UTILIZATION OF POMEGRANATE (*PUNICA GRANATUM*) PEELS AS A NATURAL SOURCE OF DIETARY FIBERS AND ANTIOXIDANTS IN SOME B AKERY PRODUCTS

Journal

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J. Biol. Chem. Environ. Sci., 2011, Vol. 6(1):445-474
www.acepsag.org

ABSTRACT

This investigation aimed to study the possibility of utilization of pomegranate peels (a by-product from pomegranate industry) as a new untraditional source of dietary fibers and natural antioxidants to produce some healthy bakery products such as cakes and biscuits. Wheat flour (72 % extraction) used for making cakes and biscuits was fortified with pomegranate peels powder at different levels of 2.5, 5, 7.5 and 10 %. The chemical, rheological, physical and organoleptical properties of the products were evaluated.

The obtained results indicated that the pomegranate peels powder contained high amounts of crude fiber, total dietary fiber (TDF) and phenolic compounds, amounted in, 16.21, 56.47 % and 522.56 mg/g (DWB), respectively. Crude protein, ether extract, crude fiber, total dietary fiber (TDF), ash and phenolic compounds were increased in parallel of pomegranate peels level increased and vice versa concerning total carbohydrates decreased in both cakes and biscuits.

Peroxide value of lipids extracted from cakes and biscuits during storage at room temperature for 6 weeks was determined and the results showed that the addition of pomegranate peels powder gave strong anti-oxidative efficiency due to its high amounts of phenolic compounds.

Rheological properties of dough for different samples were determined using farinograph and extensograph. The results indicated that water absorption of dough, arrival time and degree of weakening increased, while, dough stability decreased. The proportional number increased, while, extensibility decreased.

Also, physical properties of the products i.e., weight and density increased, while, volume and specific volume decreased as a result of increasing levels of pomegranate peels powder. Sensory evaluation characteristics of cakes and biscuits fortified with pomegranate peels powder showed greater preference up to 7.5 % substitution level.

It could be recommended that the pomegranate peels are promising natural source of dietary fiber and antioxidant, which containing associated polyphenols. This property together with the natural color and flavor make it suitable for a wide range of applications in food. So, the obtain product are considered healthy bakery products with high nutritional value.

Keywords: Pomegranate peels, chemical composition, dietary fiber, antioxidant, polyphenols, cake and biscuits.

INTRODUCTION

The pomegranate (*Punica granatum*) lies among the most popular fruits in Egypt. Such fruits are cultivated in tropical and subtropical areas and widely consumed by people in many countries. Besides, pomegranate fruit is considered as an excellent source for nutrients and characterized flavor. It is also a good source for the brilliant naturally red color called anthocyanins (Botrus *et al.,* 1984).

Several cultivars of pomegranate are cultivated in Egypt and the most famous of those varieties is Manfaloty. The total annual production of pomegranate fruit in Egypt was about 42934 tons produced from 8080 feddans (Anon, 2007).

Pomegranate plant is considered either a small tree or a large shrub. Its fruit is often deemed to be a large berry. The fruit is delimited by a leathery pericarp, containing within are numerous arils. Each is a single seed surrounded by a translucent juice-containing sac. Thus the fruit itself gives rise to three parts: the seeds, about 3 % of the weight of the fruit, and themselves containing about 20 % oil, about 30 % juice of the fruit weight, and the peels (pericarp) which also include the interior network of membranes. Other useful parts of the plant include the roots, bark, leaves and flowers (Lansky and Newman, 2007).

The fruit has a red color and medium size, weighing on average between 175-290 g. The extracted pomegranate juice can be used for the production of natural juices and canned beverages. The juice content represents 45-61 % of the fruit weight. The outer peel considered as disposal portion was determined as 28.1-39.2 %. Pomegranate peels are good source of dietary fiber and polyphenols. Also, phenolic substances could be used as natural antioxidant and antibacterial (Negi and Jayaprakasha, 2003).

In recent years, many attempts have been made to study natural antioxidants, particularly those of plant origin. Great interest has recently been focused on the addition of polyphenols to foods and biological systems, due to their well-known abilities to scavenge free radicals, i.e. antioxidant power (Zainol *et al.,* 2003).

In this concern, Laban (2004), reported that the pomegranate peels are promising source of dietary fiber containing associated polyphenols that exhibit antioxidant activity. This property together with the natural color and flavor makes it a suitable fiber for a wide range of applications as food ingredients.

Dietary fiber (DF) plays an important role in decreasing the risks of many disorders such as constipation, diabetes, cardiovascular diseases, diverticulosis and obesity. Dietary fiber can be grouped into two major types (a) soluble/viscous/fermentable and (b) insoluble/non-viscous/slowly fermentable (Ramulu and Udayasekhara, 2003). Recently FAO/WHO discussion document on carbohydrates recommended dropping the terms "soluble" and "insoluble" fiber (FAO, 1998). The physiological effects of total dietary fiber (TDF), in the forms of insoluble and soluble fractions of foods, have a significant role in human nutrition.

So, there is a trend to find new sources of DF as ingredients for the food industry .The most wide spread consumed DF products are those derived from cereals and fruits (citrus, apple and others), have been steadily introduced in the occidental world markets. Fruit DF concentrates have , in general , better nutritional quality than those found in cereals because of their significant contents of associated bioactive compounds such as flavonoids , carotenoids, etc. and more balanced composition higher overall fiber content, greater SDF/IDF ratio , water – and fat- holding capacities , lower metabolic energy value , and phytic acid content (Chau and Huang, 2003).

Dietary fiber functions works as a bulking agent increases the intestinal mobility and moisture content of the feces. It consists of cellulose, hemicellulose, lignins, pectins, gum etc. Dietary fibers from different sources have been used to replace wheat flour in the preparation of bakery products (Sudha *et al.,* 2007).

Pomegranate peels contains substantial amounts of polyphenols such as ellagic tannins, ellagic acid and gallic acid. It has been used in the preparation of tinctures, cosmetics, therapeutic formula and food recipes (Negi *et al.,* 2003).

Also, the pomegranate peel extracts have both antioxidant and anti-mutagenic properties and could be exploited as biopreservatives in food application and pharmaceuticals.The pomegranate peel extract had higher antioxidant capacity than the pulp extract (El-Anany, 2007).

Because the pomegranate peel is a rich source of antioxidants, specially polyphenols, such as ellagic acid, querecetin and punicalagin and many plant polyphenols as well as their dietary sources, have been shown to act as potent antimutagenic and anticarcenogenic agents (Gil *et al.,* 2000).

Singh *et al.*, (2002), reported that pomegranate peels have been used since antiquity in the Middle East as interesting colorant for textiles because of their high tannin and phenolic contents. Also, added that the pomegranate peels had much higher antioxidant capacity than that of seeds.

The present study is an attempt to evaluate the utilization of pomegranate peels as a natural source of dietary fiber and natural antioxidants. Also, to study the effect of this by-product on the chemical composition, functional properties, rheological characteristics, stability of lipids and sensory evaluation of some bakery products such as cakes and biscuits.

MATERIALS AND METHODS

Materials:

Mature fresh pomegranate fruits (*Punica granatum* , Manfaloty variety) used in the present study were obtained from the Agricultural Research Center, at Giza Governorate. The peels were manually removed, sun-dried, powdered in a grinder to reach 40-mesh size and then packed and stored at room temperature in black bags until used.

Wheat flour 72% extraction was obtained from Cairo Co. for Milling and Baking, Cairo, Egypt. The other ingredient materials used i.e. fresh eggs, commercial grade crystalline sucrose, shortening, skimmed milk powder, baking powder, vanillin and improvers were obtained from the local market, Giza, Egypt. All chemicals and reagents used were purchased from Merck (Darmstadt, Germany). Butylated hydroxy anisole (BHA) as synthetic antioxidant was purchased from Sigma Chemical Co. (St. Louis, Mo., USA).

Methods:

Preparation of cakes and biscuits:

Different blends of cakes and biscuits were prepared according to the method described in AACC (2002). The different blends were partially replaced by pomegranate peels powder at 2.5, 5, 7.5 and 10 % levels, but control samples were prepared without adding pomegranate peels powder.

Chemical analysis:

Wheat flour 72 % extraction, pomegranate peels and their blends were analyzed for crude protein, crude fiber, ether extract, ash , moisture and TDF, IDF and SDF contents using the methods described in AOAC (2003). Carbohydrates were calculated by difference.

Determination of total phenolic content:

The total phenolic content of the extracts was determined colorimetrically using Folin-Ciocalteu reagent according to the method of Jayaprakasha *et al.,* (2001), and the final results were expressed as tannic acid equivalents per gram dry weight of sample. All the experiments were carried out in triplicate.

HPLC of phenolic compounds :

Extraction, fractionation and quantification of phenolic compounds were determined using HPLC analysis. A Hewlett-Packard Series 1100 liquid chromatography system (Waldbronn, Germany) equipped with a loop (20 µl) diode array detector and a lichrosorb RP 15 column (4.0 mm i.d. x 250 mm ; particle size 5 mm) (Merck , Darmstadt) was used. Elution was performed at a flow rate of 1.0 ml / min with mobile phase of water / acetic acid (98: 2, v/v, solvent A) and methanol / acetonitril (50: 50, v/v, solvent B), starting with 5 % B and increasing B to levels of 30 % at 25 min, 40 % at 35 min, 52 % at 40 min, 70 % at 50 min, 100 % at 55 min, and kept at this stage for 5 min. A re-equilibration time of 15 min was then required. Quantitation was achieved at 280 nm by internal standard method (Evangelisti *et al.,* 1997)

Oxidative stability:

The oil extracted from the cake and biscuit substituted with pomegranate peels at different levels were subjected to peroxide value determination compared with control oil and that contained 200 µg/L BHA, according to the oven test described in AOCS (1993).

Rheological properties:

The Farinograph and Extensograph were used to study the characteristics i.e, water absorption, arrival time, dough development and stability, weakening of dough, extensibility, resistance of extension, proportional number of dough's and dough energy of the resulted dough under investigation according to the method described in AACC (2002).

Physical properties of different prepared cakes and biscuits:

1- Weight of different baked cakes and biscuits was recorded by using sensitive balance (0.1 gm) according to Johnson (1990).

2- The volume of different prepared samples were determined by rape seeds displacement method AACC (2002).

3- Specific volume was calculated according to the method of AACC(2002) using the following equation:

$$\text{Specific volume (cm}^3\text{/g)} = \frac{\text{Volume (cm}^3\text{)}}{\text{Weight (g)}}$$

Sensory evaluation:

Sensory evaluation of cakes and biscuits with and without pomegranate peels powder at different levels were carried out by ten panelists on the characteristics of cakes and biscuits included crust color, spongy, taste, flavor, crumb color, texture, volume and granules for cakes. Taste, odor, texture, crust color and crumb color carried out for biscuits.

Statistical analysis:

Data were analyzed by analysis of variance (SAS, 1995). Students test was used to compare the data and all tests were considered statistically significant at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Chemical composition of wheat flour (72 % ext.) and pomegranate peels powder:

The chemical analysis results of wheat flour 72% extraction and pomegranate peels powder are shown in Table (1). From these results it could be noticed that wheat flour (72%extraction) contained the highest value in crude protein (11.56 %) and total carbohydrates (85.65 %) on dry weight basis. While lowest values were (0.72 %) and (0.59 %) for crude fiber and ash contents on (DWB), respectively.

On the other hand, pomegranate peels powder (pp) had higher levels of ash (3.49 %), crude fiber (16.21 %) and total dietary fiber (56.47%) being about 7, 10, 16, times as that of wheat flour (WF), respectively. Meanwhile, the moisture content, crude protein and total carbohydrates were lower than the corresponding values of wheat flour. So, the caloric value of (pp) was 327.95 k.cal/100g compared with 402.16 k.cal/100g for WF. The obtained results coincide with the results of Aguilar *et al.,* (2008) and Doweidar et *al.,* (2010).

Phenolic contents of raw materials:

Concerning the total phenolic content, results in Table (1) showed that pomegranate peel contained nearly 4.5 fold as high as that of wheat flour which amounted 522.56 and 123.24 mg/g (on DWB), respectively.

The obtained values agree with Li *et al.,* (2006), who mentioned that the phenolic contents in the pomegranate peel extract (249.4 mg/g) was nearly 10 fold as high as that of pulp extract. They also added that the large amount of phenolics contained in peel extract were higher than that in the pulp, and that may give the first a strong antioxidant ability.

Also, the obtained values were closer to those reported by Ghasemian *et al.,* (2006), who mentioned that the total phenolic contents of peel extracts of two Iranian pomegranate cultivars were found to be 232.8 ±15.1 and 251.3 ±167 mg/g, respectively.

Dietary fiber and it's functional properties in raw materials:

The results of dietary fiber and its fractions of WF 72% ext. and pomegranate peel powder are presented in Table (1). The results indicate that values of total dietary fiber (TDF%), insoluble dietary fiber (IDF%) and soluble dietary fiber (SDF%) for pomegranate peels (PP) powder were higher than that of wheat flour 72% ext. amounted in: 56.47, 38.24 and 18.23 % of (pp) compared with 3.25, 2.17 and 1.08 % of WF 72% ext. (on DWB). These results are agreed with Laban (2004), who mentioned that pomegranate peels are promising source of dietary fiber containing polyphenols that exhibit antioxidant activity. The fibers with 15% SDF are able to bind and retain several times their weight of water.

Hydration properties of dietary fiber refers to its ability to retain water within its matrix. Fiber with strong hydration properties could increase stool weight and potentially slow the rate of nutrient absorption from the intestine (Gallaher and Scheeman, 2001). Also, it can enhance viscosity of the added food.

Table (1): Chemical composition of raw materials (on dry weight basis)

Constituents	Wheat flour (72% extraction)	Pomegranate peels powder
Crude protein (%)	11.56	4.98
Ether extract (%)	1.48	1.35
Crude fiber (%)	0.72	16.21
Ash (%)	0.59	3.49
Total carbohydrates (%)*	85.65	73.97
Phenolic compounds (mg/g)	123.24	522.56
Moisture content (%)	11.27	5.67
Total dietary fiber (%)	3.25	56.47
Insoluble dietary fiber (%)	2.17	38.24
Soluble dietary fiber (%)	1.08	18.23
Bulk density (g/cm^3)	0.62	0.57
WHC (g H_2O /g sample)**	6.43	9.24
OAC (g Oil /g sample)***	4.72	6.30
Energy (k.cal./100g)	402.16	327.95

*Total carbohydrates: Calculated by difference.
**WHC :Water holding capacity. ***OAC :Oil absorption capacity.

As shown in Table (1) the bulk density (BD), water holding capacity (WHC) and oil absorption capacity (OAC) of the pomegranate peel powder were 0.57 (g/cm^3), 9.24 (g H_2O/g sample) and 6.30 (g oil/g sample), respectively.

These values being higher than those of wheat flour (72 % extraction) and could be associated to the high amounts of insoluble dietary fiber found in pomegranate peel (Figuerola *et al.,* 2005).

The obtained results coincide with Laban (2004), who mentioned that the WHC and OAC in three cultivars of pomegranate peel ranged between 5.73-6.81 g water/g and 1.94-2.40 g oil/g, respectively. Also,Sudha *et al.,(*2007) indicated that the fiber had higher water holding capacity.

These results of the hydration properties of DF of pomegranate peels powder (pp) were also closer to those found in apple pomace reported by Essam El-Din (2008), other (WHC) found are in the range of 15.5-16.7 g of water/g of dry citrus peel fiber (Chau and Huang, 2003) and between 9.6 and 12.84 g of water/g of dry Mexican lime peel fiber. Meanwhile, OAC of citrus peel fiber (2.35-5.09 g oil/ g of dry sample). Also, the obtained results are comparable to those of El-Reifai *et al*., (2006).

From the data of (DF) and hydration properties of pomegranate peel DF presented in Table (1), it could be clearly observed that pomegranate peel fiber had high content of (DF) with a high proportion of (IDF) and exhibited adequate WHC, OAC, BD similar to apple peel fiber and closer to other fruit peel fiber (grape, mango, peach) El-Reifai *et al.,* (2006).

Generally, it could observe from these results that the DF characteristics of pomegranate peel powder suggest many potential applications, i.e., (volume replacement, thickening or texturizing) in the development of foods reduced in calories and rich in dietary fiber.

Fractionations of phenolic compounds in pomegranate peels powder using HPLC analysis:

Pomegranate peels are natural source of phenolic compounds (Table 1). The phenolic compounds extracted from pomegranate peels powder was fractionated using HPLC and the obtained results are shown in Table (2). It could be observed that the pomegranate peels contain substantial amount of polyphenols such as gallic acid, caffeic acid, catechel and vanillic acid, which were 16.38, 15.03, 9.65 and 9.16 % from total phenolic compounds, respectively.

On the other hand, the pomegranate peel powder extract contains small amounts of chlorogenic acid, catechein, caffeine and ferrulic acid. Whereas, the other phenolic compounds were found in sufficient amounts (Table 2).

These results are in good agreement with Singh *et al.,* (2002), who reported that the HPLC pattern of the pomegranate peel extracts using ethyl acetate, methanol, and water indicated the presence of gallic acid as major component. They also mentioned that the antioxidant activity may be directly correlated to the phenolic content of peel extract.

Also, Gil *et al.,* (2000), reported that the antioxidant activity shown by the pomegranate extracts may be due to the presence of polyphenols, such as ellagic tannins, ellagic acid and gallic acid.

Table (2). Identification of phenolic compounds in pomegranate peel powder extracts.

Peak No.	Components	Retention time (min.)	Percentage (%)
1	Gallic acid	2.148	16.38
2	Chlorogenic acid	2.234	1.39
3	Catechein	2.242	2.24
4	Caffeic acid	2.467	15.03
5	Catechel	2.616	9.65
6	Vanillic acid	2.633	9.16
7	Synergic acid	2.643	1.00
8	Caffein	2.869	3.58
9	Ferrulic acid	3.563	3.58
10	Coumarin	4.071	0.70
11	Naringini	4.131	0.66
12	Cinnamic acid	5.766	0.06
13	Chrisin	8.942	0.02

In this concern, it has been observed that many plant polyphenols, such as ellagic acid, catechins, chlorogenic, caffeic and ferulic acids act as potent antimutagenic and anticarcinogenic agents (Negi *et al.,* 2003).The obtained results show that the pomegranate peel is a natural source of phenolic compounds. So, it is suggested that the pomegranate peel may be used as a natural antioxidant to improve the quality, stability and safety of foods.

Chemical composition of cakes and biscuits prepared from wheat flour (72 % extraction) and pomegranate peels powder at different levels:

The chemical composition changes for both cakes and biscuits prepared with different replacement levels of pomegranate peel powder (pp) at 2.5, 5, 7.5 and 10 % instead of wheat flour compared with control for both cake and biscuit which prepared with 100% wheat flour 72% extraction are given in Table (3).

It could be observed that, moisture content, crude protein, ash and ether extract showed slight and gradual increases of the prepared cake and biscuit samples with different levels of pomegranate peels (pp) compared to the control sample. On contrary, gradual decrease in total carbohydrates with increasing of pomegranate peels levels was noticed. Meanwhile, crude fiber content, gradually increased as the substitution level increased in both prepared cake and biscuit samples. So, the increment percentages of crude fiber in supplemented cakes and biscuit samples ranged between 44.83 – 185.06 % and 22.64 – 132.08 % at levels 2.5 and 10 %, respectively (Table 3).These results were agreed with those reported by Mahfouz *et al*.,(2007), Zaki *et al.,*(2009) and Doweidar *et al.,* (2010) .

Total phenolic content in cakes and biscuits:

Concerning , the total phenolic content for different samples, the data in Table (3) show that cake and biscuit samples prepared from wheat flour only (control samples) had 91.86 and 81.49 mg/g (DWB) phenolic contents, respectively, whereas, the supplemented cake and biscuit samples had phenolic content ranging between (130.23 – 265.11) and (121.70 – 235.46) mg/g (DWB), respectively. The increment percentages ranged from (41.77 - 188.60 %) and (49.34 - 188.94 %) in supplemented cake and biscuit samples, respectively, compared with the control samples. Comparing the phenolic content of the prepared samples, it could be notice that, these values were lower than that of the original pomegranate peel powder (Table 1). However baking or drying at temperature above 60ºC is regarded as unfavorable due to the possibility of inducing oxidative condensation or decomposition of thermo-liable compounds like phenolics (Asami *et al.,* 2003 and Sudha *et al.,* 2007). Despite of these decrements in total phenolic contents of the supplemented samples, compared with pp powder, the prepared cake and biscuit samples still have sufficient amount of phenolics compared to the control sample (zero pp). The higher amount of phenolic contents in the latter cake and biscuits supplemented with 10 % pp powder can also be due to components derived from pomegranate peel, and the formation of intermediates such as endues and reductions during baking process, which interferes with the colorimetric assay (Sudha *et al.,* 2007). On the other hand, Valencia *et al.,* (2007), mentioned that bakery products prepared with mango dietary fiber (MDF) concentrates had slightly lower in phenolic contents than the original (MDF) concentrate. These results suggest that baking does not have significant impact on these compounds.

Dietary fiber and their fractions of cakes and biscuits prepared from wheat flour (72 % ext.) supplemented with pomegranate peels powder at different levels:

Dietary fiber may be divided into two parts when it is dispersed in water: a soluble and insoluble fraction (Ramulu and Udayasekhara ,2003). Each fraction has different physiological effects: The insoluble part is related to both water absorption and intestinal regulation, whereas the soluble fraction is associated with the reduction of cholesterol in blood and the diminish in the intestinal absorption of glucose.

The dietary fiber and its fractions in both cake and biscuit prepared using wheat flour supplemented with different levels of pomegranate peels powder were studied and the obtained results are shown in Table (4).

From these results, it could be noticed that the total, soluble and insoluble dietary fiber increased in all samples as a result of supplementation with different levels of pomegranate peels powder (Table 4).

Table (3) Chemical composition of cakes and biscuits prepared from wheat flour (72% extraction) supplemented with different levels of pomegranate peels powder (on dry weight basis).

Constituents	Cake					biscuits				
	Control*	Cake with pomegranate peels levels				Control*	Biscuits with pomegranate peels levels			
		2.5%	5%	7.5%	10%		2.5%	5%	7.5%	10%
Crude protein (%)	10.86	10.97	11.10	11.24	11.37	9.79	9.92	10.11	10.23	10.35
Ether extract (%)	20.54	20.58	20.63	20.72	20.90	17.82	17.89	17.93	18.10	18.48
Crude fiber (%)	0.87	1.26	1.67	2.10	2.48	1.59	1.95	2.34	2.82	3.69
Ash (%)	0.52	0.60	0.68	0.84	1.13	0.96	1.13	1.20	1.29	1.32
Total carbohydrates (%)	67.21	66.59	65.92	65.10	64.12	69.84	69.11	68.42	67.56	66.16
Moisture content (%)	22.17	23.25	23.96	24.17	24.85	5.63	6.27	6.92	7.14	7.65
Phenolic compounds (mg/ g)	91.86	130.23	173.25	234.88	265.11	81.49	121.70	146.48	221.79	235.46

*Control : 100% wheat flour (72% extraction).

Table (4). Total , soluble and insoluble dietary fiber contents of cakes and biscuits supplemented with different levels of pomegranate peels powder (% on dry weight basis).

Samples		Cakes					biscuits				
		Cakes* control	Cake with pomegranate peels powder levels				Biscuits* control	Biscuits with pomegranate peels powder levels			
			2.5%	5%	7.5%	10%		2.5%	5%	7.5%	10%
T.D.F **	(A)	2.78	3.98	5.52	7.23	8.57	3.24	4.97	6.49	8.21	9.32
S.D.F ***	(B)	0.83	1.11	1.40	2.10	2.38	0.96	1.49	1.85	2.30	2.97
I.D.F ****	(C)	1.95	2.87	4.12	5.13	6.19	2.28	3.48	4.64	5.91	6.35
S.D.F/T.D.F	B/A	29.86	27.89	25.36	29.05	27.77	29.63	29.98	28.51	28.01	31.87
I.D.F./T.D.F	C/A	70.14	72.11	74.64	70.95	72.23	70.37	70.02	71.49	71.99	68.13

* Control : 100 % wheat flour (72 % extraction).
**T.D.F : Total dietary fiber.
***S.D.F. : Soluble dietary fiber.
****I.D.F. : Insoluble dietary fiber.

Concerning, total dietary fiber (TDF), both products formulated with pp powder exhibited increased TDF levels, so, the TDF in supplemented cake and biscuit samples values ranged between 3.98 – 8.57 % and 4.97 – 9.32 %, respectively compared with 2.78 % and 3.24 % on (DWB) in the control samples. The increment percentages of TDF ranged between 43.17 – 208.27 % and 53.40 – 187.65 % in supplemented cakes and biscuits samples, respectively. Addition of pomegranate peels powder (pp) also improved SDF and IDF contents, which the increment percentages were 33.73 – 186.75 % and 55.21 – 209.38 % for SDF of supplemented cakes and biscuits samples. Meanwhile, the corresponding values of IDF ranged between 47.18 – 217.44 % and 52.63 and 178.51%, respectively, as shown in (Table 4).

In this concern, Sangronis and Reboffeda (1993) mentioned that TDF contents in commercial fiber rich cookies have been reported between 3.73 and 6.95 % (DWB).

However, the SDF/IDF ratio is important for both dietary fiber and functional property. It is generally accepted that those fiber source suitable for use as food ingredient should have an SDF/IDF ratio close to 1: 2 (Jaime *et al*., 2002).

The obtained results were closer to Sudha *et al.,* (2007), Valencia *et al.,* (2007), who reported that the high content of TDF, crude fiber and ash of fruit by products are expected to raise the nutritive value of wheat flour used for cakes making. So, it could be observed that the prepared cake and biscuit samples containing pp powder at different substitution levels (2.5 – 10%) could provide about 16 – 35 % and 20 – 37 % of the Daily Recommended Values (DRV'S) of dietary fiber, respectively.

These findings indicate that both types of bakery products prepared with pomegranate peels powder had interesting TDF contents and may be an alternative for people with special caloric requirements.

Effect of adding pomegranate peels powder on the oxidative stability of cake and biscuit lipids during storage:

Hydroperoxides are the primary products of lipid oxidation, therefore peroxide value determination can be used as oxidation index of the early stages of lipid oxidation (El -Anany , 2007)

The changes in peroxide values for all samples during storage for 6 weeks at room temperature for lipids extracted from samples are shown in Table (5).

The data in Table (5) revealed that peroxide value of the oil extracted from the control baked materials amounted in 0.64 at zero time and increased to 0.85 , 2.53 and 3.10 equiv.O_2/100g after 2 , 4 and 6 weeks for cake. Meanwhile, it was 0.48, 0.69, 2.32 and 2.83 equiv.O_2/100g for biscuits. Addition of BHA reduced peroxide value by about 50 % during storage periods. Supplementation with pp powder showed a gradual decrease in peroxide value than that of control either in control or during storage periods. For instance, supplementation with 2.5 % pp powder resulted in peroxide value of 0.36 at zero time and ranged from 0.76 to 2.12 equiv.O_2/100g during storage periods for cake. Similar trend was found concerning biscuits. It is worth to mention that the increasing of pp powder resulted in more stability of the extracted oil and in parallel increased the shelf life of the bakery products.

These results are in good agreement with (Gil *et al.,* 2000), who mentioned that the antioxidant activity shown by the pomegranate peel powder extracts may be due to the presence of polyphenols, such as ellagic tannins, ellagic acid and gallic acid. Also, Reddy *et al.,*(2005), reported that the natural antioxidants have gained considerable interest in recent years for their role in preventing the auto-oxidation of fats ,oils and fat containing food products. The addition of plant extracts to foods gave an excellent antioxidant effect on the product than that of the control and synthetic antioxidant treated samples.

Rheological properties:

Results presented in Table (6) show the effect of substitution of 2.5, 5, 7.5 and 10 % of pomegranate peels powder (by-product) to wheat flour 72 % extraction on farinograph parameters. From the results, it could be noticed that the water absorption of flours increased gradually with increasing the added different levels of pp compared with the control sample.

The increase in pomegranate peel powder (pp) content in the blend was from 0 % to 10 %, increased the water absorption from 60.1 % to 70.45 %. Similar observations were mentioned by Sudha *et al.,* (2007) and Essam El-Din (2008).

Table (5). Effect of adding pomegranate peels powder on the oxidative stability of cakes and biscuits lipids during storage period.

Samples		Peroxide value of cakes lipids				Peroxide value of biscuits lipids			
		Storage period (weeks)				Storage period (weeks)			
		Zero	2	4	6	Zero	2	4	6
Control*		0.64	0.85	2.53	3.10	0.48	0.69	2.32	2.83
Control + BHA**		0.45	0.63	1.24	1.49	0.35	0.48	1.14	1.69
Pomegranate peels powder percentage	2.5 %	0.36	0.76	1.28	2.12	0.40	0.62	0.76	0.89
	5 %	0.34	0.68	1.10	1.94	0.38	0.47	0.69	0.84
	7.5 %	0.30	0.55	0.97	1.43	0.32	0.40	0.55	0.72
	10 %	0.25	0.32	0.43	0.62	0.26	0.36	0.50	0.54

*Control : 100 % wheat flour (72 % extraction).

**BHA: Butylated hydroxy anisole (at 200 µg/L).

Table (6). Effect of adding different levels of pomegranate peels powder to wheat flour (72% extraction) on Farinograph and Extensograph parameters.

Samples		Farinograph parameters					Extensograph parameters**			
		Water absorption (%)	Arrival time (min)	Dough development (min)	Dough stability (min)	Weakening of dough (B.U.)	E (m.m)	R (B.U.)	R/E	Dough energy (cm^2)
Control*		60.10	1	1.5	14	130	110	200	1.82	37
Pomegranate peels powder percentage	2.5 %	62.40	1.5	2	12	140	95	210	2.21	34
	5 %	64.70	2	2.5	10	150	70	220	3.00	25
	7.5 %	66.12	2.5	3	9	160	60	240	4.00	22
	10 %	70.45	3	3.5	8	170	35	260	7.40	13

*Control : 100% wheat flour (72 % extraction).

E** : Extensibility.

R : Resistance of extension.

R/E : Proportional number of dough's.

Regarding the arrival time (min) and the dough development (min), results in Table (6) show that these two parameters were proportional to the increase of pomegranate (pp) dietary fiber added to the wheat flour. However, the blended sample containing 10% pp recorded the highest value of arrival time and dough development 3 and 3.5 (min) compared with only 1 and 1.5 (min) for the corresponding blended sample of 100 % wheat flour. These results reflect the directly effect of pp fiber for these characters. Sudha *et al.,* (2007) mentioned that the increase in dough development time in the blends has slowed the rate of hydration and development of gluten.

On the other hand, stability of dough (min.) decreased from 14 min. for the control samples to 12, 10, 9 and 8 min. of pomegranate peels powder at the levels 2.5, 5, 7.5 and 10 %, respectively, as a result of increasing of weakening of dough. Finally, this means that the nature of pomegranate peels fiber played an important function in farinograph parameters of dough (Table 6).

Also, these results are in accordance with those obtained by Abd El-Moniem and Yassen (1993), who mentioned that the addition of different types of fiber reduced the dough stability compared with the control. These obtained results coincide with those obtained by Sudha *et al.,* (2007), Essam El-Din (2008) and Doweidar *et al.,* (2010).

Also, extensograph parameters used to study the effect of addition of pomegranate peel powder (pp) on the elastic properties (Table 6). From these results, it could be observed that with the increase of pp powder content to 10% the extensibility values decreased from 110 to 35 mm.

On contrary, the resistance to extension increased from 200 to 260 B.U. (Table 6). These results are in accordance with those obtained by Wang *et al.,* (2002), who found that elasticity decreased by the addition of tested fibers. On the other hand, Sudha *et al.,* (2007), found that, the extensibility values decreased from 127 to 51 min. and this may be either due to the dilution of gluten proteins or interactions between polysaccharides and proteins of wheat flour. Also, results of Wang *et al., (*2002), Collar *et al.,(*2007), were in good accordance with the obtained results for extensibility reduction of fiber supplemented dough's. They mentioned that overall dough weakening effect of fibers was evidenced from low resistant to the extension fiber-enriched dough's which can be largely attributed to the increased concentration of insoluble and soluble cell wall material from fiber responsible for the partial mechanical disruption of the gluten network.

Concerning the values of proportional number (R/E) of dough's, it could be notice that the values drastically increased from 1.82 to 7.40 with the increase of pp content to 10% in the blend (Table 6). The data indicate that the dough became stiff with the increase in pomegranate peel powder.

Finally, dough energy values decreased from 37 cm^2 in the control sample to 13 cm^2 in dough containing 10 % pomegranate peels powder. This might be due to the addition of more pomegranate peels which caused breakdown of gluten network. These results are in agreement with those obtained by Rizk *et al.,* (2009).

Effect of adding pomegranate peels powder on the physical properties of cakes and biscuits:

The different prepared cakes and biscuits samples were subjected to some physical measurements including weight, volume, density and specific volume. The obtained results were statistically analyzed and represented in Table (7). Statistical analysis of the results show significant differences in all measured physical properties of the tested samples. So, as the supplemented levels of pomegranate peels powder increased the weight and density of the prepared cakes and biscuits increased.

From these results in Table (7), it could be observed that the cake and biscuits supplemented with pomegranate peels at levels 2.5 – 5 % showed slightly significant differences compared to the control samples, meanwhile, the samples supplemented with 7.5 – 10 % pomegranate peels recorded the highest significant values of their physical properties compared to the control samples. These results also, agree well with those obtained by Zaki *et al.,* (2009) and Mahfouz *et al.,* (2007).

So, the highest increase in weight and density was found when pomegranate peel powder was used at 7.5 and 10 % substitution which recorded 135.90 g and 0.793 g/cm^3 in cake and 15.83 g and 0.853 g/cm^3 in biscuits samples for these parameters, respectively, compared with the control samples which recorded 113.08 g and 0.563 g/cm^3 in cake and 12.47g and 0.409 g/cm^3 in biscuits for the same parameter (Table 7). This increase in weight of supplemented samples with the increased level of substitution may be attributed to the high levels of fibers in the supplemented samples which increased the water absorption and consequently affected weight of samples (Mahfouz *et al.,* (2007). Also, Masoodi *et al.,* (2002) and Sudha *et al.,* (2007), reported that weight and density of the cakes increased due to the strong water binding properties of apple fiber.

On contrary, significant decrease in volume and specific volume was observed with the increase in pomegranate level (Table 7).

Control cake and biscuit samples had an average volume and specific volume of 200.80 cm^3 and 1.78% cm^3/g of cake and 30.43 cm^3 and 2.44 cm^3/g of biscuits, which, decreased to 171.44 cm^3 and 1.26 cm^3/g and 18.57 cm^3 and 1.17 cm^3/g for cake and biscuits samples, respectively. Masoodi *et al.,(*2002) and Sudha *et al* .,(2007), noticed similar observations during studying the effect of fiber on cake characteristics. Increased replacements of flour with fibers have been reported to weakening the gluten matrix responsible for retaining gases in baked foods.

From the obtained results, it could be concluded that incorporation of pomegranate peel (pp) powder does not change the physical properties of cake and biscuits samples to undesirable level up to (5%) and can be used as source of natural dietary fiber.

Sensory evaluation:

Sensory evaluation of the control cake and biscuits formula prepared with pomegranate peel (pp) powder were considered one of the important test affecting their acceptability qualities to a large extent.

Sensory evaluation of cakes:

The sensory characteristics, i.e., color, spongy , taste, flavor, color of crumb, texture, volume and granules for cakes prepared from wheat flour 72 % extraction containing different levels of pomegranate peels powder were evaluated by ten panelists. The obtained data were statistically analyzed as shown in Table (8).

The results presented in Table (8) show significant changes in cakes substituted with pomegranate peels powder at all different levels and the control, especially color, spongy and taste, but other sensory characteristics had no significant difference compared with the control as shown in Table (8).

Table (7). Physical properties of cakes and biscuits prepared from wheat flour (72% extraction) substituted with different levels of pomegranate peels powder.

Treatments		Cakes				Biscuits			
		Weight (g)	Volume (cm^3)	Density** (g/cm^3)	Specific volume (cm^3/g)	Weight (g)	Volume (cm^3)	Density** (g/cm^3)	Specific volume (cm^3/g)
Control*		113.08 ^{e}	200.80 ^{a}	0.563 ^{e}	1.78 ^{a}	12.47 ^{c}	30.43 ^{a}	0.409 ^{e}	2.44 ^{a}
Pomegranate peels powder percentage	2.5 %	117.76 ^{d}	192.14 ^{b}	0.613 ^{d}	1.63 ^{b}	13.64 ^{b}	27.77 ^{b}	0.492 ^{d}	2.04 ^{b}
	5 %	121.65 ^{c}	184.65 ^{c}	0.659 ^{c}	1.52 ^{c}	13.93 ^{b}	25.16 ^{c}	0.554 ^{c}	1.81 ^{c}
	7.5 %	129.92 ^{b}	180.61 ^{d}	0.719 ^{b}	1.39 ^{d}	15.08 ^{a}	21.13 ^{d}	0.715 ^{b}	1.40 ^{d}
	10 %	135.90 ^{a}	171.44 ^{e}	0.793 ^{a}	1.26 ^{e}	15.83 ^{a}	18.57 ^{e}	0.853 ^{b}	1.17 ^{e}

* Control : 100% wheat flour (72 % extraction).

** Density : Weight / volume.

- Means in the same row with different letters are significantly different ($p \leq 0.05$).

Table (8). Sensory evaluation of cakes prepared from wheat flour (72% extraction) substituted with different levels of pomegranate peels powder.

Samples of cakes		Crust color (10)	Spongy (10)	Taste (20)	Flavor (10)	Crumb color (10)	Texture (10)	Volume (10)	Granules (10)
Control*		8.27[a]	9.40 [a]	18.73 [a]	9.07 [a]	9.40 [a]	9.73 [a]	9.07 [a]	9.13 [a]
Pomegranate peels powder percentage	2.5 %	7.47 [ab]	8.60 [a]	17.47 [a]	8.87 [a]	8.33 [b]	9.14 [a]	8.53 [ab]	8.54 [a]
	5 %	7.33 [ab]	7.93 [b]	17.13 [a]	8.23 [a]	8.07 [b]	8.97 [ab]	8.00 [b]	8.07 [ab]
	7.5 %	6.60 [b]	7.53 [b]	16.87 [a]	7.23 [b]	7.07 [b]	7.93 [b]	7.20 [c]	7.60 [b]
	10 %	6.53 [b]	6.53 [b]	14.07 [b]	7.10 [b]	6.80 [c]	7.11 [c]	6.60 [c]	6.59 [c]

*Control : 100 % wheat flour (72 % extraction).

- Means in the same row with different letters are significantly different ($p \leq 0.05$).

The data obtained in Table (8) show slight significant differences in crust color, spongy, taste, flavor and granules of the cake samples prepared with (pp) up to 7.5% level of substitution. Compared with control cake, texture, volume and granules which gave highly significance due to supplementation. The scores of all the parameters of sensory evaluation decreased significantly only at 10% levels of addition of pomegranate peel. Also, the scores for crumb color decreased significantly as it was changed from creamishely yellow to brown color. The crumb grain scores decreased as the cakes had more compact cells and were dense, being connected well with the density values of the cakes presented previously in Table (8). However, with increasing the (pp) levels up to 10 % the prepared cakes gave highly insignificance difference in most of sensory parameters compared with the control cake. Though, the significant differences found in the test panels of the cake prepared with pomegranate peel powder was highly acceptable up to 7.5 % (pp). Similar results were reported by Essam El-Din (2008) and Doweidar *et al.,* (2010).

Sensory evaluation of biscuits:

The data presented in Table (9) show the sensory characteristics, i.e., taste, odor, texture, crust color and crumb color of biscuits prepared from wheat flour 72 % extraction and supplemented with different levels of pomegranate peels powder.

From the same results in Table (9), it cold be noticed that the supplementation with pomegranate peels powder at levels 2.5 and 5 % recorded nearly the same score compared to the control sample. Meanwhile, biscuits prepared with pomegranate peels at levels 10 % recorded the lowest score (Table 9). Conclusively, biscuits samples containing 2.5 and 5% of pomegranate peels powder had no significant difference for the same sensory characteristics compared to the control sample. But other supplemented levels for all parameters of sensory evaluation showed significant differences between them and the control biscuits samples.

Concerning sensory evaluation of different prepared biscuit samples, the results in Table (9), show highly significant differences between the prepared biscuit samples with 10 % (pp) and the control in taste, odor, texture, crust and crumb color, while, slightly differences were observed in taste, odor, texture and crust color of biscuits prepared with (pp) powder up to 5%. Meanwhile the lowest mean score for odor, texture, crust and crumb color were recorded for biscuits samples substituted with 7.5 and 10 % (pp) powder. Therefore, the biscuits samples substituted with 2.5 and 5% (pp) powder recorded the highest scores and preferred parameters for judgments of sensory evaluation followed by biscuit samples substituted with 7.5 and 10 % (pp) powders, respectively. These previously observations are closer to that observed by Mahfouz *et al.*, (2007), Essam El-Din (2008) and Rizk *et al*., (2009).

Table (9). Sensory evaluation of biscuits prepared from wheat flour (72% extraction) substituted with different levels of pomegranate peels powder.

Samples of biscuits		Taste (10)	Odor (10)	Texture (10)	Crust color (10)	Crumb color (10)
Control*		9.40^{a}	9.50^{a}	9.30^{a}	9.20^{a}	9.30^{a}
Pomegranate peels powder percentage	2.5 %	8.55^{b}	8.70^{b}	8.90^{a}	8.90^{a}	8.60^{b}
	5 %	7.78^{c}	7.90^{c}	8.00^{b}	8.00^{b}	8.00^{c}
	7.5 %	7.60^{c}	7.20^{d}	7.22^{c}	7.44^{b}	7.44^{d}
	10 %	6.70^{d}	6.40^{e}	6.30^{d}	6.40^{c}	6.90^{d}

* Control : 100 % wheat flour (72 % extraction).
- Means in the same row with different letters are significantly different ($p \leq 0.05$).

Conclusion

The obtained results indicate that the high content of total dietary fiber (TDF), crude fiber, ash and phenolic compounds of pomegranate peels are expected to raise the nutritive value of wheat flour used for cakes and biscuits making .So, it could be observed that the prepared cake and biscuits samples containing pp powder at different substitution levels (2.5 – 10 %) could provide about 16 – 35 % and 20 – 37 % of the Daily Recommended Values (DRV'S) of dietary fiber, respectively.

These findings indicate that both types of bakery products prepared with pomegranate peels powder had interesting total dietary fiber (TDF), phenolic contents and may be an alternative for people with special caloric requirements. Also, it could be considered as a good and balanced diet either for the adult and /or school children.

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الاستفادة من قشور الرمان كمصدر طبيعي للألياف ألغذائية و مضادات الأكسدة في بعض منتجات المخابز

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تم إجراء هذا البحث بهدف الاستفادة من قشور الرمان كناتج ثانوي خلال تصنيع الرمان كمصدر طبيعي غير تقليدي للألياف الغذائية ومضادات الأكسدة وذلك في إنتاج بعض منتجات المخابز الصحية مثل (الكيك والبسكويت)،وبناء علي ذلك تم استبدال دقيق القمح استخراج 72% المستخدم في عمل الكيك والبسكويت بمطحون قشور الرمان عند مستويات استبدال 2.5، ، 5، 7.5 و10% وتقييم المنتجات كيميائيا ، ريولوجيا ، طبيعيا وحسيا.

أظهرت نتائج التقييم الكيميائي أن قشور الرمان احتوت علي كميات كبيرة من الألياف الخام والألياف الغذائية الكلية والمركبات الفينولية حيث كانت16.21، 56.47 % و522.56 مج/جرام (علي أساس الوزن الجاف)، علي التوالي. كما وجد أنه بزيادة نسب الإحلال من قشور الرمان ازدادت نسب كل من البروتين الخام ،المستخلص الإثيري ،الألياف الخام ، الألياف الغذائية الكلية،الرماد والمركبات الفينولية ، بينما انخفضت الكربوهيدرات الكلية في كل من الكيك والبسكويت المدعم بنسب مختلفة من قشور الرمان.

كذلك تم تقدير رقم البيروكسيد لليبيدات المستخلصة من الكيك والبسكويت أثناء فترات التخزين للعينات علي درجة حرارة الغرفة لمدة 6 أسابيع وأوضحت النتائج أن إضافة قشور الرمان لها كفاءة عالية كمواد مضادة للأكسدة لاحتوائها علي كميات عالية من المركبات الفينولية.

كما تم تقدير الخواص الريولوجية للعينات المختلفة بواسطة جهازي الفارينوجراف والإكستنسوجراف وقد أشارت النتائج إلي زيادة امتصاص الماء للعجين المصنع منها، كما زاد زمن الوصول و درجة الضعف، بينما انخفضت درجة ثبات العجين ،وارتفاع الرقم النسبي للعجائن المدعمة بينما انخفضت درجة الانسيابية لهذه العجائن. أما بالنسبة للخصائص الطبيعية وجد أن الوزن والكثافة تزداد بينما ينخفض الحجم النوعي بزيادة نسب الإحلال بقشور الرمان. كما أوضح التقييم الحسي للمنتجات زيادة القابلية للكيك والبسكويت المدعم بقشور الرمان وقد أظهرت النتائج درجة تفضيل عالية حتى نسبة 7.5 % من قشور الرمان.

وتوصي نتائج هذه الدراسة بأن قشور الرمان تعتبر مصدر طبيعي واعد للألياف الغذائية لاحتوائه علي الفينولات العديدة والتي تظهر نشاط مضاد للأكسدة، بالإضافة ألي إنها تعطي لون و رائحة مقبولة مما يجعلها أكثر ملائمة للاستخدام بمدي واسع في تدعيم الأغذية و الحصول علي مخبوزات صحية عالية القيمة الغذائية.