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EFFECTS OF PREPARATION CONDITIONS ON ANTIOXIDANT POTENTIAL OF SOME HERBAL TEAS

F. G. Akcakaya and L. Y. Aydemir*

Department of Food Engineering, Faculty of Engineering and Natural Sciences, Adana Science and Technology University, Sarıçam Campus, Çatalan Street, 01250, Sarıçam, Adana, Turkey

*Corresponding Author's Email: lyaydemir@adanabtu.edu.tr, levent.aydmr@gmail.com

ABSTRACT

In this study, the effects of extraction temperature (X1; 95-100°C) and time (X2; 5-10min), and storage time (X3;0-12 day in refrigerator) on total phenolic content (TPC), free radical scavenging (FRSA) and iron chelating (ICA) activities of dried cinnamon bark, clove, and hibiscus infusions and decoctions were determined constructing 2-level factorial design. TPC, FRSA, and ICA of infusions and decoctions were significantly changed depending on X2 and X3. Hibiscus infusions and decoctions had the highest TPC and FRSA in all parameters. The highest antioxidant activities were measured for 5-min decoctions. Strong positive Pearson's correlations were determined between TPC and FRSC of extracts ($P \leq 0.01$). After storage, significant changes were determined in TPC, FRSA, and ICA of extracts. Generally sharp decreases were observed in TPC of extracts after storage. Hibiscus infusions and decoctions were the most instable extracts. The highest FRSA stabilities or increments were determined for clove infusions and decoctions. All decoctions had significantly higher FRSA after storage. Strong positive Pearson's correlations were determined between TPC and FRSA stabilities. This study revealed the potential of infusions and decoctions of clove, cinnamon, and hibiscus as natural antioxidant drinks in daily life.

Key words: Antioxidant activity, cinnamon, clove, decoctions, hibiscus, infusion.

INTRODUCTION

Different herbs and spices have been used as refreshment, therapeutical, or disease preventive in many countries (Valdés *et al*., 2015). They are mostly consumed as infusions or oil extracts individually or as blends of different materials (Costa *et al*., 2012; Yildirim *et al*., 2017). The studies showed that these type of plants had many different bioactive properties such as antioxidant, anticarcinogenic, antihypertensive, antidiabetic, acetylcholinesterase inhibitory capacity, anti-inflammatory, antimutagenic, antimicrobial, and also the ability to reduce the risk of chronic diseases involving allergies, insomnia, headaches, anxiety, intestinal disorders, depression and high blood pressure (Barroso *et al*., 2016; Gopal *et al*., 2016; Hayat *et al*., 2015; Khan *et al*., 2016; Kumar *et al*., 2013; Lv *et al*., 2012; Shan *et al*., 2007; Tavares *et al*., 2012; Valdés *et al*., 2015; Yildirim *et al*., 2017). These bioactivity and health-related properties were mostly related to phenolic compounds which were also responsible for their attractive aroma, taste, and colour. Primarily, phenolic compounds found in plants have been drawn attention as strong natural antioxidants due to functional hydroxyl groups capable of neutralizing free radicals (Valdés *et al*., 2015). They show their antioxidant property either donating electron or proton to free radicals or chelating metal ions that act prooxidant (Okmen *et al*., 2009). In the literature, many studies were reported about the high antioxidant activity of cinnamon, clove, and hibiscus extracted by water or other organic solvents such as methanol, ethanol, etc (Chan *et al*., 2015; Dhar *et al*., 2015; El-Maati *et al*., 2016; Ereifej *et al*., 2016; Nikousaleh and Prakash, 2016; Suantawee *et al*., 2014; Tahir *et al*., 2015; Zhen *et al*., 2016). However, for daily use and human consumption water extracts of these plant are preferable. In daily life, people mostly consume these herbs or spices as infusions or decoctions and that behavior provide the opportunity to take daily phenolic compounds with high bioactive properties. Although the methods of preparation may include large similarities, small differences can have significant impact on bioactive properties (Chan *et al*., 2015; Ereifej *et al*., 2016; Khatun *et al*., 2006; Eguchi ey al., 2006; Sentkowska *et al*., 2016). Because phenolic compounds may exist in bounded form to proteins, carbohydrates or other phenolic compounds with non-covalent interactions, they can be easily become free phenolics depending on the extraction temperature and extraction time (Aydemir and Yemenicioglu, 2013; Komes *et al*., 2011). The high temperature may also disrupt the plant cell integrity that isolates the free phenolics from the outer part of the cell so that the free phenolics can be released to extracts. These infusions and decoctions are mostly fresh prepared and consumed regardless of whether they are storable in different conditions. Depending on the conditions, the phenolic compounds may polymerize becoming to insoluble or

may lost their antioxidant activities during storage (Bimpilas *et al*., 2016; Rustioni *et al*., 2012).

Free radicals are being formed continuously as products of oxidative reactions in the living organism or in the food products during processing or storage. Therefore, free radical formation processes should be inhibited or delayed by biological response mechanisms, additives, or supplements. Synthetic products such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), ethoxyquin, propyl gallate are the most extensively used antioxidants in food processing (Lv *et al*., 2012). Due to increased awareness of relation between nutrition and health, and some carcinogenic suspicious of synthetic additives, people have been demanding from industry to use natural additives during food processing (Branen, 1975). Moreover, the widespread adoption of vegetarian diet, some religious restrictions about consuming animal based products, and negative perception pertaining to animal-derived food, the popularity of plant based products have been also increased (Aydemir *et al*., 2014).

The aim of this study was to determine the antioxidant potentials of cinnamon stick, dried clove and hibiscus infusions and decoctions prepared by different conditions and the storage effects in the refrigerator on these properties. Therefore, the possibility of usage of these home-made type plant infusions and decoctions as natural antioxidant sources in daily diet and industrial applications were evaluated with determining the variations in antioxidant activities of these products during storage.

MATERIALS AND METHODS

Materials: The dried cinnamon, clove and hibiscus were purchased from local supermarket in Adana, Turkey. The chemicals were purchased from Sigma Aldrich (Germany).

Preparation of infusions and decoctions from dried plants: The teas were prepared by infusion (at 95°C) or decoction (in boiling water) using 2 g dried plant in 40 ml deionized water for 5 or 10 minutes. Then the extracts were cooled down to the room temperature immediately, filtrated, left for overnight in the refrigerator then stored for 12 days. The measurements were conducted for freshly prepared teas (day 0) and stored teas (day 12) as 3 replications.

Determination of total phenolic content of teas: The total soluble phenolic compounds and other oxidation substrates (TPC) in tea samples were determined by using the method described in Aydemir *et al*. (2014) based on the method of Singleton and Rossi (1965). The results were expressed as µg gallic acid equivalent/g dried plant.

Determination of free radical scavenging activity of teas: The antioxidant activity of tea samples based on free radical scavenging activity (FRSA) were determined by measuring the inhibition of DPPH radical (Kelebek *et al*., 2013). The results were expressed as µmol Trolox/ g dried plant.

Determination of iron chelating activities of teas: The iron chelating activities (ICA) of teas determined by the method described in Aydemir *et al*.(2014). The results were expressed as µmol EDTA/g dried plant.

Statistical Analysis: The main and interaction effects of extraction temperature, extraction time, and storage time on antioxidant potentials of cinnamon, clove, and hibiscus extracts were determined by using 2-level factorial design (Table 1). Statistical models with interaction terms were derived to examine the relative significance of the three independent variables [extraction temperature (X1:95 and 100 °C), extraction time (X2: 5 and 10 min), and storage time (X3: 0 and 12 days)] and their interactions on the responses [total phenolic content (Y1), free radical scavenging activity (Y2), and iron chelating activity (Y3)] (Table 2). Statistical analysis was performed using Minitab 17 software (Minitab, Inc., State College PA, USA). To determine the significant terms for each response analysis of variance (ANOVA-test) where $P<0.05$ was considered statistically significant in the model and Pearson's correlation tests were applied.

RESULTS

Antioxidant potentials of infusions and decoctions: Among extracts, hibiscus infusions and decoctions had significantly higher TPCs varying from 19580±195 to 52779±1575µg gallic acid/g corresponding from 2 to 5 and from 2 to 41-fold higher values than those of clove and cinnamon, respectively (Table 3) ($P<0.05$). Different preparation methods showed different effects on TPC values of individual plants. For example, cinnamon decoction had almost 10-fold higher TPC than cinnamon infusion whereas hibiscus decoction had 50% lower TPC than hibiscus infusion for 5 minutes extractions. For 10 minutes extractions, significant and small differences in TPC were observed between cinnamon and clove infusions and decoctions while hibiscus decoction had 60% lower TPC than hibiscus infusion. Extraction time was another important parameter which significantly affected the TPC of infusions and decoctions ($P<0.05$). As the extraction time was increased from 5 to 10 minutes, cinnamon and clove infusions had doubled TPC values whereas cinnamon decoctions were decreased from 11908±47 to 2883±189 µg gallic acid/g. It can be concluded that as the extraction time was increased, more phenolic compounds were released from plants into the infusions.

Hibiscus infusions and decoctions had the highest FRSA like TPC values and varied from 41.9±2.8 to 73.9±7.7 µmol Trolox/g (Table 4). The other extracts had considerably lower FRSA than those of hibiscus. Strong positive Pearson's correlations were determined between the TPC and FRSC for 5-min infusions (0.958), 10-min infusions (0.969), and 10 min-decoctions (0.932) ($P \leq 0.01$). Among all extracts, the highest antioxidant activities were measured for 5-min decoctions, but significant decreases were observed in decoctions as the extraction time was increased ($P \leq 0.05$). The most severe effects on antioxidant activities were observed for cinnamon (75% lower) and clove (85% lower) decoctions. On the other hand, FRSAs of infusions were considerably increased for increased extraction times except for clove infusions which was decreased to half ($P \leq 0.05$).

Metal chelating ability of antioxidants is another important property due to the potential of some metal ions acting as prooxidant (Table 5). The ICA of extracts were generally low but great variances were observed between the extracts (from 0.11±0.04 to 7.46±0.20 µmol EDTA/g). Unfortunately, the colour interference did not allow the ICA of hibiscus extracts to be determined with the method used in this study. The colour of hibiscus extract significantly affected the colour of formed product in the assay so that unreliable absorbance measurements were made. Among the rest, clove infusions and decoctions had generally higher ICAs than cinnamon infusions and decoctions. Almost none of the significant correlations were observed between ICA and TPC or FRSA of infusions and decoctions. Only one strong positive correlation was determined between ICA and TPC (0.998), and one strong negative correlation was determined between ICA and FRSA (-0.903) for 10-min decoctions ($P \leq 0.01$). Although ICA is important antioxidant property for the compounds, it has different antioxidant mechanism than FRSA. Therefore, the compound with FRSA might not have ICA that's why the significant correlations were not observed between the measured parameters of infusions and decoctions. The infusions or decoctions had generally higher ICAs as the extraction time was increased and decoction process mostly produced extracts with higher ICAs than infusion process by the way.

Antioxidant stability of infusions and decoctions: After 12-day storage of infusions and decoctions significant changes were determined in their TPC. Generally sharp decreases were observed varying from 33% to 85% in TPC only 5-min infusion of cinnamon (25%), 10-min infusion of cinnamon and clove (30% and 40%), and 5-min decoction of clove (70%) had higher TPC values after storage. Although the highest instabilities were determined for hibiscus infusions and decoctions, they still had high and considerable TPC compared to others. Infusion process especially for 10-minute extraction produced plant extracts with higher TPC stabilities than decoction process. Unlikely to TPC stabilities, FRSA stabilities of infusions and decoctions were mostly maintained or significantly increased during the storage however positive and moderate Pearson's correlation (0.631) was obtained between TPC and FRSA of infusions and decoctions ($P<0.01$). The highest FRSA stabilities or increments were determined for clove infusions and decoctions around 2-fold and followed by hibiscus infusions and decoctions from 18% to 33%. For cinnamon, significant decreases or moderately increases were determined in FRSA stabilities of its infusions or decoctions. All decoctions had significantly higher FRSA after storage while infusions had changeable. As the extraction time was increased FRSA stabilities of clove infusions and decoctions were affected positively whereas FRSA stabilities of cinnamon and hibiscus infusions and decoctions were affected negatively. Strong positive Pearson's correlations were determined between the TPC and FRSA stabilities of 5-min infusions (0.996), 10-min infusions (0.874), and 10 min decoctions (0.778) but strong negative Pearson's correlation were obtained for 5-min decoctions (-0.855) ($P<0.05$). During storage ICAs of infusions and decoctions were mostly increased where clove extracts had higher ICAs than cinnamons independently from the extraction conditions. However, the increments in ICAs during storage were quite high (4.5 fold for 5-min clove decoction, 3-fold for 5 min cinnamon or clove infusions) the values were not enough to satisfy the expectations to be called the infusions or decoctions as good iron chelators. In general, it was observed that 5 min extractions produced higher ICA stabilities or increments in infusions or decoctions compared to 10 min extractions. Interestingly, strong negative Pearson's correlations were determined between the ICA and TPC or ICA and FRSA values of infusions (-0.983, -0.995, -0.994, -0.930) obtained after storage whereas these correlations were strongly positive for those of decoctions (0.968, 0.959, 0.987) ($P<0.01$).

Statistical analysis of infusions and decoctions: Analysis of variances (ANOVA) was carried out to verify significant effects of independent variables (extraction temperature: X1, extraction time: X2, storage: X3) on each response variables (TPC, FRSA, ICC) for cinnamon, clove, and hibiscus (Montgomery, 2005). After elimination of insignificant variables ($P<0.05$), the relationship between response variables and the independent variables was evaluated through the linear model following regression equations:

For cinnamon:

$$TPC = -394104 + 4150\,X1 + 38113\,X2 + 14524\,X3 - 399.2\,X1{\times}X2 - 152.9\,X1{\times}X3 - 1207\,X2{\times}X3 + 12.76\,X1{\times}X2{\times}X3$$

FRSA = -1437.9 + 15.114 X1 + 155.3 X2 – 20.72 X3 – 1.617 X1×X2+ 0.2265 X1×X3- 0.1511 X2×X3
ICC = -146.27 + 1.5087 X1 + 23.555 X2 + 2.093 X3 – 0.23987 X1×X2 – 0.01908 X1×X3
For clove:
TPC =11599 - 2356 X1 + 1832 X2 + 588 X3 - 5072 X1×X2 - 2731 X1×X2×X3
FRSA =-306 + 3.62 X1 + 68.2 X2 – 2.59 X3 – 0.736 X1×X2 + 0.710 X2×X3
ICA =-24.1 + 0.205 X1 + 2.21 X2 – 12.20 X3 - 0.0110 X1×X2 + 0.1343 X1×X3 + 1.014 X2×X3 – 0.01149 X1×X2×X3
For hibiscus:
TPC =478564 - 4603 X1 + 17915 X2 - 50232 X3 – 176.4 X1×X2 + 502.4 X1×X3 + 1390 X2×X3 – 15.40 X1×X2×X3
FRSA =1527 – 15.11 X1 – 170.9 X2 + 26.53 X3 + 1.760 X1×X2 – 0.2441 X1×X3 – 0.2567 X2×X3

Table 1. 2- level factorial design generated by Minitab 17.

StdOrder	RunOrder	CenterPt	Blocks	X1 °C	X2 min	X3 day
19	1	1	1	95	10	0
10	2	1	1	100	5	0
20	3	1	1	100	10	0
8	4	1	1	100	10	12
18	5	1	1	100	5	0
12	6	1	1	100	10	0
11	7	1	1	95	10	0
3	8	1	1	95	10	0
17	9	1	1	95	5	0
16	10	1	1	100	10	12
13	11	1	1	95	5	12
24	12	1	1	100	10	12
1	13	1	1	95	5	0
23	14	1	1	95	10	12
7	15	1	1	95	10	12
6	16	1	1	100	5	12
4	17	1	1	100	10	0
15	18	1	1	95	10	12
22	19	1	1	100	5	12
9	20	1	1	95	5	0
14	21	1	1	100	5	12
21	22	1	1	95	5	12
5	23	1	1	95	5	12
2	24	1	1	100	5	0

Table 2. Independent variables and levels.

Independent variable	Symbol	Level	
		-1	+1
Extraction Temperature (°C)	X1	95	100
Extraction time (min)	X2	5	10
Storage time (day)	X3	0	12

Table 3. Total phenolic contents of plant infusions and decoctions (µg gallic acid/g).

Plant	Extraction type	Extraction time (minute)	Storage time (day)	
			0	12
Cinnamon	Infusion (95°C)	5	1136±75.77 i[a]	1421 ± 31.66m
Clove			9314±602.74i	4790 ± 362.08i
Hibiscus			47008±724.70b	12592±390.25e
		Average	14281.2	5033.4
Cinnamon		10	2090±75.15 n	2668±116.96kl
Clove			17391±875.76 e	24327 ± 995.89a

Hibiscus			52779±1575.04 a	13997±1713.15d
		Average	19175.6	14280.2
Cinnamon			11908±471.43 g	6847 ± 1227.76h
Clove		5	9312±274.02 i	15653 ± 207.58c
Hibiscus	Decoction (100°C)		19580±194.5394d	10688±1592.22f
		Average	11234	8745.4
Cinnamon			2883±189.313mn	1942 ± 6.22 lm
Clove		10	8027±340.958j	3980 ± 366.43ij
Hibiscus			20940±708.543g	3062 ± 18.64jkl
		Average	9976	4114.2

[a] Different letters in the columns show significant differences statistically at *P<0.05*.

Table 4. Free radical scavenging activities of plant infusions and decoctions (µmoltrolox/g).

Plant	Extraction type	Extraction time (minute)	Storage time (day)	
			0	12
Cinnamon			6.89±0.83jk[a]	5.7±1.43j
Clove		5	33.93±1.00f	34.7±0.3hi
Hibiscus			41.92±2.80de	52.4±2.0efg
	Infusion (95°C)	Average	36.76	34.07
Cinnamon			13.32±1.61hij	6.4±1.8j
Clove		10	18±1.85gh	76.16±25.57c
Hibiscus			67.77±1.91b	62.02±5.8def
		Average	41.73	64.09
Cinnamon			40.36±1.12ef	56.13±7.50defg
Clove		5	22.89±0.52g	45.54±0.1gh
Hibiscus			73.91±7.72b	98.2 ±3.5b
	Decoction (100°C)	Average	39.43	55.33
Cinnamon			9.69±0.35ijk	13.1 ±3.6j
Clove		10	30.29±0.45k	53.4±2.8efg
Hibiscus			54.86±6.47c	64.6±3.7cde
		Average	21.50	70.11

[a] Different letters in the columns show significant differences statistically at *P<0.05*.

Table 5. Iron chelating activities of plant infusions and decoctions (µmol EDTA/g).

Plant	Extraction type	Extraction time (minute)	Storage time (day)	
			0	12
Cinnamon			0.88±0.25hi[a]	2.56±1.54g
Clove		5	1.17±0.32h	3.23±0.05h
Hibiscus			ND[b]	ND
	Infusion (95°C)	Average	1.34	4.94
Cinnamon			4.75±0.24 b	5.78±2.04c
Clove		10	6.99±0.08a	6.44±1.00g
Hibiscus			ND	ND
		Average	5.13	6.20
Cinnamon			2.61±0.45e	4.49±0.33 g
Clove		5	1.92±0.42g	8.59±0.47b
Hibiscus			ND	ND
	Decoction (100°C)	Average	2.26	5.06
Cinnamon			0.11±0.04j	1.05±0.43i
Clove		10	7.46±0.20a	6.01±0.28de
Hibiscus			ND	ND
		Average	4.00	3.47

[a] Different letters in the columns show significant differences statistically at *P<0.05*.
[b] ND: Not detected. The values can not be detected by the method used in the study due to the colour interferences of the extract with the colour of the formed product

DISCUSSIONS

In the literature, many studies were reported related to the antioxidant potential of herbs and spices and the effects of thermal treatments on these properties. Unfortunately, it was hard to find studies about the antioxidant potentials of cinnamon, clove, and hibiscus infusions and decoctions to compare with our findings. The studies were mostly concentrated on the organic solvent extracts or oil extracts of herbs or spices, or different thermal conditions were applied on their aqueous extracts. However, the plant extracts reported in the literature mostly exhibited similar behaviors with the extracts used in this study. Chan *et al*. (2015) determined the significant TPC lost in clove and cinnamon water extracts obtained by boiling for 1 and 5 minutes where the TPC lost in clove and cinnamon decoctions were 7% and 30% while TPC lost in clove and cinnamon decoctions were 14% and 75% in our study, respectively. It is noteworthy that the decoction time was 5 and 10 minutes in our study indicating more heat was applied to our extracts. They also reported 50% antioxidant activity lost in cinnamon decoction when the extraction time increased from 1 to 5 minutes while 75% of antioxidant activity of cinnamon decoction used in this study was lost when the time was increased from 5 to 10 minutes. For clove decoctions, the antioxidant activity was preserved in their study however 30% increment was determined in our study. Thermal treatments can affect phenolic compounds and antioxidant properties of plants in different ways such as significant decreases or increases, or little or no change (Nicoli *et al*., 1999). The findings related to the increased antioxidant activity of clove extracts were also reported by Nikousaleh and Prakash (2016). They firstly roasted or heated in microwave oven the clove buds and prepared extracts with different organic solvents and determined the significant increments in antioxidant activities of clove extracts along with their total phenols, tannins and flavonoids contents after heat treatments. Khatun *et al*. (2006) also reported that thermal treatments provide improvements in the antioxidant potential of different spices. Antioxidant activity lost were mostly attributed to degradation of phenolic compounds, degradative enzymes, and inactivation of antioxidant enzymes (Chan *et al*., 2015; Lim and Murtijaya, 2007). In contrast, the enhancement of antioxidant activities was attributed to more released phenolic compounds which were previously isolated in cellular matrix or bounded to proteins or carbohydrates noncovalently. It is known that phenolic compounds are found either free or bound to the proteins and carbohydrates in foods through covalent or non-covalent interactions. The phenolic compounds bound to other molecules with non-covalent bonds which are relatively weak bonds such as hydrogen bonds or hydrophobic bonds. Thermal applications might breakdown the cellular matrix so that free phenolics were released to the medium or might disrupt the weak hydrogen and hydrophobic bonds between the phenolic compounds and other molecules so that more free-phenolic compounds were formed (Chan *et al*., 2015; Dewanto *et al*., 2002; Tomaino *et al*., 2005). Moreover, Maillard reaction's products might be formed during heat treatment providing additional antioxidant potential to the extracts (Le Bourvellec and Renard, 2012; Parada and Aguilera, 2007). The similar findings were reported by Khatun *et al*. (2006) who investigated the effect of thermal treatment on clove and determined the increased total phenolic content and antioxidant activity in heated clove samples. Ereifej *et al*. (2016) were also reported the increased extraction temperature provided releasing of more phenolic content from cinnamon and clove to their organic solvent extracts. The thermal treatment conditions affected the total phenolic content and antioxidant potentials of the extracts studied in this study. Decoctions of cinnamon had higher TPC, FRSA and ICC for 5 min extraction while decoctions of clove and hibiscus had lower values. This situation revealed that the same thermal conditions may affect differently the TPC and antioxidant potentials of different extracts due to different phenolic compound profiles of different spices or herbs which were exposed by different influences from the heat. Similar observation was reported by Sentkowska *et al*. (2016) who determined the phenolic profile of infusions and decoctions of chamomile and St. John's wort that were produced by different extraction times. For example, the content of rutin in chamomile infusion was decreased from 4.21 to 3.22 mg/L when the infusion time was increased from 10 to 20 minutes whereas the content of rutin in chamomile decoction was increased from 0.26 to 0.89 mg/L when the decoction time was increased from 10 to 20 minutes. In contrast for infusion of St. John's wort, rutin content quietly decreased from 475 to 86 mg/L for the increased time while it was increased from 266 to 436 mg/L. Similar differences were also determined for antioxidant activities of chamomile and St. John's wort infusions and decoctions. These results were correlated with our general conclusions. The amount of TPC and antioxidant potential of different herb or spice infusions and decoctions were highly dependent on their phenolic compound's structures, characteristics and sensitivities to environmental conditions. The reasons such as high sensitivity (instability) of phenolic compounds to heat or existence of oxidative enzymes such as polyphenol oxidase could be considered for lost in antioxidant activity (Buchner *et al*., 2006; Del Pino-Garcia *et al*., 2017; Ioannou *et al*., 2012; Murakami *et al*., 2004; Narita and Inouye, 2013; Prathapan *et al*., 2009).

During storage, the TPC and antioxidant activities of infusions and decoctions were either increased or decreased. The lost in TPC might be related

to the degradation of phenolic compounds during storage or the polymerization of phenolic compounds resulting to insolubility (Marquez *et al*., 2014; Reed *et al*., 2013; Wilkes *et al*., 2014). On the other hand, in some situation the decrease in TPC and antioxidant potential were observed probably increased liberation of free phenolic compounds and effect of antioxidant enzymes. The similar findings were determined by Santos *et al*. (2014) who studied the nutritional stability of fresh cut aromatic herbs. They reported that during 10-day storage of chives, coriander, spearmint, and parsley, their TPC contents were increased in chives, spearmint, and parsley whereas decreased in coriander. Moreover, depending on the type of plant their vitamin E, C, B1, B2, B3, B5, B6, B9 and Pro-vitamin A content, and antioxidant activities either were increased or decreased.

Conclusions: This study revealed that cinnamon stick, clove, and hibiscus were good sources of natural plant phenolics and antioxidants especially consumed as infusions or decoctions prepared at home in daily diet. Moreover, they can be also adapted for industrial purposes after produced as dried additives without affecting aroma, taste, and colour of the final product. The results and literature review showed that the effect of thermal treatments on the TPC and antioxidant properties of plant extracts are very complex and hardly predictable. The storage conditions were also significant in antioxidant potentials of infusions or decoctions and it was seen that during 12-day storage in the refrigerator the extracts may maintain their antioxidant potentials without significant lost. It is suggested to conduct many repetitive analyses to reach general conclusions. The further studies are also needed to evaluate the potential of these extracts to be used as functional food ingredients or health related natural antioxidant supplement.

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