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Comparative Study between the Bioactive Compounds and Antioxidant Activity of Broccoli and Cauliflower and the Effect of Domestic Processing on Them

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Abstract:
This study was performed to determine and compare the contents of some bioactive compounds of broccoli (Brassica oleacea var italica) and cauliflower (Brassica oleracea var. botrytis) as well as their antioxidant activities. Also, the effect of several domesting processing methods (blanching in hot water, steaming and microwave) on the studied bioactive contents was investigated. Data of study confirmed that fresh broccoli had higher amounts of β- carotene, vitamin A and vitamin C, total polyphenolic compounds, folic acid and glucosinolates than those of fresh cauliflower. Broccoli and cauliflower contained 4952.93, 1633.18µg/g, 8254.88, 2721.96IU/100g,869.34,575.84mg/100g, and1105.00,633.00mg/100g of β- carotene, vitamin A, ascorbic acid and total polyphenols on dry weight basis, respectively. Antioxidant activity of fresh broccoli (70.29%) was higher than that in fresh cauliflower (40.89%). More over fresh broccoli contained higher amount of glucosinolates, being 12.29 µM/g comparing with those of fresh cauliflower which were10.36 µM/g (on dry weight). Fresh broccoli contained higher amount of folic acid than that of the cauliflower. Folic acid content was 3033.75 µg/100g in fresh broccoli and it was 2168.52 µg/100g in fresh cauliflower (on dry weight). Steaming method caused the lowest reduction in all studied bioactive components in both broccoli and cauliflower,meanwhile blanching in boiled water caused the higher reduction in them .The studies of chlorophyll and its derivatives content showed that fresh broccoli contained high amounts of total chlorophyll being 1102.4 mg/100g with 496.8 and 605.4 mg/100g (on dry weight basis) for chlorophyll a, b, respectively, a significant reduction in total chlorophyll and chlorophyll a and b was recorded as a result of processing. Steamed method led to the lowest reduction in them among the three processing methods, while chlorophyll was not detected in cauliflower samples.

Keywords: *Broccoli, Cauliflower, β- carotene,Ascorbic acid, Total Polyphenols, Folic acid, Glucosinolate, Chlorophylls, Antioxidant activity, Processing.*

1. Introduction

Brassica vegetables belong to *Brassicaceae* family, which include different genus of broccoli, cabbage, cauliflower and others. Broccoli (*Brassica oleracea* sp. *Italica*), and cauliflower (*Brassica oleracea* var. *botrytis*) are widely grown and consumed. In temperate climates,their supply is limited to a few months of the year. In order to provide year-round availability, various storage conditions improving shelf-life and processing are used [1] [2] [3]. These vegetables posses both antioxidant and anticarcinogenic properties [4]. Epidemiological studies have shown an inverse association between the consumption of Brassica vegetables and the risk of cancer [5] [6], this protective effect has largely been attributed to the antioxidant power and the complement of phytochemicals, in broccoli and cauliflower which include vitamins C and E,thiamin, riboflavin, nicin, calcium, iron, phosphorous, selenium, flavonols quercetin, kaempferol, β- carotene, lutein, glucosinolates and indole-3- carbinol [7], [8]. It may be The combination of nutrients and other substances rather than the individual nutrients themselves, which provides the health enhancing effects of vegetables [9]. Vegetables are commonly cooked before being consumed. It is known that cooking or processing induce

significant changes in the chemical composition, reducing vitamins and other thermolabile compounds that may undergo oxidative degradation or be leached into the water during processing [10].
Balletin of the agric. Satatistics [11] reported that, in Egypt cauliflower is well known and commonly consumed since, the amount of cultivated aria reached 8970 fedan and the annual production was 11317 ton in year 2011. Oppositely, broccoli is recently known in Egypt in the last few years, where are annual cultivated area is 74 fedan and the annual production 1258 tons. The aim of this study was to evaluate and compare the contents of the bioactive compounds (vitamin C and A, β-carotene, total polyphenolic compounds, glucosinalates, folic acid, chlorophylls as well as total antioxidants of fresh broccoli and cauliflower. Also the effect of three common domestic processing (i.e., blanching in hot water, steaming and microwaving) on the previous bioactive compounds.

2. Materials and Methods

2.1. Plant Material and Reagents

Broccoli (*Brassica oleracea* var. *italica*) was purchased from a farm in Housh Eissa (El Behira Province, Egypt) and cauliflower (*Brassica oleracea* var. *botrytis*) was purchased from local market in Alexandria, Egypt and used directly in fresh form. All chemicals used for study were purchased from Sigma (St Louis, MO, Germany).

2.2. Processing of Broccoli and Cauliflower

The samples of the studied vegetables were undertaken for processing directly from the field. Each of broccoli and cauliflower samples were washed and then were cut into flowers of 2-3 Cm length from the top of the stem (florets). The florets were divided into 4 parts and the process was completed as following:-.
Pre-experiments were carried out as trails to adjust the optimum conditions for preparing the blanched broccoli and cauliflower according to the judgment of 12 semi trained panalists for estimating the minimum blanching time to reach tenderness for an adequate palatability and taste according to the Egyptian habits.

1- Blanching in boiling water: - broccoli or cauliflower samples (50 g of each samples) was put in 500 ml of boiling water and blanched for (4,6 and 8 min) . Then each of the blanched broccoli and cauliflower samples were put in iced water for 1 min. to prevent over cooking. Samples from fresh and cooked were stored in polypropylene bags at (16 – -18˚C) until used for analysis.

2- Steaming process:- 50 g of florets samples (broccoli or cauliflower) were steamed on boiling water vapor for (12,14 and 16 min) Also the steamed samples were cooled in iced water for I min. to prevent over cooking.

3- Microwaving process:- 50 g of florets of each of broccoli and cauliflower samples were put in microwave oven (model: Micro-Chef FM 2935Q) containing 200 ml boiling water for (2,4 and 6 min) Similarly as mentioned above the samples were cooled in iced water for 1 min. to prevent over cooking.

It was found that optimum conditions were : blanching in boiling water for 6 min, steaming for 12 min and microwaving for 4 min for both of broccoli and cauliflower.

2.3. β-carotene Determination

β-carotene was extracted and determined according to the method described by Ismail and Fun [12] . Sample (10 g) was added to 40 ml of 99.8% ethanol and 10 ml of 100% (w/v) potassium hydroxide, and homogenized for 3 min using a blender. The mixture was saponified by means of a refluxing apparatus, and heated using a heating mantle for 30 min, and then cooled to room temperature. The mixture was frequently agitated to avoid any aggregation. For the extraction step, the mixture was transferred into a separation funnel and 50 ml of n-hexane was added. The upper layer (hexane extract) was pipetted out, and the aqueous layer was re-extracted twice, each time with 50 ml of n-hexane. Then, the upper layer was pooled and washed with distilled water until free of alkali. Phenolphthalein solution (1%) was used to check for any alkali. The presence of alkali turns this indicator to pink. The extract was then filtered through anhydrous sodium sulphate to remove any water residue. The hexane residue was removed under reduced pressure at 45°C using a rotary evaporator the resulting extract was diluted to 10 ml with n-hexane and used to dtermination of β-carotene by high performance liquid chromatography (HPLC) C18 column ODS reversed phase UV detector at 280, flow rate 1 ml/min, CR4A chromatopac, SCL 6AV system controller, CTO 6A column oven, SPD 6AV UV-visible detector and LC 6AV pump.
The β-carotene composition was determined by the area percentage and confirmation of β-carotene was performed by comparison of standard β-carotene with retention time.

2.4. Vitamin A Determination

The vitamin A was calculated according to Srivastava and Kumar[13] by the following equation:

$$\text{Vitamin A (IU)} = \frac{\beta\text{-Carotene } (\mu g/100g)}{0.6}$$

2.5. Ascorbic Acid Determination

Ascorbic acid was determined using 2,6 dichlorophenolindophenols dye (the dye from BDH company) according to AOAC standard methods [14] method (No. 767.21, 2003), except that 4% oxalic acid in 8% glacial acetic acid was used as an extraction media for samples according to Plummer[15] .

2.6. Phenolic Compounds Determination

Phenolic compounds content were determined calorimetrically as tannic acid by Folin-Denis reagent method after extraction with methanol containing 0.1% HCl. according to AOAC standard methods [14]

2.7. Determination of Antioxidant activity

Antioxidant activity was measured according to Fogalino [16] by the N, N-Dimethyl-p-phenylenediamine dihydrochloride (DMPD). Two hundred and nine mg of DMPD were dissolved in 10 ml of deionized water. One ml of this solution was added to 100 ml of 0.1 M acetate buffer (PH=5.25) then 0.2 ml of 0.05 M ferric chloride solution was added to obtain coloured radical cation (DMPD) as follows

$DMPD_{(uncoloured)} + oxidant\ (Fe^{3-}) + H^{+} \rightarrow DMPD^{\cdot+}{}_{(purple\ coloured\ radical\ cation)}\ DMPD^{\cdot+}{}_{((purple\ coloured\ radical\ cation)} + AOH_{(antioxidant\ material)} \rightarrow DMPD^{+}{}_{(uncoloured)} + AO$

One ml of this solution was directly placed in a 1 ml plastic cuvette and its absorbance was measured at 505 nm. Antioxidant compounds were extracted from samples as follows: 0.1 g of Sample extracted by 10 ml methyl alcohol and shaked for 1 hour and centrifuged after that for 15 min or filtered. A volume of 50 µl of sample extraction was added in the spectrometric cuvette contained 1 ml of DMPD solution and after 10 min the absorbance was measured at 505 nm using UNICO UV-2100 spectrophotometer. The absorbance of inhibited radical cation solution (blank) according to the equation:

$$\text{Inhibition of } A_{505}\ (\%) = (1-A_f/A_0) \times 100$$

Where:-

A_0 = The absorbance of uninhibited radical cation

A_f = The absorbance measured 10 min after the addition of antioxidant samples.

2.8. Folic Acid Determination

The folic acid was extracted and determined according to the method described by House *et al.* [17] . The samples stored in polypropylene bags at (16 – -18˚C) until analyzed. Approximately 0.5 g of sample was weighed into glass tubes with lids. Ten milliliters of an extraction buffer (20 g/L sodium ascorbate; 12.1 g/L Trizma base; pH 7.8) was added to each tube, and the tubes were topped with N_2 gas, vortexed, and placed in a boiling water bath for 60 min. After boiling, the tubes were centrifuged at 4,000 × g for 30 min. The supernatant from each tube was decanted and retained. An additional 10 mL of extraction buffer was added to each tube, and the tubes were vortexed and centrifuged as before. The supernatants were pooled, and the final volume brought to 25 mL. A sample from each flask was placed into micro centrifuge tubes and frozen at −20ºC until analyzed.

Folic acid was determined by high performance liquid chromatography (HPLC) C18 column ODS reversed phase UV detector at 280, flow rate 1 ml/min, CR4A chromatopac, SCL 6AV system controller, CTO 6A column oven, SPD 6AV UV-visible detector and LC 6AV pump. The folic acid composition was determined by the area percentage and confirmation of folic acid was performed by comparison of standard folic acid with retention time.

2.9. Total Glucosinolates (GLS)

The method used was described by Croft [18] . An enzyme active extract of white mustard seeds was prepared in the following manner, 25 g of seeds were ground in a coffee grinder and placed in a 250 ml conical flask with 200 ml distilled water then was blended in high speed blender for 2 min. The mixture was set aside in an incubator at 40˚C for 2 hrs in order to breakdown all the glucosinolates present in the extract. This extract was freshly prepared before use. After the incubation produced and just before it was used, the extract was cooled to room temperature and the acid produced was neutralized by adjusting the pH to 6.0 with 0.1 and 0.025 M sodium hydroxide. The GLs extract was prepared by blending 100 g of the plant material tested with 200 ml distilled water for 2 min. Then the extract was boiled for 5 min to inactivate the enzyme present and cooled to room temperature. The pH of the extract was adjusted to 6.0 with 0.1 and 0.025 M sodium hydroxide (Occasionally the extract had a pH above six in some samples, diluted hydrochloric acid was used to adjust the pH for these samples). Eighty milliliters of the white mustard enzyme extract were added to the complete plant material extract and mixed. The enzyme-plant material mixture was incubated at 40˚C for 2 hrs. At the end of incubation period, the mixture was cooled to room temperature and titrated with 0.025 M sodium hydroxide to pH 6.0 and the titration volume was recorded.

The total glucosinolates was calculated as µM/g (micromole/g) using the following equation:

$$\mu M/g = \frac{T \times 0.025 \times 1 \times 103}{\text{Sample weight}}$$

Where T is ml of 0.025 M sodium hydroxide recorded for final titration.

2.10. Chlorophylls

The content of chlorophyll was estimated as mentioned in AOAC standard methods [14] by measuring the absorbance of sample extraction at 643, 660 nm using UNICO UV-2100 spectrophotometer, to calibrate and adjust the instrument to zero, diethyl ether was used as a blank.

The following equations were used to calculate the chlorophyll:

Total chlorophyll, mg/liter = (7.12× O.D at 660 nm) + (16.8 × O.D at 643nm).

Chlorophyll a, mg/liter = (9.93× O.D at 660 nm) – (0.777×O.D at 643 nm).

Chlorophyll b, mg/liter = (17.6× O.D at 643 nm) – (2.81×O.D at 660 nm**).**

3. Results and Discussions

3.1. β-carotene and Vitamin A

Carotenoids are biosynthesized by bacteria, fungi and plants not by animal beings which must obtain them from their foods [19]. Carotenoids reported to confer positive health promoting effects when consumed in the diet [20] . Moreover, β-carotene is the major important source of vitamin A in the human beings [21] .

In Egypt and other developing countries, the deficiency of vitamin A and its prescure, β-carotene, is one of the major publishing health problems [22]. Tables (1,2) present β-carotene and vitamin A contents in fresh and processed broccoli and cauliflower. Fresh broccoli had 435.85 µg/100g of β-carotene and 726.42 IU/100g of vitamin A of edible parts, and 4952.93 µg/100g and 8254.88 IU/100g of them (on dry weight basis), respectively. These amounts are higher than those in fresh cauliflower (120.36 µg/100g for β-carotene and 200.60 IU/100g for vitamin A) in 100g of edible parts which are being 1633.18 µg, 2721.96 IU (on dry weight basis), respectively.

Processing methods resulted in remarkable reduction of both β-carotene and vitamin A in the studied vegetables. Steaming method caused the lowest reduction in the amounts of β-carotene and vitamin A, in broccoli and cauliflower, comparing with water boiling and microwaving methods. The percentage of the reduction was 3.42% and 3.75% for β-carotene and vitamin A in steamed broccoli and steamed cauliflower, respectively.

On the other hand the data in Tables (1,2) declare that the highest decline in β-carotene and vitamin A was for the water boiled vegetables, being 56.97% and 72.67% for broccoli and cauliflower, respectively.

Yuan *et al*. [23] reported that water boiling and stir frying significantly decreased the carotenoids in broccoli. Also, Ahmed and Ali [3] found that water boiling method caused great reduction in the β-carotene in cauliflower. Moreover, the data revealed that microwave method resulted in moderate decline in β-carotene and vitamin A for broccoli and cauliflower, respectively. The reduction in both β-carotene and vitamin A in the processed broccoli and cauliflower is due to the high sensitivity of them to light, heat, thermal time and to the microwaves [24] [25]. However, Shams El-Din *et al*. [26] reported that microwave cooking caused greater loss in β-carotene in cooked broccoli than water boiling one. On the other hand the recommended daily allowance (RDA) of vitamin A for adults is 1000 RE (retinol equivalent) [27] . So, 100g of fresh and steamed broccoli can cover almost 70% and 60% of vitamin A activity/ day for adults whereas, 100g of fresh and steamed cauliflower can cover 20% and 14.4% of vitamin A activity/day, respectively.

Method of processing	Broccoli			Cauliflower		
	On fresh weight basis	On dry weight basis	% Reduction	On fresh weight basis	On dry weight basis	% Reduction
Fresh	435.85^{a}±0.05	4952.93^{a}±0.10	-----	120.36^{a}±0.10	1633.18^{a}±0.10	--------
Water boiled	152.13^{d}±0.03	2130.77^{d}±0.10	56.97	34.72^{d}±0.10	446.31^{d}±0.10	72.67
Steamed	354.91^{b}±0.10	4783.22^{b}±0.19	3.42	87.39^{b}±0.10	1571.81^{b}±0.10	3.75
Microwaved	300.10^{c}±0.10	3892.41^{c}±0.20	21.41	45.81^{c}±0.10	692.05^{c}±0.05	57.62
L.S.D $_{0.05}$	0.05	0.17	------	0.0003	0.05	------

Table 1: β-carotene content (µg /100g), in fresh, water boiled, steamed and microwaved broccoli and cauliflower

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

Method of processing	Broccoli			Cauliflower		
	On fresh weight basis	On dry weight basis	% Reduction	On fresh weight basis	On dry weight basis	% Reduction
Fresh	726.42^{a}±0.20	8254.88^{a}±0.12	-----	200.60^{a}±0.05	2721.96^{a}±0.20	-------
Water boiled	253.56^{d}±0.06	3551.28^{d}±0.28	56.97	57.87^{d}±0.07	743.85^{d}±0.15	72.67
Steamed	591.52^{b}±0.02	7972.03^{b}±0.03	3.42	145.65^{b}±0.05	2619.68^{b}±0.10	3.75
Microwaved	500.17^{c}±0.07	6487.35^{c}±0.15	21.41	76.35^{c}±0.05	1153.41^{c}±0.20	57.62
L.S.D $_{0.05}$	0.15	0.20	-----	0.05	0.09	-----

Table 2: Vitamin A content (IU/100g) in fresh, water boiled, steamed and microwaved broccoli and cauliflower

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

3.2. Ascorbic Acid

Table (3) presents the ascorbic acid content (vitamin C) in fresh and processed broccoli and cauliflower. The data indicated that fresh broccoli had higher ascorbic acid concentration (88.15 mg / 100g of edible part and 869.34 on dry weight basis) than that in fresh cauliflower (56.60 /100g of edible part and 575.84 / 100g on dry weight basis). These results are in accordance with [28] for cauliflower but higher than that found in broccoli [29].

It is well known that ascorbic acid can be easily oxidized and decomposed during preservation, storage and processing [30] . Data in Table (3) also, show that the applied processing methods (water boiling, steaming and microwaving) significantly, reduced the

ascorbic acid content. It can be seen that water boiling and microwaving methods caused greater loss in ascorbic acid content than steaming method. The highest reduction in ascorbic acid concentration among all the processing methods was for water boiling methods for both broccoli and cauliflower. It was reduced by 53.97% in water boiled broccoli and by 41.64% for water boiled cauliflower one. Meanwhile, steaming method caused the lowest reduction being 32.92% and 32.19% in broccoli and cauliflower, respectively. Also, microwaving method eliminated ascorbic acid content by 37.09% and 38.58% for broccoli and cauliflower, respectively. The loss of ascorbic acid is due to its high water dissolving property, thermal degradation and time of processing [31] [24] [26] .

It can be concluded from the aforementioned data that fresh and steamed broccoli resulted in product with good amount of ascorbic acid (vitamin C) being 88.15 and 47.40 mg/100g of edible part, respectively. These amounts can cover the RDA (Recommended Daily Allowance) which is 45 mg for adult [27]. On the other hand, 100g of fresh or steamed cauliflower can cover 100% and 58% of the Recommended Daily Allowance for adults, respectively.

Method of processing	Broccoli			Cauliflower		
	On fresh weight basis	On dry weight basis	% Reduction	On fresh weight basis	On dry weight basis	% Reduction
Fresh	88.15^{a}±0.01	869.34^{a} ±0.04		56.60^{a}±0.02	575.84^{a}±0.01	
Water Boiled	26.96^{d}±0.03	400.12^{d} ±0.01	53.97	20.26^{d}±0.03	336.05^{d}±0.04	41.64
Steamed	47.40^{b}±0.02	583.14^{b} ±0.04	32.92	26.16^{b}±0.01	390.45^{b}±0.01	32.19
Microwaved	36.80^{c}±0.02	546.87^{c} ±0.01	37.09	22.91^{c}±0.02	353.64^{c} ±0.04	38.58
L.S.D $_{0.05}$	0.05	0.05		0.01	0.07	

Table 3: Ascorbic acid content (mg/100g), in fresh, water boiled, steamed and microwaved broccoli and cauliflower

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

3.3. Phenolic Compounds

Phenolic compounds are aromatic secondary plant metabolites, widely spread throughout the plant kingdom especially in fruits, vegetables and grains. Phenolic compounds rich diets have been linked to many health benefits. Phenolic compounds are able to scaving reactive oxygen species due to their electron donating properties. In many studies, phenolic compounds found to correlate to the antioxidant capacity in a range of fruits and vegetables [32].

Table (4) shows that fresh broccoli had higher amount of total phenolic compounds (110.18 mg/100g of edible part and 1105 mg/100g on dry weight basis) than that in cauliflower 62.2 mg/100g of edible parts and 633 mg/100g on dry weight basis). Our results are in the range of phenolic compounds contents in broccoli and cauliflower that found by Koh *et al*. [33] and lower than that found by Shams El-Din *et al*. [26]. The content of total phenolic in vegetables can be influenced by various factors such as varieties, climatic conditions and maturity at harvest [33]. Data of Table (4) indicated that the applied processes methods reduced the total phenolic compounds of both broccoli and cauliflower. Water boiling and microwaving methods caused high reduction in phenolic compounds in both vegetables being 57.46% and 50.28% respectively. The findings of this study are higher than the 19% reduction which was found by Gliszczyńska-Świgło *et al*. [34] and the range of (13-37%) that found by Volden *et al*. [35] in water boiled cauliflower. While Zhang and Hamauzu [24] reported greater losses in water boiled and microwaving broccoli being 72%. On the other hand, steaming method resulted in significantly lower losses in phenolics in both broccoli and cauliflower. The reduction was by 43.86% and 33.33% in broccoli and cauliflower, respectively.Steaming method caused significant reduction in total phenolics in cooked cauliflower but less than blanching for 3 min and water boiling for 10 min. [35] .

Method of processing	Broccoli			Cauliflower		
	On fresh weight basis	On dry weight basis	% Reduction	On fresh weight basis	On dry weight basis	% Reduction
Fresh	110.18^{a}±2.34	1105.0^{a}±5.0		62.20^{a}±0.29	633.0^{a}±3.0	
Water boiled	32.79^{d}±1.94	470.0^{d}±5.0	57.46	19.59^{d}±0.36	328.0^{c}±1.0	48.18
Steamed	50.97^{b}±0.98	620.33^{b}±6.11	43.86	28.27^{b}±0.67	422.0^{b}±10.0	33.33
Microwaved	38.62^{c}±1.54	549.33^{c}±7.50	50.28	21.63^{c}±1.12	329.0^{c}±7.81	48.02
L.S.D $_{0.05}$	3.77	7.39		1.46	12.93	

Table 4: Total phenolic compounds content (mg/100g) in fresh, water boiled, steamed and microwaved broccoli and cauliflower

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

3.4. Antioxidants Activity

Antioxidant activity of broccoli and cauliflower was evaluated using DMPD scaving assay. DMPD radical scaving activity expressed in % inhibition of fresh and processed broccoli and cauliflower extractions. Data in Table (5) reveals that broccoli had higher

antioxidant power (70.29%) than that of fresh cauliflower (40.89%). These results are in accordance with [35] and [29]. Also, our results show negative effect of processing methods on their antioxidant capacity. However, steaming method was the lowest in reducing the antioxidant activity of the used vegetables among all the studied methods. Moreover, the reduction happened in steamed broccoli was significantly lower (33.83 %) than that of cauliflower (45.48%). Water boiling and microwaving were almost similar in lowering the antioxidant capacity of cooked cauliflower being 70.11% and 68.76%, respectively. While, in the case of broccoli, the highest losses in its antioxidant activity was by water boiling (67.61%) and the effect of microwaving was moderate (50.71%). It is obvious from the data of Tables 1, 2, 3, 4 and 5 that the inhibition in the antioxidant power is related to the decrease in, β-carotene, vitamin A, vitamin C and polyphenoles. These findings are in accordance with [3] [26] and [35].Table (6) shows the correlation coefficient between the antioxidant activity and the bioactive compounds (vitamin C, β-carotene, vitamin A and total polyphenol in fresh and processed broccoli and cauliflower.

Antioxidant activity in broccoli was highly significant and positive correlated with vitamin C, phenolic content, vitamin A and β-carotene where their correlation coefficients values were 0.986, 0.957, 0.859 and 0.859, respectively.

The same trend was also found for cauliflower but the phenolic compound had the highest correlation with its antioxidant activity where the antioxidant activity was highly significant and positive correlated with phenolic content, vitamin C, vitamin A and β-carotene, where their correlation coefficient values were (0.997, 0.987, 0.837 and 0.838), respectively.

Method of processing	Broccoli		Cauliflower	
	Antioxidant activity	% Reduction	Antioxidant activity	% Reduction
Fresh	70.29[a]±0.07		40.89 [a]±0.02	
Water boiled	22.76[d]±0.02	67.61	12.22 [d]±0.01	70.11
Steamed	46.51[b]±0.05	33.83	22.29 [b]±0.04	45.48
Microwaved	34.64[c]±0.05	50.71	12.77 [c]±0.01	68.76
L.S.D $_{0.05}$	0.10		0.05	

Table 5: Antioxidant activity (%) of fresh, water boiled, steamed and microwaved broccoli and cauliflower on fresh weight basis

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

	Crop	β-carotene	Vitamin A	Vitamin C	Phenolic content
Antioxidant	**Broccoli**	0.859**	0.859**	0.986**	0.957**
	Cauliflower	0.838**	0.837**	0.987**	0.997**

Table 6: Simple correlation coefficient between antioxidant activity, β-carotene, vitamin A, vitamin C and phenolic content for cauliflower and broccoli

** Significant at 0.01 probability level

3.5. Folic Acid

Folic acid content in fresh, water boiled, steamed and microwaved broccoli and cauliflower are presented in Table (7) . Fresh broccoli contained higher amount of folic acid than that of the cauliflower. Folic acid content was 3033.75 µg/100g on dry weight in fresh broccoli and it was 2168.52 µg/100g on dry weight in fresh cauliflower. These results are in confidence with that of Mukherjee and Mishra [36].

Processing the broccoli by water boiling, steaming and microwaving affected significantly the folic acid content. It is observed that water boiling of the broccoli lead to the highest reduction in folic acid (67.71%). However steaming of broccoli leads to the lowest reduction in folic acid content (35.26%), while microwaving caused (46.69%)

Mc-Killop *et al.* [37] showed that the folate content of raw broccoli was 177.1 µg/100g and after boiling for 10 min in unsalted boiling water it became 77 µg/100g as a fresh weight. While the HPLC method for 5-methyltetrahydrofolate (5-MTHF) determination in broccoli was optimized for the folate release from the food matrix. After 8 min of boiling, more than 75% of the initial 5-MTHF content was retained. Lower values of retention, were between 37% and 52% of the initial 5-MTHF content [38] .

In regards to cauliflower, the same trend was observed significantly. Fresh cauliflower contain 159.82 µg/100g and 2168.52 µg/100g of folic acid on fresh and dry weight, respectively, and it was reduced by 52.29% in microwaved cauliflower. Similar to broccoli, steaming the cauliflower caused the lowest reduction in folic acid being 8.36% while water boiling led to the highest reduction in folic acid being 75.39%.

Holasova *et al.* [38] stated that 75% of the folate content in cauliflower was retained after boiling for 8 min.

Method of processing	Broccoli			Cauliflower		
	On fresh weight basis	On dry weight basis	% Reduction	On fresh weight basis	On dry weight basis	% Reduction
Fresh	266.97[a]±0.07	3033.75 [a] ±0.05		159.82[a]±0.02	2168.52 [a] ±0.12	
Water boiled	69.94[d]±0.04	979.55 [d] ±0.05	67.71	41.51[d]±0.02	533.54 [d] ±0.14	75.39
Steamed	145.73[b]±0.03	1964.01 [b] ±0.01	35.26	110.48[b]±0.08	1987.05 [b] ±0.05	8.36
Microwaved	124.68[c]±0.08	1617.12 [c] ±0.04	46.69	68.48[c]±0.08	1034.44 [c] ±0.04	52.29
L.S.D $_{0.05}$	0.05	0.09		0.08	0.15	

Table 7: Folic acid content (µg/100g), in fresh, water boiled, steamed and microwaved broccoli and cauliflower

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

3.6. Glucosinolate

The presence and diversity of phytochemicals in vegetables are important factors for human health. Glucosinolates (GLs) have received a large amount of attention due to their potential for reducing the risk of certain cancer and cardiovascular diseases [39] . It is obvious remarkably, that fresh broccoli contained higher amount of glucosinolates, being 1.24 µM/g (micromole/g) on fresh weight and 12.29 µM/g on dry weight comparing with those of fresh cauliflower which were 1.01 µM/g on fresh weight and 10.36 µM/g on dry weight (Table 8). When comparing these results to the other researches we observed that broccoli contained 6.01 µmol/g of glucosinolates as a dry weight [40] , while broccoli contained 123 mg of sinigrin equivalent/100g of glucosinloates as a fresh weight [41] . In regards to cauliflower, Latte *et al.* [42] showed that the glucosinolate content of cauliflower was 1.8 µmol/g as a dry weight, while cauliflower content of total glucosinolates was 1737 µg/g as a dry matter [10] .

The effect of processing (water boiling, steaming and microwaving) the broccoli on the glucosinolates content are shown in Table (8) . The significant lowest loss in glucosinolates was occurred in steamed broccoli followed by microwaved and then water boiled broccoli, since glucosinolate content, were 9.84 µM/g, 6.25 µM/g and 4.46 µM/g for the steamed, microwaved and water boiled broccoli, respectively. Moreover, the fresh broccoli contained 12.29 µM/g of glucosinolate. Which indicate that the processing methods lead to loss in the glucosinolates but at different rates. These results are in good agreement with [23] and [38] whose concluded that processing methods (blanching, water boiling and steaming) lead to significant reduction in total glucosinolates. Also, Rungapamestry *et al.* [43] found that steaming had minimal reductive effect.

In regards to cauliflower the water boiled cauliflower had the least content (4.47 µM/g) of glucosinolate comparing to 10.36 µM/g for the fresh one. However, steaming the cauliflower leads to the lowest loss in glucosinolates being 8.50 µM/g comparing with that of the microwaved one being; 6.16 µM/g.

These results are in accordance with those of Volden *et al*. [44] . who concluded that steaming process for cauliflower caused the lowest change in the glucosinalate content among the other processing methods (blanching and boiling).

Method of processing	Broccoli			Cauliflower		
	On fresh weight basis	On dry weight basis	% Reduction	On fresh weight basis	On dry weight basis	% Reduction
Fresh	1.24[a]±0.02	12.29 [a] ±0.02		1.01[a]±0.01	10.36 [a] ±0.01	
Water boiled	0.30[d]±0.01	4.46 [d] ±0.01	63.71	0.26[d]±0.02	4.47 [d] ±0.03	56.85
Steamed	0.79[b]±0.01	9.84 [b] ±0.01	19.93	0.56[b]±0.01	8.50 [b] ±0.04	17.95
Microwaved	0.42[c]±0.01	6.25 [c] ±0.01	49.14	0.39[c]±0.01	6.16 [c] ±0.01	40.54
L.S.D $_{0.05}$	0.02	0.04		0.01	0.05	

Table 8: Glucosinolates content (µM/g), in fresh, water boiled, steamed and microwaved broccoli and cauliflower

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

3.7. Chlorophylls

Chlorophyll is the principal pigment in green plants and easy degraded during process [45] . The concentrations of total chlorophyll and chlorophyll a and b and their retentions in fresh and processed broccoli are presented in Table (9) . Fresh broccoli contained high amount of total chlorophyll (1102.4 mg/100g) while chlorophyll a and chlorophyll b were 496.8 and 605.4 mg/100g on dry basis, respectively, these amounts of chlorophyll components in broccoli are higher than that of Yamauchi and Watada [1] .

As expected, differences in chlorophyll a and b concentrations between fresh and processed broccoli were found to be statistically significant ($p \leq 0.05$). The data shown in Table (9) demonstrated that there is more chlorophyll b than chlorophyll a in fresh broccoli, a significant reduction in both of total chlorophyll and the derivatives a, b was recorded as a result of water boiling, steaming and microwaving the broccoli. Microwaving the broccoli leads to the highest reduction among the other processing methods (water boiling and steaming). Similarly chlorophyll a and b content were the lowest for the microwaved broccoli being 436.80 mg/100g and 81.80 mg/100g sample on dry basis, respectively. These results are in coincidence with those of Lau *et al.* [46]. For many years, dephytilation of chlorophyll by chlorophyllase was considered to be the first step in chlorophyll degradation [47] and [48]

On the other hand chlorophyll was not detected in fresh and processed cauliflower.

4. Conclusion

The results of this study concluded that broccoli had higher amounts of the studied bioactive compounds and antioxidant power than cauliflower. All the domestic processing methods used caused significant reduction in the bioactive components, but steaming method was found to be the proper processing or cooking method because it was the lowest in reducing the bioactive compounds and the antioxidant power compared to the other investigated methods.

Method of processing	Total chlorophyll		Chlorophyll a		Chlorophyll b	
	On fresh weight basis	On dry weight basis	On fresh weight basis	On dry weight basis	On fresh weight basis	On dry weight basis
Fresh broccoli	111.78^{a}±0.08	1102.4^{a}±0.40	50.37^{a}±0.07	496.8^{a}±0.60	61.38^{a}±0.08	605.4^{a}±0.30
Water boiled broccoli	39.99^{c}±0.09	593.4^{c}±0.30	32.04^{c}±0.04	475.4^{b}±0.30	7.79^{c}±0.09	115.6^{c}±0.40
Steamed broccoli	69.47^{b}±0.07	854.6^{b}±0.40	34.94^{b}±0.04	429.8^{d}±0.40	34.60^{b}±0.05	425.6^{b}±0.60
Microwaved broccoli	34.99^{d}±0.09	520.0^{d}±5.0	29.39^{d}±0.09	436.8^{c}±0.60	5.50^{d}±0.05	81.80^{d}±0.60
L.S.D $_{0.05}$	0.16	4.79	0.04	0.29	0.04	0.75

Table 9: Effect of processing methods on chlorophyll content (mg/100g) of broccoli (on fresh and dry weight basis)

Means followed by the same letter (s) in column (s) are not significantly different at ($p \leq 0.05$)

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