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Effects of Storage on Antioxidant Composition of Kiwi (*Actinidia deliciosa*) Jam

Depolamanın Kivi (*Actinidia deliciosa*) Reçelinin Antioksidan Bileşimi Üzerine Etkisi

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ABSTRACT

This study was carried out to determine the changes occurring during the production and storage of kiwifruit jam. In the study, the effect of fruit ripeness on jams quality also investigated. Jams were produced from raw and ripe kiwi fruits at 67, 70, and 73°Bx. The jams were stored at room temperature for 3 months. In the analysis, it was determined that the antioxidant capacity of fresh fruits was higher. The antioxidant activity of raw fruits was found to be 76% and the antioxidant activity of ripe fruits was found to be 75%. In ripe fruits, vitamin C, total phenolics and 1,1-diphenyl-2-picrylhydrazyl radical (DPPH$^{\cdot}$)-scavenging activity were higher than raw fruits. It was determined that raw fruits contained 37.02 mg/100 g and ripe fruits contained 58.52 mg/100 g vitamin C. The antioxidant activity and vitamin C content of the jams decreased during storage. 1,1-diphenyl-2-picrylhydrazyl radical-scavenging activity and total phenolic content of the jams increased during storage.

Keywords: Antioxidant, DPPH*, phenolic, kiwi, jam

ÖZ

Bu çalışma ham ve olgunlaşmış kivi meyvelerinden reçel üreterek farklılıklarını ortaya koymak ve depolanmasında meydana gelen değişimleri belirlemek amacıyla yapılmıştır. Bu bağlamda reçel kalitesine meyve olgunluğunun etkisinin de incelendiği çalışmada ham ve olgun kivi meyvelerinden 67, 70, ve 73 brikslerde reçeller üretilmiştir. Üretilen reçeller üç ay süresince oda sıcaklığında depolanmıştır. Yapılan analizlerde taze meyvelerin antioksidan kapasitelerinin daha yüksek olduğu belirlenmiştir. Ham meyvelerin antioksidan aktivitesi 76%, olgun meyvelerin antioksidan aktivitesi 75% bulunmuştur. Olgun meyvelerde ise C vitamini, toplam fenolik madde ve 1,1-difenil-2-pikril-hidrazil (DPPH$^{\cdot}$) radikali giderme aktivitesi ham meyvelerden daha yüksektir. Ham meyvelerin 37,02 mg/100 g, olgun meyvelerin ise 58,52 mg/100 g C vitamini içerdikleri belirlenmiştir. Reçellerin antioksidan aktivitesi ve C vitamini miktarları depolama süresince azalmaktadır. Reçellerin DPPH* radikali giderme aktivitesi ve toplam fenolik madde miktarları depolama süresince artış göstermiştir.

Anahtar Kelimeler: Antioksidan, DPPH*, fenolik, kivi, reçel

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Introduction

Actinidia species, known worldwide as kiwifruit, are valued for their sweet, slightly acidic structure, high nutritional value, and especially high vitamin C content (Salinero et al., 2009). Kiwi fruit, which started to be cultivated in our country in the early 1990s, has taken its place after tea and hazelnut, especially in the Black Sea Region agriculture. In addition, kiwi fruit, which was offered to the market by the grain in the past years in our country, has become sold by weight. In addition, the increase in production brings along some storage problems. In addition to consumption as fresh fruit, kiwifruit can be processed into different products in order to spread consumption to a wider area and to increase diversity and added value in the food industry and trade.

Fruits and vegetables contain significant amounts of biologically active compounds that fulfill physiological and biochemical functions beneficial to human health. In recent years, the concept of functional food has emerged. According to this concept, food can provide some physiological benefits while meeting nutritional requirements. Fruits are excellent foods because they contain low amounts of calories and high amounts of antioxidants (Tavarini et al., 2008). Fruits and vegetables have an important place in our diet as they are rich in various vitamins, minerals, phenolic substances, and dietary fiber. Many fruits and vegetables contain significant amounts of certain vitamins. Others are the main source of essential minerals for humans. They also help digestion due to the organic acids and cellulose they contain. Especially fresh fruits have a natural laxative effect (Demirci, 2003).

Fruits and vegetables are processed by various methods to increase their consumption and flavor as well as to extend their shelf life (Oey et al., 2008). Today, consumers pay more attention to food safety and quality. As a result, many consumers have turned to less processed and quality-preserved foods. In order to develop an effective heat treatment technology for the production of foods with high organoleptic properties and nutritional quality, the functional changes of heat-treated foods need to be extensively investigated (Roy et al., 2007).

For centuries, various fruits have been used to cure some ailments (Bayram et al., 2019). In recent years, food scientists and nutritionists have reported that daily fruit and vegetable consumption reduces the risk of many diseases such as cancer and cardiovascular diseases (Du et al., 2009). These beneficial effects are attributed to the various antioxidants contained in fruits and vegetables. Antioxidant compounds including polyphenols, ascorbic acid, carotenoids, and tocopherols scavenge radicals in various ways. Fruits are the main source of antioxidants in the human diet. Kiwifruit, one of today's most popular fruits, is characterized by its high vitamin C content and is abundant in other beneficial compounds such as vitamin E, carotenoids, flavonoids, and minerals. It also contains significant amounts of chlorophyll and carotenoid pigments (Tavarini et al., 2008). Kiwi consumption is reported to have a preventive effect against many types of cancer. Especially its protective effect on digestive system cancers attracts attention (Collins et al., 2003).

Kiwifruit is known to be a good source of vitamin C like citrus fruits. The fruits of *Actinidia* spp. are superior sources of vitamin C as citrus fruits. The most widely cultivated *Actinidia* species is *A. deliciosa* cv. Hayward. This variety is grown commercially in many countries due to its fruit size, high productivity, and storability (Ferguson, 1999). This fruit, which is consumed with pleasure, also contains coumarins called fraxin and esculin, which are known for their nutraceutical properties (Hirsch et al., 2002).

Fruits and vegetables are difficult to store fresh for long periods without spoiling, so they are processed into a variety of products to produce different products. Fruits are rendered resistant with high levels of sugar and transformed into a variety of products, most of which are not directly related to the fruit from which they are produced in terms of their qualities, usually to be consumed for breakfast. These products are generally divided into groups such as jam, marmalade, and jelly. Jam is a viscous product prepared by adding sugar to the fruit in the form of whole, half, sliced, or smaller pieces, with or without seeds and pits, with or without shells (Cemeroğlu, 2004).

Kiwifruit is generally consumed as fresh fruit. Processing practices and scientific studies on this subject are not sufficient. Therefore, in this study, in which kiwi fruit was processed into jam, which is a durable product, and composition analyses were performed at certain intervals, it was tried to reveal what changes occurred in its components as well as protecting the product with processing and storage.

Methods

Material

A. deliciosa cv. Hayward fruit, which was used as research material, was obtained from Erzurum market. Kiwifruits to be processed into jam were classified as immature and ripe. Fruits with a firm–hard texture and sour taste were accepted as raw. Fruits were considered ripe when the skin could be separated from the flesh without using a knife.

In line with the preliminary trials, it was decided to produce the jams to be produced in the study from a mixture of 50% fruit, 37.5% sugar, and 12.5% water. It was observed that citric acid and pectin addition was not necessary in the jams produced in this way. Thus, it was ensured that the jams produced were completely natural and in accordance with the extra traditional jam standard (Anonymous, 2006). Then, jam samples of 67, 70, and 73°Bx were produced from raw and ripe fruits, filled into 190 mL glass jars and stored for 3 months.

Sample Preparation for Analysis

Before the analysis of fresh kiwi fruit, the fruits selected to represent the mass were homogenized after peeling and slicing. Similarly, for the analyses to be performed on jams, a representative amount of jam samples were taken and homogenized.

To obtain the extracts to be used in the determination of total phenolic matter, antioxidant activity and DPPH radical-scavenging activity, 10 g of homogenized fresh fruit and jam samples were weighed and pure water was added and the volume was completed to 30 mL. After thorough mixing, it was filtered with Whatman 1 filter paper.

Determination of Dry Matter

Fruit and jam samples were weighed 3.0 ± 0.1 g into tared dry matter containers and kept at 65°C for 24 hours and then the temperature was increased to 105°C. The drying process was continued until a constant weighing was obtained at this temperature. Total dry matter values were calculated using the weighing values before and after drying (Keleş, 1983).

Vitamin C Assay

Vitamin C amounts in homogenized fruit and jam samples were determined by 2,6-dichlorophenolindophenol dye titration method. In the analysis, 1% oxalic acid and 0.05% 2,6-dichlo rophenolindophenol dye solution were used. In addition, the dye solution was standardized by titration with 0.02% ascorbic acid standard solution. In the analysis, fruit and jam samples were homogenized in 1% oxalic acid solution and titrated with the dye solution. Vitamin C amounts were calculated based on the amount of dye solution used in the samples and standardization (Keleş, 1983).

Determination of Total Phenolic Substance

A volume of 0.1 mL of the prepared sample extracts was transferred into measured test tubes. Then Folin–Ciocalteu and sodium carbonate (Na_2CO_3) solution were added respectively and the volume was completed to 10 mL with distilled water. The tubes were incubated at room temperature for 1 hour and absorbance was measured at 760 nm. Total phenolic content was calculated in mg gallic acid equivalent/100 g (mg GAE/100 g) of extract using the gallic acid standard curve prepared daily (Gülçin et al., 2004).

Antioxidant Activity (β-Carotene Bleaching Method)

Two milligrams of β-carotene was dissolved in 20 mL chloroform to prepare β-carotene solution. Weighed 40 mg linoleic acid and 400 mg Tween 40 into the flask and 4 mL of β-carotene solution was added. The chloroform in the mixture was removed by applying vacuum in a rotary evaporator. After adding 100 mL of oxygenated distilled water and mixing well, 3 mL was transferred into a test tube containing 1 mL of sample extract. After the first absorbance measurement, the samples were placed in a 50°C water bath and the measurement was repeated every 10 minutes for 100 minutes. Measurements were made at 470 nm wavelength. Control was prepared by adding 1 mL of distilled water to 3 mL of β-carotene solution (Kaur & Kapoor, 2002).

$\text{Control}^* = \ln(a/b) \times (1/t)$

$\text{Sample}^* = \ln(a/b) \times (1/t)$

$\%\text{AA} = ([\text{Control}^* - \text{Sample}^*]/\text{Control}^*) \times 100$

In the formula, * means reduction rate, *a* means initial absorbance value, *b* means duration absorbance value, and *t* means time.

1,1-Diphenyl-2-Picrylhydrazyl Radical-Scavenging Activity

Thirty-nine milligrams of DPPH radical was weighed and made up to 100 mL with ethyl alcohol. A weight of 10, 20, 30, and 40 mg of the sample extracts were transferred to test tubes and 0.5 mL of DPPH solution and ethyl alcohol were added to a total of 3 mL. They were kept in the dark for 30 minutes. Absorbance measurement was performed at 517 nm wavelength. Half maximal inhibitory concentration values were calculated based on the absorbance values obtained (Spada et al., 2008).

The equation of the curve obtained from the absorbance of the sample and standards was used to calculate the IC_{50} value.

$Y = \text{Control absorbance}/2$

In the equation $Y = ax + b$, the x value corresponds to the IC_{50} value.

pH Detection

The pH values were determined directly in homogenized fruit samples and jam syrup using a pH meter (ORION THERMO SCIENTIFIC) calibrated with buffer solutions (pH 4.00, 7.00, and 10.1) (Cemeroğlu, 1992).

Statistical Analysis

The data obtained as a result of the research were analyzed by applying the Statistical Package for the Social Sciences (SPSS for Win, Release 9.0-1998). The means of the statistically significant main sources of variation were compared by Duncan multiple comparison test method.

Results, Discussion, and Conclusion

Composition of the Kiwi Fruit

The chemical properties, antioxidant activity, and total phenolic substance amounts of kiwi fruit used as material in this study are given in Table 1.

Table 1.
Some Chemical Properties of Kiwifruit

	Kiwifruit	
	Raw	Ripe
Dry matter (%)	14.48	14.80
pH	3.18	3.38
Vitamin C (mg/100 g)	37.02	58.52
Total phenolics (mg GAE/100 g)	38.97	60.89
Antioxidant activity (%)	76.00	75.00
DPPH radical-scavenging activity (IC_{50})	50.29	26.88

Note: mg GAE/100 g = milligrams of gallic acid equivalents per 100 g.

It was determined that raw fruits contained 37.02 mg/100 g and ripe fruits contained 58.52 mg/100 g vitamin C. Beever and Hopkirik (1990) reported vitamin C content in kiwifruit as 37200 mg/100 g, Spada et al. (2008); 57.85 mg/100 g, Du et al. (2009); 63.41 mg/100 g, Nishiyama et al. (2004); 29–80 mg/100 g. Korkmaz (2020) stated that the vitamin C value of kiwi samples increased during storage. As seen in the literature, the vitamin C amounts of kiwi fruit are in a wide range and high values. In addition, vitamin C increases during storage. Lee and Kader (2000) determined a similar increase in peach, apricot, and papaya fruits.

The total phenolic content of raw kiwifruit was found to be 38.97 mg GAE/100 g and the total phenolic content of ripe kiwifruit was found to be 60.89 mg GAE/100 g. DPPH radical-scavenging activity was found 50.29 in raw fruits and 26.88 in ripe fruits in terms of IC_{50} value. While Wolfe et al. (2008) found the total phenolic content of kiwifruit as 60.4 mg GAE/100 g, Du et al. (2009) calculated as 41.67 mg GAE/100 g. An increase was found in phenolic compound values of all kiwi fruits during cold storage and shelf life (Korkmaz, 2020). Karakaya et al. (2019) stated that total phenolic content decreased during cold storage and shelf life. The amounts of phytochemical compounds are affected by factors such as ripening time, genotype, cultivation techniques, climatic conditions, and postharvest storage conditions (Lee & Kader, 2000).

Changes in Chemical Properties of Jam Samples

Compositions of jams produced from raw and ripe fruits at different brix ratios at first, second, and third months are given in Table 2 and 3.

Depending on the storage time, pH values decreased for 3 months. In a study conducted on quince jam, a similar pH decrease was observed in the first 3 months (Zor, 2008). The transition of acidic compounds from fruit tissue to jam syrup during storage may be effective in the emergence of this situation. As a matter of fact, pH analyses were performed directly in the jam syrup. For a good gel formation in products such as jam, marmalade, and jelly, the pH should be between 2.8 and 3.2 (Cemeroğlu, 2004). It has been reported that when the pH falls below 2.7 syneresis and water release begins and when the pH rises above 3.6 no gelation occurs (Tosun, 1998). Storage-dependent changes in kiwi jam properties are given in Table 4.

The pH decrease during storage is faster in jams produced from raw fruits. The decrease is slower in jams produced from ripe fruit. This may be due to the fact that the integrity of the raw fruit tissue is better preserved during cooking and the transfer of acidic compounds to the jam syrup continues during storage. The easier destruction of the fruit tissue in jams produced from ripe fruit may have caused most of the component transfer to the jam syrup to occur during cooking. According to the multiple comparison test results, vitamin C values decreased as the storage

Table 2.
Changes in Jams Produced from Raw Fruit

Brix	67			70			73		
Storage Period (Months)	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dry matter (%)	62.04	60.06	61.25	63.34	63.62	62.90	69.20	68.78	67.20
pH	3.21	3.16	3.11	3.21	3.15	3.08	3.26	3.15	3.09
Vitamin C (mg/100 g)	29.53	16.75	15.00	27.57	15.38	14.05	22.10	18.80	13.84
Total phenolics (mg GAE/100 g)	26.12	28.32	31.45	28.00	29.67	32.39	30.10	32.70	39.28
Antioxidant activity (%)	68.00	63.00	61.00	67.00	67.00	66.00	71.00	69.00	67.00
DPPH radical-scavenging activity (IC_{50} mg/mL)	213.91	134.24	101.65	216.53	190.0	122.46	159.68	114.92	90.10

Note: DPPH = 1,1-diphenyl-2-picrylhydrazyl; IC_{50}, half maximal inhibitory concentration; mg GAE/100 g = milligrams of gallic acid equivalents per 100 g.

Table 3.
Changes in Jams Produced from Ripe Fruit

Brix°	67°			70°			73°		
Storage Period (Months)	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dry matter (%)	62.46	59.50	60.20	66.47	64.25	64.05	69.55	66.56	66.45
pH	3.13	3.13	3.13	3.15	3.15	3.14	3.18	3.17	3.17
Vitamin C (mg/100 g)	30.30	15.00	11.18	27.64	12.69	10.27	23.82	10.00	9.73
Total phenolics (mg GAE/100 g)	24.56	33.01	44.26	23.30	27.69	35.21	21.11	35.83	42.10
Antioxidant activity (%)	72.00	71.00	70.00	71.00	69.00	67.00	73.00	68.00	63.00
DPPH radical-scavenging activity (IC_{50} mg/mL)	175.81	134.46	102.47	151.3	112.46	104.98	131.40	102.56	89.18

Note: DPPH = 1,1-diphenyl-2-picrylhydrazyl; IC_{50}, half maximal inhibitory concentration; mg GAE/100 g = milligrams of gallic acid equivalents per 100 g.

time increased. Vitamin C levels in kiwifruit jams were 26.73, 14.77, and 12.46 mg/100 g in the first, second, and third months, respectively. This decrease was more pronounced especially in the first month. Ascorbic acid is one of the most vulnerable vitamins, as it is highly susceptible to various degradation factors. Losses of ascorbic acid in heat-treated foods occur mainly as a result of chemical degradation. The effective factors on degradation are temperature, water activity, light, oxygen, pH, phenolic compounds, sugars, and metal ions (Kırca & Cemeroğlu, 2001). According to the results of Duncan multiple comparison test, it is seen that the amount of vitamin C decreases with increasing brix. It can be thought that the high amount of sugar may be effective in this situation.

Table 4.
Storage-Dependent Changes in Kiwi Jam Properties

Storage Period (Months)	1	2	3
Dry matter (%)	65.50 ± 3.23^{a}	63.88 ± 3.34^{b}	63.67 ± 2.66^{c}
pH	3.19 ± 0.046^{a}	3.15 ± 0.016^{b}	3.12 ± 0.033^{c}
Vitamin C (mg/100 g)	26.73 ± 3.07^{a}	14.77 ± 2.94^{b}	12.46 ± 2.06^{c}
Total phenolics (mg GAE/100 g)	25.56 ± 3.12^{c}	31.20 ± 3.01^{b}	37.45 ± 5.01^{a}
Antioxidant activity (%)	69.92 ± 3.20^{a}	67.58 ± 2.54^{b}	65.33 ± 3.39^{c}
DPPH radical-scavenging activity (IC_{50})	174.77 ± 32.85^{a}	131.47 ± 29.96^{b}	101.81 ± 11.55^{c}

Note: DPPH = 1,1-diphenyl-2-picrylhydrazyl; IC_{50}, half maximal inhibitory concentration; mg GAE/100 g = milligrams of gallic acid equivalents per 100 g.
[a,b]Means with the same letter are not different from each other.

Total phenolic content of jams produced at different brix values was highest at 73 brix and lowest at 70 brix ($p < .01$). The increase in the amount of phenolic substances was realized at a higher rate in the jams at 73 brix, which were heat treated for a longer period of time. This can be explained by the hypothesis that chalcone formation occurs as a result of the opening of the pyrylium ring under the influence of heat, resulting in the formation of phenolic substances. A similar increase was observed in blackberry jam during storage (Tosun, 1998). The levels of total phenolic substances in kiwifruit jams were determined as 25.56, 31.20, and 37.45 mg GAE/100 g at first, second, and third months, respectively. In this study, total phenolic matter and DPPH radical-scavenging activity, which are antioxidant properties, increased while vitamin C decreased in stored jams. The mentioned properties may affect the antioxidant activity at different levels.

Dependence of the fruit ripeness changes in kiwi jam properties are given in Table 5. Vitamin C contents of jams produced from raw and ripe fruits averaged 19.22 and 16.74 mg/100 g, respectively. Vitamin C levels in jams produced from raw fruit were higher than produced from ripe fruit. However, the total phenolic content was 30.89 mg GAE/100 g in jams produced from raw fruits and 31.90 mg GAE/100 g in jams produced from ripe fruits. Antioxidant activity of jams produced from raw and ripe fruits averaged 66.56% and 69.33%, respectively. Total phenolic content and antioxidant capacity were higher in jams produced from ripe fruit.

In this study, the changes in the composition of jams produced from raw and ripe kiwifruit at 67, 70, and 73°Bx during storage were investigated. Composition and antioxidant analyses were performed first on fresh fruits and then on jams at 1-month

Table 5.
Dependence of the Fruit Ripeness Changes in Kiwi Jam Properties

Fruit Ripeness	Raw Fruit	Ripe Fruit
Dry matter (%)	64.27 ± 3.32[a]	64.39 ± 3.26[a]
pH	3.16 ± 0.06[a]	3.15 ± 0.02[a]
Vitamin C (mg/100 g)	19.22 ± 5.9[a]	16.74 ± 8.21[b]
Total phenolics (mg GAE/100 g)	30.89 ± 3.81[b]	31.90 ± 8.26[a]
Antioxidant activity (%)	66.56 ± 3[b]	69.33 ± 3.04[a]
DPPH radical-scavenging activity (IC_{50})	149.3 ± 47.9[a]	122.7 ± 27.9[b]

Note: DPPH = 1,1-diphenyl-2-picrylhydrazyl; IC_{50}, half maximal inhibitory concentration; mg GAE/100 g = milligrams of gallic acid equivalents per 100 g.
[a,b]Means with the same letter are not different from each other.

intervals. Antioxidant properties of kiwi fruit such as antioxidant activity, DPPH radical-scavenging activity, total phenolic matter, and vitamin C were found to be quite high. Ripe fruits were found to be richer in terms of these values. The antioxidant components in jams are quite low compared to fresh fruit, but they are still significant despite the heat treatment applied. Vitamin C content and antioxidant activity decreased during storage. while DPPH radical-scavenging activity and total phenolic content increased.Vitamin C levels were higher in jams produced from raw fruit. Vitamin C loss is observed in all jam samples during storage, but the loss is higher in jams produced from ripe fruit. In addition, vitamin C loss increases with increasing brix in all jam samples.Total phenolic matter, DPPH radical-scavenging activity, and antioxidant activity, which are thought to have positive effects on health, are higher in jams produced from ripe fruit. Total phenolic matter and DPPH radical-scavenging activity increased during storage. There is a slight loss in antioxidant activity during storage.As a result, it is seen that jams produced from raw fruits at 70 and 73 brix are superior in terms of quality criteria. While storage has a negative effect on vitamin C, it has no negative effect on other antioxidant properties.

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