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Full Paper

Bioactive compounds and antioxidant activity of the non-edible parts of two taxa from Egyptian Artichoke (*Cynara scolymus L.)*

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Abstract

Artichoke by-products are a promising and cheap source of bioactive compounds and represent a potential alternative to synthetic antioxidants. This study was conducted to determine the total phenolics, flavonoids concentration and antioxidant activities of the non-edible parts (leaves, stems and outer bracts) from two taxa Egyptian "Baladi" and French "Hyrious" artichoke. The results demonstrated that the bioactive compounds and antioxidant activity in stems of the Egyptian "Baladi" are higher than the French "Hyrious". The highest flavonoids concentration were recorded in the stems of both cultivars (81.36 and 83.10 mgQE/gDW). Whereas, the outer bracts of both cultivars of artichoke contain the highest levels of the antioxidant capacity (116.66 and 112.90 mgAE/gDW), and highest concentration of total phenolics (5.02 and 4.90 mgGA/gDW). However, leaves and outer bracts of French "Hyrious" show higher concentration of the total phenolics, flavonoids, and antioxidant activity than Egyptian "Baladi". In addition, the results proved the linear correlation between the total phenolics and the antioxidant activity. Moreover, the levels of the bioactive compounds exhibited higher than the reported in the literature. Therefore, the use of non-

edible parts of Egyptian artichoke could be an environmentally friendly natural source of phenolics, antioxidants, and flavonoids for the health benefits and an economically viable solution to the problem of solid waste treatment.

Keywords: Artichoke; Antioxidant activity; Total flavonoids; Total phenolic compounds.

1. Introduction

The increasing awareness of the environmental impact of agricultural and food wastes have stimulated efforts to find possible ways of using them for producing natural antioxidants and bioactive compounds. Some plants residues contain substantial amounts of bioactive phytochemicals [1]. The use of herbal medicine represents a long history of human interactions with the environment, more than 80 % of the world's population depends upon traditional medicine for their primary healthcare needs [2]. Nowadays, there is an increasing interest of medicinal plants and naturally occurring antioxidants for use in medicinal materials as an alternative source of synthetic drug and antioxidants [3]. Organically synthesized drugs are being restricted due to their suspected carcinogenicity, and to avoid its adverse effects as well as its high-cost in drug therapy [4]. Therefore, the interest of natural antioxidants has been increased [5]. Moreover, World Health Organization (WHO) encourages, recommends and promotes traditional/herbal remedies in national health care programs because these drugs are easily available, low cost, and safe for human [6].

Phenolic compounds as antioxidants have implication in human health for the prevention of cancer, cardiovascular diseases and other pathologies [7]. They are commonly found in edible parts of the plant, and they have been reported to have multiple biological effects, including antioxidant activity. Many species have been documented to have medicinal properties and beneficial impact on health, e.g. antioxidant activity, digestive stimulation action, anti- inflammatory, the antimicrobial, hepatoprotective, hypolipidemic, and anticarcinogenic potential [8].

The ancient herbaceous perennial plant, Artichoke (Cynara scolymus L..) is well-known as a vegetable, native to the southern Mediterranean parts of North Africa which today is widely cultivated all over the world with an annual production of 1,538,108 tonnes [9]. Egypt is one of the major producers of artichoke in the Mediterranean region and there is an annual production of nearly 236314 tons [9]. Artichoke is belonging to the family of Asteraceae (Compositae), and it’s a good source of natural phenolic, antioxidant and flavonoid compounds as well as it is widely used for medicinal purposes and pharmacology [10, 11]. Many studies have demonstrated that artichoke has major medicinal properties, including antioxidative, anticarcinogenic, antigenotoxic, cholesterol-lowering, hepatoprotective, bile-expelling, diuretic, and anti-inflammatory, as well as antifungal, anti-HIV, promising effects against adverse effects of Cd toxicity, and antibacterial [10, 12, 13]. Unlike many other cultivations, the head, an immature flower of artichoke is considered edible parts which is eaten as a vegetable, has been shown to be a rich source of bioactive phenolic compounds, inulin, fibers, and minerals [14], whereas its leaves, stems

and outer bracts are not suitable for human consumption (non-food industrial by-products). So, they are often discarded and turned into a solid waste with additional treatment costs in compliance with environmental laws. Waste disposal represents an additional cost to the producers and contributes to the environmental impact of this industrial activity [15]. Artichoke by-products, produced from agricultural procedures and the processing industry, represent a huge amount of discarded material about 80–85 % of the total biomass of the plant nearly 1307391.8 tones and thus the quantity of by-product is considerable [1, 10, 16, 17]. This residue is of economic and environmental concerns, adding value to agro-industrial by-products and therefore could be used as a potential source of food additives and nutraceuticals, inulin, phenolics, carbohydrates, and other classes of chemical compounds such as including flavonoids [15]. The possibility to recover the by-products produced by the artichoke has been proposed [18, 19]. However, there is very limited data on the antioxidant concentration and activity of artichokes cultivated in Egypt. Therefore, the aim of the present study is to find out the total phenolics, total flavonoids concentration and total antioxidant capacity of non-edible parts of Egyptian Baladi and to compare with French Hyrious artichokes cultivars that produced in Egypt.

2. Materials and methods

2.1 Chemicals and reagents

Aluminum chloride, sodium acetate, sulfuric acid, Folin–Ciocalteu (FC) reagent, gallic acid, ascorbic acid, quercetin, and methanol of HPLC grade were purchased from Sigma Aldrich. Ammonium molybdate was purchased from Fluka Co. (Bushes, Switzerland). Assay of all standards, solvents, and reagents were ≥ 99%. Water was purified using a Milli-Q system.

2.2 Plant material

Two Artichoke, *Cynara scolymus L.*, cultivars namely; Egyptian Baladi and French Hyrious were collected from Markaz Abu Al Matamir, Behera governorate, Egypt, during February-April 2015. The collected plants have been identified by plant taxonomists at the Department of Botany and Microbiology, Faculty of Science, Assiut University, Assiut, Egypt.

2.3 Preparation of plant extract

Bioactive compounds were extracted from the artichoke plants according to the reported methods [20, 21]. Briefly, the artichoke non-edible parts as leaves, stems, and outer bracts, were dried under shade at room temperature. Next, the dried plants were grounded to fine powders. Then, the bioactive compounds were extracted from 20 g of the dried powder samples by using a Soxhlet extraction method with 200 mL of 80:20 (v/v) methanol/ H_2O at 68 °C for 12 h. After the mixture was filtered, the solvent was evaporated using a rotary evaporator under vacuum at 40 °C, and the dried residues were dissolved in 20 mL of 80:20 (v/v) methanol/ H_2O. Finally, the extracts were filtered and stored at -20 °C until analysis.

2.4 Phytochemical screening

2.4.1 Determination of the total phenolics concentration

The total phenolics concentration (TPC) was determined using the reported spectrophotometric method with slight

modifications [22]. The TPC of all extracts was assayed using the Folin–Ciocalteu (FC) reagent. Briefly, 300 µL of the aqueous methanolic extracts, and standards were mixed well with 0.6 mL of FC reagent (10 %), then vortexed thoroughly for 10 secs, and incubated at room temperature for 3 min. Next, the mixture was mixed with 2.4 mL of Na_2CO_3 (0.7 M). After vortexing, the mixture was incubated for 2 h at 25° C for TP quantifications. The TPC was determined using Cary 60 (Agilent technologies, German) UV–Vis spectrophotometer. A calibration curve was constructed using calibration standards of 1, 15.63, 31.25, 62.5, 125, 250 and 500 mg/L gallic acid. The absorbance was measured at 765 nm. The results were expressed in milligram gallic acid equivalents (GAE) per gram of dried weight (DW) of plant material (mgGAE/ gDW). The concentration of total phenolics in plant extracts was calculated using the following formula:

$$C = (c * V)/m \qquad \text{(Equation 1)}$$

where: C is the concentration of the total phenolics, c is the concentration of gallic acid established from the calibration curve, V is the volume of the extract, and m is the weight of the dried powder plant. All tests were carried out in triplicate and the results were averaged.

2.4.2 Determination of the total flavonoids concentration

The total flavonoid concentrations (TFC) of aqueous methanolic extracts was determined by the documented colorimetric method using Quercetin standard and aluminum chloride reagent [23]. Typically, 0.5 mL of aqueous methanolic extracts and standards were mixed with 100 µL of $AlCl_3$ (10 %), 100 µL of sodium acetate (1 M) and 4.3 mL of distilled water. After an incubation period at 25 °C for 30 min, the absorbance was measured at 415 nm using a Cary 60, Agilent Technologies, UV/VIS spectrophotometry. The TFC was calculated using a standard calibration curve of quercetin (12.5 – 400 mg/L) and expressed as quercetin equivalent (QE) per g of dry weight (DW) sample (mgQE/gDW). The concentration of total flavonoids was calculated using the following equation:

$$X = (c * V)/m \qquad \text{(Equation 2)}$$

where: X is the total flavonoids concentration, c is the concentration of quercetin standard established from the calibration curve, V is the volume of the extracts, and m is the weight of the dried powdered plant. All measurements were performed in triplicate and the results were averaged.

2.4.3 Antioxidant activity

The total antioxidant capacity (TAC) of the plant extracts was evaluated by the phosphomolybdenum method with slightly modifications according to the reported protocols [23, 24]. Firstly, 100 µL from each sample extracts were combined, in screw-capped tubes, with 3 mL of a reagent solution consisting of 0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate (1:1:1 molar ratio). Next, the tubes were incubated in a water bath at 95°C for 90 min. After the samples had cooled to room temperature, the absorbance of the developed color was measured at 695 nm against a blank using a Cary 60, Agilent Technologies, UV/VIS spectrophotometer. The experiments were performed in triplicate, and the TAC was expressed as mg ascorbic acid equivalent (A.E) per

gram dry weight (mgA.E/gDW). The TAC was calculated by the following equation:

$A = (c * V)/m$ (Equation 3)

Where A is the concentration of total antioxidant capacity, c is the concentration of ascorbic acid, V is the volume of the extracts, and m is the weight of the powdered dried plant. The concentration of ascorbic acid was obtained from a standard calibration curve constructed using a wide range of calibration standards of ascorbic acid (1- 400 mg/L).

2.5 Statistical analysis

All the experiments were performed in triplicate. Statistical analysis of the data was performed using Sigmaplot 12.5 (Systat Inc., Germany), and it was performed using the Tukey's method based on one factor ANOVA at the 95 % confidence level. Significant differences were reported when the probability of the results, assuming the null hypothesis (p) value is less than 0.05.

3. Results and discussion

3.1 Phytochemical analysis

3.1.1 Determination of total phenolic concentrations

The method used for determination of the total phenolics concentration was validated by testing the R^2 calculated from the standard calibration curve of Gallic acid as illustrated in Figure 1. It was found that the R^2 value was higher than 0.995. Thus, this method could be applied for TPC determination.

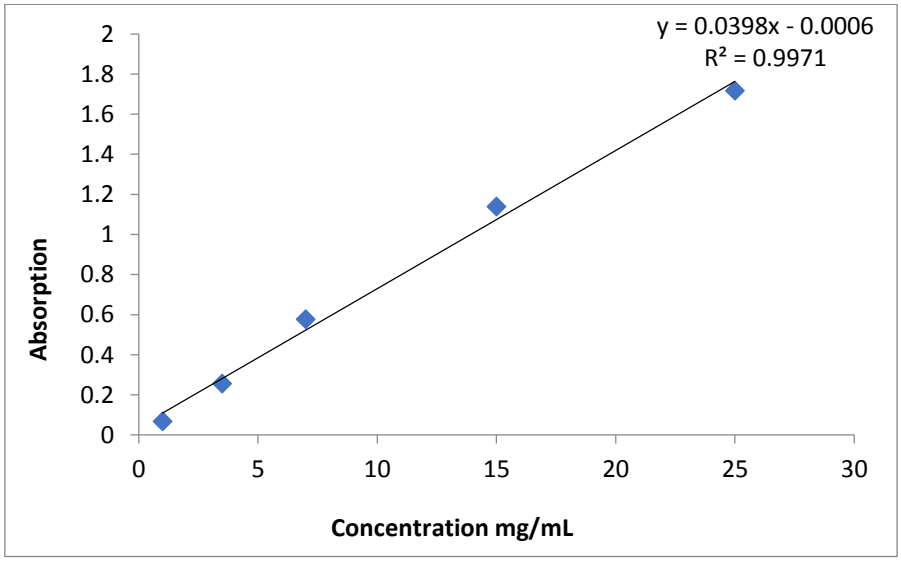

Figure 1. Gallic acid standard calibration curve for total phenolics concentration determination.

Figure 2 shows the values of the TPC for the non-edible parts; leaves, stems, and outer bracts, of the two Artichoke taxa (Egyptian Baladi and French Hyrious). In general, the results of the outer bracts from both cultivars contained the highest concentration of total phenolics. Of the two Egyptian artichoke taxa, French Hyrious outer bracts contained the highest concentration of total phenolics (5.02 mgGA/gDW), whereas the stems of French Hyrious contained the lowest amount of TPC (3.66 mgGA/gDW). Although the Egyptian Baladi had the highest amount of the TPC in the outer bracts (4.9 mgGA/gDW) as the French Hyrious, the lowest amount of TPC was observed in its leaves (4.05 mgGA/gDW). Moreover,

highly significant differences of the TPC values between the non-edible parts was found for the two taxa due to the p value was less than 0.05 ($P < 0.001$). Also, all pairwise multiple comparison procedures demonstrate that significant differences were found between the outer bracts, leaves and stems of the Egyptian Baladi. Whereas, non-significant differences were proved when comparing the outer bracts and leaves in the French Hyrious due to the p value was 0.536 as presented in Figure 2. Therefore, this work shows that the concentration of total phenolics differs according to the parts of the artichoke studied as well as for the taxa. Our data were compared with those previously reported in the literature (Table 2). The non-uniform distribution of the total phenolics in the Egyptian artichoke plant parts is in good agreement with previous studies of other artichoke taxa [25, 26]. In earlier researches, it was proved that artichoke plants accumulate more phenolics in the outer bracts than in the leaves and stems [19, 27, 28]. However, other studies showed higher phenolics concentration in stems than outer bracts [19, 29]. Although the lowest amount of TPC in the leaves of Egyptian Baladi (4.05 mg/g DW), its concentration was found to be higher than the reported one, 2.60 mg/g DW, [30]. Previous findings also indicated that the outer bracts and leaves of artichoke have a higher polyphenolic concentration, 10.23, 7.06, 54.54 and 79.20 mg/g DW, [25, 29, 31, 32] compared to our data, whereas they were slightly higher than the results reported by [33] (1.42-2.65 mg/g DW). The variation in TPC within the artichoke plant parts or taxa reported here and, in the literature, was found to be in relation to biological, physiological stage of development, technical and environmental factors during plant growth (biotic and abiotic factors) such as taxa, genetic material, plant parts, season conditions, plant arrangements. tissue age and planting density [26, 33]. The results obtained in the present study indicate that Egyptian artichoke by-products might represent an important potential source of natural antioxidant phenolic compounds which could be used for phytopharmaceutical applications and therapeutic activities as an antimicrobial agent, hepatoprotection, and anticancer.

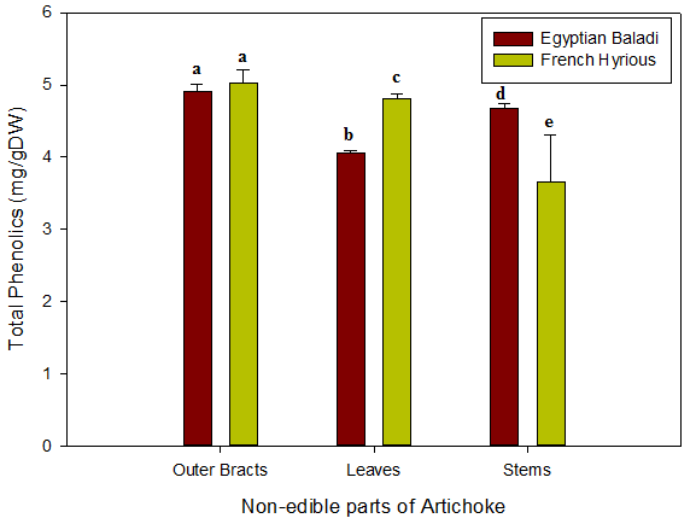

Figure 2. Total phenolics concentration (as gallic acid equivalent) of the non-edible parts; leaves, stems, and outer bracts, extracts of the two Artichoke taxa (Egyptian Baladi and French Hyrious).

3.1.2 Determination of total flavonoids concentration

Flavonoids (or bioflavonoids) are a class of plant and fungus secondary metabolites which are one of the most important polyphenols. The total flavonoids concentration (TFC) was calculated using the standard curve of quercetin as shown in Figure 3, and it was expressed as quercetin equivalent (QE) per gram of the dried extracts (mgQE /gDW). Validation of the linearity was demonstrated by the obtained R^2 value that shows 0.9991. The TFC values of the selected artichoke cultivars were found to be varied from 50.50 to 83.50 mgQE /gDW as presented in Table 1.

The results of total flavonoids concentration for the non-edible parts of the artichoke are illustrated in Figure 4. The variation of the TFC between the two taxa could be attributed to the differences of the genetic which can modify the constituents of the plant. The highest flavonoids concentration were recorded in the stems of both cultivars (81.36 – 83.10 mgQE/gDW) whereas, the lowest were observed in outer bracts organs (50.54 – 51.82 mgQE/gDW) as shown in Figure 4. The TFC of the outer bracts obtained from the two taxa of Artichoke are in agreement to the reported concentration obtained from Artichoke plant (Blanc d'Oran) that shows 51.20 mgQE/gDW as presented in Table 2 [25]. Moreover, Table 1 showed that the leaves had an intermediate level of TFC (68.30 and 76.21 mgQE/gDW) for the Egyptian "Baladi" and French "Hyrious", respectively. In addition, these values are in line with those found in previous studies by El-Boshy et al., for the TFC of leaves (75.20 mgQE/gDW), [13]. While the TFC of the Egyptian Artichoke' leaves had higher amount than other documented studies that ranged from 12.00 – 23.37 mgQE/gDW as shown in Table 2 [19, 25, 31, 33]. Also, the leaves of artichoke plant contained higher amounts of flavonoids than outer bracts, and these data are in agreement with the reported results [27]. While Dabbou et. al. found that the TFC values of bracts were higher than those obtained in leaves [25]. Besides, our results of the TFC of the outer bracts (50.54 -51.80 mgQE/gDW) showed higher TFC than previously reported (0.61 – 48.07 mgQE/gDW) [19, 34]The variation of the TFC was expected probably due to environmental factors such growing conditions of the examined cultivars and genetic backgrounds of plants [25, 33].

3.1.3 Determination of total antioxidant capacity

The total antioxidant capacity (TAC) was expressed as the number of ascorbic acid equivalent (mgA.E) per gram of dry weight, gDW, (Prieto et al., 1999). The basic principle of the TAC determination is based on the reduction of Mo(VI) to Mo(V) by the sample analyte and subsequent the formation of a green-colored phosphomolybdenum (V) complex with maximum absorption at 695 nm [24]. Also, the TAC was calculated using the standard curve of ascorbic acid as shown in Figure 5, and the linearity was verified by the obtained R^2 value (0.9998).

Figure 6 shows the antioxidant capacity of the extracts of tow artichoke taxa. The different extracts of the non-edible parts exhibited various degrees of antioxidant capacity. The results indicated in Table 1 demonstrate that the outer bracts of both cultivars of artichoke contain the highest levels of the antioxidant capacity (116.66 and 112.90 mgAE/gDW) compared to the

other parts of the Artichoke non-edible part which mean that more effective in reduction of Mo(VI) to Mo(V). Whereas, the lowest antioxidant activity was found in the stems of French "Hyrious" artichoke (71.04 mgAE/gDW) and in leaves of the Egyptian Baladi (84.91 mgAE/gDW) as shown in Figure 6. Although the lowest amount of TAC was found in the leaves of the Egyptian Baladi (84.91 mgAE/gDW), its values is higher than those reported (50.38 mgAE/gDW) [35] as presented in Table 2. The stems and leaves of artichoke, "Baladi" and French "Hyrious" showed different levels of TAC. This non-uniform distribution of the TAC in the Egyptian artichoke plant parts is in good agreement with previous studies of other artichoke taxa[25, 36].

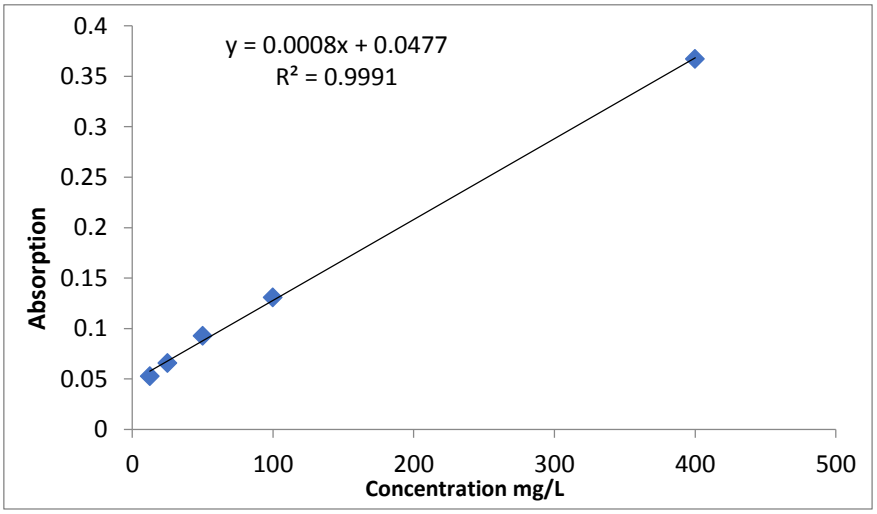

Figure 3. Quercetin standard calibration curve for total flavonoids concentration determination.

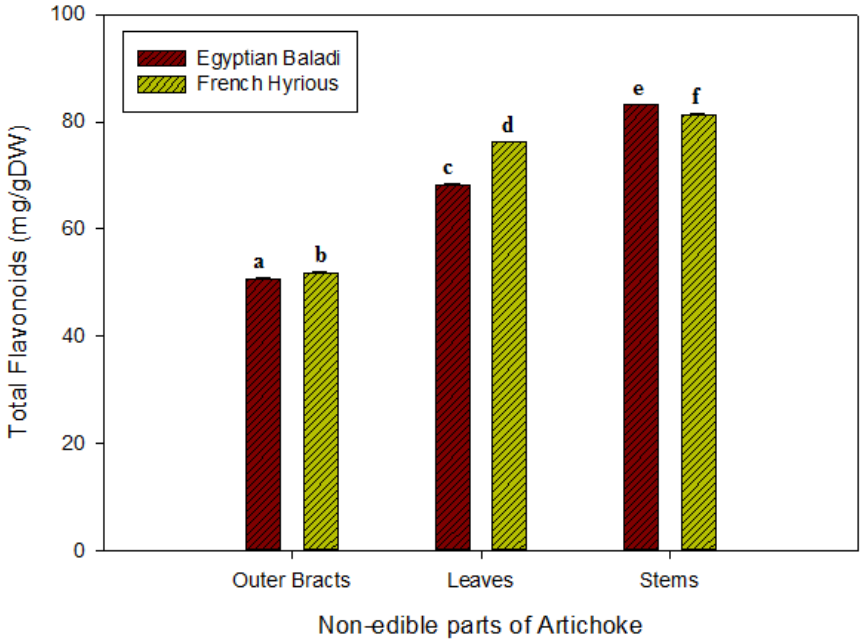

Figure 4. Total flavonoids concentration (as Quercetin equivalent) of the non-edible parts; leaves, stems, and outer bracts, extracts of the two Artichoke taxa (Egyptian Baladi and French Hyrious).

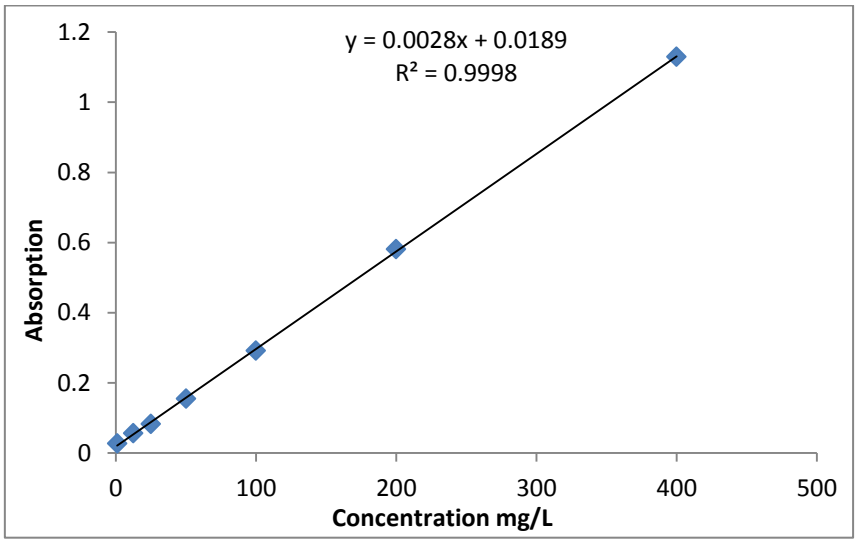

Figure 5. Ascorbic acid standard calibration curve for total antioxidant capacity evaluation.

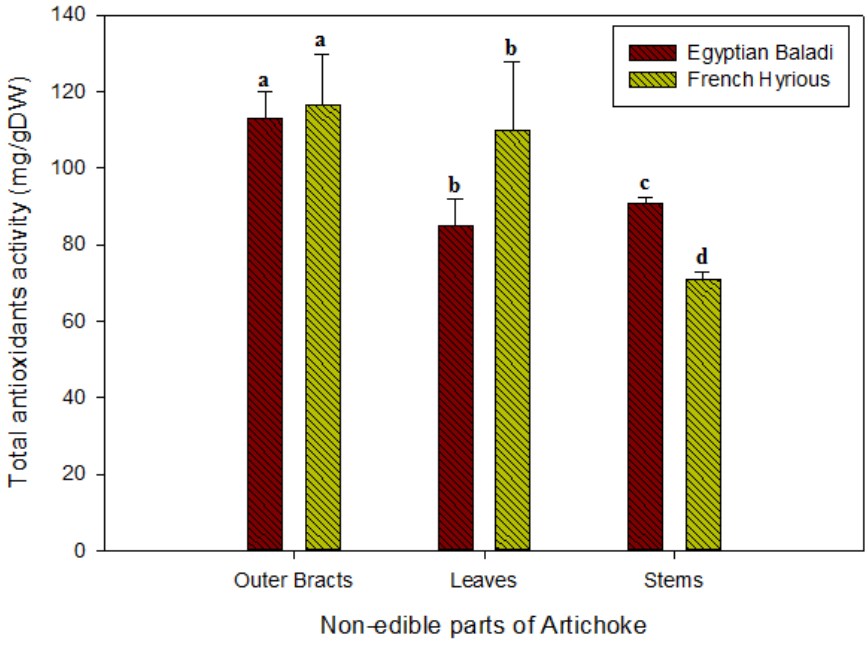

Figure 6. Total antioxidant capacity (as Ascorbic acid equivalent) of the non-edible parts; leaves, stems, and outer bracts, extracts of the two Artichoke taxa (Egyptian Baladi and French Hyrious).

Figure 7 demonstrated that a linear correlation between the TAC and the TPC. For instance, the non-edible part that had low phenolic concentration, it had lower antioxidant activity. The obtained correlation between the TAC and TPC is in agreement with the literature that antioxidant activity of plant extract is mainly due to the presence of phenolic compounds [36].

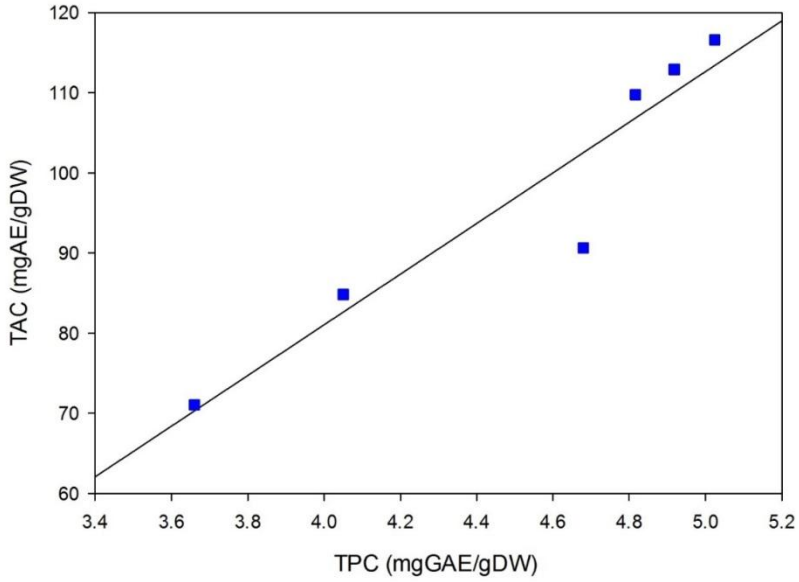

Figure 7. Correlation between TPC and TAC of the plant extracts isolated from artichoke plant (French Hyrious and Egyptian Baladi).

3.1.4 Comparison of TPC, TFC, AND TAC OF Artichoke by-products (Egyptian ''Baladi'' and French ''Hyrious'')

In the present study, the phytochemical analysis of artichoke by-products, Egyptian "Baladi" and French "Hyrious" showed higher concentrations of phenolic, flavonoid compounds as well as antioxidant activity. Table 1 shows the total phenolics and flavonoids concentration as well as the antioxidant capacity of artichoke by-products ((leaves, stems, and outer bracts) for the two taxa Egyptian "Baladi" and French "Hyrious". Quantitative differences were observed between the two taxa of artichoke under investigation. The maximum level of total phenolics was found in the outer bracts of French "Hyrious’” artichoke (5.20 mgGAE/gDW) and the minimum existed in the stems of the same variety (3.66 mgGAE/gDW). Although the TPC in the stems of French "Hyrious" artichoke is lower than that of the Egyptian "Baladi" artichoke, its level in the leaves and outer bracts are higher that Egyptian "Baladi" artichoke (Table 1). In addition, the analysis revealed that the maximum amount of flavonoids obtained from the Egyptian "Baladi’” stems (83.10 mgQE/gDW), whereas the minimum amount was presented in the leaves of French "Hyrious" artichoke (76.20 mgQE/gDW). In both leaves and outer bracts of French "Hyrious" artichoke, the amount of TFC was slightly higher than of Egyptian "Baladi" artichoke. Furthermore, Table 1 compares the total antioxidant activity of the two dried Egyptian "Baladi" and French "Hyrious" taxa artichokes. French "Hyrious" recorded the highest antioxidant capacity in the outer bracts (116.65 mgAE/gDW). On the other hand, the lowest amount of the TAC was generally found in its stems. French "Hyrious" artichoke parts (leaves and outer bracts) showed higher antioxidant activity value in comparison to that of the Egyptian "Baladi" artichoke. Therefore, there are differences between the TPC, TFC, and

TAC in different taxa and parts of artichoke products. Moreover, there are differences between our results and those reported previously. It seems possible that the variation in the amounts of TPC, TFC, and TAC in comparison to the literature depends on various parameters such as temperature, time of extraction, solvent polarity, solvent concentration, extraction efficiency, solubility of phenolic compounds, extract concentration, or extraction method [37-39]. Herein the results show that the TPC was in direct proportion with the increasing of antioxidant activity, and are in agreement with the reported foundations [35, 39-41]. Hence, these results suggest that artichoke by-products represent a potential source of natural antioxidants compounds. Also, it could be used as nutraceuticals, ingredients in the design of functional foods, an alternative to drug therapy, and/or treatment of hypertension, as well as to avoid the adverse effects of organically synthesized drugs as well as the high-cost drug therapy.

Table 1. Total phenolic concentrations (TPC), Total flavonoid concentrations (TFC)and Total antioxidant capacity (TAC) of the non-edible of Artichoke taxa (Egyptian Baladi and French Hyrious).

	Total phenolics		**Total flavonoids**		**Total Antioxidant**	
Taxa / Organ	**Egyptian Baladi**	**French Hyrious**	**Egyptian Baladi**	**French Hyrious**	**Egyptian Baladi**	**French Hyrious**
Leaves	4.051 ± 0.041	4.816 ±0.66	68.297 ±0.036	76.20 6 ±0.077	84.809 ±7.172	109.750 ±17.882
Stems	4.681 ±0.066	3.656 ±0.651	83.097 ±0.048	81.365 ±0.079	90.654 ±1.485	71.037 ±1.977
Outer bracts	4.918 ±0.100	5.024 ±0.178	50.542 ±0.0250	51.821 ±0.140	112.895 ±7.195	116.655 ±13.226

The values are means ± SD of three replicates.

Table 2. Literature survey of TPC, TFC, and TAC in different varieties and parts of artichoke [Fresh or dry weight (mg/g)]

Taxa	**Total phenolics concentration**			**Total flavonoids concentration**			**Total antioxidant capacity**			**Reference**
	Leaves	**Outer Bracts**	**stems**	**Leaves**	**Outer Bracts**	**stems**	**Leaves**	**Outer Bracts**	**stems**	
Green globe	62	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Wang et al., 2003
Violetto di Toscana	2.40	7.30	26.13	N. D	N. D	N. D	N. D	N. D	N. D	Romani et al., 2006
Terom	2.60	3.05	30.12	N. D	N. D	N. D	N. D	N. D	N. D	
Aquara	0.69	0.47	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Fratianni et al., 2007
Bianco di Pertosa	0.52	0.51	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Violet de Provence	0.68	0.58	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Tondo di Paestum	0.60	0.54	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
C3	0.32	1.79	N. D	N. D	N. D	N. D	N. D	N. D	N. D	

Globe artichoke	5.93	3.00	6.30	N. D	N. D	N. D	N. D	N. D	N. D	Lombardo et al., 2007
Violet d'Hyeres	84.50	160.80	85.70	N. D	N. D	N. D	N. D	N. D	N. D	Dabbou et al., 2016
Blanc d'Oran	79.20	134.50	80.62	N. D	N. D	N. D	N. D	N. D	N. D	
Blanca de Tudela	1.48	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Rouphael et al., 2016
Violetto di Provenza	2.50	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Locale di Fano	2.30	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Spinoso di Palermo	1.42	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Italo	2.65	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Globe artichoke	N. D	0.41	0.33	N. D	N. D	N. D	N. D	N. D	N. D	Kollia et al., 2017
Violetto di Toscana	N. D	N. D	N. D	1.22	0.17	N. D	N. D	N. D	N. D	Romani et al., 2006
Terom	N. D	N. D	N. D	1.48	0.16	N. D	N. D	N. D	N. D	
Blanc d'Oran	N. D	N. D	N. D	18.90	51.20	N. D	N. D	N. D	N. D	Dabbou et al., 2016
Violet d'Hyeres	N. D	N. D	N. D	16.70	64.90	N. D	N. D	N. D	N. D	
C3	N. D	N. D	N. D	23.37	N. D	N. D	N. D	N. D	N. D	Rouphael et al., 2016
Italo	N. D	N. D	N. D	16.63	N. D	N. D	N. D	N. D	N. D	
Bianco di Pertosa	17.50	5.10	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Imma Pagano et al., 2016
Tondo di Paestum	4.70	8.50	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Bianco di Pertosa	N. D	N. D	N. D	6.30	1.10	N. D	N. D	N. D	N. D	
Tondo di Paestum	N. D	N. D	N. D	0.62	0.61	N. D	N. D	N. D	N. D	
România	38.90	N. D	N. D	313.70	N. D	N. D	50.38	N. D	N. D	Vamanu et al., 2011
Artichoke*	N. D	10.23	16.36	N. D	N. D	N. D	N. D	N. D	N. D	Zuorro, 2014
Artichoke*	135.8	N. D	N. D	75.2	N. D	N. D	N. D	N. D	N. D	El-Boshy et al., 2017
Artichoke*	54.54	N. D	N. D	12.00	N. D	N. D	N. D	N. D	N. D	Ben Salem et al.,2017
Green Globe	8.60	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Abdel Magied et al., 2017
Violet	5.70	N. D	N. D	N. D	N. D	N. D	N. D	N. D	N. D	
Artichoke*	N. D	N. D	N. D	48.07	N. D	N. D	N. D	N. D	N. D	Mocelin et al., 2015
Artichoke*	N. D	24.14	35.71	N. D	N. D	N. D	N. D	N. D	N. D	Zuorro et al., 2014
Artichoke*	N. D	7.06	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Claus et al., 2015
Artichoke*	0.38	0.33	N. D	N. D	N. D	N. D	N. D	N. D	N. D	Palermo et al., 2013
Artichoke*	113.58	N. D	N. D	39.04	N. D	N. D	51.40	N. D	N. D	Heidarian et al., 2013
Artichoke*	38.90	N. D	N. D	313.7	N. D	N. D	50.38	N. D	N. D	Emanuel et al., 2011

N. D = Not detected

* Artichoke taxa not identified

3.2 Statistical analysis

The analysis of variance (ANOVA) for the total phenolics, flavonoids, and antioxidant activity were illustrated by letters in Figures (4-6). As shown in Figure 4, there is no statistical difference between the outer bracts of Artichoke Egyptian "Baladi" and French "Hyrious" due to the p value was found to be 0.38. This could be attributed to a low difference among the mean values of the total phenolics for the two taxa. However, highly significant difference of the mean value of total phenolics between the two taxa in Leaves due to the p value is <0.001, also significant difference was found in case of stems part of the artichoke for the taxa ($p = 0.023$). In addition, a statistically significant difference between the non-edible parts of the Egyptian artichoke was found ($P < 0.001$) as well as between the French artichoke non-edible parts ($p = 0.03$). While for the total flavonoids in the outer bracts, significant difference between the two taxa, Egyptian "Baladi" and French "Hyrious", was shown in figure 5 due to the $p = 0.01$. The same trend of the difference for the stems and leaves were proved due to the p values were estimated to be <0.001 in both cases. Moreover, statistical analysis for the total antioxidant capacity was illustrated in figure 6 and it shows that only significant difference between the two taxa in the stems part of artichoke due to the p value is less than 0.001. In case of the outer bracts and leaves between the two taxa, the p values were found to be 0.873, and 0.088 respectively. Therefore, no significant difference was found for those non-edible parts of two taxa artichoke. It is interesting to know that significant difference between the non-edible parts for the taxa was shown due to the p value is less than 0.001.

Statistically significant differences in the total phenolic, flavonoids and antioxidant activity of artichoke by-product samples were evaluated using a multiple sample comparison procedure (ANOVA) that compared two or more independent samples of variable data. A pairwise multi comparison between the stems and leaves versus the outer bracts for the two taxa were performed. The results show that in case of Egyptian artichoke, significant differences were found between the outer bracts and both stems and leaves ($p = 0.002$ and $p < 0.001$, respectively). But, between the stem and leaves, no significant difference was observed ($P = 0.191$) for the total antioxidants.

4. Conclusion

In this study, artichoke by-products (leaves, stems, and outer bracts) are rich with flavonoids and phenolics that could be a cheap and a good source of natural antioxidants. The antioxidants of the two taxa of artichokes; Egyptian "Baladi" and French "Hyrious" have been evaluated and compared with each other and with the literature. For instance, outer bracts of Egyptian "Baladi" and French "Hyrious" artichoke contained significantly higher total phenolics concentration and antioxidant activity than those of leaves and stems of the two varieties. On the other hand, the stems of both varieties showed the highest flavonoids concentration, followed by leaves and outer bracts. In conclusion, non-edible parts (waste) of the artichoke are a natural source of phenolic compounds with high antioxidant activity. Therefore, the use of non-edible part (by-products) of artichoke (mostly leaves, stems and outer bracts) as an environmentally friendly natural source of phenolic, antioxidants and flavonoid

compounds and an economically viable solution to the problem of solid waste treatment. In addition, artichoke grown in Egypt is a rich source of natural phenolics with strong antioxidant activities. Further work is in progress to evaluate their antimicrobial and anticancer activities.

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