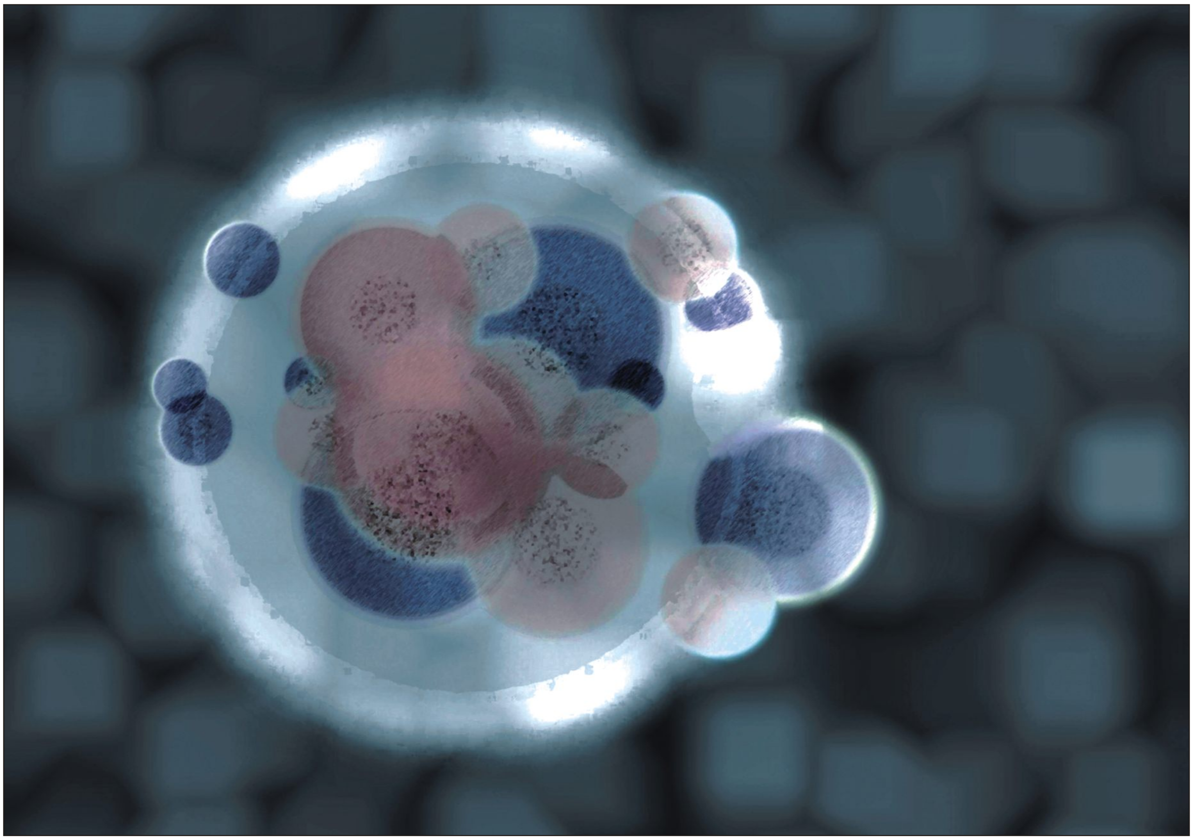

Journal of Biological Sciences

ISSN 1727-3048

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OPEN ACCESS Journal of Biological Sciences
ISSN 1727-3048
DOI: 10.3923/jbs.2019.92.100

Research Article
Potentiality of Local Wastes as a Source of Natural Antioxidant Dietary Fibers on Dry Pasta

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Abstract

Background and Objective: Nowadays fruits and vegetables by-products may be suggested as a new source of food ingredients, for their content of antioxidant dietary fiber and bioactive compounds for enhancing nutritional and health properties of cereal products. This study was aimed to investigate the bioactive compounds, dietary fiber and antioxidant potential of by-products to increase their turning possibility into processing industry. **Materials and Methods:** This study estimated the influence of fruits and vegetables by-product (outer cabbage leaves, banana peel and carrot peel) on antioxidant dietary fiber, polyphenols and antioxidant activity of the final pasta products at substituted ratios (1, 3 and 5%). Data was analyzed by one-way and two-way analysis of variance (ANOVA) at $p<0.05$ **Results:** Dried cabbage leaves have higher contents of total phenolic and total flavonoid contents than dried banana and carrot peel while, dried banana recorded highest values of antioxidant activity (RSA/DPPH%) and total dietary fiber. Maximum total phenolic and flavonoid content was recorded at 21.08 mg (GAE g^{-1}) and 5.78 mg (RE g^{-1}), in pasta substituted with 3 and 5% outer cabbage leaves, respectively. The water absorbed increased significantly as the substitution of peels and leaves were increased. The hardness values of all pasta samples were ranged between 5.77 N in carrot peel pasta 1% to 25.60 in pasta sample substitution with 5% dry cabbage leaves. **Conclusion:** Results revealed that substituted pasta with by-products can be good source of total phenolic, flavonoid and antioxidants dietary fiber contents and more acceptable evolution, subsequently extend their potential uses in nutritional, pharmaceutical and industrial application.

Key words: By-products, bioactive compounds, dietary fiber, cabbage leaves, banana peel, carrot peel, swelling index, water absorption, functional dry pasta

Received: October 21, 2018 Accepted: November 22, 2018 Published: December 15, 2018

Citation: Manal F. Salama, Safaa S. Abozed and Wafaa M. Abozeid, 2019. Potentiality of local wastes as a source of natural antioxidant dietary fibers on dry pasta. Int. J. Biol. Sci., 19: 92-100.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Nowadays, in Egypt food industry plays a main active to stodge food for the Egyptian population. Generally, about 39% of food by-product is produced by the food manufacturing industries in developed countries[1]. It causes environmental problems loss of national income if not take advantage of it. Now, researchers are fabricated new enforcement to convert by-products into beneficial products to solve the problems of environment pollution.

The municipal solid waste such as fruit and vegetable wastes, especially the peel need to be reduced and one of the advantage processes is to regain the bioactive compounds in the fruit and vegetable wastes, such as phenolic, antioxidant compound and dietary fiber to replacement synthetic antioxidant in food[2].

Dietary fibre (DF) consists of a variety of non-starch polysaccharides which include cellulose, hemicellulose, pectin, B-glucans, gums and lignin[3]. Ratio between soluble and insoluble dietary fiber is 1:2 which acceptable as a food ingredients[4]. Also, dietary fiber has a substantial role in human health as a defensive against cardiovascular diseases, diverticulosis, constipation, irritable colon, colon cancer and diabetes[5]. Functional properties of plant fibres as water-holding capacity (WHC) and swelling capacity (SWC) are concerning of porous matrix structure created by polysaccharide chains which can carry high quantity of water through hydrogen bonds[6].

Banana peel is an underutilized source of phenolic compounds. These peels are currently 40% of fresh bananas weight, which discharged as a waste instead of recycled it to use as dietary fiber where as represent (50% of banana peel) It can make them suitable as health-care food industry. Although, banana peel has major source of phenolics, pectins (9-22%) and dietary fiber, to be able to consumed as a food supplement[7].

High nutritional value of cabbage and cabbage by- products are considered as protective effects against cancer. The main components of leaves are carbohydrates, whereas 1/3 of them are dietary fiber and 2/3 of low-molecular weight compounds. It featured with low fat[8-10] content, i.e., ~1% proved that cabbage outer leaves powder containing 41-43% of total dietary fiber (dry matter basis) has a potential source of antioxidant compound and dietary fiber.

Carrot peels are a good source of bioactive compounds, including β-carotene and dietary fiber that have affect on its total radical trapping antioxidative potential value. These biological active compounds in carrot peels makes it favorite for dietary prevention of atherosclerosis and other diseases[11]. Recently, researchers have proven that the main attribute of these natural by-products is that they merge the physiological effects of both dietary fiber and antioxidants in a single material ADF(antioxidant dietary fiber)[12].

Pasta is a very popular food in several countries around the world and was among the first food to be authorized by the FDA (Food and Drug Administration) as a good vehicle for the addition of nutrients[13-14]. Pasta has a good acceptance and worldwide consumption owing to low cost, manufacturing ease, sensory attributes and long shelf life. Many researchers have trials to supplemented pasta with inexpensive source of dietary fiber, antioxidant compounds, vitamins and minerals. The objective of the present study was to examine the bioactive compounds, dietary fiber and antioxidant potential of by-products (cabbage leaves, banana and carrot peels) to extend their probability of turning them into profitable processing industry. On the other hand, evaluate the effect of substitution with three by-products on nutritional, functional and technological dry pasta properties, proving that it is possible to take advantage of food by-product to better satisfy consumer demand for healthy added-value food products.

MATERIALS AND METHODS

Materials: Durum wheat semolina and salt were purchased from local markets. Leaves and peel were collected and washed with distilled water. Then freeze-dried at 10^{-1} m bar and 30°C for 72 h (Edwards Moduly Freeze Dryer, United Kingdom). The dried leaves and peels were ground, then stored in different polyethylene bags at -18°C until analysis.

Methods

HPLC analysis and identification of phenolic compounds in by-products: The experiments were done in the Food Science and Technology Lap in National Research Centre, Cairo, Egypt during January and February 2018. Phenolic compounds in outer cabbage leaves, banana and carrot peels extracts were determined using a high-performance liquid chromatography system (Agilent, 1260 series, USA). The mobile phase and gradient program were used as previously described by Kim *et al*.[15]. The flow rate was 1.0 mL min^{-1} and injection volume was 10 μL. The peaks of all components were detected at 280 nm.

Pasta preparation: The fresh pasta was prepared with durum wheat semolina flour, distilled water and different substitution ratios (0, 1, 3 and 5 g/100 g) g/100 g) of outer cabbage leaves, banana and carrot peels powder. The pastas were coded according to the fruits and vegetables by-product added: (CPP, BPP and CLP) carrot peel pasta, banana peel pasta and cabbage leaves pasta, respectively. In each formulation, the

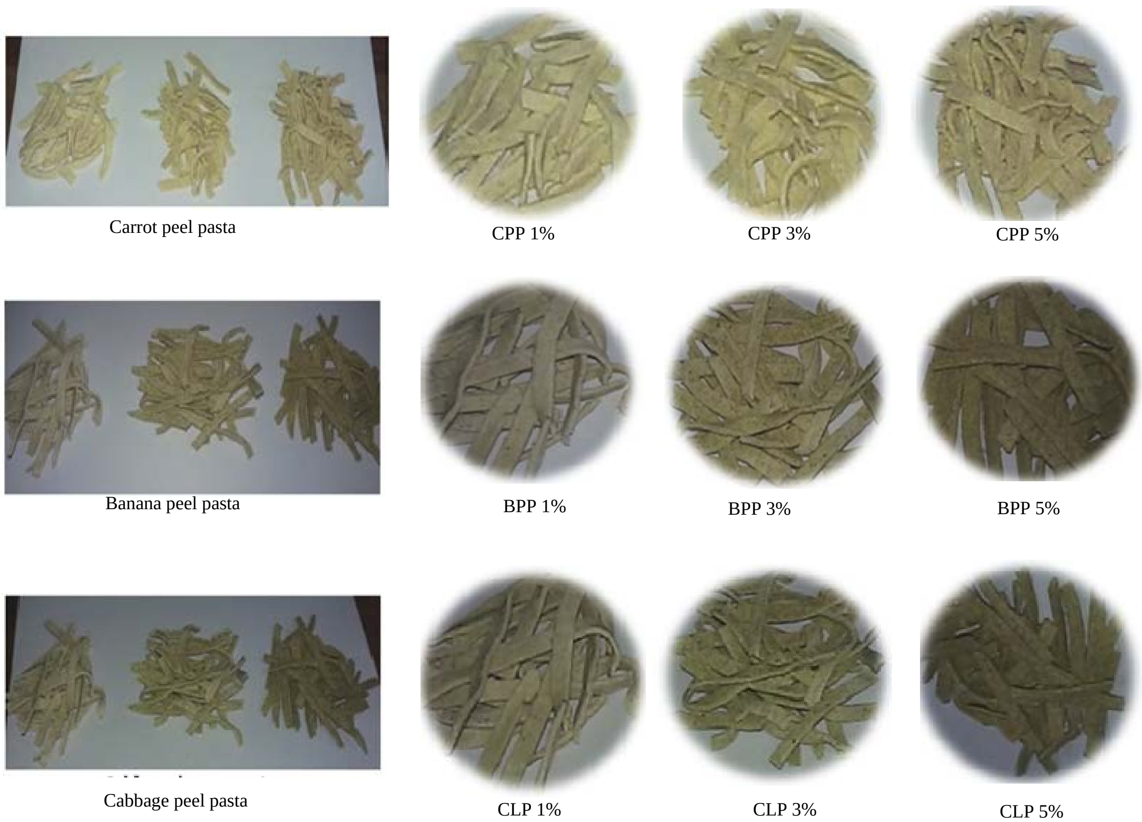

Fig. 1: Pasta samples
CPP: Carrot peel pasta, BPP: Banana peel pasta and CLP: Cabbage leaves pasta

wheat flour, leaves and peels powder and water as needed were mixed in manual kneading to make sheets for 10 min during pasta machine with removable cutters and fittings for Marcato PASTADRIVE motor then cutting into long strips shape (70×5×2 mm) length, width and depth, respectively. Dried pasta is shown in (Fig. 1).

Proximate composition: The total dietary fiber for outer cabbage leaves, banana and carrot peels was determined according to AOAC[16] approved method no. 985.29 by dietary fiber analyzer system. Prepared pasta samples were analyzed for their moisture, ash, crude protein, lipids and crude fiber contents according to the methods described in AOAC[17]. All analyses were performed in triplicate and values are expressed as g/100 g dry sample.

Phytochemical properties

Extraction and determination of total phenolic and flavonoid contents: All samples (2.0 g) were mixed with 16 mL of methanol containing 1% HCl for 24 h at room temperature. The procedure was repeated twice. The methanol extracts were centrifuged at 4000 g for15 min and the resulting supernatants were pooled. The supernatants were stored for total phenolic content (TPC) and total flavonoide contents (TFC). The TPC and TFC were determined according the method of Li *et al.*[18]. The TPC was expressed as gallic acid equivalents (mg GAE g^{-1} dry weight). TFC was expressed as rutin equivalents (mg RE g^{-1} dry weight).

Measurement of antioxidant activity (DPPH free radical scavenge): The DPPH scavenging capacity of the sample extracts was determined according to Zhang *et al.*[19]. The scavenging of DPPH was calculated according to the following equation:

$$\text{DPPH radical scavenging activity } (\%) = 1 - \frac{\text{Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

Physico-chemical properties

Pasting property parameters (cooking quality): The swelling index of cooked pasta was determined according to the procedure described by Cleary and Brennan[20]. The swelling index was expressed as follows:

$$\text{Weight of cooked pasta - } \frac{\text{Weight of pasta after drying}}{\text{Weight of pasta after drying}}$$

The water absorption of drained pasta was determined as follows:

$$\text{Weight of cooked pasta - } \frac{\text{Weight of raw pasta}}{\text{Weight of raw pasta}}$$

These measurements were performed for each analysis and the mean values were calculated.

Texture analysis: Hardness of pasta samples was performed on texturometer, Brookfield model-CT3-10 kg, USA, equipped with a cylinder probe (TA-SBA). The analyzer was set to perform one cycle measurements to give one bite texture profile curve. The values of hardness were expressed in Newton[21].

Sensory evaluation: Sensory test was carried out by 20 trained panelists from food Science and Technology Department staff. The all samples were cooked and served on disposable plates with approximately 30 g of each sample coded with a three digit random numbers. They were asked to score their preferences for sensory attributes (Appearance, color, flavor, texture, taste and overall acceptability) of cooked pasta samples, ranging on two different days using a 9-point hedonic scale[22].

Statistical analysis: All statistical analyses were performed using SPSS 18.0 statistical software (SPSS Inc., Chicago, Illinois, USA). To detect significant difference between samples, a one-way and two-way analysis of variance (ANOVA) was defined at $p<0.05$ and calculated using Duncan's multiple test.

RESULTS AND DISCUSSION

HPLC analysis and identification of phenolic compounds of by-products: The identification of the main phenolic compounds of three samples(dry outer cabbage leaves, banana and carrot peel) by HPLC analysis indicated that major phenolic profiles are presented in Table 1 and Fig. 2. Gallic acids dominated phenolic profile of the outer cabbage leaves and banana peel, values were found as 1524.26 and 944 μg g^{-1}, respectively. While, The main compounds in carrot peels is syringic acid (491.42 μg g^{-1}) then follow with gallic acids (203.74 μg g^{-1}). On the other hand, gallic, propyl gallate, coffeic, syringic and cinnamic acids are the main abundant phenolic compounds in outer cabbage leaves. For banana peels, gallic acid, rutin, quercetin, syringic acid, cinnamic, naringenin, 4.7-Dihydroxy isoflavone and propyl gallate were identified from phenolic compounds group. Fruits and vegetables by-products may be suggested as a new version of food and medicine ingredients for their content in bioactive and their high content of dietary fiber.

These results are in agreement with those of Nguyen and Scarlett[23] who investigated the bioactive compounds and antioxidant capacity of carrot peel which revealed that the carrot plants are rich sources of phenolic acids and flavonoid that greatly contributed to their potential antioxidant capacity.

Phytochemical properties

Total phenolic, total flavonoid, free radical scavenge and dietary fiber composition for three of by-products: Total phenolic content mg (GAE g^{-1}), total flavonoid mg (RE g^{-1}), RSA/DPPH% and dietary fiber (g/100 g) were shown in Table 2. All by-produces sample showed significant differences ($p<0.05$) in the TPC, TFC, DPPH and DF. The obtained data revealed that the antioxidant activity was ranged from 52.258-87.642 (RSA/DPPH%) while total diatry fiber was ranged from 28.80-41.60 (g/100 g).

In general, this data shows that outer cabbage leaves and banana peels had higher TPC, TFC, DPPH and DF than carrot peels. Outer cabbage leaves have a higher contents of total phenolic, total flavonoid contents 74.092 mg (GAE g^{-1}) and

Table 1: Phenolic compounds of carrot peel, banana peel and outer cabbage leaves (μg g^{-1} dry weight) quantitative by HPLC

Phenolic acids	Carrot peels	Banana peels	Outer cabbage leaves
Gallic acid	203.74	944.06	1524.26
Catechin	33.94	0.00	0.00
Coffeic acid	0.00	0.00	15.56
Syringic acid	491.42	4.46	4.86
Rutin	0.00	15.03	0.00
Coumaric acid	0.00	0.00	0.00
Vanillin	7.35	0.00	0.00
Ferulic acid	0.00	0.00	0.00
Naringenin	21.12	2.01	0.00
Quercetin	16.43	7.79	0.00
Cinnamic acid	3.76	2.50	1.43
Propyl gallate	1.12	1.64	81.31
4.7-dihydroxy isoflavone	14.03	1.98	0.00

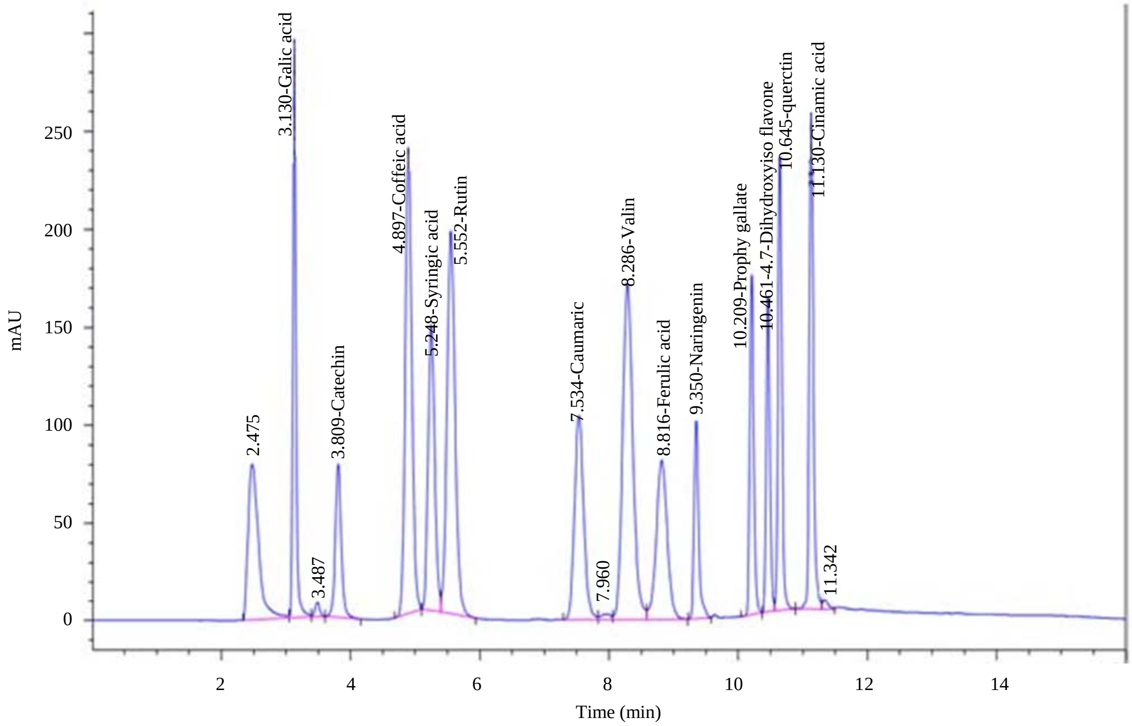

Fig. 2: HPLC chromatograms of a standard mixture of phenolic acids

Table 2: Phytochemical contents total phenolic, total flavonoids, free radical scavenge and dietary fiber composition for three by-products

Phytochemical contents	Carrot peel	Banana peel	Cabbage leaves
Total phenolic contents (mg GAE g^{-1})	28.9070[c]	71.685[b]	74.092[a]
Total flavonoid contents (mg RE g^{-1})	2.6849[c]	3.354[b]	9.781[a]
Radical scavenging activity (%)	52.2580[c]	87.642[a]	54.585[b]
Total dietary fiber (g/100 g)	28.8000[c]	41.600[a]	38.850[b]
Soluble dietary fiber (g/100 g)	11.0000[c]	9.600[a]	8.950[b]
Insoluble dietary fiber (g/100 g)	17.8000[c]	32.000[a]	29.900[b]

Each value was an average of three determinations, Means within rows showing the same letter are not significantly different (p>0.05)

9.781 mg (RE g^{-1}), respectively., These results were also in agreement with other previous work such Tanogkankit *et al.*[24] who reported that, outer leaves of white cabbage (*Brassica oleracea* L. var. capitata) has contain high dietary fiber (DF) and a good source of potentially bioactive compounds with antioxidant. On the other hand, banana peels recorded the highest mean values of antioxidant activity (RSA/DPPH%) and total dietary fiber (g/100 g). The antioxidant capacity of the carrot peels showed significantly reducing comparison with the other by-products samples.

Total phenolic, total flavonoid and free radical scavenge of pasta samples: Antioxidants are the important compounds which are required for the protection of human bodies from free radicals that causes oxidative stress. In particular, among the dried pasta samples there was a significant increase in total phenolic and flavonoid contents in pasta substituted with dried cabbage leaves in their levels of substituted than carrot and banana peel samples (Table 3). Maximum total phenolics and flavonoid contents was recorded at 21.0889 mg (GAE g^{-1}) and 5.7863 mg (RE g^{-1}), in pasta substituted with 3 and 5% cabbage, respectively. According to the obtained results, it was observed that the lower levels of antioxidant activity, total phenolic and flavonoid contents in pasta substitution with dried carrot peel comparable. DPPH scavenging activity of each sample was reported as the percentage of DPPH inhibition, with a higher value is associated to a stronger antioxidant activity. The data in the table 3 showed that DPPH scavenging activities differed significantly ($p<0.05$) among all samples of the different type of pasta products and different substitution ratios. These results were similar and agreement with Kanazawa and Sakakibara[25] and Karoui *et al.*[26].

Table 3: Antioxidant contents, total phenolic, total flavonoid and free radical scavenge for pasta samples

	Percentage		
Pasta samples	1	3	5
Radical scavenging activity (DPPH%)			
CPP	26.7744^{Cc}	28.1121^{Cb}	28.6169^{Ca}
BPP	38.5159^{Ab}	33.9727^{Bc}	44.966^{Aa}
CLP	35.7900^{Bb}	36.3325^{Ab}	38.2635^{Ba}
Total phenolic contents as (mg (GAE) g^{-1})			
CPP	11.8667^{Cb}	12.3667^{Cb}	14.6444^{Ba}
BPP	16.4056^{Bb}	16.8667^{Bb}	18.0944^{Aa}
CLP	20.8111^{Aa}	21.0889^{Aa}	19.1000^{Ab}
Total flavonoid contents as (mg (RE) g^{-1})			
CPP	0.9375^{Bc}	1.9625^{Bb}	2.8235^{Ba}
BPP	0.8906^{Bc}	1.3125^{Cb}	1.8594^{Ca}
CLP	3.7031^{Ab}	3.9000^{Ab}	5.7863^{Aa}

CPP: Carrot peel pasta, BPP: Banana peel pasta and CLP: Cabbage leaves pasta, Each value was an average of three determinations, Means within columns and rows showing the same letter are not significantly different (p>0.05)

Table 4: Proximate chemical composition (g/100 g dry weight)

Pasta samples (%)	Moisture	Protein	Fat	Crude fiber	Ash	Total carbohydrates
CPP 1	10.1085^{bc}	10.9960^{d}	1.6851^{ab}	1.9205^{e}	0.5917^{a}	74.6985^{a}
CPP 3	10.0399^{bc}	11.4415^{c}	1.2811^{cde}	2.3155^{de}	0.5777^{a}	74.1723^{a}
CPP 5	10.4756^{bc}	11.4010^{c}	1.2704^{cde}	2.6670^{d}	0.5739^{a}	71.0362^{abc}
BPP 1	10.8940^{b}	11.9884^{a}	0.5980^{f}	2.7170^{d}	0.6620^{a}	73.1407^{ab}
BPP 3	9.4105^{c}	11.8940^{ab}	0.9405^{ef}	4.2225^{c}	0.8480^{a}	72.6846^{ab}
BPP 5	10.9485^{b}	11.8500^{ab}	1.4940^{bc}	4.9795^{ab}	0.8905^{a}	69.8379^{bc}
CLP 1	9.5570^{c}	11.827^{b}	1.0880^{d}	2.3155^{de}	0.5535^{a}	74.6588^{a}
CLP 3	10.3275^{bc}	11.470^{c}	1.4270^{bcd}	4.4285^{bc}	0.6905^{a}	71.6467^{abc}
CLP 5	12.3370^{a}	11.4660^{c}	1.9275^{a}	5.0965^{a}	0.7280^{a}	68.4440^{c}

CPP: Carrot peel pasta, BPP: Banana peel pasta and CLP: Cabbage leaves pasta, Each value was an average of three determinations, Means within columns showing the same letter are not significantly different (p>0.05)

Finally, dried pasta substitution with cabbage leaves and banana peel showed higher levels for antioxidant activity, total phenolic, flavonoid contents, total fiber and nutrient contents than the dried pasta substitution with carrot peel.

Proximate composition of pasta samples: Chemical characteristics such as moisture, ash, fat, crude protein and fiber were evaluated to compare the quality of developed substituted pasta with three by-products (Table 4). The moisture, ash and fat contents of pasta ranged from 9.41-12.33, 0.55-0.89 and, 0.59-1.92%, respectively. Results showing that pasta samples has low fat content possibly due to the low lipid concentration of vegetables and fruit by-products. Besides, the low lipid content maintains stability of the residue until its processing. Also, the low moisture content in the final product is associated with the long shelf life[27]. Protein content was significantly affected by the substitution of pasta, it ranged from 10.996 (CLP1%) to 11.988 g/100 g (BPP1%). Finally, pasta samples showed significant increase in crude fiber content substituted with 5% by products, indicating that by-products considered as a source of fiber and considerable quantity of nutrients during the preparation of pasta.

Table 5: Pasting property parameters

Pasta samples (%)	CPP	BPP	CLP
Water absorption			
1	137.9834^{cB}	138.7020^{bB}	138.9903^{cB}
3	157.0248^{bB}	145.5995^{bB}	162.7235^{bB}
5	171.0232^{aB}	216.4296^{aA}	182.9077^{aA}
Swelling index			
1	2.1017^{aA}	2.3724^{abA}	2.1558^{aA}
3	2.5352^{aAB}	3.3048^{aA}	2.1372^{aB}
5	1.8573^{aB}	2.6337^{aA}	2.5024^{aA}

CPP: Carrot peel pasta, BPP: Banana peel pasta and CLP: Cabbage leaves pasta, Each value was an average of three determinations, Means within columns and rows showing the same letter are not significantly different (p>0.05)

Physico-chemical properties

Pasting property parameters (cooking quality): For all pasta samples, the optimum cooking time was 7 min. The cooking properties are an important parameter for the evaluation of pasta quality (water absorption and swelling index). Water absorbed is a guide of the quantity of water absorbed by the pasta during cooking. Swelling index is an indicator of water absorbed by the starch and proteins during cooking which is utilized for the starch gelatinization and protein hydration. Results shown in Table 5 observed that substitution with 5% dried banana peel increased water absorption from

138.7-216.4. The water absorbed increased significantly as the substitution of peels and leaves were increased. This may be due to the dietary fiber in the structure of peel contributing with them to bind with available water and resulting in an increase in water absorption and swelling index. While, the pasta samples substituted with carrot peel recorded the lowest values. These results can be interpreted in terms of competition between the fiber and starch for water absorption[28].

Table 6: Hardness of dry pasta samples

Pasta samples (%)	Hardness (N)
CPP1	5.77
CPP3	8.77
CPP5	12.48
BPP1	8.50
BPP3	9.39
BPP5	14.20
CLP1	10.87
CLP3	21.75
CLP5	25.60

CPP: Carrot peel pasta, BPP: Banana peel pasta and CLP: Cabbage leaves pasta

Texture analysis: The texture as a hardness of cooked pasta are reported in Table 6. The higher substitution of durum wheat semolina flour with dried cabbage leaves, banana and carrot peels increasing surface firmness. The hardness values of all pasta samples were ranged between 5.77 N in carrot peel pasta 1% to 25.60 in pasta sample substitution with 5% dry cabbage leaves. Incorporation of dietary fiber especially insoluble fiber may be related to make pasta more firmer, due to high hydrophilicity, having a much greater capacity to absorb water by inhibiting the swelling of the starch granules during pasta making[29]. Therefore, the addition of fruits and vegetables by-products caused an impact on the fibrous nature of pasta samples may be due to the high fiber content in leaves and peels[30].

Sensory evaluation of pasta samples: The effect of cabbage leaves, banana and carrot peels on pasta samples at different substitution ratios on sensory attributes (Appearance, color, flavor, texture, taste and overall acceptability) was studied. The result of ANOVA (Fig. 3) exhibited that the pasta samples

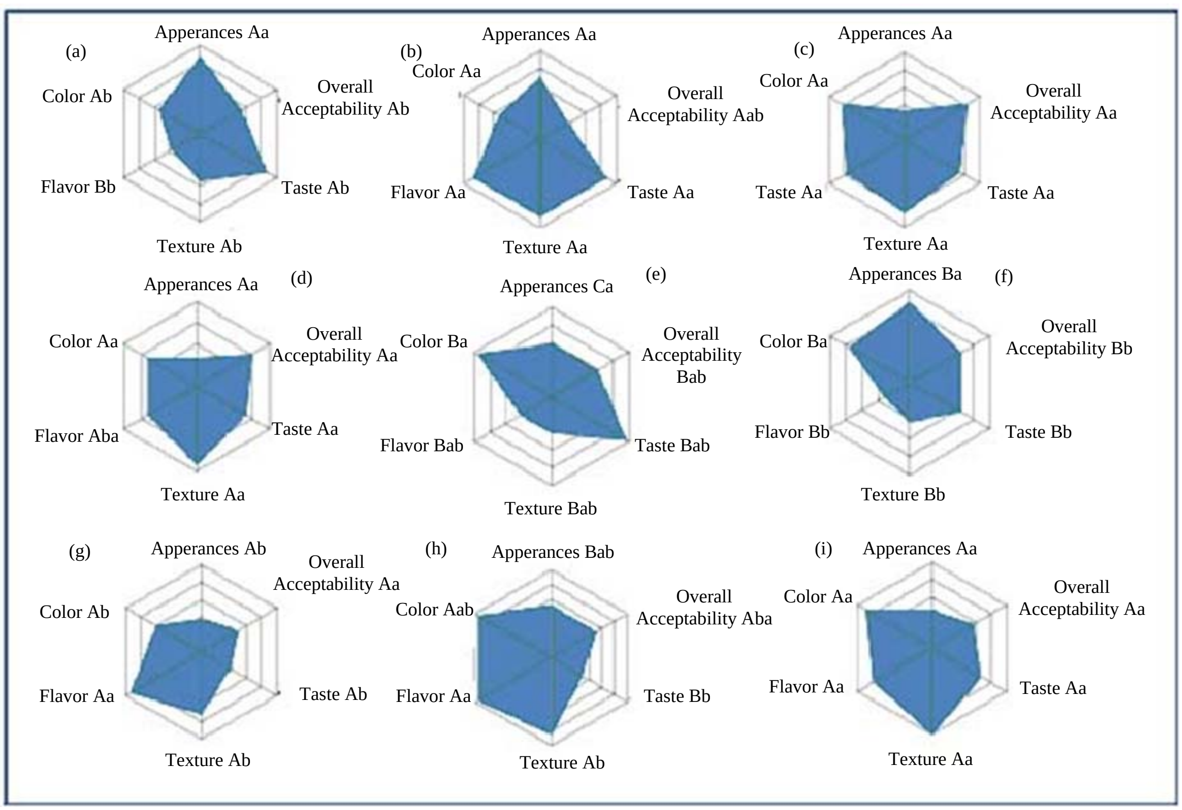

Fig. 3(a-i): Consumer acceptance of functional pasta samples with the different sources of DF: Dietary fiber. (a) CPP 1%, (b) CPP 3%, (c) CPP 5%, (d) BPP 1%, (e) BPP 3%, (f) BPP5%, (g) CLP 1%, (h) CLP 3% and (i) CLP 5%
Different letters indicate significant differences ($p \leq 0.05$)

prepared from carrot peels and outer cabbage leaves had a higher sensory score of acceptability than those pasta prepared from the banana peels. Sensory evaluation showed that appearance, color, texture and taste of cooked pasta were not affected by a 1% substitution ratio in all samples. However, the more substitution ratios were give significant increase in all sensory attributes. The same results were obtained by Essa and Mohamed[31] which proved that spaghetti supplemented with three levels (3, 5 and 7%)of Pomegranate peels powder, led to significantly increase the appearance, taste, color, odour and overall acceptability when increased in supplementation levels.

CONCLUSION

The substitution of vegetable and fruit by-products (cabbage leaves, banana and carrot peels) at substituted ratios (3, 5 and 7%) powder in dried pasta are attractive alternative for increasing phenolic compounds, flavonoid and consequently antioxidants diary fiber content. Cooking quality and textural evaluation of pasta samples showed slight increase of cooking loss and consequently the pasta was harder when supplementation levels increased. Sources of vegetable and fruit by-products must be recommended for producing a new version of food and medicine ingredients.

SIGNIFICANCE STATEMENT

This study was estimated the influence of fruits and vegetables by-product (outer cabbage leaves, banana peel and carrot peel) on the installation of phytochemicals properties such as antioxidant dietary fiber, polyphenols and flavonoid compounds of food application (dry pasta products) at substituted ratios: 1, 3 and 5%. The substitution of three vegetable and fruit by-products at levels (3, 5 and 7%) powder in dried pasta are attractive alternative for increasing phenolic compounds, flavonoid, antioxidants activity and cooking quality. This is proving that it is possible to take advantage of food by-product to better satisfy consumer demand for healthy added-value food products.

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