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Determination of total phenolic, flavonoid and monomeric anthocyanin contents and antioxidant properties of 15 different fruit vinegars produced by traditional method

Geleneksel yöntemle üretilen 15 farklı meyve sirkesinin toplam fenolik, flavonoid ve monomerik antosiyanin içerikleri ve antioksidan özelliklerinin belirlenmesi

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Abstract

In this study, vinegars were produced using traditional method from 15 different fruits (rosehip, pear, fig, wild pear, apple, plum, hawthorn (yellow and red), pomegranate, grape (cimin, cardinal), peach, cranberry, quince and medlar). It was aimed to determine the total phenolic, total flavonoid and total monomeric anthocyanin contents and antioxidant capacities of vinegars. As a result, it was concluded that the phenolic, flavonoid contents and the antioxidant capacity in all 3 methods (TEAC, FRAP and DPPH) of rosehip vinegar was significantly higher than other vinegars. In addition, wild pear and hawthorn vinegars were very rich in phenolic and flavonoid compounds and these vinegars had very high antioxidant capacity. The results of the study suggest that an alternative consumption method can be provided by producing vinegar, which is a healthy, aromatic and alternative product with high added value, from fruits such as rosehip, wild pear, hawthorn, cranberry, quince and medlar, whose usage and consumption are limited due to their natural structure.

Keywords: Vinegar, Antioxidant, Phenolic, Flavonoid, Monomeric anthocyanin

Öz

Bu çalışmada 15 farklı meyveden (kuşburnu, armut, incir, yabani armut, elma, erik, alıç (sarı ve kırmızı), nar, üzüm (cimin, kardinal), şeftali, kızılcık, ayva ve muşmula) geleneksel yöntemle sirke üretilmiştir. Sirkelerin toplam fenolik, toplam flavonoid ve toplam monomerik antosiyanin içerikleri ile antioksidan kapasitelerinin belirlenmesi amaçlanmıştır. Sonuç olarak kuşburnu sirkesinin fenolik, flavonoid içeriklerinin ve her 3 yöntemde (TEAC, FRAP ve DPPH) antioksidan kapasitesinin diğer sirkelere kıyasla oldukça yüksek olduğu, ayrıca ahlat ve alıç sirkelerinin fenolik ve flavonoid bileşikler bakımından oldukça zengin olduğu ve bu sirkelerin çok yüksek antioksidan kapasiteye sahip olduğu sonucuna varılmıştır. Çalışma sonuçları, doğal yapısı nedeniyle kullanımı ve tüketimi sınırlı olan kuşburnu, ahlat, alıç, kızılcık, ayva ve muşmula gibi meyvelerden sağlıklı, aromatik ve katma değeri yüksek alternatif bir ürün olan sirke üretilerek alternatif bir tüketim yöntemi sağlanabileceğini ortaya koymuştur.

Anahtar kelimeler: Sirke, Antioksidan, Fenolik, Flanonoid, Monomerik antosiyanin

1 Introduction

Fruits and vegetables, account for more than 42% of food waste, while they are major sources of nutrients and minerals [1]. According to the FAO, 40-50% of fruits and vegetables are wasted throughout the food supply chain worldwide [2], equivalent to 28 million tons of waste [3]. Fruits produced in large amounts every year are wasted since the excess cannot be consumed or are considered of low quality based on their defective appearance or insufficient size [4]. Considering these actions cause ecological and economic problems, and the perishability of fruits, their use in the production of high value-added products such as vinegar could be a valuable strategy to mitigate these problems.

Vinegar produced by the process of alcohol fermentation followed by acetic acid fermentation [5], and is used as a flavoring and preservative in many food products [6]. Due to containing an abundance of functional active substances, it has many positive effects on health, especially anti-inflammatory, hypoglycemic, and lipid-lowering effects. [7]. Various raw materials can be used in vinegar production and vinegars can be classified as cereal vinegars, fruit vinegars and alcohol vinegars, and are named according to the origin of the raw materials [8]. According to the Global Vinegar Market Report, the global vinegar market is attained USD 1.36 billion in 2023, and is expected to reach USD 1.50 billion by 2032 [9].

Bioactive compounds are secondary metabolites in plants [10] and are also responsible for the unique colour, smell and taste of plants [11]. These compounds generally have strong antioxidant activity, protect the cell against external factors by protecting the intracellular matrix structure and regulate intestinal flora, bile acids and pH. In addition, these compounds increase the activities of anticarcinogen enzymes and have a preventive effect on the formation of nitrosamines [12]. Phytochemicals are becoming more prominent in nutrition due to developments in science and technology,

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high costs in health expenses, increased awareness of the link between nutrition and health, and the negative effects of excessive consumption of animal foods on health [13]. Some examples of bioactive compounds can be listed as tannins, phenolic compounds (polyphenols), carotenoids, saponins, coumarins, tocopherols, terpenes, isothiocyanates, sulphites, sulforaphanes, terpenoids, alkaloids, flavonoids, phytosterols, phytoestrogens and indoles [14].

Free radicals refer to atoms or molecules which have an open electron shell configuration containing unpaired electrons in their final orbitals [15], while approximately 1-3% of oxygen is converted into reactive oxygen species by the body [16]. Radicals are formed by three main mechanisms. These are the homolytic cleavage of one of the common electrons of a covalently bonded molecule, the loss of an electron from the molecule or the heterolytic splitting of a molecule and the addition of an electron to a molecule [17]. Antioxidant balance in the human body may change due to factors such as aging and environmental pollution, fatigue, excessive calorie intake and high-fat diets. Disruption of oxidant/antioxidant balance in living things causes oxidative stress. The brain is very sensitive to oxidative stress and oxidative stress causes mental disorders such as schizophrenia, mood disorders, autism, attention deficit and hyperactivity [18], eye, brain, joint, skin, kidney and lung disorders, and type 2 diabetes [19]. Due to the side effects and toxic effects of synthetic antioxidant substances, the interest in natural antioxidants is increasing and the potential of using plant-derived substances as antioxidants in foods is being investigated.

In this study, it was aimed to use various fruits as raw materials in vinegar production to create a high added-value product, considering highly perishable fruit is utilised to produce a healthy, aromatic and alternative product. The vinegars were produced from fruits such as rosehip, wild pear, hawthorn, cranberry, quince and medlar, which have limited usage and consumption. The study's aim was to determine the total phenolic, flavonoid and monomeric anthocyanin contents and antioxidant capacities of vinegars, and to contribute to the literature.

2 Material and methods

2.1 Materials

The fruits (rosehip, pear, fig, wild pear, apple, plum, hawthorn (yellow and red), pomegranate, grape (cimin, cardinal), peach, cranberry, quince and medlar) were obtained from local greengrocers and markets. All chemicals were supplied by Sigma-Aldrich and Merck KGaA.

2.2 The production of vinegars

The productions of vinegars were carried out using the traditional method. Following sorting and cleaning, rosehip, pear, fig, wild pear, apple, hawthorn, quince and medlar fruits were sliced, the seeds of plum, peach and cranberry fruits were removed, pomegranates were peeled and granulated and the fruits were transferred to 5 L glass jars. In total, 1000 × g of fruit was mixed with 50 × g of granulated sugar and 2000 mL of distilled water in jars. The jars were covered with cheesecloth, allowing air to enter. The mixture was stirred every 12 h until the fruit pieces collected on the surface and then settled at the bottom of the jar. Fermentation was continued for approximately 8 weeks (until the mother of vinegar, formed on the surface, collapsed to the bottom) for vinegar production. Vinegars of rosehip (RV), pear (PEV), fig (FV), wild pear (WPV), apple (AV), and plum (PLV) were filtered first through a cheesecloth and then through coarse filter paper. Then the mothers of vinegar were removed from the vinegars, and the rosehip (RV), pear (PV), fig (FV), wild pear (WPV), apple (AV), plum (PLV), hawthorn (yellow (YHV) and red (RHV)), pomegranate (PGV), grape (cimin (CIGV), cardinal (CAGV)), peach (PEV), cranberry (CV), quince (QV) and medlar (MV) vinegars were filtered first through a cheesecloth and then through coarse filter paper.

2.3 Analysis of vinegars

2.3.1 Total phenolic

By modifying the method described by Singleton et al., [20] was used for the determination of total phenolic contents of vinegars. 2 N Folin-Ciocalteu phenol reagent (100 µL), vinegar (100 µL), or standard gallic acid solutions (100 µL), distilled water (and 2.3 mL) and 7% aqueous sodium carbonate solution (1 mL) were mixed and incubated at room temperature for 2 hours, and the absorbance of the samples were measured at 750 nm wavelength and the results were calculated and expressed as "g/L gallic acid equivalent".

2.3.2 Total flavonoid

The total flavonoid amounts of vinegars were determined according to Li et al. [21]. Distilled water (2 mL) and 5% $NaNO_2$ (0.15 mL) were added to vinegars (0.5 mL) and standard solutions, mixed and incubated for 5 minutes. 10% $AlCl_3$ (0.15 mL) was added to the mixture, mixed and left for 5 minutes again. After mixing with 1 M NaOH (1 mL), the mixtures were left for 15 minutes and the total flavonoid amounts were determined in a spectrophotometer at 415 nm. As a standard, 200 mg/L stock Quercetin solution prepared in ethanol was used and results were expressed as quercetin equivalents.

2.3.3 Total monomeric anthocyanin

The total amount of monomeric anthocyanin in vinegar samples was determined according to the pH differential method determined by Fuleki and Francis [22]. The pH values of vinegars (10 mL) were adjusted to 1.0 and 4.5 with HCl or NaOH solutions and stored at +4°C for 2 hours. Then, the absorbance of the samples at 516 nm and 700 nm wavelengths were measured, the absorbance differences (A_{516}–A_{700}) were calculated and the absorbance differences at pH 1.0 were subtracted from the absorbance differences at pH 4.5. In this way, the total anthocyanin concentrations of the samples were calculated according to Equation (1).

$$M = (A \times 103 \times MW \times DF)/(E \times L) \quad (1)$$

M: total monomeric anthocyanin (mg/L), A: absorbance, MW: molecular weight of pigments, DF: dilution factor, E: molar absorbance, L: optical path length of the cuvette.

2.3.4 Antioxidant capacity

The antioxidant capacities of vinegars were determined by the following 3 methods.

2.3.4.1 Ferric reducing antioxidant power (FRAP)

The antioxidant capacities of vinegars using the FRAP method were determined according to the method described by Benzie and Strain [23]. For this, 30 mM sodium acetate buffer (pH 3.6), 20 mM iron (III) chloride and 10 mM TPTZ solutions were mixed (10/1/1) for the FRAP working solution. The FRAP working solution (2.9 mL) and vinegars (100 µl) or trolox standard solutions (100 µl) were mixed and left at room temperature for 30 minutes, then their absorbance was measured at a 593 nm wavelength and the FRAP antioxidant capacities of the vinegars were calculated as mM trolox equivalent.

2.3.4.2 Radical scavenging activity (DPPH)

DPPH (2.2 diphenyl-1- picrylhydrazyl) antioxidant capacities of vinegars were determined according to the method described by Brand-Williams et al. [24]. DPPH working solution (1.95 mL) and vinegars (50 µl) or trolox standard solutions (50 µl) were mixed and left at room temperature for 10 min. Then, their absorbances were measured at a 517 nm wavelength and the DPPH antioxidant capacities of the vinegars were calculated as mM trolox equivalent.

2.3.4.3 Trolox equivalent antioxidant capacity (TEAC)

Antioxidant capacities of vinegars were determined according to the TEAC method described by Re et al. [25]. First of all, the mixture of 7 mM ABTS solution and 2.45 mM potassium persulfate solutions (1/1, v/v) was left to react in the dark at room temperature for 16 hours, and thus ABTS radical cation ($ABTS^{*+}$) stock solution was obtained. Prior to analysis, the $ABTS^{*+}$ stock solution was diluted with 20 mM sodium acetate (pH 4.5) and its absorbance was adjusted to 0.7 at a wavelength of 734 nm ($ABTS^{*+}$ working solution). Mixtures of $ABTS^{*+}$ working solution (2.9 mL) and vinegars (0.1 mL) or trolox standard solutions were left to react for 30 minutes at room temperature and the TEAC antioxidant capacities of the vinegars were calculated as mM trolox equivalent by measuring their absorbance at a 734 nm wavelength.

2.4 Statistical analysis

The results were calculated as the mean±standard deviation of three replications. The SPSS statistical program (IBM SPSS Statistics 22, Inc., Chicago, IL, USA) was used to analyse the results and analyses of variance (ANOVA) of the results were performed and the differences between the groups were statistically evaluated using the Duncan multiple comparison test at a 95% confidence interval.

3 Results and discussions

3.1 Total phenolic

Polyphenols and flavonoids are the primary bioactive compounds in vinegars, are the main substances with antioxidant properties, and are responsible for various positive effects on health [26]. In this study, the total phenolic contents of vinegars were analysed according to the Folin–Ciocalteu method, which is simple, reliable and reproducible [27]. When the results were examined, it was determined that the total phenolic contents of vinegars ranged from 28.24 to 550.70 mg GAE/100 mL, that RV, WPV, RHV and YHV had the highest contents, that AV, PEV and QVs had the lowest contents, respectively, and that PLV and MV, PGV and CIGV, and QV and PEV were not statistically significant (P>0.05) (Figure 1).

In other studies, the total phenolic contents were reported as 110.35 mg GAE/100 mL [28] and 760 mg GAE/100 mL [30] for rosehip vinegar, as 84.2 mg GAE/100 mL [31], 52.12 mg GAE/100 mL [26], 158.37 mg GAE/100 mL [32] and 102.51 mg GAE/100 mL [28] for grape vinegar, as 45.9 mg GAE/100 mL [31], between 73.45 and 111.06 mg GAE/100 mL [33], 269 mg GAE/100 mL [34] and 98.80 mg GAE/100 mL [28] for apple vinegar, as 104.4 mg GAE/100 mL [28], 285.41 mg GAE/100 mL [32], 182.35 mg GAE/100 mL and 576.47 mg GAE/100 mL [35] for pomegranate vinegar, as 57.79 mg GAE/100 mL [26] for quince vinegar, as 39.51 mg GAE/100 mL [26], 43.76 mg GAE/100 mL [36] and 118.02 mg GAE/100 mL [37] for peach vinegar, as 14.86 mg GAE/100 mL [36] for pear vinegar, as 93.55 mg GAE/100 mL [28] and 93.55 mg GAE/100 mL [28] for fig vinegar, as 9.55 mg GAE/100 mL, 33.16 mg GAE/100 mL [36] and 105.7 mg GAE/100 mL [28] for plum vinegar and as 242 mg GAE/100 mL [32] and between 104.22 mg GAE/100 mL and 116.99 mg GAE/100 mL [38] for hawthorn vinegar. The literature review has indicated that total phenolic contents of vinegars are highly variable. The phytochemical compounds such as phenolics and flavonoids are widely depended on the raw materials and on the strain of yeast and acetic acid bacteria responsible for fermentation [26]. Along with these, the reason for this variable has been thought to be related to fruit/water ratio and different production methods in vinegar production.

3.2 Total flavonoid

The total flavonoid contents of the vinegars were measured using the method based on the precipitation of vinegars with aluminium chloride ($AlCl_3$). Al^{+3} forms an intense yellow colour by binding with ketone and hydroxyl groups of flavonoids via electron transfer, and the resulting colour intensity can be measured as absorbance in a spectrophotometer [39]. It was determined that the total flavonoid contents of vinegars varied between 11.90 and 318.30 mg QE/100 mL, RV, WPV and RHV had the highest flavonoid contents, respectively, and AV had the lowest flavonoid content, as in phenolic contents (Table 1 and Figure 1).

In studies, flavonoid contents were reported as 24.45 mg QE/100 mL [26], 2.03 mg QE/100 mL [36], between 79 and 153 mg CE/100 mg [31], 29.8 mg CE/100mL [40] and 22.18 mg CE/100mL [28] of grape vinegars, as between 1.87 and 13.10 mg QE/100 mL [26], 0.3 mg QE/100 mL [36], between 42 and 240 mg CE/100 mg [31] and 17.48 mg CE/100mL [28] of apple vinegars, as 13.18 mg QE/100 mL of quince vinegar [26], as 19.44 mg QE/100 mL [26] and 3.03 mg

QE/100 mL [36] of peach vinegars, as 1.23 mg QE/100 mL [36] of pear vinegars, as between 13.18 and 15.89 mg CE/100 mL [38] of hawthorn vinegar and as 47.09, 17.85, 23.42 and 26.51 mg CE/100mL of plum, fig, rosehip and pomegranate vinegars, respectively [28]. The literature review revealed that the flavonoid contents of vinegars are highly variable, as is the phenolic content, and that rosehip, hawthorn, peach, pear, quince and grape (except for [31]) vinegars had higher contents than those in the literature, whereas fig, pomegranate and apple (except for [36]) vinegars had lower contents. This variability has been thought to depend from differences in raw materials and fermentation methods, similar to phenolic substances.

3.3 Total monomeric anthocyanin

When the total monomeric anthocyanin contents were examined, it was determined that the results ranged from 4.13 mg/L to 120.06 mg/L, PEV, PLV, FV and PGV had the highest contents, and AV and YHV had the lowest contents, respectively (Table 1). In studies, the total monomeric anthocyanin contents were reported as 109.8 mg/L [41] and 50.40 mg/L [29] in rosehip vinegar, 1.01 mg/L in grape vinegar [42], 1.14 mg/L and 32.39 mg/L [35] in pomegranate vinegar, 0.51 mg/mL in hawthorn vinegar [43], between 0.4 and 1.3 mg/kg in strawberry vinegars [44], varied between 14.29 and 31.08 mg/L in 7 different red wines [45], and as 119.51 mg/L in pomegranate juice [46]. As a result of the study, it was determined that the total monomeric anthocyanin contents were lower in rosehip vinegar and higher in grape, pomegranate and hawthorn vinegars. The fact that the anthocyanin contents depend on various factors (growing area, climatic conditions, harvest time, positioning conditions, etc.) [8] may contribute to the observed differences in contents.

3.4 Antioxidant capacity

Since antioxidant capacity is affected by several factors, multiple methods should be used [47]. DPPH, free radical scavenging capacity, is a method that is frequently used to measure antioxidant capacity and is based on measuring the colour change throughout the conversion of the violet-coloured 2-2-diphenyl-1-picrihydrazil radical to 2-2-diphenyl-1-picrihydrazine in a spectrophotometer [48]. However, this assay is not suitable for assessing changes in foods with high protein content [30]. $ABTS^{*+}$ radical scavenging capacity can be applied to both lipophilic and hydrophilic components [27] and is a widely employed method for the standardization of antioxidant activity in foods [49]. However, this assay has received criticism as the ABTS radical is not found in any biological or food system [30]. The iron reduction method is based on the ability of substances with antioxidant properties to reduce ferric ions (III) to ferrous (II) ions. The colour change due to the reduction of iron by phenolic compounds provides information about its antioxidant power [47]. However, this assay cannot accurately measure the capacity of antioxidants containing Fe^{2+} and SH groups [30]. Given their specific advantages and disadvantages, these three assays were applied to determine the antioxidant capacity of vinegars.

In this study, it was determined that the antioxidant activity of vinegars changed between 0.55 and 167.06 mmol TE/L according to the FRAP assay, between 0.33 and 24.33 mmol TE/L according to the DPPH assay, and between 0.98 and 31.41 mmol TE/L according to the TEAC assay; that RV, WPV, RHV and CV had the highest antioxidant capacity, while AV had the lowest antioxidant capacity in all methods, respectively (Table 1). Among the vinegars, the antioxidant capacities of RV were significantly higher than other vinegars in all methods.

In other studies, antioxidant activities were determined as 51.39 mmol TE/mL [30], 0.44 mmol TE/L [28] (DPPH), 84.20 mmol TE/mL [30] and 2.29 mmol TE/L [28] (TEAC) for rosehip vinegar, between 5.39 mmol TE/L and 14.43 mmol TE/L [50], 0.47 mmol TE/L [28] (DPPH), 17.54 mmol TE/L [32], between 7.72 mmol TE/L and 17.96 mmol TE/L [50] and 1.76 mmol TE/L [28] (TEAC) for grape vinegar, between 2.65 mmol TE/L and 14.69 mmol TE/L [50], 0.59 mmol TE/L [28] (DPPH), between 4.05 mmol TE/L and 20.19 mmol TE/L [50], 10.27 mmol TE/L [32] and 2.09 mmol TE/L [28] (TEAC) for apple vinegar, 8.05 mmol TE/L [37] (DPPH) for peach vinegar, 0.57 mmol TE/L [28] (DPPH), 22.33 mmol TE/L [32] and 2.06 mmol TE/L [28] (TEAC) for pomegranate vinegar, 23.01 mmol TE/L [32] (DPPH) and 13.01 mmol TE/L [51] (TEAC) for hawthorn vinegar, 0.19 mmol TE/L [28] (DPPH) and 2.38 mmol TE/L [28] (TEAC) for fig vinegar and 1.21 mmol TE/L [28] (DPPH) and 2.15 mmol TE/L [28] (TEAC) for plum vinegar. The antioxidant capacities of 18 different commercial vinegars (apple, grape, pomegranate, balsamic, blueberry, rosehip, gilaburu, lemon, blackberry, artichoke, mulberry, rice, apricot, date and hawthorn) were determined as 0.13-1.49 mmolTE/L (TEAC), 0.06-2.07 mmolTE/L (DPPH) and 0.08-1.68 mmolTE/L by Bakır et al. [52].

The literature review indicated that, similar to phenolic and flavonoid contents, the antioxidant capacities of vinegars are highly variable. This difference between antioxidant capacities in the present work and those studies could be due to many factors. Genetics, environment, post-harvest storage and processing influence the antioxidant properties of plants [53]. Moreover, the use of whole rosehip, pear, fig, wild pear, apple, hawthorn, quince and medlar fruits in vinegar production may have effect on the antioxidant capasities of the vinegars. The antioxidant activity of vinegars is highly affected by the phenolic and flavonoid composition of vinegars [54]. It was concluded that the high amount of phenolic substances and flavonoids in RV, WPV and RHV significantly increased the antioxidant activities of these vinegars.

The results of the study were highly variable compared to commercial vinegars. Although the phenolic contents of vinegars were lower than those of [28, 31, 45] (grapes), [28, 31] (apple), [28] (plum, pomegranate and fig) and [36] (peach), they were higher than those of [36, 52] (grapes and apple), [52] (pomegranate), [28, 52] (rosehip) and [36] (pear). Similarly, the flavonoid contents of vinegars were lower than those of [31, 45] (grapes), [28, 31, 52] (apple) and [28, 52] (pomegranate), but higher than those of [28, 36] (grapes and plum), [36] (apple), [28] (fig), [28,52] (rosehip)

and [36] (pear and peach). When the antioxidant capacities of vinegars were compared with commercial vinegars, it was found that the results were higher than those of [28] (grapes), [28, 52] (rosehip), [28, 36] (plum), [28] (fig) and [36] (pear and peach), but lower than those of [31, 45, 50] (grapes), [50] (rosehip), [28, 31, 50] (apple) and [28, 52] (pomegranate). Differences between our study and commercial vinegars may be due to many factors such as raw materials, genetics, environment, post-harvest storage and processing conditions, fermentation methods, the strain of yeast and acetic acid bacteria responsible for fermentation, and the fruit/water ratio in vinegar production.

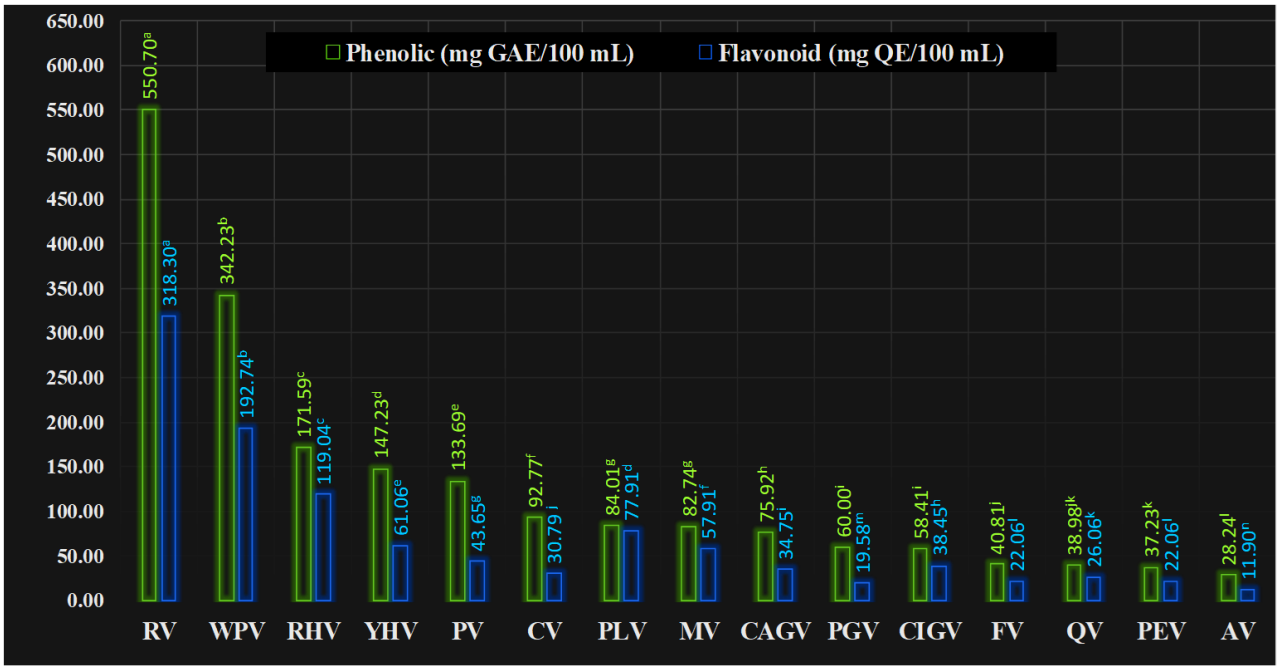

Figure 1. Total phenolic and flavonoid contents of vinegars

Rosehip (RV), pear (PV), fig (FV), wild pear (WPV), apple (AV), plum (PLV), hawthorn (yellow (YHV) and red (RHV)), pomegranate (PGV), grape (cimin (CIGV), cardinal (CAGV)), peach (PEV), cranberry (CV), quince (QV) and medlar (MV) vinegars. [a, b, c, d, e, f, g, h, I, j, k, l, m] Means followed by different column within the same line represent significant differences ($p \leq 0.05$). Data are the average of triplicates

Table 1 Total monomeric anthocyanin contents and antioxidant capacities of vinegars

	M. Anthocyanin (mg/L)	FRAP (mmol TE/L)	DPPH (mmol TE/L)	TEAC (mmol TE/L)
RV	9.45±0.14^{k}	167.06±0.87^{a}	24.03±1.18^{a}	31.41±0.60^{a}
WPV	33.86±1.05^{e}	45.75±0.41^{b}	6.40±0.71^{b}	13.24±0.42^{b}
RHV	6.61±0.07^{l}	28.50±0.22^{c}	4.96±0.04^{c}	8.45±0.13^{c}
CV	15.71±0.42^{j}	19.40±0.19^{d}	3.22±0.01^{d}	4.85±0.13^{d}
PGV	39.72±1.05^{d}	15.13±0.33^{e}	1.75±0.15^{e}	3.18±0.07^{f}
CIGV	31.47±0.07^{f}	14.09±0.57^{f}	0.34±0.01^{g}	3.50±0.08^{f}
MV	22.52±0.07^{g}	11.52±0.14^{g}	1.17±0.01^{efg}	3.40±0.10^{f}
QV	18.05±0.07^{h}	10.80±0.23^{h}	1.57±0.04^{ef}	2.23±0.04^{gh}
PEV	120.06±0.35^{a}	5.31±0.27^{i}	1.03±0.02^{efg}	1.07±0.09^{i}
PV	16.95±0.49^{i}	3.72±0.06^{j}	1.21±0.05^{ef}	3.32±0.01^{f}
YHV	5.12±0.63^{m}	3.59±0.06^{j}	1.32±0.03^{ef}	4.40±0.09^{e}
PLV	55.68±0.28^{b}	3.47±0.08^{j}	1.69±0.01^{e}	2.62±0.04^{g}
CAGV	30.72±0.56^{f}	2.22±0.03^{k}	1.15±0.02^{efg}	2.51±0.11^{g}
FV	43.30±0.49^{c}	1.73±0.10^{k}	0.79±0.00^{fg}	2.00±0.04^{h}
AV	4.13±0.21^{m}	0.55±0.02^{l}	0.33±0.02^{g}	0.98±0.05^{i}

RV: Rosehip vinegar, PV: pear vinegar, FV: fig vinegar, WPV: wild pear vinegar, AV: apple vinegar, PLV: plum vinegar, YHV: yellow hawthorn vinegar, RHV: red hawthorn vinegar, PGV: pomegranate vinegar, CIGV: cimin grape vinegar, CAGV: cardinal grape vinegar, PEV: peach vinegar, CV: cranberry vinegar, QV: quince vinegar and MV: medlar vinegar.

[a, b, c, d, e, f, g, h, I, j, k, l, m] Means followed by different column within the same line represent significant differences ($p \leq 0.05$). Data are the average of triplicates

4 Conclusions

In this study, it was aimed to determine the total phenolic, total flavonoid and total monomeric anthocyanin contents and antioxidant capacities of vinegars produced from 15 different fruits using traditional methods. As a result of the study, it was concluded that the vinegars included in the study differed in terms of their total phenolic, total flavonoid and total monomeric anthocyanin contents and antioxidant capacities; that rosehip, wild pear and hawthorn vinegars have particularly high total phenolic and flavonoid contents and antioxidant capacities that have biological effects. These differences were attributed to the fruit varieties used in vinegar productions.

The use of alternative fruits in the production of vinegar, an innovative, alternative and healthy product, is a significant issue. As a result of the study, it is believed that various fruits could be alternatives for vinegar production. In addition, an alternative consumption method was provided for fruits such as rosehip, wild pear, hawthorn, cranberry, quince and medlar, which have limited usage due to their natural structure. Further studies are needed to determine the effect of the fermentation process on antioxidant capacity, antimicrobial activity, physicochemical and metabolite analysis.

Conflict of interest

The authors declare that there is no conflict of interest.

Similarity rate (iThenticate): 19%

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