020). In addition to postharvest treatments, there are also pre-harvest uses (Nia et al., 2021). A barrier is created on the fruit surface with biofilm, thus reducing the permeability and delaying water loss (Ncama et al., 2018). In addition, edible coatings provide elasticity on the fruit surface and provide protection against external factors (McHugh & Senesi, 2000). In research conducted (Vance & Strik, 2018), it has been reported that the firmness of the fruit flesh is preserved, and the visual quality is increased in blueberry fruit with biofilm (Parka^{TM}) treatments.

Similarly, it was determined that the softening of the fruit flesh firmness was delayed by Parka treatment in jujube fruit (Ozturk et al., 2018). The effectiveness of the biofilm or growth regulators sprayed during the fruit development stage may vary depending on the variety, treatment time and treatment frequency (Faizy et al., 2021). There is no study in the literature that determined the change in fruit size and color development depending on the biofilm (Parka^{TM}) treatment regimes in blueberry.

This study aimed to determine the effect of biofilm (Parka^{TM}) treatment regimes on the color and physical properties of blueberry fruit.

2. Materials and Methods

2.1. Plant materials

The research was carried out in a commercial blueberry orchard of 15 years old in Erikli village (40°52.983' N, 38°14.087' E, altitude 517 m) of the Bulancak district of Giresun province in the 2021 year. Blueberry (*Vaccinium corymbosum* cv. 'Bluecrop') plants propagated by tissue culture were planted in an east-west direction with planting spacing of 2.0 × 2.5 m. The pH of the orchard's soil was 5.14, slightly calcareous, clay loam, and had an organic matter content of 5.84%. Cultural practices such as irrigation, fertilization, weed control and pruning were carried out regularly in the blueberry orchard.

2.2. Experimental design and treatments

The experiment was designed according to the randomized block design with 3 replications. Each block was treated as a replication. A total of 60 shrubs were selected, 6 shrubs for each treatment in each block. A shrub was used as a buffer shrub to reduce the impact of treatments on each other. Parka [Cultiva, (5% cellulose, 7.5% stearic acid and 1% calcium)] at a concentration of 1%, which is an edible-based biofilm with natural ingredients, was used as an application. Details of the treatment regimes are presented in Table 1. Blueberry fruit are harvested gradually. Therefore, the first application time was 4 weeks before the commercial harvest. This date was the most intense ripening period of the fruit (the period when the fruit on the plant are about 50-60% ripe). This period was determined based on many years of observation of blueberry producers. Biofilm was sprayed on the trial plants at 4, 3, 2, and 1 week before commercial harvest by a low-pressure back pump.

Mass, width, length and color characteristics of fruit were determined one week after commercial harvest (17 July 2021) to observe the maturity retarding effect of biofilm in addition to commercial harvest. The fruit were placed in packages of 250 cc volume with 4 holes on them and transferred to the Post-Harvest Physiology Laboratory of the Horticulture Department of the Faculty of Agriculture of Ordu University within 1 h with a refrigerated vehicle (10-12 °C and 85% RH).

Table 1. Treatment regimes of biofilm

Biofilm (Parka™) treatments (1%)	Weeks before commercial harvest			
	4	3	2	1
T-1 (Control)	-	-	-	-
T-2	1%	1%	1%	1%
T-3		1%	1%	1%
T-4			1%	1%
T-5	1%	1%	1%	
T-6	1%	1%		
T-7	1%		1%	
T-8		1%		1%
T-9	1%			1%
T-10		1%	1%	

2.3. Mass, width and length

Measurements were carried out on 30 fruit of each treatment in each replication. Digital scales with an accuracy of 0.01 g (Radwag PS/C/1, Poland) were used for fruit mass measurements. Dimensional properties were measured with a digital caliper (Model CD-6CSX, Mitutoyo, Japan) with 0.01 mm precision. Fruit mass was stated as g, and fruit dimensional characteristics (width and length) were stated as mm (Ozturk et al., 2018).

2.4. Color characteristics

Color characteristics were determined on 30 fruit of each treatment at each replication. Fruit color was determined in terms of CIE L*, a* and b*. Values of color characteristics (L*, a* and b*) were measured at 2 opposite poles of the equatorial region of the fruit with a colorimeter (Minolta, model CR-400, Tokyo, Japan). According to the prepared scale, a* value represents redness-greenness, b* value represents yellowness-blueness (McGuire, 1992).

2.5. Statistical analysis

The normal distribution of the data was controlled with Kolmogorov-Smirnov's test, and the homogeneity of the variance was checked with Levene's test. The descriptive statistics of the data that met the conditions were calculated, and variance analysis was performed. The significance level between treatments was determined by Tukey multiple comparison tests ($p \leq 0.05$). Statistical analyzes were performed in Minitab® 17 Statistical software (Minitab Inc., State College, PA, USA).

3. Results

The effects of biofilm treatment regimes on fruit mass, length and width were significant. Although a similar level of fruit mass was detected in the harvest from T1, T3, T4 and T8 treatments, significantly higher values were measured compared to other treatments. On the contrary, similar fruit mass was obtained from T2, T5, T6, T9 and T10 treatments. However, it was observed that the obtained values were lower than other treatments. The effect of biofilm on fruit mass was not determined at harvest +7. A significant difference was found in T3 and T8 treatments when the harvest periods were compared. It was determined that the fruit mass obtained at harvest was higher than harvest +7. In other treatments, there was no difference in fruit mass between harvest periods (Table 2).

The highest fruit length was detected in T1 (control) at harvest. In addition, when the fruit length data were examined, it was observed that the fruit length of T2 and T5 treatments were significantly lower than the T1 treatment. In harvest +7, the lowest fruit length was measured in T8. While other treatments had higher values from the T8 treatment, no significant differences were observed between each other. When harvesting periods were compared, significant differences were found between T3, T6, T7, T8, T9 and T10 treatments. There was no difference between harvest periods in T1, T2, T4 and T5 treatments. In general terms, fruit length in the first harvest period was higher than in the second harvest period in all treatments (Table 2).

Table 2. Effects of biofilm treatment regimes on fruit mass, length and width of blueberry fruit

Biofilm	Fruit mass (g)		Fruit length (mm)		Fruit width (mm)	
Treatments	Harvest	Harvest +7	Harvest	Harvest +7	Harvest	Harvest +7
T1	2.03 ab-A	1.64 a-A	12.23 a-A	11.10 a-A	15.45 a-A	14.70 a-A
T2	1.70 de-A	1.62 a-A	11.02 b-A	10.83 ab-A	14.69 a-A	14.44 ab-A
T3	2.04 a-A	1.49 a-B	11.49 ab-A	10.24 ab-B	15.40 a-A	13.24 ab-B
T4	2.03 ab-A	1.65 a-A	11.45 ab-A	11.09 a-A	15.12 a-A	14.59 ab-A
T5	1.73 cde-A	1.54 a-A	10.89 b-A	10.79 ab-A	14.78 a-A	13.34 ab-B
T6	1.77 cde-A	1.51 a-A	11.30 ab-A	10.03 ab-B	14.71 a-A	13.25 ab-B
T7	1.83 bcd-A	1.68 a-A	11.74 ab-A	10.75 ab-B	15.66 a-A	14.06 ab-A
T8	1.92 abc-A	1.39 a-B	11.64 ab-A	9.59 b-B	15.59 a-A	12.12 b-B
T9	1.76 cde-A	1.47 a-A	11.47 ab-A	10.03 ab-B	15.12 a-A	13.24 ab-B
T10	1.59 e-A	1.52 a-A	11.54 ab-A	10.35 ab-B	14.80 a-A	13.53 ab-A

Means in the same line with the same capital letter do not differ according to the *t*-test at $p \leq 0.05$. According to Tukey's test, the means in the same column with the same lowercase letter do not differ at $p \leq 0.05$.

It was determined that biofilm treatment regimes did not affect fruit width at harvest. Similar levels of values were measured in all treatments. In harvest +7, a significant difference was detected between T1 treatment and T8 treatment, but no difference was found between other treatments. However, significantly higher values were observed in other treatments, except for the T8 treatment. When fruit width was compared between harvest periods, it was determined that there was a difference between T3, T5, T6, T8 and T9 treatments. There was no difference in fruit width in T1, T2, T4, T7 and T10 treatments. The fruit width data obtained at harvest for all treatments were higher than those obtained at harvest +7 (Table 2).

Table 3. Effects of biofilm treatment regimes on color characteristics (L*, a* and b*) of blueberry fruit

Biofilm	L*		a*		b*	
Treatments	Harvest	Harvest +7	Harvest	Harvest +7	Harvest	Harvest +7
T1	28.64 b-B	34.84 a-A	0.01 a-A	1.39 a-A	-2.40 a-A	-2.95 a-A
T2	29.91 ab-B	36.19 a-A	-0.07 a-B	1.64 a-A	-2.68 a-A	-3.51 a-A
T3	31.21 a-B	37.22 a-A	0.11 a-B	1.30 a-A	-3.11 a-A	-3.56 a-A
T4	31.31 a-B	35.55 a-A	-0.10 a-B	0.67 a-A	-3.13 a-A	-3.17 a-A
T5	31.30 a-B	37.08 a-A	0.08 a-A	0.41 a-A	-2.95 a-A	-3.37 a-B
T6	31.82 a-B	34.88 a-A	0.24 a-A	0.69 a-A	-2.67 a-A	-3.41 a-B
T7	29.84 ab-B	35.85 a-A	-0.05 a-B	0.23 a-A	-2.61 a-A	-3.22 a-B
T8	30.99 ab-B	35.26 a-A	-0.10 a-B	1.24 a-A	-2.94 a-A	-3.10 a-A
T9	31.50 a-B	37.27 a-A	0.37 a-A	0.99 a-A	-3.16 a-A	-3.33 a-A
T10	29.41 ab-B	36.45 a-A	0.41 a-A	0.43 a-A	-2.65 a-A	-3.63 a-A

Means in the same line with the same capital letter do not differ according to the *t*-test at $p \leq 0.05$. According to Tukey's test, the means in the same column with the same lowercase letter do not differ at $p \leq 0.05$.

Considering the L* values during the harvest period, it was determined that the values of T3, T4, T5, T6 and T9 were significantly higher than the T1 treatment. It was observed that the T1 treatment had the lowest L* value and was no different from T2, T7, T8 and T10 treatments. In harvest +7, the L* values of all treatments were determined at a similar level. Significantly higher L* values were detected in harvest +7 than harvest in all treatments. Similar levels of a* and b* values were measured in all treatments at harvest and harvest +7.

In terms of a* value, significantly higher values were measured in harvest +7 than harvest in T2, T3, T4, T7 and T8 treatments. In addition, T1, T5, T6, T9 and T10 treatments were similar in terms of a* value. It was observed that there was a significant difference in terms of b* values between harvest periods in T5, T6 and T7 treatments. Higher b* values were measured at harvest rather than harvest +7 (Table 3).

4. Discussion and Conclusion

Edible biofilm treatments are an agricultural technology used to reduce the effects of diseases and pests on fruits and vegetables (Güneş, 2020), retard fruit cracking (Ozturk et al., 2018) and delay fruit quality losses during postharvest cold storage and shelf life (Fakhouri et al., 2012; Karakaya et al., 2020). In many studies conducted (Castro & Paulin, 2012; Han et al., 2014; Aglar et al., 2017; Measham et al., 2020), it has been stated that edible biofilms are based on the tasks they undertake to maintain and increase fruit quality. In our study, the significant effect of Parka, an edible natural biofilm, on fruit mass was observed in the commercial harvest. Fruit mass was lower in T2, T5, T6, T9 and T10 treatments compared to control. Other treatments were found to be insignificant from the control. Again, at commercial harvest, the fruit size of T2 and T5 treatments was lower than the control. In addition, fruit length and fruit width were lower in harvest +7 only in T8 treatment rather than control. In addition, in some treatments (T3 and T8), both fruit mass and dimensional fruit characteristics decreased with delayed harvest. Gradual harvest is performed in blueberry fruit, and with the harvest period's progress, decreases in the fruit's physical properties can be observed. The researcher also reported (Kalt et al., 2003; Ribera et al., 2010) that there may be differences in some quality criteria of the fruits depending on the harvest time. Zorenc et al., (2016) harvested 3 blueberry cultivars, including the 'Bluecrop' cultivar, grown in different regions at regular intervals, and the fruit mass of all varieties differed according to the harvest periods. It was reported that the mass decreased with the prolongation of the harvesting periods. Again, Ozturk et al., (2018) reported that pre-harvest biofilm and gibberellic acid treatments had no effect on fruit mass and width, but had a positive effect on length in jujube fruits. Measham et al. (2020) stated that biofilm treatments positively affect width in a study conducted in sweet cherry.

In general, no effect of biofilm on color properties was observed. However, increases in L* value were determined with delayed harvest. The a* value increased with delayed harvest in some treatments (T3, T4, T7 and T8). Like this, Castrejón et al., (2008) reported that the coloration increased with the progression of maturity in the study conducted on 'Bluecrop', 'Reka', 'Puru' and 'Berkeley' blueberry cultivars.

As a result, it was determined that the biofilm sprayed at different treatment regimes significantly affected the mass, width, and length of the blueberry fruit. However, the effect on the color characteristics was not significant. However, it was revealed by this research that the values of fruit mass and dimensional characteristics decreased with the delay of harvest, but color development was promoted.

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