International Journal of Secondary Metabolite
2022, Vol. 9, No. 2, 238–247

https://doi.org/10.21448/ijsm.1078277

Published at https://dergipark.org.tr/en/pub/ijsm Research Article

The Use of Organic Sun-Dried Fruits for Delivery of Phenolic Compounds

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Abstract: The aim of this study is to characterize and increase the total soluble (water soluble + alcohol soluble) phenolic (SPC_T) and flavonoid content (SFC_T) and total soluble free radical scavenging based antioxidant capacity (SAC_T) of major sun-dried fruits such as raisins, figs, prunes and apricots. Due to their high insoluble dietary fiber content, the bound antioxidant capacity formed 61 to 67% of the overall antioxidant capacity (water soluble + alcohol soluble + bound) of sun-dried fruits. The SPC_T, SFC_T and SAC_T of sun-dried fruits changed between 1675 and 3860 µg catechin/g (d.w.), 161 and 495 µg catechin/g (d.w.) and 13 and 28.5 µmol Trolox/kg (d.w.), respectively. The incorporation of green tea polyphenols into sun-dried raisins, figs and apricots by controlled rehydration conducted in green tea extracts increased their SPC_T, SFC_T and SAC_T 1.5 to 1.8 fold, 1.3 to 1.6 fold, and 1.5 to 2.6 fold, respectively. The method applied caused limited increases in SPC_T (1.1 fold) and SFC_T (1.2 fold) of prunes, but it increased SAC_T of these fruits 1.6 fold. This study showed the possibility of using sun-dried fruits not only as source of dietary fiber, but also for delivery of phenolic compounds. The methods used in this study for delivery of green tea phenolic compounds to selected organic sun-dried fruits could be an alternative method to increase intake of these invaluable antioxidant compounds and increase functionality of sun-dried fruits which are already accepted as good source of dietary fiber.

ARTICLE HISTORY

Received: Feb. 23, 2022

Accepted: May 19, 2022

KEYWORDS

Sun-dried fruits,
Green tea polyphenols,
Phenolic content,
Antioxidant capacity,
Phenolic enrichment

1. INTRODUCTION

The dried fruits have attracted an increasing interest since they are invaluable sources of dietary fiber. There is an increasing consensus among scientists that a fiber-rich diet might have important metabolic effects to reduce cardiovascular diseases, diabetes and cancer (Kendall *et al.*, 2010). The pectin found in most dried fruits is a functional fiber that exists both in soluble and insoluble forms. The viscous fibers like soluble pectin are important since they increase the consistency of intestine contents, slow down digestion, and reduce the amount of glucose and cholesterol diffused from the intestinal lumen (Kendall *et al.*, 2010). On the other hand, the insoluble pectin prevents constipation by hydrating and increasing movement of waste through intestine. The organic sun-dried fruits are particularly attractive source of dietary fiber since

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ISSN-e: 2148-6905 / © IJSM 2022

they are free from pesticides, hormones and other chemical contaminants, and dried without using fossil energy.

In addition to dietary fiber, sun-dried fruits also contain polyphenols which are known with their health benefits and show preventive effects on major diseases. The phenolic compounds owe their health benefits mostly to their antioxidant activity that is mainly originated from their free radical scavenging capacity (Blažeković *et al.*, 2012). The frequent and long term intake of phenolic compounds by consumption of fresh fruits and vegetables helps improving pro-oxidant/antioxidant balance which plays important role in immune system to suppress oxidative stress and its damages on cells. Thus, it is accepted that the phenolic antioxidants provide protection against many major diseases including cardiovascular diseases, cancer, diabetes, neurodegenerative disorders, autoimmune disorders, and aging (Blažeković *et al.*, 2012). Dried fruits including raisins, prunes, figs and apricots are good sources of antioxidant phenolic compounds. A recent study demonstrated that raisins are good dietary source of flavonols and phenolic acids (Karadeniz *et al.*, 2000; Williamson & Carughi, 2010). The dried figs are good sources of phenolic compounds such as proanthocyanidins, flavonols, flavones and phenolic acids (Vallejo *et al.*, 2012) while dried prunes and apricots are rich mainly in phenolic acids (Chang *et al.*, 2016). However, it has been recently reported that the polyphenols in dietary fiber rich fruits might have low bioaccesibility and bioavailabilities (Palafox-Carlos *et al.*, 2011). The polar groups of carbohydrates that form majority of dietary fiber could bind phenolic hydroxyl groups with non-covalent interactions such as hydrogen bonds and van der Waals forces (Barros *et al.*, 2012; Palafox-Carlos *et al.*, 2011; Wu *et al.*, 2009). Thus, it is thought that the binding of the phenolic compounds by dietary fiber could prevent the adsorption of phenolic compounds in stomach and small intestine. The pectin-like polysaccharides that are normally accepted as invaluable dietary fibers reduce bioaccesibility and bioavailability not only for the phenolic compounds, but also for carotenoids by entrapping these antioxidants and reducing their diffusivity and contact with other essential components necessary for their absorption (Palafox-Carlos *et al.*, 2011; Pandey & Rizvi, 2009). The *in-vivo* data about the bioavilability of phenolics from sun-dried fruits are scarce, but recent *in-vitro* studies of Kamiloğlu *et al.* (2014) showed that the bioaccessible phenolic contents of sun-dried apricots, raisins and figs could be only between 8 % and 19 % of total phenolic compounds following gastric digestion. The binding of antioxidant phenolic compounds by food hydrocolloids including dietary fiber is also an important problem limiting bioaccesibility and bioavailability of phenolics in legumes and cereals. It was reported that 25 to 85% of total antioxidant activity might be formed by bound phytochemicals in legumes such as lentils, chickpeas, yellow and green beans, and soybeans (Han & Baik, 2008). Serpen *et al.* (2007) reported that 50% of the total antioxidant activity in cereal based food is formed by bound antioxidants. Thus, the enrichment of fiber rich food by phenolic compounds and increase of their soluble phenolic content and antioxidant activity could be a good strategy to improve their functional properties.

In this work the soluble and bound free radical scavenging based antioxidant capacity of sun-dried fruits such as raisins, figs, apricots and prunes were characterized, and green tea polyphenols were incorporated into sun-dried fruits by controlled rehydration conducted in solutions of green tea extracts. The green tea is one of the most abundant and popular sources of phenolic compounds. Thus, catechins ($C_6C_3C_6$), the major phenolic constituent in green teas, are among the most thoroughly characterized phenolic class in the literature for their molecular structure (Zaveri, 2006), bioavailability and *in-vivo* and *in-vitro* health benefits (Shimizu & Weinstein, 2005; Thielecke & Boschmann, 2009). Recently, dried fruits have been used for delivery of probiotics (Betoret *et al.*, 2003; Rêgo *et al.*, 2013). This study aimed at improving benefits from sun-dried fruits and using them for the first time for delivery of phenolic compounds.

2. MATERIAL and METHODS

2.1. Materials

The sun-dried organic fruits, figs (Cultivar Sarılop), plums (red colored plums), raisins (sultanas) and apricots (non-sulfited apricots), were purchased from Işık Tarım Ürünleri Sanayi ve Ticaret A.Ş in İzmir (Turkey). The organic green tea was provided by the Beta Tea (Turkey). ABTS (2,2'-Azino-bis (3-ethylbenzo-thiazoline-6-sulfonic acid) was purchased from Sigma Chem. Co. (St. Louis, MO, USA). Aluminum chloride phosphate and Folin-Ciocalteu's phenol reagent were purchased from Fluka (Switzerland).

2.2. Preparation of Green Tea Extract

The green tea extract was prepared by mixing 50g of green tea with one hundred milliliters of distilled water at 85 °C for 20 minutes under continuous magnetic stirring. The green tea infusion obtained was then filtered from cheese cloth to remove the debris and clarified by centrifugation at 15000 x g for 15 minutes. Centrifuged extract was lyophilized and stored at -18 °C until it was used in phenolic enrichment studies.

2.3. The Use of Green Tea Extract in Phenolic Enrichment of Sun-Dried Fruits

The incorporation of green tea polyphenols into sun-dried fruits was conducted by 3h rehydration of fruits in 1% (w/w) solutions of green tea extract at room temperature (fruit/extract ratio (w/v): 1/7.5). Controls were rehydrated in distilled water at the same conditions. After rehydration, the free water at the surface of fruits was removed using a filter paper and the fruits were weighted to determine their green tea extract intake. The moisture contents of the fruits were determined by the standard vacuum oven method (AOAC 1996). The final moisture contents of raisins, figs, apricots and prunes rehydrated in green tea extract were 39%, 40%, 44% and 37%, respectively.

2.4. Extraction of Soluble Phenolic Compounds from Dried Fruits

The extraction of water soluble phenolic compounds was conducted by homogenization of 20 g rehydrated fruits with 150 mL distilled water using a blender equipped with a stainless still jar (Waring blender, USA) for 2 min. The obtained slurry was further homogenized with a homogenizer-disperser (IKA, DI 18, Basic, Brasil) at 18000 rpm for 2 min and it was centrifuged at + 4°C for 30 min at 15000 x g. The supernatant (S1) was separated and the collected pellet was once more homogenized with an additional 150 mL distilled water using the homogenizer-dispenser at 18000 rpm for 2 min. The homogenate was then centrifuged at + 4°C for 30 min at 15000 x g. The supernatant (S2) was combined with S1 and the pellet (P1) separated for extraction of alcohol soluble phenolic compounds. The combined extract containing S1 and S2 was named as water soluble extract.

The extraction of alcohol soluble phenolic compounds was conducted by mixing the 2 times water extracted pellet (P1) with 150 mL of ethanol and conducting homogenization with the homogenizer-disperser at 18000 rpm for 2 min. The homogenate was clarified by centrifugation at +4°C for 30 min at 15000 x g for 30 min and the supernatant (S3) containing the hydrophobic (lipophilic) phenolic compounds was named as alcohol soluble extract. The pellet (P3) collected from the centrifugation was separated and used in bound antioxidant activity determination.

2.5. Determination of Total Soluble Phenolic Content

The phenolic content of water and alcohol soluble extracts were determined using the Folin-Ciocalteu method according to Singleton and Rossi (1965). A 0.2 mL sample of appropriately diluted extract was mixed with 1 mL of 1/10 diluted Folin-Ciocalteu reagent. After 3 minutes incubation, 0.8 mL of a 7.5 % Na_2CO_3 solution was added to the mixture. The final mixture was further incubated for 2 hours and its absorbance at 765 nm was measured with a spectrophotometer (Shimadzu, UV-VIS Model 2450, Japan). Total phenolic contents of samples were expressed as milligrams of catechin equivalents per kg dry weight (d.w.). All measurements were conducted five times. The total soluble phenolic content (SPC_T) was determined by finding the sum of phenolic contents of water soluble extract (SPC_W) and alcohol soluble extract (SPC_A) for each fruit.

2.6. Determination of Total Soluble Flavonoid Content

The flavonoid content of water and alcohol soluble extracts were determined using the method described by (Jia *et al.*, 1999). Before analysis 250 µl of extract was diluted with 1 mL of distilled water. Then, 75 µl of 5 % $NaNO_3$ was added onto the diluted sample. The reactants were mixed and incubated for 5 min. Then, 75 µl of 10% $AlCl_3$ was added onto the mixture and it was further incubated for 1 min. At the end of the incubation period, 0.5 mL of 1 M NaOH solution and 0.6 mL distilled water were added onto the final mixture and its absorbance was determined at 510 nm. The total flavonoids content was expressed as milligrams of catechin equivalents per kg d.w. All measurements were conducted five times. The total soluble flavonoid content (SFC_T) was determined by finding the sum of flavonoid contents of water soluble extract (SFC_W) and alcohol soluble extract (SFC_A) for each fruit.

2.7. Determination of Total Soluble Antioxidant Capacity

The free radical scavenging based soluble antioxidant capacities (SAC) of samples were determined using the classical ABTS method given by (Re *et al.*, 1999). The ABTS free radical solution was obtained by treating 7 mM ABTS solution with 2.45 mM potassium persulfate. The ABTS was diluted with 5 mM pH 7.4 phosphate buffer containing 150 mM NaCl (PBS) until its absorbance reached 0.70 spectrophotometric absorbance units at 734 nm. The reaction mixture was prepared by mixing 25, 50 and 75 µl of extract with 2 mL of ABTS solution. The absorbance of each reaction mixture was then monitored and recorded after 1, 3, 6, 9, 12 and 15 min. To calculate the AUC, the percent inhibition/concentration values for the extracts were plotted separately against test periods. All measurements were conducted three times and antioxidant activity was expressed as Trolox equivalents (µmol) per kg dry weight. The total soluble antioxidant capacity (SAC_T) was determined by finding the sum of antioxidant capacities of water soluble extracts (SAC_W) and alcohol soluble extracts (SAC_A).

2.8. Determination of Total Bound Antioxidant Capacity

The total bound antioxidant capacities (BAC_T) of samples were determined according to (Arda Serpen *et al.*, 2007) with some minor modifications. The BAC_T was determined using water and ethanol extracted pellet (P3). The pellet was prepared for measurements following 2 times additional washing with 2 x 40 mL ethanol. Each washing was conducted under continuous magnetic stirring at 500 rpm for 30 min and pellet was collected each time by centrifugation at 15000 x *g* for 10 min. The washed pellet was then lyophilized and used in BAC_T measurements. The tests were conducted by mixing 20 mg lyophilized pellet with 1.9 mL of ABTS solution and incubating this reaction mixture for 12 min at 30°C under continuous shaking at 150 rpm. The absorbance of the reaction mixture was measured at 734 nm after centrifugation of reaction mixture at 6000 x g for 2 min. All measurements were performed five times and antioxidant activity was expressed as Trolox equivalents (mmol) per kg d.w.

2.9. Determination of Overall Antioxidant Capacity

The overall antioxidant capacity (OAC) was determined by finding the sum of SAC_T and BAC_T.

2.10. Statistical Analysis

The statistical analyses were carried out by using ANOVA with analyzing data for the analysis of variance. Values were significantly different at $p<0.05$ as determined by Fisher's protected least significant difference.

3. RESULTS and DISCUSSION

3.1. Phenolic and Flavonoid Contents of Organic Sun-Dried Fruits

The SPC_T and SFC_T of organic sun-dried raisins, figs, prunes and apricots were given in Table 1. The SPC_T and SFC_T of sun dried fruits varied between 1675 and 3860 µg catechin/g (d.w.), and 161 and 495 µg catechin/g (d.w.), respectively. The prunes had the highest SPC_T that was 1.9 to 2.3 fold higher than those of the other fruits. The SPC_T values of figs and apricots were quite similar, and these fruits contained slightly higher (almost 1.2 fold) SPC_T than that of raisins. In all sun-dried fruits, the water soluble phenolic content (SPC_W) formed 92 to 96 % of SPC_T while the remaining minor fraction in the water extracted fruits was formed by alcohol soluble phenolic compounds (SPC_A). The results for SPC_W showed a high parallelism with those of SPC_T. The prunes showed 2.0 to 2.4 fold higher SPC_W than the other fruits. The figs and apricots contained similar SPC_W values while raisins showed almost 1.2 fold lower SPC_W than these fuits. On the other hand, it should be reported that there was no statistically significant difference between SPC_A values of prunes and figs, but these fruits showed 1.3 to 1.4 fold higher SPC_A than raisins and apricots which also showed similar SPC_A values.

Table 1. Total soluble phenolic and flavonoid contents of different organic sun-dried fruits.

Product	Phenolic Content (µg catechin/g d.w.)			Flavonoid Content (µg catechin/g d.w.)		
	SPC_W	SPC_A	SPC_T	SFC_W	SFC_A	SFC_T
Raisin	1555 ±30.5^c	120 ±7.0^b	1675	120±3.74^b	107 ±4.7^b	227
Fig	1790 ±36.0^b	150 ±31.0^{ab}	1940	315±30.0^a	180 ±22.9^a	495
Prune	3690 ±50.0^a	170 ±4.5^a	3860	328 ±11.9^a	64 ±5.3^c	392
Apricot	1895 ±38.5^b	135 ±4.0^b	2030	72 ±2.6^c	89 ±1.5^b	161

$^{a-c}$ Values followed by different letters are significantly different at $p<0.05$.

The figs showed the highest SFC_T that was almost 1.3, 2.2 and 3.1 fold higher than those of prunes, raisins and apricots, respectively. Different from their SPC_W and SPC_A values, the raisins and apricots showed a more balanced distribution of flavonoids in water and alcohol extracts. However, the SFC_W in figs and prunes was 1.8 and 5 fold higher than the SFC_A in these fruits, respectively.

3.2. Antioxidant Capacities of Organic Sun-Dried Fruits

The SAC_T, BAC_T and OAC of sun-dried fruits are given in Table 2. The prunes showed the highest SAC_T that was 1.7, 2.1 and 2.2 fold higher than those of apricots, figs and raisins, respectively. Thus, it is clear that the results of SAC_T showed parallelism with those of SPC_T. However, it is important to note that the SAC_W in different fruits formed 93 to 96% of SAC_T while remaining residual antioxidant capacity was formed by SAC_A. The prunes also had the highest SAC_W that was 1.7 to 2.3 fold higher than those of the other fruits. The apricots showed the second highest SAC_W that was almost 1.2 fold higher than those of figs and raisins. On the other hand, the prunes and apricots showed similar SAC_A values that were 1.3-1.4 fold higher than those of figs and raisins.

The BAC_T of prunes was also 1.6, 1.7 and 2.1 fold higher than those of figs, apricots and raisins, respectively. Thus, the prunes ranked first also in OAC. The apricots and figs showed similar OAC while raisins showed slightly lower OAC than that of these fruits. It is important to note that the BAC_T formed almost 61 to 67 % of OAC in sundried fruits. This result clearly showed that the majority of antioxidant compounds in sun-dried fruits are bound by food hydrocolloids. In the literature different percentages of bound antioxidant capacities were reported for different products. For example, it was reported that in lentils 82-85 % of total antioxidant activity was formed by bound phytochemicals while the percentage of bound antioxidant capacity changes between 25 and 39 % in many other legumes including chickpeas, yellow beans, green beans, and soybeans (Han & Baik, 2008). A. Serpen *et al.* (2007) reported that 50% of the total antioxidant activity in cereal based food is formed by bound antioxidants. Thus, it appeared that the sun-dried fruit hydrocolloids had a considerable phenolic binding capacity and this could be a limiting factor for the phenolic bioavailability.

Table 2. Total soluble, total bound and overall antioxidant capacities of different organic sun-dried fruits (All units in µmol Trolox/g d.w.).

Product	Soluble			Bound	Overall
	SAC_W	SAC_A	SAC_T	BAC_T	OAC
Raisin	12.1 ± 0.5[c]	0.86 ±0.01[b]	13.0	22.8 ±0.40[c]	36.0
Fig	12.6 ±0.16[c]	0.91 ±0.03[b]	13.5	28.3 ±3.35[b]	42.0
Prune	27.3 ±0.69[a]	1.16 ±0.08[a]	28.5	45.7 ±2.44[a]	74.0
Apricot	15.8 ±0.29[b]	1.20 ±0.16[a]	17.0	27.6 ±1.96[b]	45.0

[a-c] Values followed by different letters are significantly different at $p<0.05$.

3.3. Phenolic and Flavonoid Contents of Organic Sun-Dried Fruits Incorporated with Green Tea Polyphenols

The SPC_T and SFC_T of organic sun-dried raisins, figs, prunes and apricots incorporated with green tea polyphenols are given in Table 3. The SPC_T and SFC_T of green tea polyphenol incorporated sun-dried fruits varied between 2820 and 4215 µg catechin/g (d.w.), and 257 and 658 µg catechin/g (d.w.), respectively. The green tea polyphenol incorporated prunes had the highest SPC_T that was almost 1.5 fold higher than the other green tea polyphenol incorporated fruits. It is also important to note that the SPC_T values of green tea polyphenol incorporated sun-dried fruits except prunes were considerably higher than those of the standard fruits. For example, the SPC_T of raisins was 1.8 fold higher than those of standard raisins while green tea polyphenol incorporated figs and apricots showed almost 1.5 fold higher SPC_T than the standard figs and apricots. In contrast, it is interesting to report that the green tea polyphenol incorporated prunes showed only slightly higher (almost 1.1 fold) SPC_T than that of the standard prunes. On the other hand, in green tea polyphenol incorporated sun-dried fruits, the SPC_W formed 84 to 94% of SPC_T while the remaining phenolic fraction was formed by SPC_A. The green tea polyphenol incorporated prunes showed 1.5 fold higher SPC_W than green tea polyphenol incorporated raisins and apricots, and 1.7 fold higher SPC_W than green tea polyphenol incorporated figs. However, it is important to note that the incorporation of green tea polyphenols caused only a very limited increase in the SPC_W of prunes while it caused 1.3, 1.4 and 1.7 fold increases in SPC_W of figs, apricots and raisins, respectively. The green tea polyphenol incorporated figs showed the highest SPC_A that was 1.3, 1.4 and 2.7 fold higher than those of green tea polyphenol incorporated raisins, apricots and prunes, respectively. The analysis of results also showed that the incorporation of green tea polyphenols caused significant increases in SPC_A fraction of raisins (2.8 fold), apricots (2.3 fold) and figs (2.9 fold) compared to standard fruits. In contrast, the SPC_A of prunes remained almost same by incorporation of green tea polyphenols.

Table 3. Total soluble phenolic and flavonoid contents of different organic sun-dried fruits incorporated with green tea phenolics.

Product	Phenolic content (µg catechin/g d.w.)			Flavonoid content (µg catechin/g d.w.)		
	SPC_W	SPC_A	SPC_T	SFC_W	SFC_A	SFC_T
Raisin	2625 ±40.0[a]	330 ±28.0[b]	2955	196 ±6.6[b]	162 ±16.6[b]	357
Fig	2380 ±94.0[b]	440 ±23.5[a]	2820	362 ±62.4[a]	296 ±19.4[a]	658
Prune	3950 ±26.0[b]	165 ±4.0[c]	4215	403 ±15.1[a]	68 ±2.0[d]	471
Apricot	2670 ±72.5[a]	315 ±7.0[b]	2985	149 ±6.1[b]	108 ±6.2[c]	257

[a-d] Values followed by different letters are significantly different at $p<0.05$.

On the other hand, the results of flavonoid analysis showed that the green tea polyphenol incorporated figs had the highest SFC_T that was almost 1.4, 1.8 and 2.6 fold higher than those of green tea polyphenol incorporated prunes, raisins and apricots, respectively. The incorporation of green tea polyphenol into raisins and apricots caused 1.6 and 2.0-fold increase in their SFC_W, respectively. However, there were only slight increases in SFC_W of figs and prunes by incorporation of green tea polyphenols into these fruits. It is also worth noting that the green tea polyphenol incorporation caused 1.5 and 1.6-fold increase in SFC_A of raisins and figs, respectively, but this process caused slight or inconsiderable increases in SFC_A of green tea incorporated prunes and apricots.

3.4. Antioxidant Capacities of Organic Sun-Dried Fruits Incorporated with Green Tea Polyphenols

The SAC_T, BAC_T and OAC of sun-dried fruits incorporated with green tea polyphenols are given in Table 4. The green tea polyphenol incorporated prunes showed the highest SAC_T that was 1.8 fold higher than those of green tea polyphenol incorporated apricots and figs, and 1.4 fold higher than that of green tea polyphenol incorporated raisins. Thus, the results of SAC_T for green tea polyphenol incorporated fruits showed a high parallelism with their SPC_T results. On the other hand, it is important to note that the green tea polyphenol incorporation increased the SAC_T of apricots, prunes, figs and raisins 1.5, 1.6, 1.9 and 2.6 fold, respectively. The increases in SAC_T of apricots, figs and raisins were expected since the green tea polyphenol incorporation into these fruits caused 1.5 to 1.8-fold increase of SPC_T. The maximal increase of SAC_T by incorporation of green tea polyphenols occurred in raisins that also showed a maximal increase in SPC_T by polyphenol enrichment (1.8 fold). This result was not surprising since absorption of green tea extract into raisins during rehydration is easy due to their small size. However, it is important to note that the high soluble antioxidant activity of raisins is also an indication of low amounts hydrocolloids capable to bind incorporated phenolic compounds. In contrast, it was interesting to report a 1.6-fold increase in SAC_T of prunes that showed an inconsiderable increase in its SPC_T value (1.1 fold) by green tea polyphenol incorporation. This result suggested that the incubation of prunes in green tea infusion caused loss of some water soluble intrinsic prune phenolic compounds from fruits to green tea extract by diffusion. However, it also appeared that almost the same amount of green tea phenolic compound diffused from solution to prunes, and these green tea phenolics got higher antioxidant potential than lost prune phenolics. The SAC_W in different green tea polyphenol incorporated fruits formed 83 to 93% of SAC_T while remaining residual antioxidant capacity was formed by SAC_A. The prunes had the highest SAC_W that was 1.4 to 2.1 fold higher than the other fruits. The raisins showed the second highest SAC_W that is 1.4 fold higher than those of figs and apricots that had similar SAC_W values. The increases in SAC_W of fruits by incorporation of green tea phenolic compounds were similar to those of SAC_T and determined as 1.5, 1.6, 1.7 and 2.5 fold for apricots, prunes, figs and raisins, respectively. Thus, it was clear that 1.3 to 1.7-fold increase in SPC_W of apricots, figs and raisins by incorporation of green tea polyphenols resulted with 1.5 to 2.5-fold increase in their SAC_W values. In contrast, the result of SAC_W for the prunes did not show a high parallelism with results of SAC_T for these fruits. Thus, only a 1.1-fold increase in SPC_W by incorporation of green tea polyphenols caused a 1.6-fold increase in SAC_W of prunes. On the other hand, it is also important to report that the incorporation of green tea polyphenols caused significant increases in SAC_A fraction of all fruits. In green tea polyphenol incorporated apricots, figs and raisins 2.3, 2.8 and 2.9 fold increases in SPC_A by incorporation of green tea polyphenols resulted with 3.0, 4.5 and 3.3 fold increases in SAC_A of these fruits, respectively. In contrast, similar to SAC_T and SAC_W results, a 2.2-fold increase in SAC_A of prunes was observed while there was almost no increase in SPC_A of these fruits. This finding supports our hypothesis that the exchange of green tea phenolic compounds and prune phenolic compounds occurred during rehydration of prunes in green tea extract.

Table 4. Total soluble, total bound and overall antioxidant capacities of different organic sun-dried fruits incorporated with green tea phenolic compounds (All units in µmol Trolox/g d.w.).

Product	Soluble			Bound	Overall
	SAC_W	SAC_A	SAC_T	BAC_T	OAC
Raisin	30.4 ±0.45 ^{b}	2.84 ±0.09^{b}	33.2	30.7 ±1.64^{c}	64.0
Fig	21.1 ±0.53^{c}	4.1 ±0.19^{a}	25.2	39.4 ±3.29^{b}	65.0
Prune	43.8 ±1.13^{a}	2.55 ±0.17^{b}	46.4	68.4 ±4.18^{a}	115
Apricot	21.6 ±0.16^{c}	3.64 ±0,18^{a}	25.2	32.98 ±2.28^{bc}	58.0

$^{a\text{-}c}$ Values followed by different letters are significantly different at $p<0.05$.

The results of bound antioxidant activity measurements showed that the green tea polyphenol incorporated prunes showed 1.7, 2.1 and 2.2 fold higher BAC_T than green tea polyphenol incorporated figs, apricots and raisins, respectively. The increases in BAC_T of fruits by incorporation of green tea polyphenols was between 1.4 and 1.5 fold for raisins, figs and prunes while it was only 1.2 fold for the apricots. These results clearly showed that the incorporation of green tea polyphenols caused a considerably higher increase in soluble antioxidant capacity of prunes, raisins and figs than the bound antioxidant capacity of these fruits. In contrast, the incorporation of green tea polyphenols caused almost similar increases in soluble and bound antioxidant capacities of apricots.

The overall antioxidant capacities (OAC) of fruits clearly showed 1.8 to 2.0 fold higher OAC of green tea polyphenol incorporated prunes than the other green tea polyphenol incorporated fruits that showed similar OAC values. It is important to note that in green tea incorporated fruits the BAC_T formed 48 to 61% of OACs. This result clearly indicated the drop of the percentage of BAC_T in OAC due to the greater increases in soluble antioxidant capacity of fruits than bound antioxidant capacity by incorporation of green tea polyphenols (BAC_T formed 61 to 67 % of OAC in standard sun-dried fruits).

4. CONCLUSION

The results of this study clearly showed the possibility of incorporating green tea polyphenols into sun-dried fruits using controlled rehydration conducted in phenolic rich mediums such as green tea extracts. The procedure applied increased both the soluble phenolic content and soluble antioxidant capacity of raisins, apricots and figs considerably. In prunes that are already a good source of phenolic compounds the rehydration in green tea infusion did not cause a considerable increase in soluble phenolic content, but it increased soluble antioxidant capacity. The use of sun-dried fruits for delivery of green tea phenolic compounds could be an alternative method to increase intake of these invaluable antioxidant compounds and increase functionality of sun-dried fruits which are already accepted as good source of dietary fiber. Further studies are continuing to employ different tea infusions, phenolic extracts and solutions of pure phenolic compounds as alternative to green tea infusions.

Acknowledgments

This manuscript was produced from the degree of Master of Science thesis named with "Characterization of Antioxidant Properties for Dried Organic Fruits in Turkish Market and Development of Novel Strategies to Increase Their Potential Health Benefits". In addition, all studies were performed in Biotechnology and Bioengineering of The Graduate School of Engineering and Sciences of İzmir Institute of Technology.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Authorship contribution statement

Gokhan Dervisoglu: Performed the experimental part and statistical analysis. **Ahmet Yemenicioglu**: supervised the experimental work, wrote and edited the manuscript.

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