

Bioactive Compounds and Antioxidant Potential of Food Industry By-products in Egypt

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Abstract The present study was carried out to examine the bioactive compounds and antioxidant potential of four food industry by-products (potato peel, cauliflower leaves, onion skin and mango peel) in Egypt. The total dietary fiber content for all tested by-products was ranged 27.15-42.71 g.100g⁻¹, total carotenoids was 92.43- 412.14 mg.100g⁻¹ and total phenolics was 1104-7129 mg GAE.100 g⁻¹. The mango peel powder (MPP) was recorded the highest content of total dietary fiber and total carotenoids while red onion skin powder (ROSP) recorded the highest values of total phenolics. The food by-product extracts showed considerable differences in antioxidant activity when it was calculated by the four different methods used in this study. The antioxidant value (AOX, A/h), antioxidant activity (AA,%), oxidation rate ratio (ORR) and Antioxidant activity coefficient (AAC) were ranged 0.017-0.106, 81.23-96.98, 0.030-0.187 and 584.46-858.27, respectively. ROSP showed strong antioxidant activity followed by MPP, PPP and CLP, respectively. Correlation analysis indicated that there were a strong positive significant relationship ($r^2 = 0.741-0.962$, $p \leq 0.01$) between total phenolics content and antioxidant activity and a positive significant relationship ($r^2 = 0.604-0.718$, $p \leq 0.05$) between total carotenoids content and antioxidant activity in all tested by-products. These correlations confirm that phenolic compounds mainly with carotenoids partially are responsible for the antioxidant activity of the tested by-products. In conclusion, data of the present study revealed that food industry by-products can be good sources of valuable bioactive compounds and antioxidants subsequently extend their potential uses in nutritional and therapeutic applications.

Keywords: potato peel, cauliflower leaves, onion skin, mango peel, phenolics, carotenoids, dietary fiber

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1. Introduction

Food industry is probably one of the largest, if not the largest, industrial activities in Egypt. It plays a major role in the supply of the food needs of the Egyptian population (about 90 millions in 2015). Recently, it was reported that 39% of food waste is produced by the food manufacturing industries in developed countries including Egypt [1]. The large amount of waste produced by the food industries causes serious environmental problems and also results in economic losses if not utilized effectively [2,3,4]. Additionally, the costs to dry, store and ship food by-products are economically limiting factors [5]. Thus, different research reports have revealed that food industry by-products can be good sources of potentially valuable bioactive compounds. In Egypt, some major source of food industry by-products are potatoes, cauliflower, onion and mango some of the most popular vegetables and fruits.

Mango (*Mangifera indica* L.) is one of the major tropical fruits and the world's annual production is 25 MMT [6]. Mango puree, slices in syrup, nectar, leather, pickles, canned slices and chutney are the main industrial products obtained from mango fruits [7]. The major by-

products from mango processing are peels and seeds. Depending on the cultivars and products made, its industrial by-products, namely peels and seeds, represent 35–60% of the total weight of the fruit [8].

Potato (*Solanum tuberosum* L.) is the largest vegetable crop worldwide, amounting to approximately 320 million metric tons annually [9]. Processing of potatoes (mainly for the production of chips, French fries, and dehydrated products) has presented a steady increase during the last decades, exceeding considerably the amount of the vegetable consumed as fresh [5,10,11]. Solid waste generated during processing consists mostly of potato peels but also contains green, immature, and cull potatoes and amounts to 15–45% depending on the procedure applied [5].

Onions (*Allium cepa* L.) are the second most important horticultural crop worldwide, after tomatoes, with current annual production around 66 million tonnes. Over the past 10 years, onion production has increased by more than 25% [12]. The main onion waste include onion skins, two outer fleshy scales and roots generated during industrial peeling and undersized malformed or damaged bulbs [13].

Cauliflower (*Brassica oleracea* var. botrytis) belongs to cruciferous family *Cruciferae* (Brassicaceae), which comprises also: cabbage, broccoli, Brussels sprouts, turnip,

Swedish turnip. Cauliflower leaves considered as a waste by-product which obtained it during processing (freezing and cooking) of Cauliflower, huge amount of leaves is generated, and its disposal is a major problem and causes environmental pollution [14]. Leaves constitutes about 40-50% of cauliflower fruit.

This paper examines the bioactive compounds and antioxidant potential of these four food industry by-products (potato peel, cauliflower leaves, onion skin, and mango peel) in a trial to extend their potential uses in nutritional and therapeutic applications.

2. Materials and Methods

2.1. Materials

Red onion skin (ROS) was obtained from the New Beni Suef company for Preservation, dehydration and Industrialization of Vegetables, Beni Suef Elgudida City, Nile East, Beni Suef; potato peel (PP) from SFCO for Manufacturing and Export Agricultural Products, El Negila, Kom Hamada, Behira Government; mangoes (*Mangifera indica* L. cv Copania) fruits used for mango peels preparation from a local farm, Ismalia Road (El-Salhyia), Sharqia Governorate and cauliflower (*Brassica oleracea* L. cv Copania) leaves from Shebin ElKom market, Menoufiya Governorate, Egypt during the 2014 harvesting period. The collected samples were transported to the laboratory and used immediately for by-products powder preparation.

All chemicals and buffers, except stipulated, were in analytical grade and purchased from Al-Gomhoria Company for Drugs, Chemicals and Medical Instruments, Cairo, Egypt.

2.2. Methods

2.2.1. Preparation of Food by-products Peel Powder

(i). Mango peel powder (MPP)

Unripe mango peel were soaked in 0.1% sodium metabisulphite solution for 30 min, washed, sliced and dried in two stages at 60°C for 12 and 40°C for 12 hours in hot air oven (AFOS Mini Smoker, England). This is followed by milling with grinder (Retsch Micro Universal Bench Top Grinder, Germany) to produce the respective flour types.

(ii). Red onion skin powder (ROSP) potato peel powder (PPP)

Red onion skin and potato peel were washed and then dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc., Philadelphia, PA) at 55°C for 14. The dried peels were ground into a fine powder in high mixer speed (Moulinex Egypt, Al-Araby Co., Egypt). The material that passed through an 80 mesh sieve was retained for use.

(iii). Cauliflower leaves powder (CLP)

Cauliflower leaves were washed and then dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc., Philadelphia, PA) at two stages 50°C for 6 hrs followed by 40°C for 10 hrs. The dried peels were ground into a fine powder in high mixer speed (Moulinex Egypt, Al-Araby Co., Egypt). The material that passed through an 80 mesh sieve was retained for use.

2.2.2. Determination of Chemical Composition

By-product samples were analyzed for moisture, protein (T.N. \times 6.25, micro - kjeldahl method using semiautomatic apparatus, Velp company, Italy), fat (soxhelt miautomatic apparatus Velp company, Italy, petroleum ether solvent), ash and fiber contents were determined using the methods described in the A.O.A.C. [15]. Carbohydrates calculated by differences:

$$\text{Carbohydrates (\%)} = 100 - \left(\begin{array}{l} \% \text{ moisture} + \% \text{ protein} \\ + \% \text{ fat} + \% \text{ Ash} + \% \text{ fiber} \end{array} \right)$$

2.2.3. Determination of Total Phenolics, Carotenoids And Dietary Fiber

Total phenolics, carotenoids and total dietary fiber in selected by-products samples were analyzed as follow: By-products samples were extracted with 80% acetone and centrifuged at 10,000g for 15 min at room temperature. The supernatants obtained were used for the analysis of total phenolics, carotenoids and antioxidant activity.

Total phenolics were determined using Folin-Ciocalteu reagent [16]. Two hundred milligrams of sample was extracted for 2 h with 2 mL of 80% MeOH containing 1% hydrochloric acid at room temperature on an orbital shaker set at 200 rpm. The mixture was centrifuged at 1000g for 15 min and the supernatant decanted into 4 mL vials. The pellets were combined and used for total phenolics assay. One hundred microliters of extract was mixed with 0.75 mL of Folin-Ciocalteu reagent (previously diluted 10-fold with distilled water) and allowed to stand at 22°C for 5 min; 0.75 ml of sodium bicarbonate (60g/L) solution was added to the mixture after 90 min at 22°C, absorbance was measured at 725 nm. Results are expressed as gallic acid and equivalents. The total carotenoids in 80% acetone extract were determined by using the method reported by Litchenthaler, [17]. Total dietary fiber content in the MPP was estimated according to the method described by Asp *et al.*, [18].

2.2.4. Determination of Antioxidant Activity

Antioxidant activity of tested by-products extracts and standards (α -tocopherol and BHT; Sigma Chemical Co., St. Louis, Mo) was determined according to the β -carotene bleaching method following a modification of the procedure described by Marco, [19]. For a typical assay, 1mL of β -carotene (Sigma) solution, 0.2 mg/mL in chloroform, was added to round-bottom flasks (50 mL) containing 0.02 mL of linoleic acid (J.T. Baker Chemical Co., Phillipsburg, NJ) and 0.2 mL of Tween 20 (BDH Chemical Co., Toronto, On). Each mixture was then dosed with 0.2 mL of 80% MeOH (as control) or corresponding plant extract or standard. After evaporation to dryness under vacuum at room temperature, oxygenated distilled water (50 ml) was added and the mixture was shaken to form a liposome solution. The samples were then subjected to thermal autooxidation at 50°C for 2 h. The absorbance of the solution at 470 nm was monitored on a spectrophotometer (Beckman DU-50) by taking measurements at 10 min intervals, and the rate of bleaching of β -carotene was calculated by fitting linear regression to data over time. All samples were assayed in triplicate. Various concentrations of BHT, BHA, and α -tocopherol in 80% methanol was used as the control.

Antioxidant activity was calculated in four different ways. In the first, absorbance was plotted against time, as a knit curve, and the absolute value of slope was expressed as antioxidant value (AOX). Antioxidant activity (AA) was all calculated as percent inhibition relative to control using the following equation [20].

$$AA = (R_{\text{control}} - R_{\text{sample}}) / R_{\text{control}} \times 100$$

Where: R_{control} and R_{sample} were the bleaching rates of beta-carotene in reactant mixture without antioxidant and with plant extract, respectively.

The third method of expression based on the oxidation rate ratio (ORR) was calculated according to the method of Marinova *et al.*, [21] using the equation:

$$ORR = R_{\text{sample}} / R_{\text{control}}$$

Where: R_{control} and R_{sample} are the same in the previous equation.

In the fourth method, the antioxidant activity coefficient (AAC) was calculated as described by Mallet *et al.*, [22].

$$(AAC) = (Abs_{S120} - Abs_{C120}) / (Abs_{C0} - Abs_{C120}) \times 1000$$

Where: Abs_{S120} was the absorbance of the antioxidant mixture at time 120 min, Abs_{C120} was the absorbance of the control at time 120 min, Abs_{C0} was the absorbance of the control at zero time.

2.2.5. Statistical Analysis

All measurements were done in triplicate and recorded as mean \pm SD. Statistical analysis was performed with the Student *t*-test and MINITAB 12 computer program (Minitab Inc., State College, PA).

3. Results and Discussion

3.1. Chemical Composition of Selected Food by-products

The proximate composition of food by-products is shown in Table 1. The results showed that the moisture content was ranged 3.62- 6.12%, total protein was 3.07-12.57%, crude fat was 0.99-9.95%, crude fiber was 10.38-24.89%, ash content was 2.92-6.89% and total carbohydrate content was 49.74-74.64%. The CLP was recorded the highest values of crude fat, crude fiber and ash. The proximate composition reported was not accordance with that observed by Ajila *et al.*, [23] regarding the MPP. In potato peel, Hanan, [24] found that the chemical composition of dried potato peels were ash, 9.42%; total protein, 9.2%; total dietary fiber, 11.7%; fat, 0.1% and total carbohydrate, 11.7%. Also, potato peels contained 21.6% dry matter in raw material and 2.0% acid detergent fiber in dry matter, [25]. Also, Block *et al.*, [26] found that abrasion peeled contained 2.5% moisture, 10.5% protein, 9.0% starch, 20.6% crude fiber, 5.0% ash, 78% dietary fiber, 0.0% phytic acid and 0.0% fat. In similar study carried out recently by Ahmed [27] found that PPP was recorded the highest content of protein while ROSP recorded the highest values of moisture, crude fat, crude fiber and ash. Regarding the cauliflower leaves and onion skin, there is a dearth of information related to its chemical composition which makes the comparison and confirmation the present data is relatively difficult. In addition to the type of plant by-product, Vasso and Constantina, [11] reported that varieties of plant affected well on the chemical composition of peels. Data of the present study with the others confirmed that such tested food by-product could be used successfully in food technology and nutritional applications due to their high nutritional value, good sources for protein, fiber and ash.

Table 1. Proximate chemical composition (g.100g⁻¹) of food by-products

Parameter	PPP	CLP	ROSP	MPP
Moisture	6.12 \pm 0.11 ^a	3.62 \pm 0.56 ^b	5.48 \pm 0.33 ^a	6.04 \pm 1.05 ^a
Total protein	10.21 \pm 1.33 ^b	12.57 \pm 1.32 ^a	3.07 \pm 0.09 ^d	4.13 \pm 0.74 ^c
Crude fat	0.99 \pm 0.13 ^d	2.63 \pm 0.78 ^b	9.95 \pm 1.41 ^a	1.55 \pm 0.16 ^c
Crude fiber	14.39 \pm 1.65 ^b	13.05 \pm 1.07 ^b	24.87 \pm 3.12 ^a	10.38 \pm 1.25 ^c
Ash	4.15 \pm 0.21 ^b	2.92 \pm 0.37 ^{bc}	6.89 \pm 1.06 ^a	3.26 \pm 0.89 ^{bc}
Carbohydrates (by difference)	64.14 ^b	65.21 ^b	49.74 ^c	74.64 ^a

^c Each value represents the mean of ten replicates \pm SD. Mean values with the different letters in the same raw mean significantly different at level $p \leq 0.05$.

Table 2. Total dietary fiber, carotenoids and phenolics contents of food by-products

Parameter	PPP	CLP	ROSP	MPP
Total dietary fiber (g.100g ⁻¹)	39.18 \pm 2.98 ^a	27.15 \pm 1.99 ^b	25.91 \pm 2.76 ^b	42.71 \pm 2.09 ^a
Total carotenoids (mg.100g ⁻¹)	130.35 \pm 6.84 ^b	154.84 \pm 7.04 ^b	92.43 \pm 8.14 ^c	412.17 \pm 20.63 ^a
Total phenolics (mg GAE.100 g ⁻¹)	2077 \pm 141 ^c	1104 \pm 170 ^d	7129 \pm 398 ^a	5984 \pm 367 ^b

^c Each value represents the mean of ten replicates \pm SD. Mean values with the different letters in the same column mean significantly different at level $p \leq 0.05$.

3.2. Total Dietary Fiber, Carotenoids and Phenolics Contents of Selected Food by-products

Total dietary fiber, carotenoids and phenolics contents of selected food by-products are shown in Table 2. The results showed that the total dietary fiber content was ranged 27.15-42.71 g.100g⁻¹, total carotenoids was 92.43-412.14 mg.100g⁻¹ and total phenolics was 1104-7129 mg EGA.100 g⁻¹. The MPP was recorded the highest content of total dietary fiber and total carotenoids while ROSP

recorded the highest values of total phenolics. In similar studies, Ajila *et al.*, [23,28] found that polyphenol, carotenoid and dietary fiber contents in raw and ripe peels of Raspuri and Badami mango varieties, which ranged from 55 to 110 mg GAE/g, 387 to 3337 mg/g, 44 to 78%, respectively. Thus, total carotenoid and SDF contents determined in the present study were higher than that reported by the others. Finally, studying the bioactive compounds in PPP, MPP and OSP showed that the total dietary fiber content was ranged 47.87-64.80 g.100g⁻¹, total carotenoids was 89-348 mg.100g⁻¹ and total phenolics was 1679-8946 mg EGA.100 g⁻¹ in [27].

Data of the present study with the others confirmed that such tested by-product could be constituted central position in nutritional/pharmaceutical applications through their high content of bioactive compounds. In this concern, Al-Weshahy and Rao [29] reviewed that dietary fiber is well known as a bulking agent, increasing the intestinal mobility and hydration of the feces. Several authors have reviewed the importance of consumption of moderate amounts of dietary fibers for human health [30-31]. Scientifically speaking, dietary fiber is a broad term that includes several carbohydrates; cellulose, hemicelluloses, lignins, pectins, gums etc. [32]. Camire *et al.*, [33] reported that potato peel fibers are primarily insoluble, and can bind bile acids *in-vitro*. It is believed that binding of bile acids is one of the mechanisms whereby certain sources of dietary fibers lower plasma cholesterol. Lazarov and Werman, [34] studied the hypocholesterolemic effect of dietary fiber from PP and found that after four weeks of feeding on potato peels, rats showed 40 % reduction in plasma cholesterol content and 30% of hepatic fat cholesterol levels were reduced as compared with animals fed only with cellulose supplemented diet. Defects of dietary fiber on lipid-profile influence several health related issues. High concentrations of low-density lipoprotein (LDL) cholesterol, other dyslipidemia (high concentration of triglycerides and low concentration of

high-density lipoprotein [HDL] cholesterol), leads to blood platelets aggregation [35], risk factors for cardiovascular diseases (CVD) [36], and hypertension [37]. Moreover, high intake of dietary fibers has a positive influence on blood glucose profile and it is related health complications, in healthy and diabetic individuals of both types. By altering the gastric emptying time, dietary fibers are able to affect the absorption of other simple sugars. The effect of dietary fibers on blood glucose and insulin response has been demonstrated by many other authors as well [29,38]

3.3. Antioxidant Activities of Selected Food by-products

The antioxidant activities of four food by-products are shown in Table 3. From such data it could be noticed that the by-product extracts showed considerable differences in antioxidant activity when it was calculated by the four different methods used in this study. The antioxidant value (AOX, A/h), antioxidant activity (AA,%), oxidation rate ratio (ORR) and Antioxidant activity coefficient (AAC) were ranged 0.017-0.106, 81.23-96.98, 0.030-0.187 and 584.46-858.27, respectively. ROSP showed strong antioxidant activity followed by MPP, PPP and CLP, respectively.

Table 3. Antioxidant activity of tested food by-products

Samples	Antioxidant value ^{a*}		Antioxidant activity ^{b*}		Oxidation rate ratio ^{c*}		Antioxidant activity coefficient ^{d*}	
	AOX (A/h)		AA (%)		(ORR)		(AAC)	
PPP	0.085±	0.027 ^c	85.04±	8.78 ^c	0.149±	0.040 ^b	650.70±	70.01 ^c
CLP	0.106±	0.02 ^b	81.23±	9.22 ^d	0.187±	0.017 ^b	584.46±	62.89 ^d
ROSP	0.017±	0.009 ^c	96.98±	4.22 ^a	0.030±	0.013 ^d	858.27±	92.35 ^a
MPP	0.044±	0.016 ^d	92.17±	12.71 ^b	0.078±	0.029 ^c	774.65±	83.35 ^b
Control	0.565±	0.023 ^a	0.00±	0.00 ^c	1.000±	0.116 ^a	0.00±	0.00 ^e
α -tocopherol, 50 mg/L	0.007±	0.002 ^f	98.79±	7.15 ^a	0.012±	0.009 ^e	889.73±	95.74 ^a

^{a*} Antioxidant value (AOX, A/h) = The absolute value of slope (Abs was plotted against time).

^{b*} Antioxidant activity (AA, %) = (R control - R sample) / R control x 100 where: R control and R sample were the bleaching rates of beta-carotene in reactant mixture without antioxidant and with plant extract, respectively

^{c*} Oxidation rate ratio (ORR) = R sample / R control

^{d*} Antioxidant activity coefficient (AAC) = (Abs S 120 - Abs C 120) / Abs C 0 - Abs C 120) x 1000 where: .Abs S 120 was the absorbance of the antioxidant mixture at time 120 min, Abs C 120 was the absorbance of the control at time 120 min, Abs C 0 was the absorbance of the control at zero time.

* Each value represents mean \pm SD. Values with the different letters in the same column are significantly different P \geq 0.05.

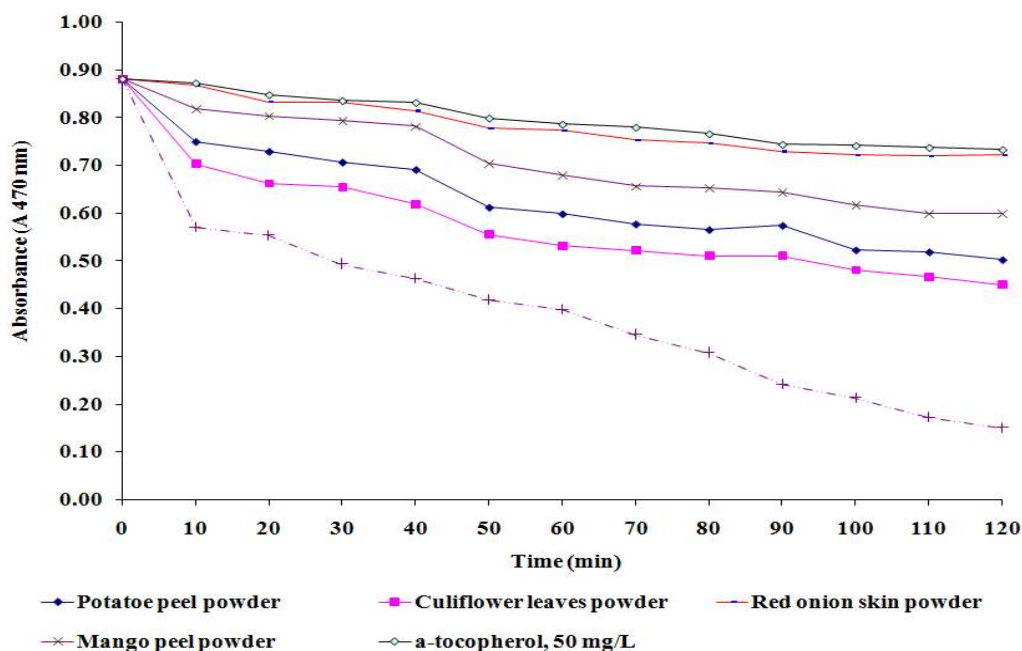


Figure 1. Activity of food by-products added to meat balls processed samples assayed by the β -carotene bleaching method (α -tocopherol at 50 mg/L concentration was used as a reference)

The decrease in absorbance of β -carotene in the presence of different methanolic plant by-products extracts (and well-known antioxidants used as standards) with the oxidation of β -carotene and linoleic acid is shown in Figure 1. Such data indicated that ROSP recorded the lowest decreasing followed by MPP, PPP and CLP, respectively. The values of ROSP absorbance through 120 min are coming well i.e. closing the line of 50 mg/L of α -tocopherol followed by the rest food by-products. These data proved the high stability of the all tested plant by-products when comparing with that more common standard α -tocopherol.

Many similar studies indicated that big differentiations have been recorded amongst different vegetables by-products. For example, Kumar *et al.*, [39] and Onyeneho and Hettiarachchy [40] reported that the peels from the red potatoes contained more polyphenols than those from

the brown-skinned varieties. Furthermore it was shown that the peel and the pulp of the tubers contain nine phenolic acids differed in their concentrations and appeared to be mainly responsible for the strong antioxidant activities of the peel extracts. El-Saadany, [41] found that the mean of phenolic acids content was 2439.21 ± 113.8 mg/100 g extract of potato peel. Also, Elhassaneen *et al.*, [42] indicated that the antioxidant activities of control and enriched MPP biscuits. The antioxidant activity (AA) in control biscuits was 31.34% which increased to 37.92 and 45.12% with the incorporation of MPP by 5 and 10%, respectively. MPP enriched biscuits showed strong activity probably due to its high bioactive compounds (carotenoids and phenolics) content. The same date and antioxidant behavior for ROSP, and PPP are recorded by Shalaby, [43] and Ahmed, [27].

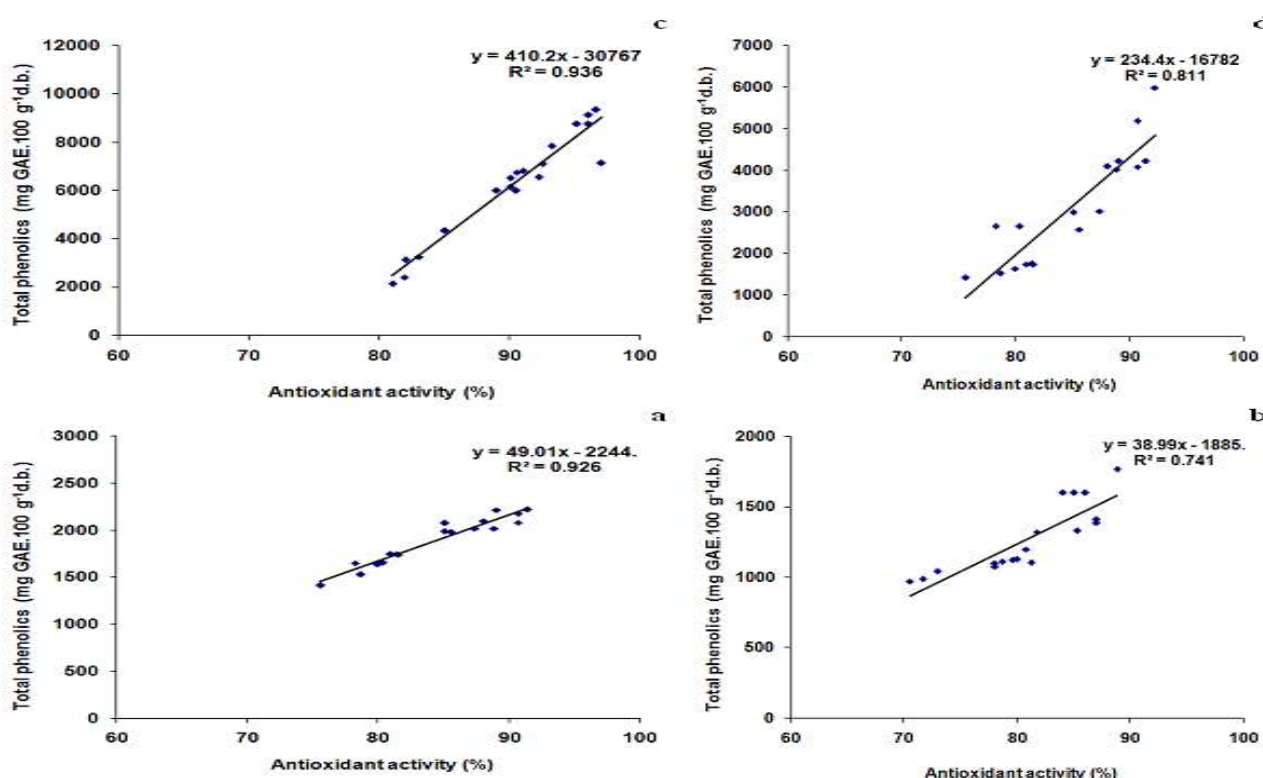


Figure 2. Correlation between total phenolics content detected and antioxidant activity of tested by-products: (a) PPP, (b) CLP, (c) ROSP, and (d) MPP

3.3. Relationship between Phenolics, Carotenoids and Antioxidant Activity

In the correlation analysis, important differences were found between phenolics, carotenoids and antioxidant activity of food by-products (Figure 2-Figure 3). When all food by-products were included in the statistical analysis, there was a strong positive significant ($p \leq 0.05$) relationship between total phenolics content in PPP ($r^2 = 0.962$), CLP ($r^2 = 0.741$), ROSP ($r^2 = 0.936$), MPP ($r^2 = 0.811$), and antioxidant activity. Also, a positive significant ($p \leq 0.05$) relationship between total carotenoids content in PPP ($r^2 = 0.604$), CLP ($r^2 = 0.648$), ROSP ($r^2 = 0.619$), MPP ($r^2 = 0.718$), and antioxidant activity. These correlations confirm that phenolic compounds mainly with carotenoids partially are responsible for the antioxidant activity of the tested by-products. In similar study, Velioglu *et al.*, [44] reported that the correlation coefficient

between total phenolics and antioxidative activities of 28 plant products, including sunflower seeds, flaxseeds, wheat germ, buckwheat, several fruits, vegetables, medicinal plants and plant by-products was statistically significant. Also, positive and significant ($p < 0.01$) relationship between total phenolics and antioxidant activity in different plant parts including food by-products was reported by El-Mokadem, [45], Hegazy, [46], and Abou-Elella and Ali [47]. On the other side, data of the present study indicated that many other bioactive compounds beside phenolics and carotenoids such as vitamins, fibers, minerals etc. probably contribute in the antioxidant activity of the tested by-products. This information was confirmed by Osuna-Martínez *et al.*, [48] who reported that antioxidant properties that has been proposed by having interesting antioxidant activity and protective capacities due to the presence of components such as vitamins C and E, phenolics and other non-nutrient substances in *Opuntia ficus indica* (L).

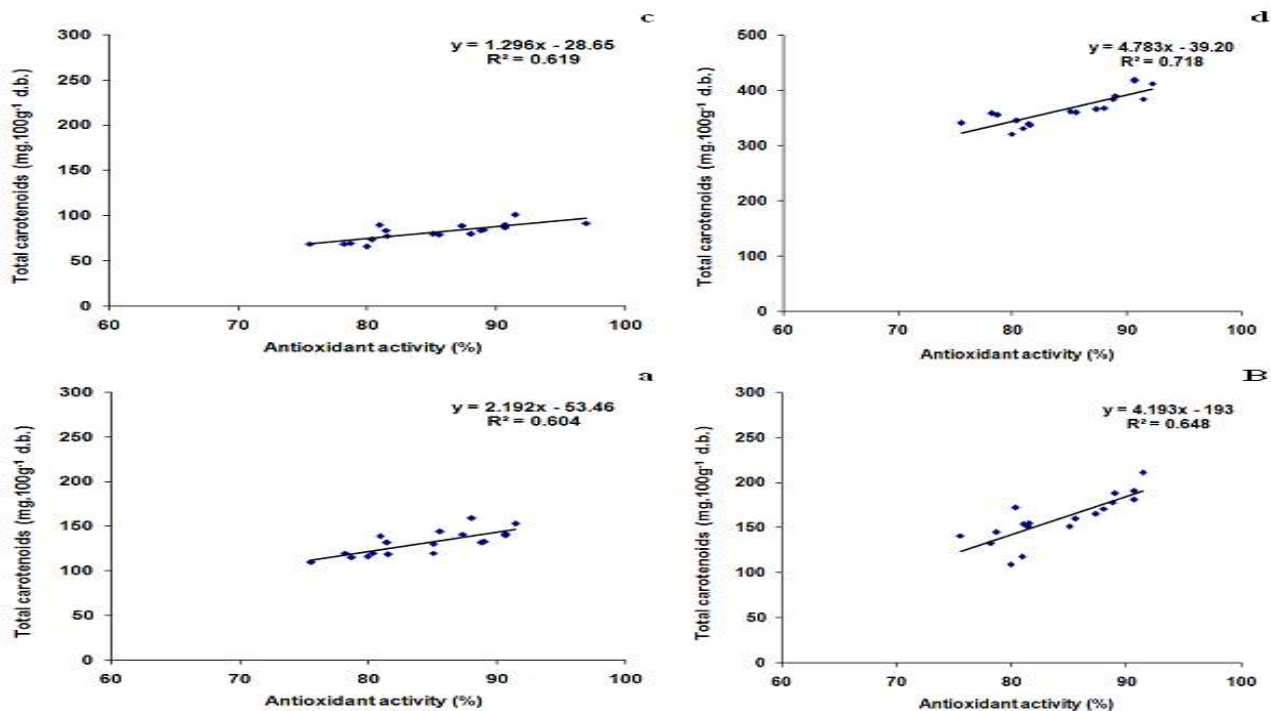


Figure 3. Correlation between total carotenoids content detected and antioxidant activity of tested by-products: (a) PPP, (b) CLP, (c) ROSP, and (d) MPP

4. Conclusion

In conclusion, data of the present study revealed that food industry by-products can be good sources of valuable bioactive compounds and antioxidants subsequently extend their potential uses as natural antioxidants in nutritional and therapeutic applications. Synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have been used as antioxidants since the beginning of the last century. Restrictions on the use of these compounds, however, are being imposed because of their toxicity/carcinogenicity [49-51]. Thus, the interest in natural antioxidants has increased considerably.

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Statement of Competing Interests

Authors have no competing interests.

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