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Artichoke (*Cynara scolymus* L.) Byproducts as a Potential Source of Health-Promoting Antioxidant Phenolics

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The present study reports a fast, economical, and feasible way to extract antioxidant phenolics from artichoke byproducts: raw artichoke (RA), blanched (thermally treated) artichoke (BA), and artichoke blanching waters (ABW). These byproducts represent a huge amount of discarded material in some industries. Two protocols, with possible industrial applicability, based on both methanol and water extractions were used. Phenolic contents (expressed as caffeic acid derivatives) (grams per 100 g of dry extract) were 15.4 and 9.9 for RA when extracted with methanol and water, respectively; 24.3 and 10.3 for BA when extracted with methanol and water, respectively; and finally, 11.3 g of phenolics/100 mL of ABW. Therefore, methanol extracts yielded more phenolics than water extracts, especially when BA byproducts were used. The higher amount of phenolics in BA could be due to the inactivation of polyphenol oxidase (PPO) at the industrial scale (due to blanching process), avoiding PPO-catalyzed oxidation of these phenolics, a phenomenon that could occur in RA byproducts. Artichoke extracts from industrial byproducts showed a high free radical scavenging activity (versus both DPPH$^{\bullet}$ and ABTS$^{\bullet+}$ radicals) as well as capacity to inhibit lipid peroxidation (ferric thiocyanate method). According to these results, the use of artichoke extracts from industrial byproducts as possible ingredients to functionalize foodstuffs (to decrease lipid peroxidation and to increase health-promoting properties) is suggested.

KEYWORDS: Antioxidant; artichoke; byproduct; *Cynara scolymus*; ABTS; DPPH; ferric thiocyanate; extraction protocol

INTRODUCCTION

The packing houses and food-processing industry dealing with vegetables produce large amounts of wastes and residues (leaves, stems, wastewaters, etc.). Sometimes, these byproducts can reach ∼60% of harvested vegetal as in the case of the industrial manipulation of artichoke. According to FAO estimations, Spain is the second highest artichoke producer in the world (Italy is the first one) with a production of 285000 annual tons (*1*). Within Spain, the region of Murcia is one the first producers, with an annual production of nearly 113000 tons of artichoke, with 66% dedicated to the industrial production (*2*). In fact, the artichoke-based industry yielded ∼45000 tons of byproducts in the region of Murcia in 1997. Other important and typical residues in the canning industry are the blanching waters. These residues are very perishable products that are difficult to manage because of environmental problems in the industries.

Natural antioxidants are in great demand nowadays due to both consumers' preference and health concerns associated with the use of synthetic antioxidants such as BHT and BHA (*3*, *4*). In general, agricultural and industrial residues are interesting sources of natural antioxidants. A number of byproducts have been previously studied as potential sources of antioxidants such as potato peel (*5*−*7*), olive oil waste waters (*8*), grape seeds (*9*−*11*), grape pomace peels (*12*, *13*), and cocoa (*4*). In fact, an interesting approach to give an added value to byproducts is their use as sources of natural antioxidant compounds, mainly phenolic compounds, which, in some cases, have activities comparable to those of synthetic antioxidants (*4*, *13*−*16*).

Artichoke byproducts have been studied with regard to their application for animal feedstuff (*17*) and fiber production (*18*, *19*). However, to our knowledge, the extraction of phenolic compounds as natural antioxidants from artichoke byproducts has not been previously reported.

Different studies about artichoke have demonstrated their health-protective potential, especially their hepatoprotective (*20*, *21*), anticarcinogenic (*22*), and hypocholesterolemic (*23*, *24*) activities. In fact, artichoke is a potential good source of antioxidant activity because it contains large amounts of caffeic acids (*25*, *26*). Caffeic acid derivatives are the main phenolic compounds in artichoke heads, with a wide range of caffeoylquinic acid derivatives (*27*) with chlorogenic acid (5-*O*-caffeoylquinic acid) as the most important of these derivatives (*28*). Other phenolics such as the flavonoids apigenin and luteolin (both glucosides and rutinosides) (*29*) as well as different cyanidin caffeoylglucoside derivatives (*30*) have been identified.

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The aim of this work is to use fast and feasible protocols to obtain phenolic-rich extracts from artichoke byproducts. In addition, the in vitro antioxidant activity of these extracts will be assayed in order to discuss the potential role of artichoke byproducts as a source of health-promoting phenolics associated with their antioxidant activity.

MATERIALS AND METHODS

Reagents. Ammonium thiocyanate, 2,2′-azinobis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS), 2,2′-azobis(2methylpropionamidine) dihydrochloride (AAPH), 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•), chlorogenic acid (5-*O*-caffeoylquinic acid), ferrous chloride, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), linoleic acid, manganese dioxide (MnO_2), and 3-*tert*-butyl-4-hydroxyanisole (BHA) were purchased from Sigma (St. Louis, MO). All other reagents were of analytical grade and supplied by Merck (Darmstadt, Germany). Milli-Q system (Millipore Corp., Bedford, MA) ultrapure water was used throughout this research.

Plant Material. Green tea was obtained from a local supermarket. Ten grams of green tea was placed in 100 mL of boiling water (0.1 g/mL). The solution was filtered after 5 min and used as standard in the ferric thiocyanate method.

Artichoke (*Cynara scolymus* L.) byproduct is the residue from fresh-handling and industrial canning processing of artichoke hearts. These industries produce two types of artichoke byproducts: vegetable stuff composed of outer bracts and stems and also the water used in the blanching process. Artichoke byproducts used in the present study were designated "raw artichoke" (RA), "blanched artichoke" (BA), and "artichoke blanching waters" (ABW).

RA (byproduct mainly composed of bracts, receptacles, and stems) was supplied by Agrosol Cooperative (Lorca, Murcia, Spain). BA byproducts are produced by the industrial canning processing of artichokes and mainly are blanched bracts, receptacles, and stems. ABW is the water used in the industrial thermal processing of artichoke heads. Usually, these waste waters are recycled for 24 h and further stored in special tanks. Both BA and ABW were supplied by Halcon Foods, S.A. (Campos del Río, Murcia, Spain).

Extraction Protocols. *Methanol Extract.* One kilogram of artichoke byproducts (fresh weight) was extracted with boiling methanol for 1 h. The plant material was then hand-squeezed to improve the extraction of methanol-soluble material. Afterward, the resultant extracts were pooled. These extracts were further filtered, and the methanol was removed under reduced pressure at 40 °C. The remaining aqueous extract was freeze-dried at −50 °C and further stored at −20 °C.

Water Extract. One kilogram of artichoke byproducts (fresh weight) was extracted with boiling water in an extraction reactor for 1 h. After extraction, the plant material was squeezed and a second extract was recovered and pooled. The final extract was freeze-dried at −50 °C and further stored at −20 °C.

Artichoke Blanching Waters. ABW is recycled for 24 h in the industry. After this time, ABW is stored in special tanks. A randomly chosen volume of 35 L was obtained from different tanks at the industry. This volume was homogenized, and 1 L was freeze-dried at −50 °C and stored at −20 °C for further assays.

"Extract yield" was defined as the amount of freeze-dried material (extract) (grams) obtained from 100 g (or 100 mL in the case of ABW) of fresh weight of byproducts. "Phenolic yield" was defined as the amount of phenolic compounds (caffeic acid derivatives) (grams) obtained from 100 g (or 100 mL in the case of ABW) of fresh weight of byproducts.

HPLC Analysis. Ten milligrams of each extract was dissolved in 1 mL of methanol/water (80:20 v/v) and filtered through a 0.45 μm membrane filter Millex-HV_{13} (Millipore Corp.). Twenty microliter samples of each extract were analyzed using an HPLC system equipped with a model L-6200 (Merck Hitachi) pump and a Shimadzu SPD-M6A photodiode array UV−vis detector. Separations were achieved on a Licrochart column (Merck) (RP-18, 25 × 0.4 cm; 5 μm paticle size). The mobile phase was water with 5% formic acid (v/v) (solvent A) and HPLC grade methanol (solvent B) at a flow rate of 1 mL min^{-1}. The linear gradient started with 5% B in A to reach 20 B in A at 5 min, 25% B in A at 50 min, 30% B in A at 60 min, and 80% B in A at 62 min. Chromatograms were recorded at 335 nm.

Phenolic Compound Identification and Quantification. The different caffeic acid derivatives were identified by chromatographic comparisons (HPLC) with green coffee bean extracts (*Coffea arabica* L.) containing a complete series of monocaffeoyl quinic and dicaffeoyl quinic derivatives as reported previously (*31*). Their purity was tested by the UV spectra recorded with a diode array detector, and the relative retention times were calculated by comparison with authentic markers of chlorogenic acid (5-*O*-caffeoylquinic acid) and cynarin (1,3-*O*-caffeoylquinic acid). A sample of cynarin was kindly provided by Dr. Marie Jo Amiot (INRA, Montfavet, France). These caffeic acid derivatives were quantified as chlorogenic acid in the HPLC chromatograms recorded at 335 nm, using an external standard. Repeatability of the quantitative analysis was ±4%. Analyses were replicated (n = 3), and the contents are given as mean values ± standard deviation.

Antioxidant Activity. *DPPH• Assay.* Free radical scavenging activity using the free radical DPPH• (*32*) was evaluated by measuring the variation in absorbance at 515 nm after 1 h of reaction in Parafilm-sealed glass cuvettes (to avoid methanol evaporation) at 25 °C (*33*). Artichoke byproduct extracts (10 mg) were dissolved in 1 mL of MeOH/water (80:20 v/v). The reaction was started by adding 20 μL of the corresponding sample to the cuvette containing 80 μM (980 μL) of the free radical (DPPH•). The final volume of the assay was 1 mL. Reaction was followed with a UV-1603 Shimadzu spectrophotometer (Tokyo, Japan). The DPPH• assay was repeated three times. The coefficient of variation was always <5%.

$ABTS^{•+}$ Assay. The $ABTS^{•+}$ radical cation was chemically generated with MnO_2 as described by Espín and Wichers (*34*).

The extracts (10 mg) were dissolved in 1 mL of Milli-Q water. The reaction was started by adding 5 μL of the corresponding sample to the cuvette containing 32 μM (980 μL) of the free radical ($ABTS^{•+}$). The final volume of the assay was 1 mL. The disappearance of $ABTS^{•+}$ was determined by measuring the decrease of absorbance at 414 nm (in the above-described spectrophotometer) for 60 min at 25 °C (*34*). Antiradical activity was expressed as Trolox equivalent antioxidant capacity (TEAC) following the nomenclature of Rice-Evans and Miller (*35*). The coefficient of variation was always <5%.

The "antiradical yield" (AY) correlated the antiradical activity (grams of TEAC) in 100 g of fresh artichoke byproducts by taking into account the "extract yield": AY = (g of TEAC/g of extract) × extract yield (%).

Ferric Thiocyanate Assay (FTC). The FTC method (*36*, *37*) was used with some modifications to determine the in vitro inhibition of lipid oxidation. Reagents were freshly made up before the assay. The assay mixture (2.525 mL) consisted of linoleic acid (2.5%) in ethanol (0.25 mL), 50 mM sodium phosphate buffer, pH 7 (1 mL), ethanol (0.25 mL), Milli-Q water (900 μL), and sample (100 μL) (artichoke extracts and standards BHA, ascorbic acid, Trolox, and green tea) and 1.8 mM AAPH (25 μL) to accelerate the reaction. No bulk oil was assayed because commercial brands contain antioxidants (such as added vitamin E) that could interfere with our determinations. Incubation assay amounts corresponding to 100 μL of sample (final incubation assay of 2.525 mL) were 1 mg of freeze-dried extract of artichoke byproduct, 250 μg of BHA, 22 μg of ascorbic acid, 6.3 μg of Trolox, and 1 mg of green tea extract. Afterward, the mixture was placed in a screw-capped tube, stirred, and incubated in an oven at 50 °C. Aliquots of 30 μL of this mixture were removed every 2 h and added to 2910 μL of ethanol plus 30 μL of ammonium thiocyanate (3.86 M). Afterward, 30 μL of ferrous chloride (20 mM) was added (final volume of the assay was 3 mL). Linoleic acid peroxidation was determined by measuring hydroperoxide accumulation as the increase in absorbance at 500 nm in the above spectrophotometer. Absorbance readings were taken 3 min after the addition of ferrous chloride. Blank of the reaction was performed in the absence of sample, and after 3 min, the autozero was made. Peroxidation inhibition (percent) was expressed as $100 - (A_{sample}/A_{control} \times 100)$ (*37*). The ratio $A_{sample}/A_{control}$ was calculated after 10 h of reaction. One hundred percent oxidation was taken as the maximum absorbance reached by control sample (without antioxidant) after 10 h of reaction. The FTC assay was repeated three times. The coefficient of variation was always <10%.

Table 1. Yield and Phenolic Content of Artichoke Byproducts

	methanol extract	water extract
Raw Artichoke (RA)		
extract yield (freeze-dried extract, g/100 g of fresh weight byproduct	1.94	3.2
phenolic content (g/100 g of freeze-dried extract	15.42 ± 0.42	9.89 ± 0.99
phenolic yield (g/100 g of fresh weight of byproduct	0.30 ± 0.03	0.32 ± 0.03
Blanched Artichoke (BA)		
extract yield (freeze-dried extract, g/100 g of fresh weight byproduct	1.94	3.6
phenolic content (g/100 g of freeze-dried extract	24.28 ± 0.80	10.29 ± 0.12
phenolic yield (g/100 g of fresh weight of byproduct	0.44 ± 0.06	0.36 ± 0.02
Artichoke Blanching Water (ABW)		
extract yield (freeze-dried extract, g/100 mL byproduct	5.84	
phenolic content (g/100 mL freeze-dried extract	11.26 ± 0.36	
phenolic yield (g/100 mL byproduct)	0.66 ± 0.021	

Graphs and Data Analysis. Plots and fittings were carried out by using the Sigma Plot 6.0 program (SPSS Science, Chicago, IL).

RESULTS AND DISCUSSION

Extraction of Phenolic Compounds from Artichoke Byproducts. Water extracts showed higher extract yield than methanolic extracts in both raw artichoke (RA) and blanched artichoke (BA) byproducts (**Table 1**), although phenolic content in methanolic extracts was higher than in water extracts in both RA and BA (**Table 1**). However, taking into account the different extract yield, phenolic content extracted from fresh artichoke byproducts was the same by using water and methanol protocols in RA (**Table 1**). This meant that both water and methanol showed approximately the same efficiencies in extracting phenolic compounds from artichoke byproducts (**Table 1**). Therefore, the same initial amount of fresh weight artichoke byproducts will provide the same amount of phenolic compounds when either extraction protocol is used. However, more freeze-dried extract from water protocol will be needed when RA byproducts are used to provide the same amount of phenolics (**Table 1**). In the case of BA, the methanol protocol proved to be slightly more efficient than the water protocol to extract phenolic compounds (**Table 1**). However, taking into account that methanol is much more expensive than running water for extraction protocols, the use of boiling water could be a fast, economical, and nonpolluting way to extract phenolic compounds from artichoke byproducts.

It is of note that the highest phenolic yield is obtained from BA byproducts extracted with methanol (**Table 1**). A likely explanation for the higher amount of phenolics in BA compared to that in RA could be the oxidation of phenolic compounds in polyphenol oxidase (PPO)-catalyzed reactions. PPO is the main enzyme involved in melanin biosynthesis. Because melanins (brown heterogeneous polymers) affect the sensory properties of foodstuffs, PPO plays an important role in the quality of fruits and vegetables (*38*). In fact, artichoke is a rich source of PPO activity (*39*), and therefore PPO could be responsible for the loss of phenolic compounds in raw artichoke (RA) byproducts in the industry. In the case of BA, the use of boiling water to blanch byproducts could involve PPO inactivation with the subsequent preservation of phenolics.

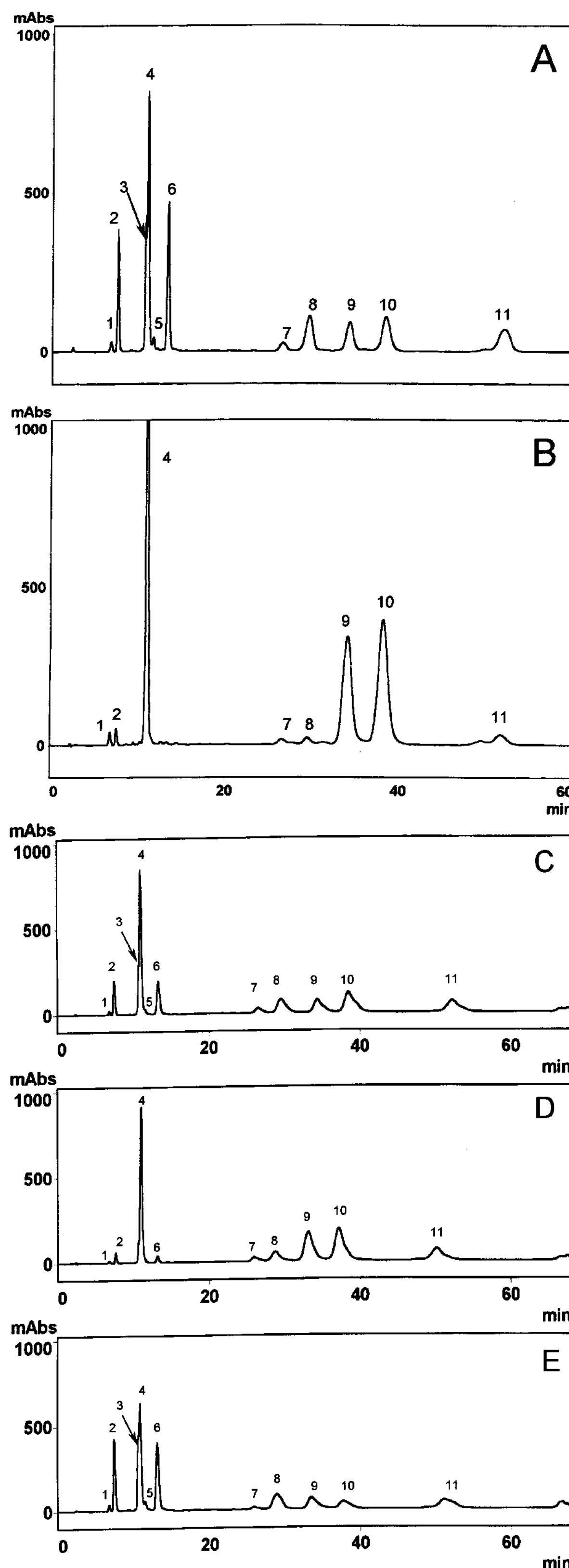

Figure 1. HPLC chromatograms of artichoke byproduct extracts: (A) methanolic extract from RA; (B) water extract from RA; (C) methanolic extract from BA; (D) water extract from BA; (E) ABW extract. Peaks: (1) 1-caffeoylquinic acid (tentatively); (2) neochlorogenic acid; (3) cryptochlorogenic acid; (4) chlorogenic acid; (5) caffeic acid; (6) cynarin; (7 and 8) other caffeic acid derivatives; (9) 1,5- + 3,5-dicaffeoylquinic acids; (10) 1,4- + 4,5-dicaffeoylquinic acids; (11) other caffeoylquinic derivatives. Conditions are detailed under Materials and Methods.

Table 2. Antiradical Activity of Artichoke Byproducts[a]

assay		raw artichoke		blanched artichoke (BA)		artichoke blanching water (ABW)
		methanol extract	water extract	methanol extract	water extract	
DPPH•	antiradical yield (g of TEAC/100 g of byproducts)	0.39	0.55	0.52	0.56	0.95[b]
	g of TEAC/g of freeze-dried extract	0.20	0.17	0.26	0.17	0.16
ABTS•+	antiradical yield (g of TEAC/100 g of byproducts)	0.14	0.25	0.18	0.27	0.40[b]
	g of TEAC/g of freeze-dried extract	0.072	0.078	0.092	0.75	0.069

[a] Coefficients of variation in antiradical assays were always <5%. [b] Antiradical yield as g of TEAC/100 mL of byproduct.

Caffeic acid derivatives present a high similarity in their UV spectra, which makes their proper identification difficult. Nevertheless, most of them have been previously identified in artichoke (*29*, *40*).

Some caffeic acid derivatives can undergo isomerization as previously reported (*40*). Isomerization has been reported in warm aqueous media, which could lead to a variation in the extract composition. **Figure 1** shows the HPLC profile of artichoke byproducts upon extraction with both water and methanol protocols. It is of note that extraction with boiling water causes the appearance of different isomers such as cynarin (1,3-*O*-dicaffeoylquinic acid) (peak 6, **Figure 1A**,**C**−**E**), which comes from the isomerizacion of 1,5-*O*-dicaffeoylquinic acid (peak 9, **Figure 1**) (*41*). Neochlorogenic acid (3-*O*-caffeoylquinic acid) increases (peak 2, **Figure 1A**,**C**,**E**) at the expense of chlorogenic acid (5-*O*-caffeoylquinic acid) depletion (peak 4, **Figure 1A**,**C**,**E**). Cryptochlorogenic acid (4-*O*-caffeoylquinic acid) also increases (peak 3, **Figure 1A**,**C**,**E**) to lesser extent, but its corresponding peak is overlapped with that of chlorogenic acid and it is only clearly visible in water extracts from RA (**Figure 1A**). In addition, the different isomers of isochlorogenic acid (4,5-*O*-dicaffeoylquinic acid) (*40*) decrease (peak 10; **Figure 1**) with concomitant increase of other caffeic acid derivatives (peaks 7 and 8, **Figure 1A**,**C**,**E**; nonelucidated structures). The presence of cynarin in methanolic extracts from BA can be justified because this material suffers in the blanching process. The similar contents of cynarin in both water extracts from RA and ABW should also be noted. In the latter extracts (water extracts), caffeic acid is also detected (peak 5, **Figure 1A**,**C**,**E**).

Therefore, more investigations are required to elucidate the structure of the nonidentified compounds because, for instance, characteristic tricaffeoyl and tetracaffeoyl derivatives have been found in the Asteraceae family (*42*).

Antioxidant Activity of Extracts from Artichoke Byproducts. Three in vitro antioxidant assays were approached as a routine ways to assess the potential antioxidant activity of extracts from artichoke byproducts as well as its correlation with their total phenolics content.

Free Radical Scavenging Capacity. Extracts from artichoke byproducts showed strong scavenging activity against both DPPH• and ABTS•+ radicals (**Table 2**). However, this activity was higher against DPPH• than against ABTS•+ by factors of 2.8 and 2.2 when methanol and water extracts were assayed (from both RA and BA), respectively. This factor showed the intermediate value of 2.4 when ABW was assayed (**Table 2**).

Antiradical activity (TEAC) against DPPH• was linearly correlated with the total phenolics concentration of extracts

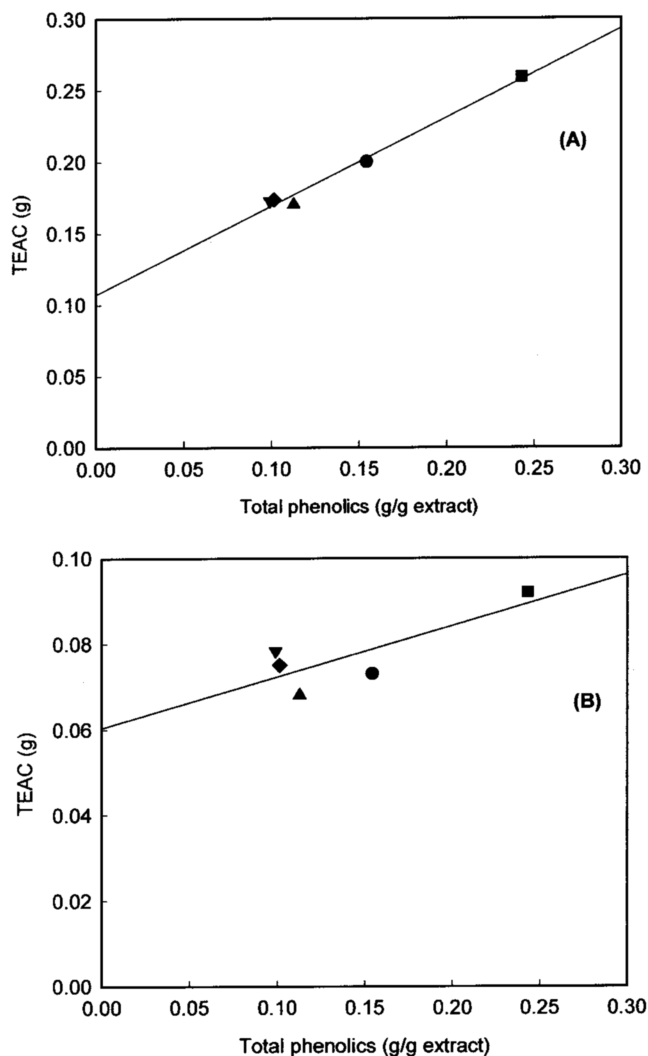

Figure 2. Dependence of antiradical activity (TEAC) on phenolic content of artichoke byproduct extracts: (A) DPPH assay; (B) ABTS•+ assay; (●) RA-MeOH; (▼) RA-water; (■) BA-MeOH; (◆) BA-water; (▲) ABW; (—) linear regression fitting of experimental data. Conditions are detailed under Materials and Methods.

(**Figure 2A**). The highest antiradical activity versus DPPH• was found in methanol extracts from blanched artichoke byproducts (BA) (**Table 2**). This linear dependence was statistically significant ($R = 0.98$; $P = 0.002$). It is of note that the ordinate value (0.11 g of TEAC) can be interpreted as the theoretical scavenging activity against DPPH• present in artichoke byproduct extracts, which is due to other nonphenolic compounds

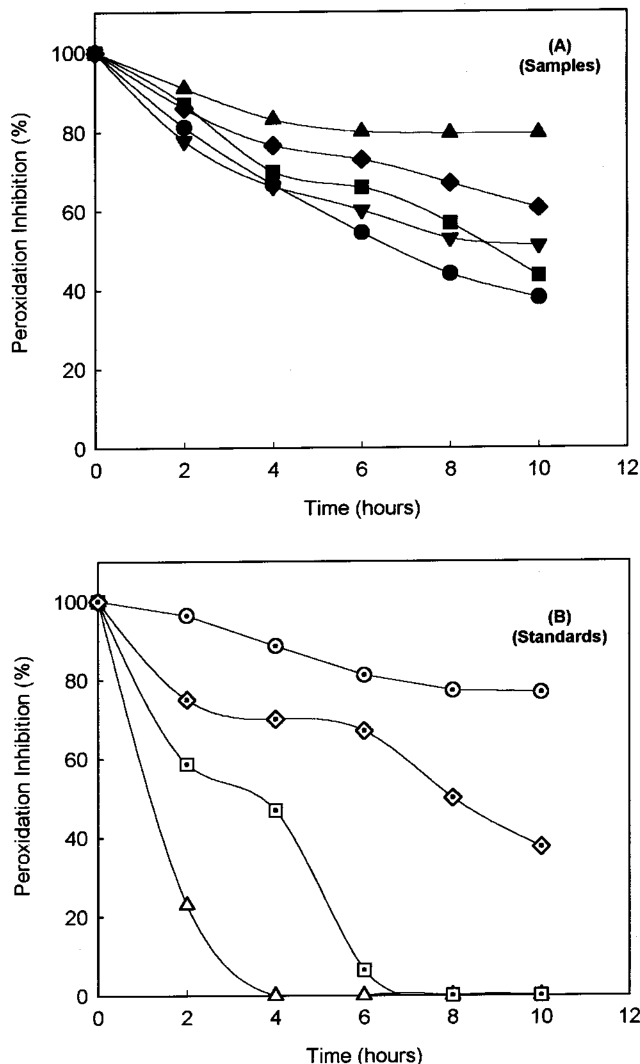

Figure 3. Inhibition of linoleic acid peroxidation (FTC method): (A) artichoke byproducts [(●) RA-MeOH, (▼) RA-water, (■) BA-MeOH, (◆) BA-water, and (▲) ABW]; (B) standards [(⊙) 250 μg of BHA; (dotted diamond) 1 mg of green tea; (⊡) 22 μg of ascorbic acid; (△) 6.3 μg of Trolox]. Conditions are detailed under Materials and Methods. The mean of three separate experiments is shown. Coefficient of variation was always <10%.

(probably fiber) (**Figure 2A**). In fact, the antioxidant capacity of vegetable fiber has been previously reported (*36*, *43*, *44*).

Antiradical activity (TEAC) against $ABTS^{\bullet+}$ did not show statistically significant correlation ($R = 0.78$; $P = 0.18$) versus total phenolics content in artichoke byproduct extracts (**Figure 2B**). In this case, water extracts from both RA and BA (both with the lowest phenolics content) showed relatively high activity. In fact, if TEAC data for water extracts from both RA and BA are omitted (**Figure 2B**), then a high correlation ($R = 0.99$) between TEAC and total phenolics is obtained (data not shown). The relatively high scavenging activity of water extracts could be due to a more favorable action of aqueous soluble compounds (water extracts in aqueous assay), probably water-soluble fiber.

Inhibition of Linoleic Acid Oxidation. Extracts from artichoke byproducts showed a high capacity to inhibit linoleic acid peroxidation when the FTC assay was performed (**Figure 3**). ABW showed the highest activity to inhibit lipid peroxidation under these assay conditions (see Materials and Methods) (**Figure 3A**). The activity of 1 mg of ABW (80% prevention of lipid peroxidation) was equivalent to that of 250 μg of BHA and >2-fold higher than that of 1 mg of green tea extract (**Figure 3B**). The rest of the artichoke byproduct extracts showed different activities for preventing lipid peroxidation that ranged from 40% (RA extracted with water) to 61% (BA extracted with methanol) (**Figure 3A**).

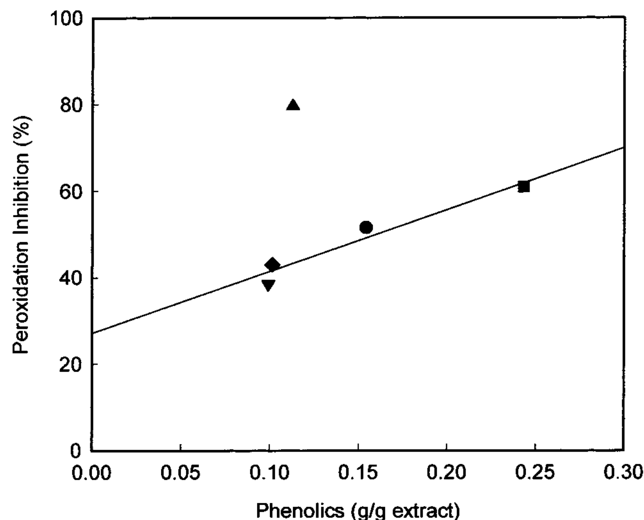

Figure 4. Dependence of peroxidation inhibition (percent) on phenolic content of artichoke byproduct extracts: (●) RA-MeOH; (▼) RA-water; (■) BA-MeOH; (◆) BA-water; (▲) ABW; (—) linear regression fitting of experimental data except that for ABW. Conditions are detailed under Materials and Methods.

Under these assay conditions, ascorbic acid was able to prevent 50% peroxidation through 4 h of assay. However, after 6 h of assay, ascorbic acid was no longer effective. The standard Trolox was able to prevent 20% peroxidation only during the first 2 h assay, and after 4 h, no peroxidation inhibition was observed (**Figure 3B**).

The capacity to inhibit linoleic acid peroxidation (percent) was plotted versus total phenolics of artichoke byproduct extracts (**Figure 4**). A good correlation ($R = 0.98$, $P = 0.01$) was obtained only if ABW activity was not considered in the fitting. The ordinate value of 27% indicates that, theoretically, 27% of prevention of peroxidation is due to nonphenolic compounds. ABW showed a very high activity that was related not just to the total phenolics content. Again, some other nonphenolic compounds could exert a high activity to prevent lipid peroxidation. Maybe, industrial recycling of waters at high temperature for 24 h could either improve the extraction of the above compounds or give rise to the formation of new substances with such high activity.

Artichoke dry extracts are currently commercialized as drugs mainly against liver diseases: these include Cynara (200 mg of artichoke extract; Vesta Pharmaceuticals, Inc.), Artichoke 500 mg (artichoke leaf extract; Jarrow Formula, Inc.), among others. Other commercial uses of artichoke extracts are as ingredients of liquors such as Cynar (Wessanem do Brasil). These liquors are characterized by the presence of cynarin (**Figure 1**). In this context, ABW could be a good source of cynarin.

Taking into account the extract yield, 100 g of fresh artichoke byproducts (100 mL in the case of ABW) will provide an antiradical activity versus $DPPH^{\bullet}$ that will range from 0.39 g of TEAC (RA extracted with methanol) to 0.95 g of TEAC (ABW) (**Table 2**). The same fresh artichoke byproducts will provide antiradical activity versus $ABTS^{\bullet+}$ in the range of 0.14 g of TEAC (RA extracted with methanol) to 0.4 g of TEAC (ABW) (**Table 2**). These values mean that from an industrial

point of view, and always theoretically, 45000 tons of discarded artichoke byproducts (for example, RA) in the region of Murcia (Spain) in 1997 is potentially (RA extracted with water) equivalent to 247.5 tons of TEAC (the equivalent antioxidant capacity of 247.5 tons of Trolox), an incredibly huge amount of antioxidant and potential health-promoting activity wasted.

Therefore, more investigations are highly recommended to elucidate the potential use of artichoke byproducts as a rich source of natural antioxidant phenolics. In this way the "functionalization" of foodstuffs by using artichoke byproduct extracts should be taken into account. To this purpose, sensory modification of foodstuffs, as well as the stability and activity of artichoke extracts within food matrices, should be investigated. In addition, toxicological studies should be also carried out to ascertain the boundary between health-beneficial effects and risk damage.

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