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Research Article

Some Physicochemical and Sensory Properties of Cactus Fruit (*Opuntia ficus-indica* L.) Vinegar Produced by Traditional Method

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Abstract

In this study, chemical, physical and sensory quality properties of vinegar produced from cactus fruit (*Opuntia ficus-inidica* L.) by conventional method were investigated. At the end of the study, it was determined that dry matter values were 1.13±0.11%, total acidity was 16.15±0.21 g/L, pH was 3.06±0.04 and conductivity was 1.90±0.09 µS/cm. The total phenolic and antioxidant values of the samples were determined to be 731.11±39.28 mg gallic acid equivalent (GAE)/L and 49.71±4.85 µg trolox equivalent (TE)/mL, respectively. Density, brix, and color (L*, a*, b*) values were determined to be 1.023±0.11 g/cm^3, 1.28±0.09 °Brix, L* (28.98±0.56), a* (2.23±0.41) and b* (-1.60±0.36), respectively. Nevertheless, the presence of alcohol was not detected in any of the samples after nine months of storage. The mineral material contents of cactus vinegar samples were determined as Na (38.48±0.07 ppm), Mg (15.35±0.91 ppm), K (354.46±2.91 ppm), Ca (14.11±0.83 ppm), P (20.4±0.16 ppm), Fe (0.19±0.00 ppm), B (0.36±0.00 ppm), Mn (0.32±0.00 ppm), Zn (0.10±0.00 ppm), Al (0.14±0.00 ppm), Cu (0.01±0.00 ppm), Sn (7.17±0.06 ppb). The sensory analysis scores of the samples were given by the panelists as follows: appearance (6.01±0.42), odor (7.25±0.81), aroma (6.75±0.23), color (5.75±0.45) and general appreciation (6.85±0.53). The results obtained were compared with apple cider vinegar which is the most consumed type of vinegar all over the world. Based on the results, cactus vinegar produced from cactus fruit by conventional method can be considered as a new type of vinegar, which is functional and useful for human health.

Keywords: Cactus fruit, Cactus vinegar, Fermentation.

Geleneksel Yöntemle Üretilen Kaktüs Meyve (*Opuntia ficus-indica* L.) Sirkesinin Bazı Fizikokimyasal ve Duyusal Özellikleri

Öz

Yapılan bu çalışmada kaktüs meyvesinden (*Opuntia ficus-inidica* L.) geleneksel yöntemle üretilen sirkenin bazı kimyasal, fiziksel ve duyusal kalite özelliklerinin belirlenmesi araştırılmıştır. Araştırma sonunda; kuru madde değerleri 1.13±0.11%, toplam asitlik 16.15±0.21 g/L, pH 3.06±0.04, iletkenlik 1.90±0.09 µS/cm olarak belirlenmiştir. Örneklerin toplam fenolik ve toplam antioksidan değerleri ise sırasıyla 731.11±39.28 mg gallik asit eşdeğeri (GAE)/L ve 49.71±4.85 µg troloks eşdeğeri (TE)/mL olarak tespit edilmiştir. Yoğunluk, brix ve renk (L*, a*, b*) değerleri sırasıyla 1.023±0.11 g/cm^3, 1.28±0.09 °Brix, L*(28.98±0.56), a* (2.23±0.41) ve b* (-1.60±0.36) olarak tespit edilmiştir. Buna karşın dokuz aylık depolama sonucunda numunelerin hiçbirisinde alkol varlığı tespit edilememiştir. Kaktüs sirkesi örneklerinin mineral madde içerikleri Na (38.48±0.07 ppm), Mg (15.35±0.91 ppm), K (354.46±2.91 ppm), Ca (14.11±0.83 ppm), P (20.4±0.16 ppm), Fe (0.19±0.00 ppm), B (0.36±0.00 ppm), Mn (0.32±0.00 ppm), Zn (0.10±0.00 ppm),

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Al (0.14±0.00 ppm), Cu (0.01±0.00 ppm), Sn (7.17±0.06 ppb) olarak belirlenmiştir. Panelistlerce örneklerin duyusal analiz skorları ise; görünüş (6.01±0.42), koku (7.25±0.81), aroma (6.75±0.23), renk (5.75±0.45) ve genel beğeni (6.85±0.53) olarak verilmiştir. Elde edilen sonuçlar tüm Dünyada en fazla tüketilen sirke türü olan elma sirkesi ile kıyaslanmıştır. Sonuçlar ışığında kaktüs meyvesinden geleneksel yollarla üretilen kaktüs sirkesi fonksiyonel özellikte ve insan sağlığına faydalı yeni bir sirke çeşidi olarak değerlendirilebilir.

Anahtar Kelimeler: Kaktüs meyvesi, Kaktüs sirkesi, Fermantasyon.

1. Introduction

Vinegar is a liquid food product produced as a result of alcohol fermentation of carbohydrate sources and then acetic acid fermentation (Ho et al., 2017). Alcoholic fermentation is the conversion of sugar into alcohol under anaerobic conditions, and acetic acid fermentation is the conversion of alcohol into acetic acid under aerobic conditions (Tan, 2003; Budak et al., 2014; Dabija & Hatnean, 2014). Vinegar is consumed directly and also plays an important role in the production of food products since it is used as a spice or preservative substance in a wide range of products, including sauces, mayonnaise, and ketchup (Tesfaye et al., 2002; Salbe et al., 2009). Vinegar contains polyphenolic compounds and natural antioxidants at various and different ratios (Alonso et al., 2002; Verzelloni et al., 2007). It was indicated that these components in vinegar had effects such as protecting heart and brain cells, preventing anti-inflammatory, anticarcinogenic, chronic diseases, hypertension, and hyperlipidemia (Visioli et al., 2000; Conte et al., 2003; Osada et al., 2006; Chou et al., 2015).

In the world, there are many types of vinegar, including black vinegar, rice vinegar, balsamic vinegar, and white wine vinegar. All these kinds of vinegar are produced using different raw materials, yeast species, and fermentation procedures, and thus, they gain their own unique tastes and flavors (Ho et al., 2017).

Cactus fruit (Opuntia *ficus-indica*) originated from the American continent and spread to the Mediterranean countries in the 16th century (Vignon et al., 2004). Cactus fruit has antioxidant activity such as fiber, polyunsaturated fatty acids, vitamins, amino acids, flavonols, flavonoids, carotenes, and ascorbic acid. Furthermore, it is rich in bioactive compounds and has low calorie content (27 cal/100 g). Therefore, it is considered as a functional food (Ginestra et al., 2009). Cactus fruit was reported to have anti-inflammatory, antioxidant, hypoglycemic, antimicrobial, and neuroprotective properties (Kaur et al., 2012).

2. Material and Method

2.1. Material

Cactus fruit (*Opuntia ficus-indica*) to be used in the study was obtained from local markets in Afyonkarahisar province.

2.2. Methods

The cactus fruit was kept in water for 1 day so that its spines would be removed. The cactus fruit was washed, cleaned, and chopped. Then, it was allowed to be aired in the laboratory environment for 1 day. The cactus fruits prepared were added in 1/3 of 10-liter jars. Then, 50 g honey and 50 g molasses were added to it for the natural fermentation process to take place. It was ensured to create fermentation conditions by adding 150 mL of natural fermented cactus vinegar and 50 g chickpeas. Water was added to the product prepared to complete 10 L. The samples in the jars prepared were covered with cheesecloth to be aired for 30 days. Furthermore, they were mixed twice a day to be aired. This process was continued for approximately 30 days until a vinegar mother appeared on the surfaces of the jars. After the formation of the vinegar mother following the fermentation process, filtration was performed from the raw material. Then, the jars were sealed and stored without exposing to light at room temperature for 9 months. Their analyses were then performed under laboratory conditions. This study was conducted in triplicate were used for each repetition.

2.3. Analyzes

The pH values of cactus vinegar samples were determined by Hanna (HI 2215, Germany), and conductivity value (Sension 5 model, HACH, CO, USA) was determined by hand conductivity. Dry matter analysis was performed using the oven (Ecocell 55, Germany), and the ash content was determined in the electromag (M 1811, Turkey) ash furnace (AOAC, 2000). Alcohol content measurements were performed using a vinometer (AOAC, 1992). While the brix value was determined by an Atago (N-1E) brand hand refractometer according to Akbas and Cabaroglu 2010, total acidity was determined according to Cemeroglu 2007, total antioxidant and total phenolic content were determined according to Chu and Chen 2006, density determination was performed according to Alak 2015, and mineral matter analysis was performed according to the method described by Jorhem 1993. Sensory analysis was performed according to Altug and Elmaci 2005 and color analysis was performed according to Alak 2015.

Table 1. Physical Analysis Results of Cactus Vinegar

Analyzes / **Samples**	**Brix (°Brix)**	**Density (g/cm^3)**	**Color**			**Sensory Scores**				
			L*	**a***	**b***	**Color**	**Aroma**	**Odor**	**Appearance**	**General Appreciation**
Cactus Winegar	1.28±0.09	1.023±0.11	28.98±0.56	2.23±0.41	-1.60±0.36	5.75±0.45	6.75±0.23	7.25±0.81	6.01±0.42	6.85±0.53

Table 2. Chemical Analysis Results of Cactus Vinegar

Analyzes / **Samples**	**Dry Matter Content (%)**	**pH**	**Ash (g/L)**	**Conductivity (µS/cm)**	**Alcohol (%)**	**Total Acidity (g/L)**	**Total Antioxidant (µg TE/mL)**	**Total Phenolic (mg GAE/L)**
Cactus Winegar	1.13± 0.11	3.06±0.04	4.1±0.12	1.90±0.09	-	16.15±0.21	49.71±4.85	731.11±39.28

Table 3. Mineral Analysis Results of Cactus Vinegar

Analyzes / **Samples**	**Na (ppm)**	**Mg (ppm)**	**K (ppm)**	**Ca (ppm)**	**P (ppm)**	**Fe (ppm)**	**B (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**Al (ppm)**	**Cu (ppm)**	**Sn (ppb)**
Cactus Winegar	38.48±0.07	15.35±0.91	354.46±2.91	14.11±0.83	20.4±0.16	0.19±0.00	0.36±0.00	0.32±0.00	0.10±0.00	0.14±0.00	0.01±0.00	7.17±0.06

3. Results and Discussion

The Brix ratio of cactus vinegar was determined to be 1.28±0.09 °Brix (Table 1). In similar studies, the brix value in apple cider vinegar was determined to be between 3.83-11.67 g/100 mL (Budak, 2010) and 1.02-12.90 (Ozturk et al., 2015). The brix values of cactus vinegar samples were found to be lower than the brix values of apple cider vinegar.

The density value of cactus vinegar was determined to be 1.023±0.11 g/cm^3 (Table 1). In the studies on apple cider vinegar, it was reported that density value varied between 0.9987-1.0517 g/cm^3 (Budak, 2010) and 1.013-1.024 g/cm3 (Plessi, 2003), similarly to our results.

In cactus vinegar samples, it was determined that the mean L* value was 28.98±0.56, a* values were 2.23±0.41, and b* values were -1.60±0.36 (Table 1). In a study carried out in six different traditional apple cider vinegar samples, it was reported that the mean L* value was between 4.58-20.15, the a* value was between 0.09-6.66, and the b* value was between 3.71-11.98 (Ozturk et al., 2015). It was determined that cactus vinegar was brighter than apple vinegar when compared to similar studies. The a* value of cactus vinegar samples and the a* values of apple vinegar samples were similar. When the results of the study carried out with the vinegar of both different fruits were evaluated, it was determined that b* values were in "-" (green) values in cactus vinegar and in "+" (yellowness) values in apple cider vinegar. These differences between the studies were considered to be due to the natural color of the fruit.

The total amount of dry matter of cactus vinegar was determined to be 1.13±0.11% (Table 2). In similar studies, it was determined that the total dry matter ratios of apple cider vinegar samples were 1.37-10.26% (Budak, 2010), 2.14% (Aykin, 2013), and 16.38 g/L (Gerbi et al., 1998) on average. It is considered that the differences in dry matter amounts as a result of our study and the studies on apple cider vinegar samples were due to the fact that the dry matter content of cactus fruit was lower than the dry matter content of apple. According to TS 1880 EN 13188 vinegar standard, no limit on dry matter content was reported TS (2003).

The mean pH value of cactus vinegar was found to be 3.06±0.04 (Table 2). In the studies on apple cider vinegar, pH value was found to be 2.71-3.5 (Ozturk et al., 2015), 2.9-5.7 (Hill et al., 2005), and 2.83-3.21 (Budak et al., 2011), similarly to the results of our study.

The mean conductivity values of cactus vinegar samples were determined to be 1.90±0.09 µS/cm (Table 2). In the study on hawthorn vinegar, Kadas (2011) reported that the conductivity value was found to be 3.86 µS/cm, which was higher than the results of our study.

No alcohol was detected in any of the cactus vinegar samples after nine months of storage. In a similar study, Caligiani et al. (2007) reported that they determined the amount of alcohol in apple cider vinegar as 0.37 g/L. It is considered that the whole alcohol present in cactus vinegar samples was fermented to acetic acid during storage.

Total acidity in cactus vinegar was determined to be 16.15±0.21 g/L (Table 2). In the studies carried out with apple cider vinegar, total acidity amounts were determined to be 0.19-7.37% (Budak, 2010), 1.04-10.57% (Hill et al., 2005), 0.66-7.20% (Ozturk et al., 2015), and 5.40-6.60 g/100 mL (Gerbi et al., 1998). According to TS (2003) vinegar standard, it is stated that "total acid amounts should not be less than 60 g/L (6 g/100mL) in wine (grape) vinegar (in free acetic acid in water) and 50 g in other kinds of vinegar." The total acidity amounts of all our samples were not in accordance with the values specified in the standard.

The total antioxidant values of the samples were found to be 49.71±4.85 µg TE/mL on average (Table 2). In similar studies, the total amount of antioxidants in apple cider vinegar was determined to be 3.00-5.89 µmol TE/mL (ORAC method) (Wu et al., 2004), 4.71 µg TE/mL (Pinsirodom et al., 2008), 5640 µmol TE/kg (ORAC method) (Ninfali et al., 2005), and 3.00-5.89 µmol TE/mL (ORAC method) (Budak et al., 2011). It is considered that the reason why antioxidant values in vinegar samples were found to be different between the studies may be due to the differences in raw materials used in production and in storage conditions.

The mean total phenolic content of cactus vinegar samples was determined to be 731.11±39.28 mg GAE/L (Table 2). In similar studies on apple cider vinegar, the total phenolic content was determined to be 757.65 mg/L (Budak et al., 2011), 202.00 mg/L (Ninfali et al., 2005), 551 mg/L (Gerbi et al., 1998), and 40.44-434.88 GAE/L (Ozturk et al., 2015). The total phenolic content in vinegar varies depending on aging conditions and storage (Samanidou et al., 2001).

In cactus vinegar samples, it was determined that Na content was 38.48±0.07 ppm, Mg content was 15.35±0.91 ppm, K content was 354.46±2.91 ppm, Ca content was 14.11±0.83 ppm, P content was 20.4±0.16 ppm, Fe content was 0.19±0.00 ppm, B content was 0.36±0.00 ppm, Mn content was 0.32±0.00 ppm, Zn content was 0.10±0.00 ppm, Al content was 0.14±0.00 ppm, Cu content was 0.01±0.00 ppm, and Sn content was 7.17±0.06 ppb (Table 3). In the studies carried out, it was reported that Na content was 25.70-4070.20 mg/L (Ozturk et al., 2015), Mg content was 0.64 ppm (Kapukaya, 2017), K content was 25814.17 mg/L (Aykin, 2013), Ca content was 627.10-1599.70 mg/L (Ozturk et al., 2015), Fe content was 1.37 ppm (Kapukaya, 2017) in apple cider vinegar. When the mineral material contents of our samples were compared with apple cider vinegar samples, it was found that Mg content was high while Fe content was lower.

In the comparison of antioxidant, phenolic, and mineral substance analysis results in cactus vinegar with the studies on the relevant issue, the use of different fruits, the changes during and after the production and differences between analysis procedures made it difficult to compare the results of the study with each other. Therefore, it is considered that the differences that emerged with the comparison of our study results with apple cider vinegar, which is one of the most preferred vinegar varieties in the world, were due to this.

4. Conclusions

It has been revealed by the studies that vinegar supports calcium absorption, regulates blood pressure and serum insulin, and has a protective effect against antitumor and cardiovascular diseases. The importance of vinegar is increasing with each passing day since it has many beneficial health effects. Nowadays, many types of vinegar are produced worldwide. Cactus fruit to be processed in vinegar is rich in phenolic compounds, antioxidants, and fiber. Since these compounds it contains are effective in the prevention of various diseases (cancer, diabetes, cardiovascular diseases), they provide many beneficial effects for health. However, the limited production area of cactus fruit and the fact that it is grown without cultivation and the fruit has a thorny structure make its consumption difficult. It is clear that increasing the amount of production of the fruit through cultivation and facilitating consumers' access to fruit will increase the production and consumption of cactus vinegar with bioactive properties, which is a highly valuable product with functional properties.

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