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Antioxidant Activity of Ethanolic Extracts from Several Asparagus Cultivars

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Three different methods (antiradical activity, inhibition of primary oxidation, and ferric reducing power) have been used to evaluate the antioxidant activity of eight different asparagus cultivars and byproducts: white and green asparagus from Alcalá del Río (Guadalquivir Valley, Seville) and American hybrids, native spears, and their byproducts from Huétor-Tájar (Vega de Granada). The correlation between antioxidant activity and total phenol content was studied. Six standards were also tested to validate the modified methods for antioxidant activity determination. Results obtained for antiradical capacity and reducing power were very similar, and a high correlation with phenols was found ($R \geq 0.9$ for both tests). Sample origin was an important factor, spears from Huétor-Tájar having higher values (ARC between 7 and 10 and P_R of 0.25−0.33) than those from Alcalá del Río (ARC 0.6−2 and P_R of 0.05−0.07). Significant differences were found between spears with the same origin, suggesting that genetics are another factor to take into account. Asparagus inhibits lipid primary oxidation, but no correlation between the inhibition percentage and phenols was observed. Asparagus origin was the only factor that led to significant differences: samples from Huétor-Tájar had higher values (POIC between 18 and 32) than those from Alcalá del Río (POIC of 5−9). Byproducts from the canning industry at Huétor-Tájar were also assayed for antioxidant activity; the results obtained suggested that byproducts could be considered as an excellent source of natural antioxidants.

KEYWORDS: Asparagus; antioxidant capacity; phenols; byproducts; functional foods

INTRODUCTION

There is an increasing concern about having a more convenient diet that contains not only nutrients but also "minor" components that have been demonstrated to produce beneficial effects on human health. The nutritional value of plant food as a source of essential minerals, vitamins, carbohydrates, proteins, and fiber is well recognized.

On the other hand, epidemiological studies have reported that there is an inverse association between vegetable consumption and chronic disease reduction, such as different types of cancer and cardiovascular diseases. Phytochemicals in vegetables have been demonstrated to be the active component responsible for this protective effect (*1*, *2*); among them, antioxidants appear to play a major role in that fact. Hence, the bioactivity of food components is usually tested as their antioxidant capacity.

Oriental millenary cultures have traditionally used plants of the genus *Asparagus* as ayurvedic drugs. It has been reported that several species from Asiatic and African countries have significant medicinal properties and can be used for the treatment of gastrointestinal disorders and inflammatory pains (*3*). Asparagus extracts and isolated compounds have revealed a wide range of biological activities, such as antitumoral (*4*), antifungal (*5*), and immunostimulatory (*6*). Although the mechanism of action of the crude extracts and purified fractions is not well established yet, because free radical damage is implicated in the etiology of different human diseases, the antioxidant properties of asparagus may at least partly explain its therapeutic properties (*7*).

Among the vegetables commonly consumed in the United States and Europe, asparagus has been reported as the richest in total quality and quantity of antioxidants (*8*, *9*). However, its consumption is very small compared to that of other vegetables, which is in great extent associated with its relatively high cost. To increase asparagus consumption, there should be much more information not only about asparagus nutritional properties but also about its bioactive characteristics.

On the other hand, the spears portions that are discarded during the processing represent a promising, but unknown, source of new value-added functional compounds (*10*). Very recent studies on bioactive components of asparagus have revealed that the byproducts are also rich in many of the phytochemicals located in the edible part of the spears (*11*, *12*).

The main components responsible of asparagus bioactivity are phenols (flavonoids and hydroxycinnamic acids) and saponins, although other compounds, such as sterols, sulfur-

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Table 1. Abbreviations and Descriptions of the Different Asparagus Samples Tested

code	plant material	cultivar	external color	origin
WA	spear	Ramada hybrid	white	Alcalá del Río
GA	spear	Ramada hybrid	green	Alcalá del Río
GHTAm	spear	Grande hybrid	green	Huetor-Tájar
GHTN	spear	native	green (G)	Huetor-Tájar
BHTN	spear	native	bronze (B)	Huetor-Tájar
PHTN	spear	native	purple (P)	Huetor-Tájar
BPN	byproduct	native	G–C–P	Huetor-Tájar
BPAm	byproduct	Grande hybrid	green	Huetor-Tájar

containing acids, oligosaccharides, carotenoids, and amino acids, can also contribute to the functional properties of this vegetable (*13*, *14*). In addition to these soluble compounds, asparagus spears are very rich in dietary fiber, with potential favorable effects (*15*).

Asparagus bioactivity does not depend on single components but is related to a diversity of chemicals. Their interactions within the food matrix also affect their activity, which makes difficult its measurement "in vitro". During the recent years several methods have been developed for measuring the total antioxidant capacity of plant food (*9*, *16*, *17*). However, as different antioxidant compounds may act in vivo through different mechanisms, no single method can fully evaluate the total antioxidant capacity of foods. In the present work, the antioxidant capacity of asparagus spears and byproducts from several origins and varieties has been measured with three different methods (radical scavenging, inhibition of primary oxidation, and ferric reducing power), and a correlation with phenol content of different samples has been done.

MATERIALS AND METHODS

Plant Material. The samples that have been investigated are listed in **Table 1** and consisted of several cultivars of *Asparagus officinalis* L. Native cultivars are tetraploid subspecies (commonly known as "triguero" spears) from Huetor-Tájar, hand-classified by their external color. For those harvested in Huetor-Tájar, the byproducts resulting from canning (around half of the total spear length) were also collected in two batches: from hybrids and from Huetor-Tájar native spears.

Standards and Reagents. 2,2-Diphenyl-1-picrylhydrazyl (DPPH$^\bullet$ free radical, 90% purity), linoleic acid (99% minimum purity), 2,2′-azobis(2-amidinopropane) dihydrochloride (ABAP, 97% purity), ferric chloride, 2,2′-dipyridyl (99% minimum purity), Trolox (97% purity), citric acid (puriss p.a.), Folin−Ciocalteu 2 M phenol reagent, sodium carbonate (ACS reagent), ferulic acid, rutin (95% purity, HPLC grade), and quercetin (98% purity, HPLC grade) were purchased from Sigma-Aldrich Química (Madrid, Spain). Methanol (HPLC grade), sodium dodecyl sulfate (SDS, p.a.), disodium sulfate (p.a.), and trichloroacetic acid (p.a.) were obtained from Merck (Darmstadt, Germany), ethanol was from Alcoholes del Sur (Córdoba, Spain), α-tocopherol (99% purity) was from Roche (Basel, Switzerland), and ascorbic acid was from Panreac Química S.A. (Barcelona, Spain).

Asparagus Extraction. Freshly harvested spears and their byproducts (100 g) were cut into small pieces and homogenized in a Janke & Kunkel Ultraturrax T-25 (IKA-Labortechnik, Staufen, Germany) at top speed for 2 min with 96% ethanol in a proportion of 4:1 (liquid/solid). Suspension was filtered through Albet glass fiber paper (Barcelona, Spain) under vacuum. Solid residue was washed with the same volume of 80% ethanol and filtered again. Both ethanol filtrates were collected and concentrated at 35 °C under vacuum in a Laborota 4002 rotary evaporator from Heidolph (Kelheim, Germany). Water was added up to 100 mL, to have extracts of 1 g of spear/mL. From this initial extract several dilutions were tested to study the effect of antioxidant extract concentration.

Determination of Total Phenols. Total phenols content was quantified in each asparagus extract according to the Folin−Ciocalteu spectrophotometric method, using rutin as reference standard. Aliquots of 0.2 mL of each sample were dosified by triplicate, and 0.5 mL of Folin−Ciocalteu phenol reagent (0.2 M) was added to each tube and mixed. Afterward, 0.4 mL of Na_2CO_3 (75 g/L) was added and mixed well. The microplate reader was set at 630 nm, and the absorbance was measured after 60 min. Results were expressed as rutin equivalents (mg/g).

Antiradical Activity. A modification of the method described by Sánchez-Moreno et al. (*18*, *19*) was used. For the determination of the steady time, 25 μL of the assayed extract of dilution was placed in the cuvette of the UV−vis spectrophotometer (V-530 model from Jasco) with the addition of 0.975 mL of 3.8 mg/50 mL of DPPH$^\bullet$ solution in methanol (stable radical of 2,2-diphenyl-1-picrylhydrazyl). The decrease in DPPH$^\bullet$ concentration was measured by monitoring the decrease in the absorbance continuously at 515 nm during 1 h. A period of 30 min was enough to reach the steady absorbance with all of the asparagus extracts and standards. For the determination of the antiradical activity of extracts, a microplate reader (550 model from Bio-Rad, Hercules, CA) was used. Aliquots of 5 μL of each extract, standards, and their dilutions and 195 μL of the DPPH$^\bullet$ solution were placed in each microplate well in triplicate. For each sample, a blank with methanol instead of DPPH$^\bullet$ solution was included. When the microplate was dosified, a delay of 30 min was programmed in the reader.

For each extract and standard, the decrease in absorbance (expressed as percent of the initial absorbance) was plotted against the concentration of the antioxidant solution in the reaction mixture. The efficient concentration EC_{50}, which represents the amount of antioxidant necessary to decrease the initial absorbance by 50%, was calculated from a calibration curve by linear regresion for each antioxidant solution. EC_{50} was expressed in terms of the concentration of asparagus extract or standard (mg/mL). As the lower the EC_{50} the higher the antiradical capacity, for reasons of clarity the final antiradical capacity (ARC) was expressed as $ARC = (1/EC_{50}) \times 100$.

Inhibition of Primary Oxidation. The method is based on the spectrophotometric determination of conjugated dienes from linoleic acid with and without a potential antioxidant (*20*), with some modifications. A 0.1 M solution of SDS was prepared in aqueous 0.01 Na_2HPO_4 and adjusted to pH 7.4. Linoleic acid was added to a concentration of 2.6 mM and stirred until complete emulsion. A solution 0.07 M of ABAP in water was used as radical initiator. In a test tube, 5 μL of ABAP solution, 25 μL of antioxidant solution, and 1 mL of the linoleic solution were added. Each extract and standard dilutions were assayed in quadruplicate. A blank without linoleic acid was run for each sample. Test tubes were incubated at 50 °C in an oven from Binder (Tuttlingen, Germany) during 1 h, and after this period, the absorbance at 232 nm was measured. The absorbance of linoleic acid without antioxidant solution was considered as 100% oxidation.

The results were expressed as in the case of antiradical activity. EC_{50} was calculated from the regression curves and expressed as milligrams per milliliter. The final value of the primary oxidation inhibition capacity (POIC) was defined as $POIC = (1/EC_{50}) \times 100$.

Ferric Reducing Power. A modification of the Psarra et al. (*21*) method was used. $FeCl_3$ was employed as oxidant. Fe^{2+} ion produced from the redox reaction forms a colored product with 2,2′-dipyridyl. For the determination of the reducing power of extracts, a microplate reader was used. Ten microliters of each extract, standard, and their dilutions and 10 μL of 6 mM $FeCl_3$ in 5 mM citric acid were placed in each microplate well in quadruplicate. For each sample, a blank without $FeCl_3$ was included. After dosification, the microplate was incubated during 20 min at 50 °C in an oven. Following this, 180 μL of 5 g/L dipyridyl solution in 1.2% trichloroacetic acid was added to each well. Afterward, a delay of 30 min was programmed in the reader before reading at 490 nm.

To express the results, a calibration curve was established by plotting A_{490} against a known concentration of quercetin ranging from 0.56 to 0.059 mg/mL [correlation coefficient (R) = 0.9936]. Reducing power (P_R) was expressed as quercetin equivalents (mg/mL QE) from the equation as determined from linear regression:

$$P_R = 0.2172 \times A_{490} - 0.018$$

Table 2. Total Phenol Content and Antioxidant Activity (Antiradical Activity, Inhibition of Primary Oxidation, and Reducing Power Tests) of the Different Asparagus Samples[a]

		antiradical activity		inhibition of oxidation		reducing power
	total phenols[b]	EC_{50}	ARC	EC_{50}	POIC	P_R
WA	1.62 ± 0.05	158.41	0.63	17.05	5.86	0.057
GA	2.25 ± 0.04	72.42	1.38	11.47	8.72	0.068
GHTAm	5.11 ± 0.02	12.58	7.95	5.57	17.95	0.25
GHTN	6.40 ± 0.11	10.61	9.42	3.64	27.47	0.33
BHTN	5.26 ± 0.10	10.47	9.55	3.07	32.57	0.33
PHTN	5.94 ± 0.04	10.86	9.21	4.69	21.32	0.27
BPN	3.71 ± 0.17	20.20	4.95	4.36	22.93	0.21
BPAm	2.84 ± 0.06	31.43	3.18	3.92	25.51	0.12

[a] Antiradical activity was expressed as EC_{50} (mg of dry extract/mL of solution) and ARC ($100/EC_{50}$), inhibition of oxidation as EC_{50} and POIC ($100/EC_{50}$), and reducing power as QE (mg of quercetin/mL). [b] Total phenols: mg of rutin/g of fresh product ± SD of triplicate measurements.

Statistical Analysis. Correlation coefficients (R) were determined using regression analysis at the 95% significant level. Comparisons among samples were done by ANOVA test and LSD method, at the same confidence level.

RESULTS AND DISCUSSION

Total Phenol Content. The content of extractable phenols of different samples, quantified as rutin equivalent, is presented in **Table 2**. There were significant differences among all of the samples. Samples from Huetor-Tájar had higher levels than those from Alcalá del Río. Among Huetor-Tájar's native spears "triguero" had the highest content. Byproducts had lower levels of phenols than complete spears (around half content), suggesting that phenols are mainly located in the edible part of the spears.

This phenol content was very similar to those reported for several berry and mushroom types (*22*, *23*), higher than that quantified in some fruit juices (*24*) and several tomatoes varieties (*25*), and lower than those from white (*21*) and red wines (*19*). Other vegetable byproducts from lettuce, artichoke, and cauliflower, considered as potential sources of natural antioxidants (*26*), had similar phenol content as asparagus byproducts.

Antiradical Activity. Figure 1 represents the diminution of DPPH• with different concentrations of asparagus extracts. There is a linear correlation ($y = a + bx$) between both variables ($R \geq 0.99$ for all extracts). Spears from Huetor-Tájar were the samples with the highest slope and, therefore, with the highest ARC (**Table 2**). There are significant differences at a dilution of 50 mL extract/100 mL among almost all of the samples. Only spears with different external colors, from Huetor-Tájar, were not different among them. The gradation of antiradical activity was as follows: GHTN, BHTN, PHTN > GHTAm > BPN > BPAm > GA > WA.

ARC values varied from 9.55 in BHTN to 0.63 in WA. It is noteworthy that in spears from Huetor-Tájar ARC varied from 8 to 10, whereas those from Alcalá del Río had lower values. Also, higher differences among them were found, 1.38 and 0.63 for GA and WH, respectively. This fact evidences that sample origin had great influence on antiradical activity. Similar results were observed by comparing green spears (Huetor-Tájar native, Huetor-Tájar hybrid, and Alcalá del Río hybrid—GHTN, GHTAm, and GA, respectively): the difference in EC_{50} between native and hybrid spear from Huetor-Tájar was ~2 mg/mL and between those from Huetor-Tájar and those from Alcalá del Río was ~60 mg/mL. Byproducts had higher ARC than the complete spear. In both samples (Huetor-Tájar native triguero and American hybrid) the antiradical activity was around twice as high in spears as in byproducts. This behavior is very similar to that observed for the content of total phenols. The correlation between ARC and phenols content is very high, as shown in the inset of **Figure 1** ($R = 0.9636$). The same high correlation was found for grapefruit (*27*) and several vegetable byproducts (*28*), enhancing the relevance of phenols in antioxidant activity.

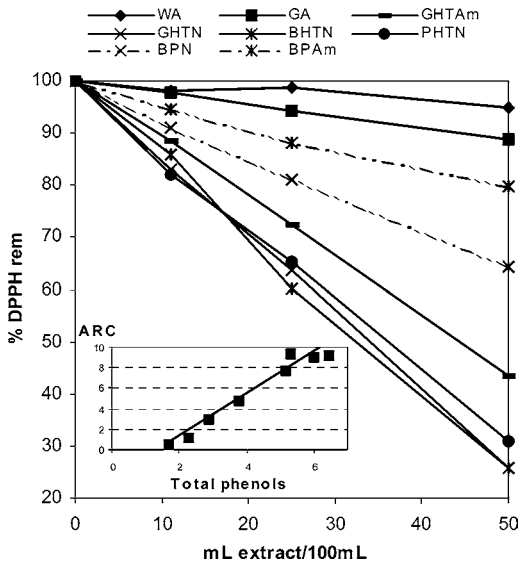

Figure 1. Dose–response lines of antiradical capacity of ethanolic extract from different asparagus samples. Antiradical capacity is expressed as percent DPPH• remaining in solution (%DPPH• rem) after 30 min of reaction. (Inset) Linear regression analysis of ARC as a function of total phenol in the different asparagus samples.

Table 3. Antiradical Activity, Inhibition of Primary Oxidation, and Reducing Power of the Different Standard Tested[a]

	antiradical activity		inhibition of oxidation		reducing power
	EC_{50}	ARC	EC_{50}	POIC	P_R
ferulic acid	2.61	38.31	1.03	97.09	0.22
rutin	0.49	204.08	1.04	96.15	0.31
Trolox	0.45	222.22	0.12	833.33	0.44
quercetin	0.21	476.19	0.10	1000.00	1.00
α-tocopherol	0.78	128.20	0.07	1428.57	0.24
ascorbic acid	0.31	322.58	0.48	208.33	0.35

[a] Antiradical activity was expressed as EC_{50} (mg of dry extract/mL of solution) and ARC ($100/EC_{50}$), inhibition of oxidation as EC_{50} and POIC ($100/EC_{50}$), and reducing power as QE (mg of quercetin/mL).

The regression analysis of the decrease of DPPH• and concentration (mg/mL) of standard assayed resulted in a linear model ($R \geq 0.9$ in all cases). Quercetin had the highest ARC and ferulic acid the lowest activity (**Table 3**), the gradation being as follows: quercetin > ascorbic acid > Trolox > rutin > α-tocopherol > ferulic acid. These results agreed with those of other authors (*19*, *29*). The amount of fresh byproduct necessary to have an antiradical capacity equivalent to 100 mg/L of each standard was estimated, and the results are presented in **Table 4**. α-Tocopherol and ascorbic acid at 100 mg/L, antioxidants very common in the cosmetic and food industries, could be replaced by a solution of the dried ethanolic extract from 8−30 g of fresh byproduct in 100 mL (240−945 mg of dried extract/100 mL), depending on the type of byproduct and standard.

Inhibition of Primary Oxidation. The inhibition of linoleic acid oxidation by the different asparagus extracts is shown in

Table 4. Equivalence in Antioxidant Activity between Asparagus Byproducts and Standards, Expressed as Grams of Fresh Byproduct To Be Extracted and Diluted to 100 mL To Have the Same Activity as a Solution of 100 mg/L of the Tested Standards

		α-tocopherol	ascorbic acid
ARC	BPN	8.11	19.44
	BPAm	14.93	32.6
POIC	BPN	20.40	2.57
	BPAm	21.54	2.08
P_R	BPN	11.43	16.67
	BPAm	20.00	29.17

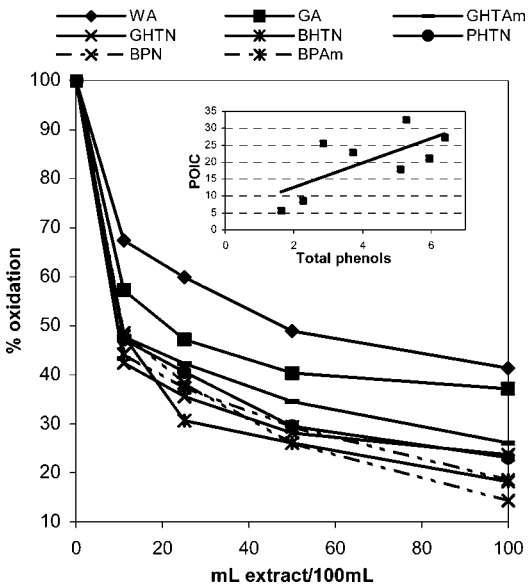

Figure 2. Dose–response lines of primary oxidation inhibition capacity of ethanolic extract from different asparagus samples. Inhibition of primary oxidation is expressed as percent oxidation after 1 h of reaction. (Inset) Linear regression analysis of POIC as a function of total phenol in the different asparagus samples.

Figure 2. Unlike for antiradical activity, in this case the response was not linear but reciprocal [$y = 1/(a + bx)$], as it happens for reported essencial oil components (*20*). Almost all of the samples from Huetor-Tájar had similar POIC values (**Table 2**). Only American hybrid spears showed significant differences, having even lower capacity than their byproducts. Greater differences were quantified between Huetor-Tájar and Alcalá del Río populations. EC_{50} of Huetor-Tájar samples ranged between 3 and 6 mg of dried extract/mL, which is much lower than those of Alcalá del Río samples (11 and 17 mg of dried extract/mL for GA and WA, respectively). The difference between GA and WA spears was significant also. EC_{50} in lipid oxidation inhibition was between 2- and 9-fold lower than in radical scavenging capacity due to the different model of response: the same amount had a higher effect in a reciprocal model than in a linear model. The correlation between phenols content and POIC is presented in the inset of **Figure 2**. Unlike ARC, the correlation coefficient between both variables was low ($R = 0.488$), suggesting that other compounds besides phenols might be implied in this inhibitory capacity, probably ascorbic acid and saponins (*2*, *24*, *30*).

The same standards used in the previous test have been assayed (**Table 3**). All standards showed a square root-*x* model ($y = a + bx^{-2}$, $R \geq 0.9$) except for ferulic acid, which followed a linear one. In this assay, α-tocopherol had the highest inhibitory activity (POIC = 1428.57), whereas rutin had the lowest (POIC = 96.15), the gradation being as follows: α-tocopherol > quercetin > Trolox > ascorbic acid > ferulic acid > rutin. As explained by Becker et al. (*31*), in an oil-in-water emulsion system, lipid-soluble antioxidant tended to provide better protection because the oxidation is located at the water−oil interface where the lipophilic antioxidants are located. Looking at the equivalence between spear byproducts and a solution of 100 mg/L of α-tocopherol and ascorbic acid (**Table 4**), it is noteworthy that the extract from 2 g of fresh byproduct in 100 mL (∼70 mg of dried extract/100 mL) had the same inhibitory activity as 100 mg/L ascorbic acid. In comparison to α-tocopherol, being the most active standard, 20 g of fresh byproduct in 100 mL was necessary to reach the same antioxidant activity level as the above-described α-tocopherol solution.

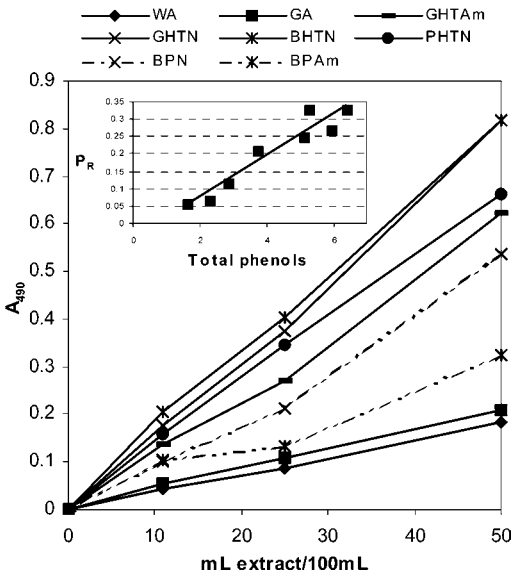

Figure 3. Dose–response lines of ferric reducing power of ethanolic extract from different asparagus samples. Ferric reducing power is expressed as absorbance at 490 nm after 30 min of reaction. (Inset) Linear regression analysis of P_R as a function of total phenols in different asparagus samples.

Reducing Power. Figure 3 represents the values of A_{490} against asparagus extract concentration. The correlation between both variables was linear ($y = a + bx$). The samples had the same P_R gradation found in radical scavenging capacity (**Table 2**): GHTN, BHTN > PHTN > GHTAm > BPN > BPAm > GA, WA. In this case, there were no significant differences between green and bronze spears from Huetor-Tájar, neither between green and white spears from Alcalá del Río. As was concluded for antiradical activity, the sample origin had great influence on reducing power, Huetor-Tájar spears having ∼4-fold higher power than those from Alcalá del Río. Byproducts had also less reducing power than complete spears, being between 1.5- and 1.75-fold less effective than spears. As for ARC, there was high correlation between phenol content and P_R (**Figure 3**, inset) with $R = 0.9178$, as was reported for several fruit juices (*24*). Phenols could be mainly responsible for this activity.

Correlation between A_{490} and concentration of standard solutions was also linear, quercetin being the most effective standard and ferulic acid the least. The gradation in P_R (**Table 3**) was very similar to that of their antiradical capacity, only ascorbic acid and Trolox being in exchanged positions: quercetin > Trolox > ascorbic acid > rutin > α-tocopherol > ferulic acid. Between 10 and 30 g of fresh byproducts (330−870 mg of dried ethanolic extract) in 100 mL was needed to have the

same reducing power as that of a solution 100 mg/L of most usual antioxidant standards (**Table 4**). These results are very similar to those presented for radical scavenging capacity.

Conclusions. Three different methods for measuring the antioxidant capacity of several asparagus cultivars and origins have been assayed. The results obtained were very similar for antiradical activity and ferric reducing power. In both assays, a high correlation between activity and total phenol content was found, suggesting that phenols could be mainly responsible for both activities, as happens for other vegetable products (*24*, *27*, *28*). The sample origin and cultivar were important factors to take into account: spears from Huetor-Tájar had higher capacities than those from Alcalá del Río, probably due to agronomical and climatological factors. Among Huetor-Tájar populations, there were cultivar differences: triguero native spears had better values than commercial hybrids. It is noteworthy that complete spears had higher capacities than the byproducts, suggesting that the edible part of spears must have much higher activities than those expressed for the complete spears. This fact would increase the consideration of asparagus spears as healthy vegetables. In a comparative study among 34 fruits and vegetables (*9*), asparagus was placed 7th in the rank of radical scavengers and 13th in ferric reducing power.

Asparagus inhibits also the primary oxidation of lipids. In this activity, sample origin was the main factor that leads to significant differences among the six spear types studied. Again, Huetor-Tájar samples showed the highest levels of inhibition, supporting the idea of the significance of agronomical and climatological conditions of growing areas on the functional properties of the spears. The correlation between phenols and this characteristic was very low, suggesting that other compounds besides phenols, such as ascorbic acid and saponins (*2*, *24*, *30*), should be also implied in the inhibition mechanisms. The activity of byproducts was similar to that of complete spears. In the case of hybrid cultivars, the byproducts were more active against oxidation than the complete spears. These results imply that responsible compounds were not mainly located at the upper part of spears, as happens for antiradical activity and total phenol. In this case, oxidation inhibitor compounds seem to have a similar distribution along the spear or are even slightly more concentrated in the basal section. The identification and isolation of these compounds will be the aim of further investigations.

Special attention should be paid to byproducts. In the canning industry, they account for a half or a third of the spear length and constitute an environmental challenge. In this paper it has been shown that they also have important antioxidant activity and that their dried extracts might replace other antioxidants in the food and cosmetic industries. In studies with other vegetable byproducts (*28*, *32*) the best dose for consumer acceptability was between 2000 and 500 mg of dried extract/100 mL of the functional beverages, depending of the type of byproduct. In this paper, the amounts of dried extract of asparagus byproducts that must be added to 100 mL of solution to reach the same antioxidant activity as 100 mg/L of α-tocopherol or ascorbic acid have been presented. They ranged from 1000 to 60 mg of dried extract/100 mL. These results suggest that asparagus byproducts should be considered as an excellent source of natural antioxidants. Obviously, studies about consumer acceptance in foodstuffs (sensory evaluation panel), toxicity, and bioavailability will be necessary. Therefore, further works on this byproduct will be of great interest from environmental, economical, and nutritional points of view.

ABBREVIATIONS USED

WA, white spears from Alcalá del Río; GA, green spears from Alcalá del Río; GHTAm, green spears, American hybrids, from Huétor-Tájar; GHTN, green spears, native cultivars, from Huétor-Tájar; BHTN, bronze spears, native cultivars, from Huétor-Tájar; PHTN, purple spears, native cultivars, from Huétor-Tájar; BPAm, green spear byproducts, American hybrids, from Huétor-Tájar; BPN, Huétor-Tájar native spear byproducts; DPPH$^{\bullet}$, 2,2-diphenyl-1-picrylhydrazyl (free radical); ABAP, 2,2′-azobis(2-amidinopropane) dihydrochloride; SDS, sodium dodecyl sulfate; EC_{50}, amount of antioxidant necessary to decrease the initial absorbance by 50%; ARC, antiradical capacity; POIC, primary oxidation inhibition capacity; P_R, reducing power; QE, quercetin equivalent; *R*, correlation coefficient.

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