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A Comparative Study of Three Brassicaceae Vegetables Grown in Canakkale: Determination of Total Phenolic Content and Antioxidant Activity of Pulp and Juice Samples of Radish (*Raphanus sativus* L.), Cabbage (*Brassica oleracea* L. var capitata L) and Cauliflower (*Brassica oleracea L.)*

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Abstract − Brassicaceae that contains well known species from genus Brassica is an important family for crucifers, cabbage etc. The main goal of this study was to investigate the total phenolic contents and antioxidant activities of 25% aqueous ethanol and methanol extracts of selected vegetable pulps such as radish, cabbage, and cauliflower. These analyses were also applied to the freshly prepared juices. For this purpose, studied vegetables which were grown in villages of Canakkale were obtained from district bazaar in Canakkale. Antioxidant activities of selected vegetables have been determined by using DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) free radical, ABTS ((2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) radical scavenging assay and CUPRAC (cupric reducing antioxidant capacity) method. Total phenolic content was determined by using Folin-Ciocalteu reagent. The results show that total phenolic contents in pulp extracts of 25% aqueous ethanol of red cabbage (1071 ± 25.12 mg FAE/100 g) and brussels sprout (594.00 ± 13.93 mg FAE/100 g) have higher than the other used vegetables. The 25% aqueous ethanol extracts of white and red radish pulps showed the greatest IC_{50} value with DPPH assay (50.00 µg/mL). The higher phenolic content in the ethanol and methanol extracts of red cabbage may contribute to its increasing CUPRAC activity (4.73 ± 0.11 and 4.78 ± 0.11 quercetin equivalent of flavonoid concentration). In addition, black radish juice showed the highest inhibition value with ABTS assay (70.83 ± 1.83%). This study which may be important for food and health applications, also emphasizes the importance of the cultivation area and the valuable parts of vegetables.

Keywords − *Antioxidant activity, Brassicaceae, cabbage, cauliflower, radish*

1. Introduction

Natural products that have taken secondary role in drug discovery, contribute to medicine and health. This circumstance allows the evaluation of the biological effects of natural compounds and determination of the synergistic effects of different chemical compounds from the isolated extracts (Ji et al., 2009; Gosslau et al., 2011). In recent years, the effect of consumption of Brassicaceae (cruciferous) includes different genera of cultivated plants have been reported by some of the researchers (Beev, Mangamoori & Gowda 2012; Fernández-León et al., 2014). Cruciferous vegetables provide valuable natural antioxidants (Soengas et al., 2011). The family vegetables have been reported with their contributions to the prevention of several diseases such as various types of cancers, cardiovascular disease, chronic diseases like asthma and Alzheimer's disease (Karadeniz et al., 2005; Li et al., 2018). Especially, radish (*Raphanus sativus* L.),

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Brassicaceae family, its composition possesses highly medicinal and nutritional value (Koley et al., 2017). Antioxidant activity of *R. sativus* sprouts has been reported in order to determine the major phenolic components (Takaya et al., 2003). Polyphenolic content and antioxidant activity of red radish have been examined in several studies (Eugenio et al., 2017). Among *Brassica oleracea* species, various types of cabbages, cauliflower, Brussels sprouts exhibit antioxidant and anticarcinogenic properties (Chu et al., 2002). Some of the effects of cabbage (*Brassica oleracea* L. var. capitata) on diseases have been shown in clinical research (Cheney 1949; Wiczkowski, Szawara-Nowak & Topolska, 2013). The antioxidant properties of cabbage varieties have been shown in previously reported studies (Ciska, Karamaæ & Kosiñska, 2008; Rokayya et al., 2013; Zanfini et al., 2010). Cauliflower belongs to the cruciferous family and antioxidant activity of its valuable extracts has been determined in several studies (Fouad & Rehab, 2013; Koksal & Gulcin, 2008; Mamsour et al., 2015; Podsedek, 2007).

Up to date, various assays have been reported with small modifications in order to evaluate the antioxidant capacities of the plant samples (Pisoschi et al., 2016). Especially, DPPH (2,2'-diphenyl-1-picrylhydrazyl) and TEAC (trolox equivalent antioxidant capacity assay with ABTS radical cation) have been determined as easier and convenient to be used in the applications (Tiveron et al., 2012). Also, CUPRAC (cupric reducing antioxidant capacity) method may provide many benefits to measure all antioxidants (Apak et al., 2007). This is the first study to be reported the examination of phenolic contents and antioxidant activities of aqueous ethanol, methanol extracts of pulps and freshly used vegetable juices of all radish, cabbage and cauliflower varieties that were provided from Canakkale district bazaar. Furthermore, this study indicates that the importance of valuable parts, organs of these vegetables and their relationship on the effect of a grown area like ecological properties. Herein, we have investigated the antioxidant activity and total phenolic contents of valuable parts of Brassicaceae vegetables using Folin-Ciocalteu phenolic content assay, DPPH, TEAC and CUPRAC methods. Our findings were compared with each other to examine the antioxidant capability of the valuable parts of the vegetables. These results may be a new avenue for the studies of food chemistry.

2. Materials and Methods

2.1. Chemicals

All chemicals were purchased from Sigma-Aldrich Chemie (Steinheim, Germany). Analytical grade solvents were obtained from Merck. Perkin Elmer LAMBDA 25 UV-Vis spectrophotometer and IKA RV 10 were used for measuring of absorbances and removing of the solvents, respectively.

2.2. Vegetable Material

Radish (white, red and black) (*Raphanus sativus* L.) were provided from district bazaar in Canakkale. Cabbage (white and red varieties), brussels sprouts (*Brassica oleracea*) and cauliflower (*Brassica oleracea* L. var. botrytis) that were grown in Kumkale and Asagi Okcular villages of Canakkale, were provided from district bazaar in Canakkale. The vegetable materials were washed well and the all varieties were divided into two categories such as juice and pulp by using a blender and then, stored at +4 °C and –18 °C in the fridge, respectively.

2.3. Extraction of Vegetable Material

The solvents including methanol and 25% aqueous ethanol were selected in order to obtain more hydrophilic components from the vegetables. This process was carried out by using Soxhlet extraction method to evaluate total phenolic content and antioxidant capacities of the pulp samples (each of 100 g pure sample) according to our previous study (Cömert Önder, Sarker & Ay, 2013).

2.4. Determination of Total Phenolic Contents

The amount of total phenolics was performed by using Folin-Ciocalteu reagent according to Velioglu's method and the detailed procedure was given in the previous studies (Cömert Önder, Sarker & Ay, 2013; Velioglu et al., 1998). The standard calibration (0.01–0.05 mg/mL) curve was obtained using ferulic acid.

The total phenolic content was expressed as ferulic acid equivalents in milligram per 100 g vegetable extract and per mL juice. The measuring was performed in triplicate.

2.5. Evaluation of Antioxidant Activity

DPPH, TEAC and CUPRAC assays were reported in previous studies (Apak et al., 2007; Cömert Önder, Sarker & Ay, 2013; Kumarasamy et al., 2002; Re et al., 1999). Freshly prepared stock solutions from extracts (10 mg/mL, 1 mg/mL and 2 mg/mL) and their serial dilutions (1 mg/mL, 0.1 mg/mL, 0.01 mg/mL, 0.001 mg/mL, 0.0001 mg/mL) and juices (1 mL) were used for each experiment. Calculations were done as QREFC (quercetin equivalent flavonoid concentration) for CUPRAC and Trolox equivalent for TEAC.

2.6. DPPH Radical Scavenging Activity

Radical scavenging activities of the studied samples against DPPH radical were evaluated spectrophotometrically (Cömert Önder, Sarker & Ay, 2013; Kumarasamy et al., 2002; Takao et al., 1994). Serial dilutions of the samples were treated with the prepared DPPH solution (80 µg/mL), stand at room temperature for 30 min and the absorbances were measured at 517 nm. When the changes in the colours from purple to yellow were observed, antioxidant activity value was obtained in desired yields.

2.7. Trolox Equivalent Antioxidant Capacity (TEAC)

To determine the trolox equivalent antioxidant capacities of the samples, we used well known procedure and detailed information was given in previously reported studies (Cömert Önder, Sarker & Ay, 2013; Re et al., 1999). For this purpose, the volumes (50, 75 and 100 µL) from the determined effective concentrations of the samples were used and solution of prepared ABTS radical cation (1 mL for each sample) was mixed with the small amounts of sample solutions. The absorbances were measured at 734 nm during 6 min.

2.8. Cupric Reducing Antioxidant Capacity (CUPRAC)

The method was applied to the samples according to the previously reported studies (Apak et al., 2007; Cömert Önder, Sarker & Ay, 2013). To determine the cupric ion reducing antioxidant capacity of the samples, copper (II) chloride solution ($1.0x10^{-2}$ M), a neocuproine alcoholic solution ($7.5x10^{-3}$ M), and an ammonium acetate aqueous buffer (pH 7) were used. Freshly prepared plant solutions at active concentrations were treated with prepared solutions at room temperature for 30 min and then, the absorbances were measured at 450 nm.

2.9. Statistical Analysis

Results were expressed as mean ± standard error that was shown in Table 2-4.

3. Results and Discussion

In this study, we examined the three vegetables (Brassicaceae) including radish (white, red, black), cabbage (white, red and brussels sprout) and cauliflower (white part and leaves) that were grown in the villages of Canakkale. However, the most common plant, cauliflower which is a highly modified form of cabbage, was studied in two parts of the plant as white cauliflower and green leaves (Anonyms). The general properties of the vegetables were given in Table 1.

Table 1
The general properties of the vegetables

Vegetables	Family	Latin Name	Varieties	Village(s)/City/Country
Radish	Brassicaceae	*Raphanus sativus* L.	Red,black,white	Canakkale/Turkey
Cabbage	Brassicaceae	*Brassica oleracea* L. var. capitata	White	Kumkale and Asagi Okcular/Canakkale/Turkey
		Brassica oleracea L. var. rubra	Red	
		Brassica oleracea L. var. gemmifera	Brussels sprout	
Cauliflower	Brassicaceae	*Brassica oleracea* variety, botrytis	White	Kumkale/Canakkale/Turkey

3.1. Total Phenolic Content of the Pulps and Juices of Selected Vegetables

The total phenolic contents are shown in Table 2-4. According to our findings, 25% aqueous ethanol extract of red radish has higher value (317.40 ± 7.44 mg/100 g) within other samples and varieties. Among methanol extracts of radish, high amount of phenolic content was observed in black radish extract (182.00 ± 427 mg/100 g) and then, it was followed by white (26.00 ± 0.61) and red (4.33 ± 0.10 mg/100 g) radish extracts, respectively. The total phenolic contents of aqueous ethanol extracts within all radish pulp extracts have been found higher than all methanol extracts' contents. The aqueous ethanol extract of black radish (176 ± 4.13 mg/100 g) has been determined as similar to methanol extract (182.00 ± 4.27 mg/100 g). Although red radish juice has the lowest total phenolic content (0.48 ± 0.10 mg/mL), the values of white and black radish juices were determined as 3.29 ± 0.08 mg/mL and 1 ± 0.02 mg/mL, respectively (Table 2). As a result, 25% aqueous ethanol extract of red radish showed higher value than the other samples.

Table 2
Total phenolic content and antioxidant activities of radish samples

	Radish (*Raphanus sativus* L.)								
	Red			Black			White		
	Aqueous Ethanol	MeOH	Juice	Aqueous Ethanol	MeOH	Juice	Aqueous Ethanol	MeOH	Juice
TPC[a]	317.40 ± 7.44	4.33 ± 0.10	0.48 ± 0.10	176.00 ± 4.13	182.00 ± 4.27	1.00 ± 0.02	53.35 ± 1.15	26.00 ± 0.61	3.29 ± 0.08
DPPH[b]	49.16 ± 1.15	50.90 ± 1.19	55.20 ± 1.19	49.30 ± 1.16	47.66 ± 1.12	53.60 ± 1.26	54.50 ± 1.28	47.66 ± 1.12	58.40 ± 1.37
DPPH[c]	50.00 ± 1.70	70.00 ± 1.64	60.00 ± 1.64	60.00 ± 1.41	60.00 ± 1.41	60.00 ± 1.41	50.00 ± 1.17	60.00 ± 1.41	70.00 ± 1.64
CUPRAC[d]	1.85 ± 0.04	2.76 ± 0.06	1.76 ± 0.06	0.68 ± 0.02	1.27 ± 0.03	2.45 ± 0.06	0.15 ± 0.00	0.59 ± 0.01	2.25 ± 0.05
ABTS[e]	57.14 ± 1.34	49.03 ± 1.15	49.03 ± 1.15	52.25 ± 1.23	23.86 ± 0.56	70.83 ± 1.66	43.27 ± 1.01	23.86 ± 0.56	55.14 ± 1.29
ABTS[f]	0.20 ± 0.00	0.22 ± 0.01	0.22 ± 0.01	0.19 ± 0.00	0.12 ± 0.00	0.30 ± 0.01	0.21 ± 0.00	0.13 ± 0.00	0.26 ± 0.01

[a]Total Phenolic Contents (TPC). Data is expressed as mg of ferulic acid equivalent (FAE)/100 g of extract
[b]Data is expressed as value of percentage of DPPH inhibition (%)
[c]Data is expressed as IC50 value of DPPH (µg/mL)
[d]CUPRAC (QERFC) (Quercetin equivalent of flavonoid concentration).
[e]Data is expressed as value of percentage of ABTS inhibition (%)
[f]Data is expressed as mM of Trolox equivalent per gram of sample.
Results were expressed as mean ± standard error

Some of the researchers determined the content of total phenolics of radish leaves using gallic acid standard antioxidant and the results were given as gallic acid equivalent per gram (91.8 ± 2.9 mg GAE/g). Also, total phenolics contents of methanol and acetone extracts have been determined higher for radish leaves (Eugenio et al., 2017). Total phenolic content of aqueous ethanolic red radish extract was found as higher value (317.40 ± 7.44 mg/100 g) in our study (Table 2). When the total phenolic content value of radish root is comparable with our red radish ethanolic extract's value (317.40 ± 7.44 mg FAE/100 g), the amount of con-

tent shows similarity with each other. According to our findings, total phenolic contents of 25% aqueous ethanol extracts within cabbage samples (white, red and brussels sprout) were measured as 1071.00 ± 25.12 and 594.00 ± 13.93 mg FAE/100 g for red cabbage and brussels sprouts, respectively. However, the total phenolic content in methanol extract of red cabbage was determined as 399.22 ± 9.36 mg FAE/100 g.
Although total phenolic contents of juice samples of white cabbage and brussels sprouts were found similar, red cabbage juice had approximately two-fold total phenolic content (Table 3). Total phenolic content of red cabbage, especially 25% aqueous ethanol extract has been determined as higher ferulic acid equivalent (Table 3). 25% Aqueous ethanol extract of white cauliflower has higher phenolic content (285.60 ± 6.70 mg/100 g), also phenolic content of methanol extract leaves has been found as 291.70 ± 6.84 mg/100 g. This result indicates that the similar phenolic content may be found in each of the extracts for white part and leaves of the cauliflower. Additionally, both of cauliflower juices have been determined as 2.69 ± 0.06 mg/mL and 2.24 ± 0.05 mg/mL. The values are given in Table 4. In three types of Brassicaceae family and all varieties of these vegetables, the higher total phenolic content has been found in 25% aqueous ethanol extract of red cabbage and it is followed by brussels sprouts, white cabbage, red radish, white cauliflower, black radish, cauliflower leaves and white radish extracts. The results are given in Tables 2-4.

Table 3
Total phenolic content and antioxidant activities of radish samples

	Cabbage (*Brassica oleracea* L. var capitata L)								
	White			Red			Brussels sprout		
	Aqueous Ethanol	MeOH	Juice	Aqueous Ethanol	MeOH	Juice	Aqueous Ethanol	MeOH	Juice
TPC[a]	338.29 ± 7.93	178.25 ± 4.18	1.90 ± 0.04	1071.00 ± 25.12	399.22 ± 9.36	3.60 ± 0.08	594.00 ± 13.93	196.12 ± 4.60	1.93 ± 0.05
DPPH[b]	50.00 ± 1.17	57.39 ± 1.35	50.53 ± 1.18	50.56 ± 1.19	50.73 ± 1.19	58.14 ± 1.36	59.78 ± 1.40	53.37 ± 1.25	54.83 ± 1.9
DPPH[c]	155.00 ± 3.63	160.00 ± 3.75	158.00 ± 3.71	63.00 ± 1.41	60.00 ± 1.41	56.00 ± 1.31	76.00 ± 1.78	138.00 ± 3.24	135.00 ± 3.17
CUPRAC[d]	1.89 ± 0.04	0.88 ± 0.02	0.42 ± 0.01	4.73 ± 0.11	4.78 ± 0.11	2.56 ± 0.06	2.35 ± 0.06	1.37 ± 0.03	1.43 ± 0.03
ABTS[e]	57.00± 1.34	68.64 ± 1.61	69.77 ± 1.64	50.48 ± 1.18	64.16 ± 1.50	67.45 ± 1.58	71.22 ± 1.67	65.90 ± 1.55	66.42 ± 1.56
ABTS[f]	0.22 ± 0.01	0.26 ± 0.01	0.28 ± 0.01	0.25 ± 0.01	0.22 ± 0.01	0.25 ± 0.01	0.25 ± 0.01	0.27 ± 0.01	0.25 ± 0.01

[a]Total Phenolic Contents (TPC). Data is expressed as mg of ferulic acid equivalent (FAE)/100 g of extract
[b]Data is expressed as value of percentage of DPPH inhibition (%)
[c]Data is expressed as IC50 value of DPPH (µg/mL)
[d]CUPRAC (QERFC) (Quercetin equivalent of flavonoid concentration).
[e]Data is expressed as value of percentage of ABTS inhibition (%)
[f]Data is expressed as mM of Trolox equivalent per gram of sample.
Results were expressed as mean ± standard error

3.2. Antioxidant Activity of the Pulps and Juices of Selected Vegetables

Radical scavenging capacities of all vegetable samples have been determined by using DPPH and ABTS assays. According to the inhibitory concentration of samples in DPPH assay, 25% aqueous ethanol extracts of red and white radish have higher value as 50.00 µg/mL for each other and it is followed by red cabbage juice (56.00 ± 1.31 µg/mL). All black radish samples, red radish juice, methanol extract of white radish and red cabbage are similar to IC_{50} values (Table 2 and 3). Inhibitory concentrations of these selected vegetables are approximately ranged from 50 to 400 µg/mL. Since these values compared to each other and known antioxidant quercetin as standard, it is seen that quercetin has higher radical scavenging capacity with its IC_{50} value (4.75 µg/mL) (Cömert Önder, Sarker & Ay, 2013). The higher value (422.7 ± 6.9 µg/g) of free radical scavenging capacity has been determined in radish leaves against to other vegetable samples by using DPPH assay according to the previously reported study (Eugenio et al., 2017). However, in our present study, radical scavenging capacities of red, black and white radish varieties have been indicated approximately between 50.0-70.0 µg/mL. There was no positive correlation between leaves, pulp and radish juice samples. The results of determined antioxidant capacity using DPPH indicate that juice of cauliflower leaves and 25% aqueous ethanol extract of brussels sprouts have a low and high percentage of inhibition values, respectively

(Tables 2-4). Various studies have been reported that ethanol and water extracts of cauliflower were used with DPPH, TEAC, FRAP, CUPRAC assays and water extract was used to determine the total phenolic content. Higher antioxidant activity (68.91%) of methanolic extract of fresh cauliflower has been determined in one of the reported studies (Fouad & Rehab, 2013).

In the ABTS assay, the antioxidant capacities have been found ranging from 23.86 ± 0.56% to 71.22 ± 1.67% for all samples. Methanol extracts of black and white radish have been determined with lower antioxidant capacities (23.86%) and black radish juice had higher ABTS inhibition (70.83 ± 1.66%). TEAC values showed that the differences between the radish samples (Table 2). Aqueous ethanol extract (25%) of brussels sprouts exhibited the higher antioxidant capacity (71.22 ± 1.67% ABTS inhibition) and then, it was followed by white cabbage juice (69.77 ± 1.64%), methanol extract of white cabbage (68.64 ± 1.61%), red cabbage juice (67.45 ± 1.58%) in cabbage varieties. In addition, TEAC values were calculated and the results showed that trolox equivalent values of cabbage samples have been found similar with each other (from 0.22 mM/g to 0.28 mM/g) (Table 3). In cauliflower samples, the ABTS results have been determined as better in 25% aqueous ethanol extract of leaves and juice of white cauliflower 31.00 ± 0.73% and 69.26 ± 1.62%, respectively. Whereas, TEAC values have been shown as trolox equivalent in Table 4 (0.20 mM to 0.27 mM).

Table 4
Total phenolic content and antioxidant activities of radish samples

	Cauliflower (*Brassica oleracea*, variety botrytis)					
		White			Leaves	
	Aqueous Ethanol	MeOH	Juice	Aqueous Ethanol	MeOH	Juice
TPC[a]	285.60 ± 6.70	129.60 ± 3.04	2.69 ± 0.06	148.50 ± 3.48	291.70 ± 6.84	2.24 ± 0.05
DPPH[b]	55.06 ± 1.29	55.06 ± 1.29	46.48 ± 1.09	52.46 ± 1.23	54.02 ± 1.27	44.41± 1.04
DPPH[c]	140.00 ± 3.28	300.00 ± 7.04	300.00 ± 7.04	400.00 ± 9.38	350.00 ± 8.21	400.00 ± 9.38
CUPRAC[d]	1.06 ± 0.02	1.17 ± 0.03	0.61 ± 0.01	2.01 ± 0.05	2.66 ± 0.06	0.96 ± 0.02
ABTS[e]	64.69 ± 1.52	63.28 ± 1.48	69.26 ± 1.62	31.00 ± 0.73	54.15 ± 1.27	58.71± 1.38
ABTS[f]	0.23 ± 0.01	0.23 ± 0.01	0.27 ± 0.01	0.20 ± 0.00	0.26 ± 0.01	0.25 ± 0.01

[a]Total Phenolic Contents (TPC). Data is expressed as mg of ferulic acid equivalent (FAE)/100 g of extract
[b]Data is expressed as value of percentage of DPPH inhibition (%)
[c]Data is expressed as IC50 value of DPPH (µg/mL)
[d]CUPRAC (QERFC) (Quercetin equivalent of flavonoid concentration).
[e]Data is expressed as value of percentage of ABTS inhibition (%)
[f]Data is expressed as mM of Trolox equivalent per gram of sample.
Results were expressed as mean ± standard error

ABTS radical scavenging capacities of all samples have been determined with a higher percentage, except methanol extracts of black and white radish (23.86%), 25% aqueous ethanol cauliflower leaves (31.00%) and red radish juice (49.03%). Although all cabbage samples had higher ABTS inhibition values (%). TEAC values showed that similar and low values in all samples in comparison with trolox as 1 mM/g (Table 2-4). According to our CUPRAC assay results, the values were evaluated with the lower and higher values for 25% aqueous ethanol extract of white radish and methanol extract of red cabbage, respectively. Commonly various vegetables in Brazil have been studied by researchers and the results showed that the values of antioxidant activity of ethanol extract of radish have been found as 26.1 ± 0.40 and 61.7 ± 0.21 µmol Trolox/g by using DPPH and ABTS assays. It is seen that there was no correlation between ABTS and DPPH assays in a previously reported study (Tiveron et al., 2012).

The total phenolic contents (1056 ± 106.8 mg/kg and 2166 ± 7.1 mg/kg) and antioxidant activities (29.4 ± 0.4% and 40.8 ± 3.7%) of red radish and red cabbage 70% aqueous methanol extracts have been determined according to the reported study (Ha Park et al., 2016; Karadeniz et al., 2005). When these results compared to our findings, red radish phenolics in aqueous methanol have been found 25-fold higher only methanol extract (4.33 ± 0.10 mg/100 g) (Table 2). Whereas, in our study, 25% aqueous ethanol extract is 3-fold higher (317.40 mg ± 7.44 mg /100 g) and phenolic contents of black radish aqueous ethanol (176.00 ± 4.13 mg/100 g) and methanol (182.00 ± 4.27 mg/100 g) extract values are higher than previously reported results (Table 2). This result indicates that the solvent polarity is one of the most important parameters to isolate the phenolics and evaluate the contents from the plants. In addition, researchers found that red cabbage possesses higher antioxidant activity and total phenolic concentration (Ha Park et al., 2016; Karadeniz et al., 2005).
The higher antioxidant activity has been determined in some of the red and white cabbage species (Sugiastuti, Farida & Sari, 2011). In our present study, antioxidant activities against DPPH of juice, methanol and, 25% aqueous ethanol extracts of red cabbage have been found 56.00 ± 1.31 µg/mL, 60.00 ± 1.41 µg/mL and 63.00 ± 1.41 µg/mL and of white cabbage 155.00 ± 3.63 µg/mL, 160.00 ± 3.75 µg/mL and 158.00 ± 3.71 µg/mL, respectively. When the results are compared to each other, it is seen that raw and steamed red cabbage, juice and its extracts of red cabbage have higher value against boiled red cabbage.

The level of phenolic substances has reported in cabbage varieties and found higher in red cabbage against white cabbage cultivars (Leja, Kamińska & Kołton, 2010). Furthermore, in our study, all white cabbage results have been found similar to raw white cabbage within a previously reported study (Sugiastuti, Farida & Sari, 2011). However, we found higher percentage of antioxidant activity of all red radish samples (ranged from 49.16% to 55.2%) such as black and white samples (ranged from 47.66 to 58.4) and all cabbage samples such as brussels sprout (ranged from 50.00% to 59.78%) in this study (Tables 2, 3). 12 Cruciferous vegetables have been reported for their antioxidant activities and brussels sprout showed higher result with DPPH assay (Li et al., 2018). We mentioned that the radish pulp extracts and juices have higher total phenolic content and antioxidant activity than cabbage, cauliflower pulp, and juice samples in this study (Table 2).

Among studied Brassicaceae family vegetables, the highest IC_{50} value with DPPH has been found in 25% aqueous ethanol extract of white and red radish as 50.00 ± 1.17 and 50.00 ± 1.70 µg/mL, respectively. It is followed by red cabbage methanol extracts, red radish juice, black radish juice and methanol extract (Table 2-4). Although CUPRAC results showed good correlation with total phenolic contents of 25% aqueous ethanol and methanol extracts, red cabbage pulp exhibited higher value.

4. Conclusion

Herein, we discussed the total phenolic contents and antioxidant activities of the extracts for three selected vegetables provided from Canakkale-Turkey district bazaar using common assays to the comparison of the results. Up to now, some of the parts such as roots, seeds, and leaves of these vegetables have been reported within previous studies. Indeed, pulp extracts and freshly prepared juices of the selected vegetables were studied for the first time in this study. The solvent effect was observed among the pulp extracts of the selected vegetables that were obtained by Soxhlet extraction method. Furthermore, when antioxidant capacity measurements were performed by using combination assays such as DPPH, TEAC and CUPRAC, specific analysis of individual antioxidants that may support the evaluation of widely antioxidant status, could be performed. Our antioxidant capacity findings show the differences for all parts of studied vegetables. This is the evidence of having valuable active components in the vegetables and performed assays support the measuring of all antioxidants.

Author Contributions

Ferah CÖMERT ÖNDER and Mehmet AY: Conceived, designed, supervised and coordinated the study, edited the data, wrote and finalized the paper.

Nuriye DOĞRULAR, Ecem GÜNDÜZ and Sedef BARLAK: Performed the experimental studies and obtained the data.

All authors read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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