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Analyzing Biological Properties of Some Plum Genotypes Grown in Turkey

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ABSTRACT

In the current study, the biochemical components, antioxidant activity, antibacterial activity, and antimutagenic activity of 5 plum (Demal, White Cancur, Cancur, Red plum, and Sugar plum) fruits grown in Posof/Ardahan, Turkey were investigated. While other genotypes are cultured, Demal genotype grows wild. The highest total ascorbic acid (TAC; 454 mg/100 g FW (fresh weight)) and total flavonoid content (TFC; 29.1 mg/100 g FW) were detected in Red plum genotype. The Ferric Reducing *Antioxidant* Power (FRAP) and 2,2′-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid (ABTS) values were obtained highest in Sugar plum (563.8 µmol/g and 50.9%, respectively). 2,2-diphenyl-1-picrylhydrazyl (DPPH) content among the plum genotypes was also insignificant. Gallic acid, naringin, resveratrol, and caffeic acid were the predominant phenolic compounds in plum fruits. The resveratrol content in Red plum was significantly higher. The total sugar was found maximum in White Cancur and Cancur genotypes (545.15 and 546.08 mg/g, respectively). Twenty-three fatty acids were identified and quantified. Palmitic acid was the most abundant saturated fatty acid (SFA) in all samples. It was observed that all the plum extracts, except Cancur, exhibited antibacterial activity against the experimental bacteria. Further, different doses of plum extracts exhibited the antimutagenic effect.

KEYWORDS

Antibacterial; antioxidant; fatty acid; phenolic; plum; sugar

Introduction

Plums (*Prunus* subg. *Prunus*) are one of the most commonly produced fruits in Turkey and to the Rosaceae family. The FAO (2019) reported that the global plum production in 2017 was 11.758.135 t and it was 291.934 t in Turkey. Plum fruits contain many important nutrients that contribute to the nutritive value and taste of plums (Ertekin et al., 2006; Lucas et al., 2004).

The primary and secondary metabolites have pharmaceutical properties like antioxidant, antihypertensive, anti-diabetic, and anti-atherosclerotic effects (Giampieri et al., 2015; Rupasinghe et al., 2006; Vinson, 2001) that prevent the occurrence of many diseases (Stacewicz-Sapuntzakis et al., 2001). The content of the phytochemicals depends upon the cultivar, soil, habitat, and growing season that in turn control the fruit quality of plums (Arion et al., 2014; Sahamishirazi et al., 2017). The previous reports have focused only on the phytochemical content in plums (Gornas et al., 2017; Kaulmann et al., 2014; Tomas-Barberan et al., 2001; Wang et al., 2018) but data related to the fatty acid content or the antimutagenic effects in plums have not been investigated in detail. The current research aimed to compare the biochemical components, antioxidant activity, antibacterial activity and antimutagenic activity of the plum fruits commonly grown in Ardahan/Turkey.

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Materials and Methods

Fruit Materials and Experimental Site

The plum fruits (Demal (*Prunus divaricata*), White Cancur (*Prunus domestica*), Cancur (*Prunus domestica*), Red plum (*Prunus domestica*), and Sugar plum (*Prunus domestica*)) were collected during July 2017 from the Yurtbekler village in Posof/Ardahan, Turkey (Elevation: 1530 m). While other genotypes are cultured, Demal genotype grows wild. The samples at commercial maturity stage were transferred to the laboratory in polyethylene bags and stored at 4°C until analysis. The analyses were done at three replicates and the approximately 1000 g fruit was collected.

Extraction of Pulp

Plum fruits (40 g) devoid of seeds were homogenized with 200 mL distilled water. The samples were rotated at 190 g for 72 h at room temperature followed by centrifugation at 5000 g for 10 min. The collected supernatants were concentrated by vacuum (SCILOGEX RE100-Pro, USA) and filtered (0.2 µm, Sartorius Minisart® Syringe Filter). The extracts were frozen (–20°C) until used for determining the antibacterial and antimutagenic activities. Moreover, 5 g plum samples were homogenized by mixing with 50 mL of 85% methanol solution and incubated at 30°C for 24 h at 150 g. The mixtures were then centrifuged at 5000 g for 10 min. The supernatants were collected and analyzed for total phenolic content (TPC), total flavonoid content (TFC) and antioxidant content. Using oxalic acid as a solvent, the same extraction method was employed for the determination of total ascorbic acid content (TAC).

Analysis of TPC, TFC, and TAC

TPC was determined by the Folin-Ciocalteu method (Spanos and Wrolstad, 1992). Using a gallic acid standard, the absorbance values were measured in a visible Spectrophotometer (UNICO, S1205) at 765 nm, and the results were expressed in milligrams of gallic acid equivalents (GAE) per 100 g of fresh weight (FW). TFC was detected according to the protocol standardized by Quettier-Deleu et al. (2000). Rutin was used for calibration and TFC was expressed in milligrams per 100 grams (mg/100 g) FW. TAC was also analyzed by spectrophotometric method (AOAC, 1990) and expressed in milligrams of ascorbic acid content per 100 gram of fruit (mg/100 g FW).

Antioxidant Capacity

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay was performed according to the method suggested by Bakhshi and Arakawa (2006). The absorbance values of the samples and standards were measured at 515 nm. The formula, "DPPH% = $(A_{control}-A_{sample})/A_{control}x100$", was used to determine the antioxidant potential of the samples. According to the method reported by Re et al. (1999), the 2,2′-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assay for free radical scavenging activity was performed. The absorbance values were measured at 734 nm. The formula, "ABTS% = $(A_{control}-A_{sample})/A_{control}x100$", was used to determine the antioxidant potential. The Ferric Reducing Antioxidant Power (FRAP) was determined using the method of Benzie and Strain (1996) and absorbance was taken at 593 nm. A standard curve was made using $FeSO_4$ solution and the results were expressed in micromoles of Fe (II) per gram (µmol Fe (II)/g).

Sugar Content

Glucose, fructose, and sucrose in plum samples were analyzed according to the procedure described by Miron and Schaffer (1991) using HPLC (HP 1100 series) on a Shim-Pack HRC NH2 column (300 × 7.8 mm, 5 m) with RID (Refractive Index Detector). The sample (1 g) was powdered using

liquid nitrogen in a mortar and transferred to a microcentrifuge tube added with 20 mL of ethanol (80%, v/v). The mixture was placed in an ultrasonic bath, sonicated for 15 min at 80°C and filtered. The filtered extract was evaporated until completely dried. The residue was then dissolved in dimethyl sulfoxide (12.5 mg/mL), filtered, and 20 µL was injected in the HPLC column. The sugar content (mg/g) of the samples was calculated from the calibration curves drawn using standards of fructose, glucose, and sucrose.

Fatty Acid Composition

Fatty acids were extracted according to Santos et al. (2013) and analyzed with the help of GC-MS system, using a Clarus 500 gas chromatograph equipped with an autosampler (PerkinElmer, Shelton, CT, USA), a flame ionization detector and a fused-silica capillary SGE column (30 m × 0.32 mm, ID 0.25 µm, BP20 0.25 UM; PerkinElmer, Austin, TX, USA). The oven temperature was maintained at 140°C for 5 min, which was raised to 200°C at a rate of 4°C min^{-1} and then to 220°C at a rate of 1°C min^{-1}. The injector and detector were set at 220°C and 280°C, respectively. A sample volume of 2 µL was injected and the carrier gas was controlled at 16 psi. The split ratio was 1:100. Fatty acids were detected by comparing the retention indices of the FAMEs with a standard 37-component FAME mixture (Supelco, Bellefonte, PA, USA). The results were expressed as the mean GC area (%) value.

Determination of Individual Phenolic Compounds

The phenolic compounds were determined via HPLC following the protocol of Nour et al. (2013). The sample volume of 20 µL was injected in the HPLC column. The mobile phase of pump A consisted of 10% methanol, 89% distilled water, and 1% acetic acid solution. In pump B, the mobile phase included 99% methanol and 1% acetic acid solution. The HPLC system consisted of an Ecom pump (Prague, Czech Republic), Rheodyne injector valve (20 µL), Hewlett-Packard UV variable powerful detector (1100 model; HP), and an SGX C18 (5 µL) column (4.6 mm × 250 mm). The column temperature was programmed at 25°C and the analysis time was fixed for 30 min. The wavelengths for the detection of chlorogenic acid, coumaric acid, naringenin, and naringin were used as 285 nm; ellagic acid, rutin hydrate, and myricetin at 257 nm; kaempferol and quercetin at 370 nm. Compounds were identified by comparing their retention time values with those of the standards. The phenolic content was expressed in milligrams per liter (mg/L).

Antibacterial Activity Assay

The antibacterial activities of the plum extracts were determined by the agar well diffusion method as described by Collins et al. (1989). *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 8739, *Bacillus cereus* ATCC 11778, *Streptococcus agalactiae* ATCC 13813, and *Enterobacter aerogenes* ATCC 13048 were used as the experimental bacteria. Agar wells were prepared using a sterilized cork borer of 11 mm diameter, and 150 µL of each extract was added to the wells. Erythromycin was used as a positive control. The inhibition zones were measured via a digital caliper and all the tests were performed in triplicate.

Antimutagenic Activity Tests

Salmonella typhimurium strains TA 98 and TA 100 were used for the assessment of antimutagenic activity. The antimutagenic activities of the aqueous fruit extracts were determined by the Ames test (Maron and Ames, 1983). In the test, 10 µg/plate of 4-nitro-*O*-phenylenediamine (4-NPD; Product Number: 1088898–5 G, Sigma Aldrich, St. Louis, MO, USA) was used as a positive control for TA 98 strain. For TA 100, 100 µg/plate of sodium azide (SA; Cat. No. S 2002, Sigma Aldrich) was used as a positive control. In addition, 2-aminofluorene (2-AF) (cat. no A–9031; Sigma) was used as a positive

mutagen (20 µg/Petri) in the presence of S9 mix on both TA 98 and TA 100 test strains. The plates were incubated at 37°C for 48–72 h.

Statistical Analysis

All the tests were performed in triplicate. All the experiments were set up in a completely randomized block design. The results of this study were analyzed by the SPSS statistical analysis package program (version 20). All statistical data were subjected to the analysis of variance (ANOVA). Means were compared by Duncan's multiple range test (DMRT) (Duncan, 1955) at $p \leq 0.05$.

The data of the antimutagenic activity tests showed normal distribution according to the Shapiro-Wilk test. Other data were analyzed by one-way ANOVA, followed by Dunnett's test considering $p \leq 0.05$ as statistically significant.

Results and Discussion

Phenolics and flavonoids in plants are the major bioactive compounds, which are a significant source of antioxidants (Zhang et al., 2016). The consumption of phenolics and flavonoids provides significant health benefits because these compounds possess antioxidant, anti-inflammatory, anti-viral, and anticarcinogenic properties (Catel-Ferreira et al., 2015; Zhang and Tsao, 2016). The results of TAC, TPC, TFC, and antioxidant activities of plum extracts are presented in Table 1. The highest TAC and TFC values were detected in Red plum genotype (454 mg/100 g and 29.1 mg/100 g FW). These observations indicated that red-flesh plum genotypes had higher contents of TAC and TFC compared with other cultivars. TPC was found non-significant ($p \leq 0.05$) among the Red plum, White Cancur, and Sugar plums. TAC, TPC, and TFC in plum fruits have been reported previously by different researchers. Abacı et al. (2014) recorded that TPC and TAC values in Cancur plum as 278.2 mg/100 g and 25.7 mg/100 g. Gil et al. (2002) reported that TAC in plums was in the range of 3–10 mg/100 g FW, which was remarkably much lower than the outcome found in the present work. On the other hand, Rupasinghe et al. (2006) observed TPC and TAC within the range of 86–413 mg/100 g and 105–424 mg/100 g FW, respectively, in 20 European plum genotypes. Kim et al. (2003a) reported TPC (174–375 mg/100 g FW) in six plum cultivars. Chun and Kim (2004) also recorded the average TPC in 13 plum genotypes as 370 mg/100 g FW. Parallel to our results, several other studies reported the TPC and TFC in plum genotypes ranging from 5.8–10.5 and 144–563 mg/100 g FW, respectively (Karakaya et al., 2001; Cevallos- Casals et al., 2006; Rop et al., 2009; Arion et al., 2014; Kaulmann et al., 2014; Mehta et al., 2014).

When fruits are regularly consumed in daily life, the risk of chronic diseases is dramatically reduced. The antioxidant constituents of fruits consumed in daily life play an important role in the maintenance of health and prevention of diseases (Pérez-Jiménez and Saura-Calixto, 2015). The plum extracts have scavenger activity against free radicals (Murcia et al., 2001). The antioxidant activity was evaluated via three methods: ABTS, FRAP, and DPPH (Table 1). The data indicated that FRAP (563.8 µmol/g) and ABTS (50.9%) were maximum in Sugar plum. Significant differences among DPPH values of plum genotypes were not observed. Kaulmann et al. (2014) reported that FRAP in plums varied from 587 to 2919 µmol/100 g. Saraswathi et al. (2020) also recorded the DPPH in *Prunus cerasifera* as 82.11% and ABTS as 88.64%. Yu et al. (2020) revealed that DPPH, ABTS and FRAP in Japanese plum cultivars varied from 92.49 to 96.14%, 55.10 to 99.84% and 4.79 to 13.12 µmol/g, respectively. Brar et al. (2020) determined that DPPH varied from 44.51 to 87.59% in Yellow European Plums. The data of the present study demonstrated that the antioxidant property of plum fruits was not influenced by the genotypes.

The phenolic profile of the plum genotypes was detected by HPLC (Table 2). The phenolic content depends upon genotypes, maturity, climate, season, and horticultural practices (Freitas and Glories, 1999). Gallic acid, naringin, resveratrol, and caffeic acid were the predominant phenolic compounds in plum genotypes. A wide range of the phenolic acid content was recorded, such as gallic acid (0.9 to

Table 1. Results of the TAC, TPC, TFC and Antioxidant Activity.

	Total Ascorbic Acid Content (mg/100 g)	Total phenolik Content (mg/100 g)	Total Flavanoid Content (mg/100 g)	FRAP (µmol Fe II/g)	DPPH (%)	ABTS (%)
Demal	421.5 ± 28.8b	169.6 ± 9.8b	12.1 ± 1.5d	532.3 ± 22.8c	63.6 ± 0.3a	50.3 ± 0.3a
White Cancur	424.8 ± 31.5b	171.6 ± 10.2a	14.9 ± 0.8 c	501.7 ± 10d	64.3 ± 0.9a	48.9 ± 1.1b
Cancur	389.8 ± 12.3c	168.8 ± 9.3b	20.5 ± 1.6b	532.1 ± 10.4c	64.1 ± 0a	50.3 ± 0.3a
Red plum	454 ± 10.9a	171.8 ± 4.1a	29.1 ± 1.6a	544.5 ± 19.2b	64.2 ± 1a	49.9 ± 0.3b
Sugar plum	421.5 ± 31.3b	172.4 ± 10.7a	26.7 ± 0.8ab	563.8 ± 20.1a	64.3 ± 1a	50.9 ± 0a

All values are presented as means ±SD (n = 4). Different letters (a-d) within the columns indicate statistically significant differences by Duncan's multiple range test at $p < 0.05$.

Table 2. Phenolic profile of of plum fruits.

(mg/L)	Demal	White Cancur	Cancur	Red plum	Sugar plum
Gallic acid	21 ± 1a	1.8 ± 0.2b	2.4 ± 0.05b	0.9 ± 0.06d	1.48 ± 0.2b
Vanilic acid	11 ± 0.9a	6.1 ± 0.3b	5.3 ± 0.05 c	6.1 ± 0.08b	6.2 ± 0.06b
Caffeic acid	8.4 ± 0.9a	7.4 ± 0.02 c	7.3 ± 0.5 c	4.8 ± 0.05d	10.8 ± 0.4b
p-coumaric acid	13.1 ± 4a	5.3 ± 0.01 cd	6.1 ± 0.08b	1.3 ± 0.09d	4.7 ± 0.6c
Trans-ferulic acid + sinaptic acid	7 ± 0.2a	4.1 ± 0.02b	2.8 ± 0.01 c	2.4 ± 0.02 c	2.1 ± 0.2 c
Naringin	13.8 ± 1a	8.1 ± 0.09 c	9.8 ± 0.06b	9.3 ± 0.05b	12.2 ± 0.1a
Rutin trihydrate	6.6 ± 1a	2.2 ± 0.09 c	3.8 ± 0.02b	2.1 ± 0.01 c	1.9 ± 0.2 c
Resveratrol	14.11 ± 3b	3.7 ± 0.09 c	4.2 ± 0.06 c	73.1 ± 0.6a	3.3 ± 0.3c
Ellagic acid	11.7 ± 1.5a	0.9 ± 0. 01e	5.9 ± 0.1c	7.5 ± 0.06b	2.7 ± 0.2d
Trans-cinnamic acid	4.1 ± 0.3a	1.3 ± 0.01 c	1.3 ± 0.28 c	2.9 ± 0.01b	2.9 ± 0.5b
Quercetin	4.7 ± 0.1a	2 ± 0.03 c	3.1 ± 0.04b	3.3 ± 0.03b	2.2 ± 0.1 c

Different letters (a-d) within the lines indicate statistically significant differences by Duncan's multiple range test at $p < 0.05$.

21 mg/L), vanillic acid (5.3–11 mg/L), caffeic acid (4.8–10.8 mg/L), *p*-coumaric acid (1.3–13.1 mg/L), trans-ferulic acid+synaptic acid (2.1–7 mg/L), naringin (8.1–13.8 mg/L), rutin trihydrate (1.9–6.6 mg/L), resveratrol (3.3–73.1 mg/L), ellagic acid (0.9–11.7 mg/L), trans-cinnamic acid (1.3–4.1 mg/L), and quercetin (2–4.7 mg/L). All these compounds have been substantiated by many researchers (Donovan et al., 1998; Kaulmann et al., 2014; Kim et al., 2003b; Lombardi-Boccia et al., 2004; Tomas-Barberan et al., 2001; Wang et al., 2018). Yu et al. (2020) revealed that the catechinic acid and vanilic acid was the most abundant phenolic compounds in Japanese plum genotypes. Unlike other studies, ellagic acid in plum genotypes was also identified in this study. The resveratrol in Red plum was significantly higher than other genotypes. Sebastia et al. (2012) reported that resveratrol in the peel of Japanese plum ranged between 0.1 and 6.2 µg/g.

The concentration of sugar has a critical impact on fruit flavor and quality (Borsani et al., 2009). The sugar profiles vary with the genotypes, which have different qualitative traits (Bae et al., 2014). The sugar content of plum genotypes is shown in Table 3. Glucose was identified as the most abundant sugar in Sugar plum, Red plum, and White Cancur fruits, while sucrose content was maximum in Cancur. The content of fructose was superior in Demal fruit. The highest total sugar was found to be 545.15 and 546.08 mg/g in White Cancur and Cancur fruits, respectively. The lowest total sugar content was observed in Red plum (265.68 mg/g) and sucrose was not detected. Kaulmann et al. (2014) reported that the total sugar content in plums varies between 8.5 and 19.6 g/100 g FW. Similarly, glucose, fructose, and sucrose were dominant sugars in 'Friar' plums (Wang et al., 2018).

The fatty acid composition of the plum fruits is represented in Table 4. Significant differences ($p < .05$) were observed among the samples. Twenty-three fatty acids were identified and quantified. The major fatty acid found in the demal fruit was linoleic acid and in Sugar plum was Cis-11-eicosanoic acid, while in other fruits was palmitic acid. Palmitic acid was the most abundant saturated fatty acid (SFA) in all samples. In plant tissues, the most abundant fatty acids available are palmitic, stearic, oleic, and linoleic (Tvrzicka et al., 2011). The highest SFA content was found in Demal

Table 3. The sugar contents of plum fruits.

mg/g	Demal	White Cancur	Cancur	Red plum	Sugar plum
Fructose	138.76 ± 1.1b	163.1 ± 6.2a	134.92 ± 5.6b	111.48 ± 8.4c	148.9 ± 2.4ab
Glucose	91.36 ± 4.6d	194.68 ± 9.1b	103.24 ± 1.3d	154.2 ± 4.9c	283.64 ± 5.6a
Sucrose	70.32 ± 0.7c	187.36 ± 4.1b	307.92 ± 11.9a	nd	31.04 ± 1.1d
Total sugar	300.44 c	545.14a	546.08a	265.68d	463.58b

Different letters (a-d) within the lines indicate statistically significant differences by Duncan's multiple range test at $p < 0.05$.
nd = not detected

Table 4. The fatty acid content of plum fruits.

Fatyy acids (%)		Demal	White Cancur	Cancur	Red plum	Sugar plum
Octaonic acid	C8:0	5.04 ± 0.002a	nd	0.29 ± 0.03 c	0.36 ± 0.02b	0.20 ± 0.04 c
Lauric acid	C12:0	4.10 ± 0.01a	nd	nd	0.35 ± 0.03b	0.08 ± 0.01 c
Myristic acid	C14:0	4.63 ± 0.03a	nd	0.29 ± 0.07 c	0.81 ± 0.02b	0.16 ± 0.04 c
Pentadecanoic acid	C15:0	2.08 ± 0.007b	nd	nd	nd	3.08 ± 0.01a
Palmitic acid	C16:0	13.3 ± 1.4 c	26.4 ± 2.8a	16.36 ± 0.19b	17.4 ± 0.7b	15.9 ± 2.4bc
Heptadecanoic acid	C17:0	3.16 ± 0.008 c	nd	9.35 ± 0.17a	nd	7.17 ± 0.04b
Stearic acid	C18:0	2.32 ± 0.01d	9.85 ± 0.12a	7.43 ± 0.09 c	8.41 ± 1.1b	8.15 ± 1.2b
Heneicosanoic acid	C21:0	2.33 ± 0.02	nd	nd	nd	nd
Behenic acid	C22:0	3.33 ± 0.07a	0.82 ± 0.08b	nd	0.12 ± 0.04 c	0.16 ± 0.04 c
Lignoceric acid	C24:0	nd	0.4 ± 0.09a	0.25 ± 0.02b	0.21 ± 0b	0.23 ± 0.04b
ΣSFA		40.29a	37.47ab	33.97 c	27.66d	35.13b
Palmitoleic acid	C16:1	2.17 ± 0.06b	nd	nd	5.20 ± 0.03a	nd
Cis-9-oleic acid	C18:1 n-9	9.91 ± 0.55a	9.75 ± 0.07a	9.14 ± 0a	9.87 ± 0.59a	nd
Cis-11-eicosanoic acid	C20:1	5.36 ± 0.01d	12.62 ± 0.32b	10.66 ± 0.09 c	9.23 ± 0.43 c	19.45 ± 0.19a
Erucic acid	C22:1 n-9	3.27 ± 0.02b	nd	nd	nd	8.02 ± 0.06a
ΣMUFA		20.71 c	22.37b	19.8 c	24.3b	27.47a
Linolelaidic acid	C18:2 n-6	nd	nd	nd	nd	0.09 ± 0.007
Linoleic acid	C18:2 n-6	16.51 ± 1.01a	14.65 ± 0.02b	13.04 ± 0.03b	12.12 ± 1.01 c	nd
Cis-11,14-eicosadienoic acid	C20:2	0.09 ± 0.009	nd	nd	nd	nd
Cis-13,16-docosadienoic acid	C22:2	nd	nd	5.31 ± 0.04 c	7.15 ± 0.01b	8.14 ± 0.03a
Gamma-linolenic acid	C18:3 n-6	9.82 ± 0.27a	nd	7.36 ± 0.04 c	7.56 ± 0.06 c	8.15 ± 0.02b
13,04+ Linolenic acid	C18:3 n-3	0.94 ± 0.007	nd	nd	nd	nd
Cis-11,14,17-eicotrienoic acid	C20:3 n-3	4.25 ± 0.03e	12.65 ± 0.17a	9.26 ± 0.11d	11.14 ± 0.09b	10.92 ± 0.1 c
Cis-5,8,11,14-eicosatetraenoic acid	C20:4 n-6	0.20 ± 0.07	nd	nd	nd	nd
Cis-5,8,11,14,17-eicosapentaenoic acid	C20:5 n-3	7.19 ± 0.26d	12.86 ± 0.19a	11.26 ± 0.19b	10.07 ± 0.53 c	10.1 ± 0.03 c
ΣPUFA		39 c	40.16 c	46.23b	48.04a	37.4d

Different letters (a-e) within the lines indicate statistically significant differences by Duncan's multiple range test at $p < 0.05$.
nd = not detected

(40.29%), while the highest monounsaturated fatty acid (MUFA) was found in Sugar plum and the highest polyunsaturated fatty acid (PUFA) contents were found in the Red plum (27.47 and 48.04%, respectively). The plum genotypes contained more unsaturated fatty acids than saturated fatty acids. The fatty acid content in plum fruits has not been determined in detail before. Gornas et al. (2017) identified nine fatty acids in plum seeds, out of which the oleic and linoleic acids were predominant and ranged between 22.6 and 45.3%. Velickovic et al. (2016) determined six fatty acids in plum kernels. They were the oleic acid (59.5%), linoleic acid (27.1%), palmitic acid (7.5%), stearic acid (1.5%), palmitoleic acid (1.4%), and arachidic acid (0.1%). Matthaus and Özcan (2009) reported that the main fatty acids of *Prunus* spp. kernel oils were oleic acid (43.9–78.5%), linoleic acid (9.7–37%), and palmitic acid (4.9–7.3%).

The results of the antibacterial property of the plum fruits are presented in Table 5. The highest antibacterial activity was recorded in Red plum extract against *Streptococcus agalactiae* ATCC 13813. All the plum extracts, except cancur plum, exhibited remarkable antibacterial effect against the tested bacteria. Yaqeen et al. (2013) tested the antibacterial activity of *Prunus domestica* ethanol extract as well as the ethyl acetate and chloroform fractions obtained from this extract. They found that the ethyl acetate fraction exhibited the highest antibacterial activity. Saraswathi et al. (2020) also recorded the antibacterial effect of *Prunus cerasifera* extracts showed antibacterial effect against *Staphylococcus aureus, Bacillus subtilis, Proteus vulgaris*, and *Escherichia coli*. In a similar study, the antibacterial activity of *Prunus domestica* fruits was found positive on both Gr (+) and Gr (–) bacteria (El-Beltagi et al., 2019). In another report, the antibacterial effect of dry and fresh plum extracts showed antibacterial effect against *Staphylococcus aureus* and *Escherichia coli* (Belhadj and Marzouki, 2014). Sójka et al. (2015) results haven't shown antimicrobial effects of plum extracts against gram-negative bacteria *E. coli*. When the results of the previous studies were compared with the current study, it was found that the plum extracts possess a considerable antibacterial effect.

Table 5. The antibacterial activity results of plum fruits.

Bacteria	Demal (mm)	White Cancur (mm)	Cancur (mm)	Red plum (mm)	Sugar plum (mm)	Erytromycin (mm)
Staphylococcus aureus ATCC 6538	17.11 ± 0.88	14.15 ± 1.16	-	26.86 ± 0.33	-	24.60 ± 1.23
Escherichia coli ATCC 8739	13.10 ± 0.81	14.67 ± 3.57	-	21.31 ± 1.02	-	10.27 ± 1.16
Bacillus cereus ATCC 11778	23.48 ± 0.92	22.33 ± 0.33	-	29.65 ± 0.97	16.05 ± 0.55	27.01 ± 0.49
Streptococcus agalactiae ATCC 13813	26.01 ± 1.28	25.52 ± 0.77	-	32.24 ± 1.82	21.40 ± 0.47	28.08 ± 1.12
Enterobacter aerogenes ATCC 13048	13.87 ± 1.19	20.62 ± 0.57	-	22.09 ± 1.92	17.12 ± 0.82	9.61 ± 0.30

The antimutagenic activities of the plum fruits are presented in Tables 6 and 7. Antimutagenicity of plums extracts (10, 20, 40, and 80 µL/Plate) was investigated on *S. typhimurium* TA 98 and TA100 strains. In the experiment performed on *S. typhimurium* TA 98 strain in the absence of S9, only Red plum extract at the dosage of 10 µL/plate dose exhibited antimutagenic effect (Table 6). On the other hand, all doses of Demal and Red plum extracts;10 µL/plate and 20 µL/plate doses of Sugar plum; 40 µL/plate and 80 µL/plate doses of White Cancur;

Table 6. Antimutagenicity of plum fruits in *Salmonella typhimurium* TA 98 and TA 100 strains without S9 mix.

	TA 98 strain		TA 100 strain	
	Concentration	Revertant colonies Mean±Sd***	Concentration	Revertant colonies Mean±Sd
Demal	Control	28.00 ± 5.86	Control	145.33 ± 3.93
	Positive control (4-NPD)*	3821.3 ± 25.7	Positive control (SA) **	3360 ± 457
	10 µl/plate	3464 ± 218	10 µl/plate	3160.7 ± 43.6
	20 µl/plate	3547 ± 449	20 µl/plate	4156 ± 104
	40 µl/plate	3330 ± 484	40 µl/plate	3486 ± 818
	80 µl/plate	4543 ± 360	80 µl/plate	3361 ± 251
Red plum	Control	28.00 ± 5.86	Control	145.33 ± 3.93
	Positive control (4-NPD)	3821.3 ± 25.7	Positive control (SA)	3360 ± 457
	10 µl/plate	2617 ± 337a	10 µl/plate	3910 ± 173
	20 µl/plate	3306 ± 243	20 µl/plate	3618 ± 434
	40 µl/plate	3776 ± 298	40 µl/plate	3889 ± 499
	80 µl/plate	3492 ± 319	80 µl/plate	2792 ± 271
Sugar plum	Control	28.00 ± 5.86	Control	145.33 ± 3.93
	Positive control (4-NPD)	3821.3 ± 25.7	Positive control (SA)	3360 ± 457
	10 µl/plate	3655 ± 108	10 µl/plate	3746 ± 232
	20 µl/plate	2849 ± 643	20 µl/plate	4062 ± 400
	40 µl/plate	4070 ± 447	40 µl/plate	4575 ± 363
	80 µl/plate	2804 ± 242	80 µl/plate	5630 ± 450a
White Cancur	Control	28.00 ± 5.86	Control	145.33 ± 3.93
	Positive control (4-NPD)	3821.3 ± 25.7	Positive control (SA)	3360 ± 457
	10 µl/plate	4411 ± 426	10 µl/plate	4029 ± 281
	20 µl/plate	3499 ± 614	20 µl/plate	4518.0 ± 35.4
	40 µl/plate	3741 ± 131	40 µl/plate	3410 ± 458
	80 µl/plate	4422 ± 49.0	80 µl/plate	4700 ± 412
Cancur	Control	28.00 ± 5.86	Control	145.33 ± 3.93
	Positive control (4-NPD)	3821.3 ± 25.7	Positive control (SA)	3360 ± 457
	10 µl/plate	3461 ± 400	10 µl/plate	4162 ± 656
	20 µl/plate	4876 ± 762	20 µl/plate	3882 ± 640
	40 µl/plate	3824 ± 683	40 µl/plate	4165 ± 273
	80 µl/plate	4842 ± 372	80 µl/plate	5044 ± 531

*4-NPD: 4-nitro-o-phenylenediamine; **SA: Sodiumazide; ***Sd: Standard deviation a: significant difference between positive control; a$P \leq 0.05$

Table 7. Antimutagenicity of plum fruits in *Salmonella typhimurium* TA 98 and TA 100 strains with S9 mix.

	TA 98 strain		TA 100 strain	
	Concentration	Revertant colonies Mean±Sd**	Concentration	Revertant colonies Mean±Sd
Demal	Control	126.3 ± 20.1	Control	127.0 ± 16.0
	Positive control (2-AF)*	300.0 ± 26.1	Positive control (2AF)	221.3 ± 14.4
	10 µl/plate	173.7 ± 22.9a	10 µl/plate	245.3 ± 60.9
	20 µl/plate	192.7 ± 12.7a	20 µl/plate	250.3 ± 22.0
	40 µl/plate	160.3 ± 12.2 a	40 µl/plate	204.3 ± 15.5
	80 µl/plate	155.7 ± 19.4a	80 µl/plate	196.3 ± 12.1
Red plum	Control	126.3 ± 20.1	Control	127.0 ± 16.0
	Positive control (2-AF)	300.0 ± 26.1	Positive control (2AF)	221.3 ± 14.4
	10 µl/plate	180.0 ± 10.8 a	10 µl/plate	238.3 ± 35.5
	20 µl/plate	191.3 ± 13.7a	20 µl/plate	187.3 ± 21.2
	40 µl/plate	149.0 ± 22.4a	40 µl/plate	151.0 ± 13.1
	80 µl/plate	148.7 ± 24.6a	80 µl/plate	153.33 ± 5.70
Sugar plum	Control	126.3 ± 20.1	Control	127.0 ± 16.0
	Positive control (2-AF)	300.0 ± 26.1	Positive control (2AF)	221.3 ± 14.4
	10 µl/plate	202.33 ± 3.28 a	10 µl/plate	163.3 ± 17.3
	20 µl/plate	189.7 ± 12.8 a	20 µl/plate	194.33 ± 5.24
	40 µl/plate	226.3 ± 25.6	40 µl/plate	171.7 ± 16.2
	80 µl/plate	214.3 ± 29.2	80 µl/plate	152.7 ± 23.1a
White Cancur	Control	126.3 ± 20.1	Control	127.0 ± 16.0
	Positive control (2-AF)	300.0 ± 26.1	Positive control (2AF)	221.3 ± 14.4
	10 µl/plate	250.7 ± 15.0	10 µl/plate	192.7 ± 50.5
	20 µl/plate	251.7 ± 19.2	20 µl/plate	188.0 ± 33.6
	40 µl/plate	181.667 ± 0.667a	40 µl/plate	167.0 ± 10.8
	80 µl/plate	175.0 ± 11.4a	80 µl/plate	152.3 ± 11.3
Cancur	Control	126.3 ± 20.1	Control	127.0 ± 16.0
	Positive control (2-AF)	300.0 ± 26.1	Positive control (2AF)	221.3 ± 14.4
	10 µl/plate	252.3 ± 30.4	10 µl/plate	213.67 ± 1.86
	20 µl/plate	219.3 ± 25.9	20 µl/plate	193.3 ± 13.7
	40 µl/plate	177.00 ± 5.00a	40 µl/plate	136.67 ± 5.36a
	80 µl/plate	212.3 ± 14.9	80 µl/plate	167.0 ± 10.0a

*2AF: 2-aminoflouren **Sd: Standard deviation; a: significant difference between positive control; a $P \leq 0.05$

40 µL/plate dose of Cancur determined the antimutagenic effect on *S. typhimurium* TA 98 strain in the presence of S9 (Table 7). In the experiment performed on *S. typhimurium* TA 100 strain in the absence of S9, only 80 µL/plate dose of Sugar plum extracts showed antimutagenic effect (Table 6). Whereas the experiment performed on *S. typhimurium* TA 100 strain in the presence of S9, 80 µL/plate dose of Sugar plum; 40 µL/plate and 80 µL/plate doses of Cancur plum showed antimutagenic effect (Table 7). The antimutagenic effect of plums has not been investigated in detail, previously. Ederhander et al. (1994) reported the antimutagenic potential of 28 fruit and 34 vegetable juices (consumed in Germany) on *Salmonella typhimurium* TA98 and TA100. Strong antimutagenic activities were determined in bananas, blackberries, blueberries, sweet and sour cherry, pineapple and watermelon. The moderate antimutagenic activity was determined in kiwi, mango, sweet melon, and plums. While weak antimutagenic activities were found in apple, apricot, pear, peach, and strawberries. Java plum (*Syzygium cumini*) was tested by *E. coli* rifampicin resistance and showed strong antimutagenicity (Saxena et al., 2013). The antimutagenic potential of acetone and 2-propanol extract of plums was reported to be significant (Edenharder et al., 1994). The outcome of this study corroborates the previous reports in regards to the antimutagenic effect of plum extracts.

Conclusion

This study revealed that the bioactive compounds, fatty acids, sugars, antibacterial activity, and antimutagenic activity of plums were highly variable. All the plum fruits used in this study were grown at the same geographic location and climatic conditions, yet the differences in the biosynthesis of compounds depict the genotype dependency. The Red plum genotype contained a high amount of TAC and TFC, while Sugar plum genotype had higher FRAP and ABTS. No significant differences among the DPPH and TPC values of plum genotypes were observed. Gallic acid, naringin, resveratrol, and caffeic acid possessing antimutagenic and antioxidant effects were the predominant phenolic compounds in plums. Especially, the resveratrol content in Red plum fruit was significantly higher than other plums. Sugar content was variable among the plum genotypes. Twenty-three fatty acids were determined. All the plum extracts, except Cancur plum, exhibited antibacterial activity against the tested bacteria. In addition, different doses of plum extracts showed antimutagenic effect. The result suggests that plums could be a good source of bioactive compounds, which may provide health-promoting effects to humans.

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