Pomegranate Peel Powder as a Functional Ingredient in Cookies: Application for Maximizing Waste Utilization

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ABSTRACT

Recently, the objective of the food industry is to minimize the impact of processing waste on human health. Pomegranate peel powder (PPP) was used as a functional ingredient in cookie products. PPP was added in cookies by a ratio of 4% and other replacement ratios. The results indicate that there was no significant difference between the control cookies sample and cookies sample containing 4% (PPP) in the organoleptic characteristics scores, with no marked effect on the calorie value. The cookies containing 4% PPP showed high content of phosphorus, sodium, potassium, calcium, iron, zinc and manganese. The results of storage stability of cookies showed that PPP addition reduces oxidative degradation of cookies during storage and no significant difference was found between the two cookie samples (0 and 4% containing PPP) in thickness, diameter and spread ratio after the storage time. Further, storage for 3 months significantly decreased the moisture content of the control and cookies containing 4% PPP to 4.31% and 4.29%, respectively. After storage for 3 months, the results showed significant decrease in DPPH scavenging ability, ascorbic acid equivalent and FRAP assay to 64.59%, 0.83 mg/g and 844.90 mmol Fe^{+2} equivalent/ 100g dried sample, respectively, compared with control. Pomegranate peel powder supplemented cookies showed relatively good microbial stability during storage for 3 months, as a significant reduction in microbial load was noticed. All the cookies' sensory parameters showed good acceptability during storage.

Keywords: Pomegranate peels, wastes, Antioxidant Activity, Cookies.

INTRODUCTION

Food wastes have been used as animal feed or brought to landfills, or sent for composting. This attitude has recently changed for environmental concerns, minimizing the impact of waste on human health, the high disposal costs and the growing awareness of the marketable components present in food wastes. The Waste Resources Action Program estimates the value of global consumer food waste at more than 400 billion US$ / year (Zoair *et al*., 2016). Food wastes produced throughout food processing represent 38% along the whole chain. This valorization can be achieved through the extraction of high-value components such as antioxidants, polysaccharides, fibers, and many other phytochemicals. Wastes of fruits and vegetables are of great concern in such aspects. Zoair *et al*. (2016) used peels of each of orange, banana and potato in preparing functional products.

Pomegranate peels are an important source of minerals, complex polysaccharides and high levels of a diverse range of bioactive compounds. Pomegranate peel powder (PPP) is of great interest for improving the functionality of food products and formulating functional foods with health benefits (Jalal *et al*., 2018). Rowayshed *et al*. (2013) reported that food industry by-products such as PPP contain the most determined nutrient elements to the human body, so they have a great therapeutic and nutrient effect as they supply vitamins, minerals, polyphenols, antioxidants, as well as crude fiber at an adequate concentration. Noor *et al*. (2021) reported that globally large amount of pomegranate wastes are produced in huge quantities, such as during processing, agricultural production and industrial manufacturing.

According to Health Canada (2000), functional foods can be eaten as part of an ordinary diet and look comparable to conventional foods. They have physiological advantages beside their fundamental nutritional benefits and can lower the risk of chronic disease.

The baking sector is regarded as a vital food processing industry globally. Cookies and biscuits are examples of baked goods that are unhealthy to eat because they are low in vitamins and minerals and rich in fat and carbohydrates. In the last few years, using plant extracts and peel powder of different fruits, vegetables and plants in biscuits has become popular.

Adding a source of natural vitamins, minerals, dietary fiber, or antioxidants from plant sources is the primary goal of this approach, which aims to increase the overall nutritional quality of products.

Having a balanced diet with all of the vital elements our bodies need can help us maintain a healthy diet.

The significance of necessary nutrients and components cannot be overlooked, as they are crucial for a healthy life.

Food produced today has less necessary nutrients, compared to food produced about 50 years ago and some prolonged, unsuitable agricultural techniques have also reduced the quality of soil for agricultural growth. Cookies are regarded as an energy source because they

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are often made with wheat flour, fat and sugar. But, conventional cookies lack fiber and phytochemicals. Recently, many studies have been directed toward fortifying cookies. Consequently, the fortification of foods or formulations of new food products with health-promoting effects such as anti-diabetic, anti-inflammatory, anticancer, and antioxidant properties is on the rise (Masood *et al*., 2021).

The low moisture level of cookies distinguishes them from other baked goods like bread and cakes. This extends the shelf life and minimizes the risk of microbiological spoilage, facilitating large-scale manufacturing and distribution (Ranjitha *et al*., 2018).

Therefore, the aim of the study was to investigate some of the main chemical, physicochemical, and technological parameters concerned with the use of peel wastes of Wonderful cultivar pomegranate fruit, in preparing functional food products. Also, the evaluation of sensory properties and storage stability for these products.

MATERIAL AND METHODS

Wonderful cultivar pomegranate fruits were purchased from the local fruits market in Alexandria Governorate, and they were separated, cleaned, washed and peels were dried in hot air oven.

All the chemical reagents used in the present study were of analytical grade. Plate count agar (PCA) and yeast-malt extract agar (YMA) were used for microbial count.

Technological Methods:

Cookies preparation:

Cookies were prepared as described by Ismail *et al*. (2014) with some modification. Wheat flour (500 g) was used in preparing the control sample. Five blends of cookies were prepared by replacing 4, 8, 12, 16 and 20% of the flour with pomegranate peel powder. Each of the flour mixes was thoroughly mixed and blended with baking powder (10 g). Sugar (250 g), butter (250 g), three eggs, vanilla (0.5 g) and salt (0.5 g) were added to the flour or the flour mixed with PPP. The resulting mixed hard batter was rolled out to uniform thickness with the help of a rolling pin. Cookies were cut out with a cookie cutter in discs of 4 cm diameter and placed in trays. Baking was carried out at 180^{o}C for 25 min. Cookies were allowed to cool at room temperature for 8-10 minutes. Baked cookies were stored in polyethylene bags and placed in plastic containers and kept at room temperature up to 3 months for further study.

Chemical methods:

Proximate composition: Moisture, crude protein, crude ether extract, ash and crude fiber content were determined according to A.O.A.C. (2006). Total carbohydrate was calculated by difference. Caloric value (K.Cal/ 100 g) was calculated according to A.O.A.C. (1980) using the following equation :

Caloric value (K.Cal/ 100 g) = [protein (g) x4 + fat (g) x9 + carbohydrates (g) x4].

Minerals content: Calcium (Ca), iron (Fe), zinc (Zn) and manganese (Mn) were determined in ash solution by using an atomic absorption spectrometer (Model Thermo SCIENTIFIC S SERIES AA, India), while sodium (Na) and potassium (K) were determined using a flame analyzer photometer (Model JENWAY, England). Phosphorus content was determined colourimetrically at a wavelength of 410 nm by phosphomolybdate reagent according to Kalra (1998).

Dietary fibers: Neutral detergent fibers (NDF) and acid detergent fibers (ADF) were determined according to the A.O.A.C. method No 985.29 (2006).

Colour measurement:

The colour values, namely; lightness (L*), redness (a*) and yellowness (b*) of samples were measured using a Hunter Lab Ultra Scan VIS model, colorimeter (USA) according to Santipanichwing and Suphantharika (2007). The instrument was standardized during each sample measurement with a black and a white tile. The total colour difference Δ E was calculated using the following formula:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1\backslash 2.}$$

Where Δ L^{*2}, Δ a^{*2} and Δ b^{*2} is the difference between reference and samples.

pH measurement:

Measurement of pH was carried out by a digital pH meter (1985 Orion Research Incorporated, USA). A weight of 5 g sample was added to 20 ml of distilled water, stirred and measured, according to A.O.A.C. (2000).

Thickness and width of cookies:

According to A.A.C.C. (2000), the width or diameter (W) of cookies was measured with a scale by laying six cookies edge to edge. The same set of cookies was rotated 90° and the diameter was remeasured. Average values were reported in cm. Thickness (T) was measured by stacking six cookies on top of one another and the average of thickness in cm was calculated.

Spread ratio of cookies:

Spread ratio of cookies was calculated by dividing diameter (W) by thickness (T) according to A.A.C.C. (2000).

Texture measurement:

Compression measurements of cookies samples were performed with a Texture Analyzer (Texture Pro

CT3 V1.2, Brookfield, Middleboro, USA) equipped with a 10000 g load cell at a speed of 1 mm/s to a distance of 2 mm with a 6 g trigger load for 20 sec (Musa *et al*., 2017).

Total phenolic content of the produced cookies was determined in the phenolic extract using a spectrophotometric method as described by El-Falleh *et al*. (2012).

Antioxidant activity: Two different methods were used to determine the antioxidant activity of various sample extracts. DPPH radical scavenging assay was performed according to the modified method described by Brand-Williams *et al*. (1995). Ferric reducing antioxidant power (FRAP) assay also was carried out as described by Jayanthi and Lalitha (2011).

Thiobarbituric acid (TBA): Test was performed for stored cookies was estimated according to the method described by Park *et al*. (2007). The TBA value was calculated as mg malonaldehyde / Kg sample. All the chemical determinations were carried out in triplicate.

Microbiological Methods:

Total viable count (TVC):

TVC was carried out according to Difco (1998) using plate count agar (PCA). The plates were incubated at 37 °C for 48 hrs. The results were expressed as log CFU/g.

Yeast and mould count (YMC):

Yeast and mould count was performed using yeast-malt extract agar (YMA) according to Lodder (1970). The results were expressed as log CFU/g after 3 days of incubation at 30 °C.

Sensory evaluation:

The sensory properties of cookie samples, included colour, taste, odour, texture and overall acceptability were evaluated by 20 panelists of the Food Science and Technology Department, Faculty of Agriculture, Alexandria University.

Statistical analysis:

The present results were subjected to proper statistical analysis of variance according to Gomez and Gomez (1984), using SAS (Statistical Analysis Systems) version 9.01 (2002).

RESULTS AND DISCUSSION

According to Jalal *et al*. (2018) PPP could be considered as a potential functional ingredient in food products, improving their technological properties with health benefits. In the present study, the hot air oven dried (PPP) was used in the preparation of functional cookies. Such bakery products are widely consumed worldwide. The consumption of cookies is covered by all consumers' ages from infancy to the elderly. According to Asefa *et al*. (2017) and Masood *et al*. (2021), the low moisture content of cookies makes them stable in storage and easy to handle. Numerous types of cookies are utilized as quick and healthy snacks. Cookie dough is made up of three main ingredients: flour, sugar, and fat. These ingredients affect the final product's quality.

Sensory evaluation:

Cookies containing PPP in proportions of 4-8-12-16-20% were formulated, baked and subjected to a taste testing panel in the present study.

Results shown in Table (1) indicate that there was no significant difference between the control cookies and cookies containing 4% PPP either in colour, odour, taste, texture, crispiness or overall acceptability scores. The colour, odour and taste scores of cookies containing 8% PPP insignificantly decreased when compared with cookies containing 0 and 4% PPP, while both the texture and crispiness scores significantly decreased compared with the control and cookies containing 4% PPP. The overall acceptability of cookies containing 8% PPP also showed significantly decreased scores compared with the control. All the sensory scores as well as the overall acceptability of cookies containing 12, 16 and 20% PPP showed significantly decreased scores as compared with the control (0% PPP). The panelists confirmed that they felt a more sour and bitter taste in cookies prepared with 20% PPP. Moreover. the lowest taste score was recorded in the cookies which contain 20% PPP. This may be due to the astringent flavour of phenolic compounds. The results are in agreement with Ismail *et al*. (2014); Ranjitha *et al*. (2018) and Urganci & Isik (2021), as they mentioned that the overall acceptability of cookies markedly declined with increasing supplementation levels of PPP.

The results presented in Table (1) indicated that the increment of PPP in cookies formulation to more than 8% of the flour resulted in inferior sensory quality, indicated by significantly low scores. On the other hand, the quality characteristics concerned with the texture, crispiness and overall acceptability are slightly affected in comparison with the score upon addition of PPP at a proportion of 4%. Accordingly, an addition of PPP at a proportion of 4% was suggested for further study to investigate the effect of adding PPP as a functional ingredient in cookie formulation.

Cookies supplemented with bioactive compounds like polyphenols and dietary fibers yield a wide range of health benefits to consumers (Ismail *et al*., 2016).

Table 1. Sensory properties of functional cookies containing (PPP)

PPP %	Colour	Odour	Taste	Texture	Crispiness	Overall Acceptability
Control 0%	8.32 ± 0.75 [a]	8.50± 0.69 [a]	8.53± 0.96[a]	8.26± 0.87[a]	8.44 ± 0.84[a]	8.50± 0.76 [a]
4%	8.18±0.77 a	8.08± 0.89[ab]	8.16± 0.92 [a]	8.16± 0.71[a]	8.18 ± 0.71[a]	8.23± 0.72[ab]
8%	7.84 ±0.96[ab]	7.95 ±1.31 [ab]	7.87± 1.15 [a]	7.37 ± 0.83 [b]	7.32 ± 0.75 [b]	7.69± 0.87 [bc]
12%	7.32±1.06 [cb]	7.50±1.28 [b]	7.05± 1.35 [b]	7.0±1.15 [b]	7.05 ± 1.18 [b]	7.25± 1.23 [c]
16%	7.03±1.23 [c]	6.79± 1.23 [c]	6.42±1.39 [b]	6.0 ± 1.15 [c]	6.16 ± 1.39 [c]	6.57 ± 1.31 [d]
20%	6.76 ± 1.34 [c]	6.74 ± 1.24[c]	5.66± 1.76 [c]	5.79± 1.32 [c]	5.61 ±1.46 [c]	5.88 ± 1.46 [e]

Means in a column not sharing the same letters are significantly different at $p \leq 0.05$.

Table 2 .Chemical composition of cookies containing PPP (on dry weight basis)

Component (%)	Control, 0%PPP	4% PPP
Moisture	6.04 ±0.1[a]	5.08±0.10[b]
Crude ether extract	24.65± 1.86[a]	25.05± 2.75 [a]
Crude protein	1.59± 0.36 [a]	1.23± 0.51 [a]
Total ash	0.86± 0.12[a]	0.98±0.03[a]
Total carbohydrate	72.89 ± 1.33 [a]	72.73 ± 3.29 [a]
Crude fiber	0.42 ± 0.06 [a]	0.52 ± 0.11 [a]
Calorie value (Kcal/100g)	519.78 ± 9.97[a]	521± 13.58 [a]

The difference in letters in the same row demonstrates a significant difference at $p \leq 0.05$.

Chemical composition:

a) Proximate Analysis:

The results presented in Table (2) demonstrated that the moisture content of the cookies with PPP substitution at a concentration of 4% was significantly affected as compared with the control, 0.0%. That is an indication that the presence of PPP had a marked effect on water migration and retention through the baking process of the cookies. The crude ether extract, total ash, crude fiber and caloric values insignificantly increased, while the crude protein and total carbohydrate showed an insignificant decrease in cookies containing 4% PPP as compared with control sample.

The obtained results were found to be very close to those recorded by Ismail *et al*. (2014), as they found non-significant changes in moisture contents for control compared to PPP-supplemented cookies might be related to the poor water-binding capacity of pomegranate peel as compared to wheat flour. Incorporation of 4.0% markedly affected both the ash and the crude fiber content, with no marked effect on the calorie value. That, in spite of the effect, is insignificant, yet further chemical analysis is suggested to investigate the effect of PPP addition on dietary fibers and minerals content as two parameters that have an important role in functional products.

b) Dietary fibers and minerals:

The results presented in Table (3) show the dietary fibers content of control and cookies containing 4% PPP. The neutral detergent fibers (NDF), which give a measure of total cell wall materials including cellulose, hemicellulose and lignin were 41.92 % and 25.99 % for the control and cookies containing 4% PPP, respectively. Acid detergent fibers (ADF), which is an indication for the presence of cellulose and lignin, were 0.55% and 1.84% for the control and cookies containing 4% PPP, respectively. Acid detergent lignin content (ADL) was 0.40 % and 1.23 % for control and cookies containing 4% PPP, respectively.

Moreover, as shown in Table (3), the difference between NDF and ADF gives the insoluble hemicellulose, which was 41.37 % and 24.15 % for the control and cookies containing 4% PPP, respectively. Also, cellulose was measured by the difference between ADF and ADL and was 0.15 % and 0.61 % for control and cookies containing 4% PPP, respectively.

As shown in Table (3), in cookies containing 4% PPP, the ADF content increased by 234.5% compared to its content in the control sample, while NDF content decreased by 38%. The dietary fibers components of cookies were significantly affected by replacing a proportion of wheat flour with PPP, according to Urganci and Isik (2021). El-Habashy (2017) states that adding dietary fibers to baked products enriches their health benefits because it permits a lower level of fat content by substituting dietary fibers for fat without affecting product quality. The most commonly available and often consumed foods that are rich in fiber are breakfast cereal and baked products like cookies and integral breads. The results shown in Table (4) represent

some of the main mineral composition of the control and cookies containing 4% PPP. The cookies containing 4% PPP showed high content of phosphorous, sodium, potassium, calcium, iron, zinc and manganese (237.36, 435.78, 141.58, 5.42, 3.49, 1.13, 0.70 mg/100 g, respectively), compared with the mineral content of control cookies that contained (201.17, 129.15, 106.16, 4.39, 2.87, 1.14 and 0.45 mg/100g, respectively). The results show that PPP-supplemented cookies could provide better levels of mineral content, particularly for sodium, potassium and phosphorus. Foods with adequate fiber, minerals, vitamins and other macronutrients significantly contribute to reducing cardiovascular disorders and are considered of an important functional role with many health benefits (Ismail *et al*., 2014 and Urganci & Isik, 2021).

Table 3 .**Dietary fibers content of cookies containing PPP**

Component (%)	Control, 0%PPP	4% PPP
Neutral detergent fibers (NDF)	41.92	25.99
Acid detergent fibers (ADF)	0.55	1.84
Acid detergent lignin (ADL)	0.40	1.23
Hemicellulose	41.37	24.15
Cellulose	0.15	0.61

Table 4. **Minerals content of cookies containing PPP (on dry weight basis)**

Mineral content (mg/100 g)	Control, 0%PPP	4% PPP
Phosphorous	201.17	237.36
Sodium	129.15	435.78
Potassium	106.16	141.58
Calcium	4.39	5.42
Iron	2.87	3.49
Zinc	1.14	1.31
Manganese	0.45	0.70

Storage stability of cookies:

The keeping of the physical and sensory qualities related to freshness and quality through the food chain from producers to consumers is identified as storage stability or the shelf-life of baked goods. Shelf life plays an important role in food safety of the processed products (Nadarajah & Mahendran, 2015 and Sharma & Riar, 2020).

In the present study, the results of the sensory evaluation indicated that 4% PPP replacement ratio in cookies showed the best sensory properties, compared with the other replacement ratios of pomegranate peel powder in cookies. Therefore, the cookies containing 4% PPP were selected to evaluate the storage stability during storage for 3 months at room temperature (22 ± 2°C) compared with the control.

Thickness, diameter and spread ratio:

Thickness, width (diameter) and spread ratio of control and cookies containing 4% PPP were measured at zero time and after storage at room temperature for 3 months. Table (5) presents the results of diameter, thickness and spread factor of freshly prepared and stored cookie samples. The diameter of control and cookies containing 4% PPP at zero time was 6.14 and 5.82 cm, respectively. These results also showed no significant difference at ($p \leq 0.05$) in diameter between control and cookies containing 4% PPP. Also, there was no significant difference at ($p \leq 0.05$) in the diameter of cookies between zero time and after storage at room temperature for 3 months. Also, as shown from Table (5) the thickness of cookies containing 4% PPP at zero time (1.17 cm) was significantly higher than its value for control (1.12 cm), moreover the statistical analysis revealed that there was significant difference as a result of storage time, since the thickness increased for control and cookies containing 4% PPP after 3 months of storage at room temperature.

For spread ratio, the results showed that the cookies containing 4% PPP had a spread ratio significantly lower than the control. That is due to the presence of higher fibers content in cookies containing PPP. No significant difference at ($p \leq 0.05$) was shown between the two cookies after the storage time.

Cookie spread is a ratio of diameter to thickness. The most desired cookies are those with a higher spread ratio. Higher spread ratios and larger cookie diameters are recognized as good quality properties, Peter *et al*. (2017). The obtained results were found to be close to the results which were recorded by Jandal and Naji (2021), who studied the physical properties of cookies substituted with 1.5, 3 and 4.5% pomegranate peel powder (PPP), and the diameter was 4.71, 4.66 and 4.56 cm, respectively. The thickness and spread ratio decreased with increasing concentration of cookies containing PPP, and the spread ratio was (3.46, 3.45 and 3.43) for different addition ratios (1.5, 3 and 4.5% PPP, respectively). The reason for the decrease in thickness with increasing concentrations of PPP may be due to the decrease in gluten content.

Table 5. Diameter, thickness and spread ratio of cookies containing PPP after storage at room temperature for 3 months

Property	Type of cookies	Storage time (month)		Mean
		0	3	
Diameter (cm)	Control, 0%PPP	6.14 ± 0.28	6.20 ± 0.11	6.17 [a]
	4% PPP	5.82 ± 0.38	5.84 ± 0.33	5.83 [a]
Mean		5.98 [a]	6.02 [a]	
Thickness (cm)	Control, 0%PPP	1.12 ± 0	1.17 ± 0	1.15 [b]
	4% PPP	1.17 ± 0	1.32 ± 0	1.25 [a]
Mean		1.15 [b]	1.25 [a]	
Spread ratio (Diameter/ thickness)	Control, 0%PPP	5.50 ± 0.21	5.30 ± 0.09	5.40 [a]
	4% PPP	4.98 ± 0.33	4.42 ± 0.25	4.69 [b]
Mean		5.24 [a]	4.86 [a]	

The difference in letters in rows and columns demonstrates a significant difference at $p \leq 0.05$.

Colour:

The colour of cookies is one of the characteristics that affect their acceptability. The colour values of the cookies samples, represented by lightness (L*), redness (a*) and yellowness (b*) at zero time and after 3 months of storage at room temperature are presented in Table (6) The control cookies showed higher L* values which were 61.79 at the beginning of storage and 61.73 after 3 months, compared with the cookies containing 4% PPP which these values were 51.04 at the beginning of storage and 50.16 after 3 months. Also, b* values were higher in the control cookies, which were 35.89 at the beginning of storage and 35.42 after 3 months, compared with cookies containing 4% PPP, which were 29.97 at the beginning of storage and 28.69 after 3 months.

The cookies containing 4% PPP showed higher a* values (9.78) than the control (8.77) at the beginning of storage, while they reached 10.12 and 10.65 for 4% PPP cookies and the control, respectively after 3 months of storage. Also, as shown in Table (6) the total colour difference (ΔE*) values between the control and cookies containing 4 % PPP were 12.31 at the beginning of storage and 13.39 after 3 months of storage at room temperature. The results of the present study are in agreement with Topkaya & Isik (2019) and Urganci & Isik (2021), who demonstrated that the colour of biscuits became significantly darker with PPP substitution. Anthocyanidins change colour at different pH and temperatures, which may cause the changes in b* values. Colour change during storage is also due to the Maillard browning reaction.

Texture:

In the present study, the texture profile analysis of cookies was evaluated at zero time and after 3 months' storage period at room temperature. As shown in Table (6) the hardness values of cookie samples at the beginning of storage were 977 g and 793 g for the control and cookies containing 4% PPP, respectively.

After 3 months, hardness values increased to 4806 g and 6615 g for the control and cookies containing 4% PPP, respectively. Cohesiveness and chewiness (mJ) for control samples were 0.09 and 0.5, respectively, at the beginning of storage and were 0.05 and 3.4, respectively, after 3 months, while these parameters for 4% PPP cookies were 0.16 and 0.9 at the beginning of storage and were 0.04 and 1.5 after 3 months of storage at room temperature.

The results showed that the hardness and chewiness values of all the stored cookies increased while cohesiveness decreased after 3 months of storage. Moreover, the cohesiveness and chewiness of cookies containing 4% PPP were higher than those values for the control sample at the beginning of storage, except for hardness, but after 3 months of storage, the values of hardness increased as compared with control samples. According to Mirani and Goli (2021), there was a positive correlation between fiber and protein contents with the hardness value of cookies. Also, Urganci and Isik (2021) showed that hardness decreased significantly with PPP addition in biscuits. Gluten network present in wheat flour is mainly responsible component in the hardness of biscuits.

Table 6. Colour and texture of cookies containing PPP after storage at room temperature for 3 months

Type of cookies	Control, 0%PPP		4% PPP	
Storage time (month)	0	3	0	3
Colour units				
Lightness (L*)	61.79	61.73	51.04	50.16
Redness (a*)	8.77	10.65	9.78	10.12
Yellowness (b*)	35.89	35.42	29.97	28.69
Δ E	-	-	12.31	13.39
Texture Profile Analysis (TPA) Hardness (g)	977	4806	793	6615
Cohesiveness	0.09	0.05	0.16	0.04
Chewiness (mj)	0.5	3.4	0.9	1.5

$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

Moisture:

According to Nadarajah and Mahendran (2015), the shelf stability of food products is mostly determined by their moisture content. Food that undergoes physicochemical changes during storage may lose shelf life and deteriorate in quality. The results presented in Table (7) show that there is a significant effect between days of storage and some parameters of the stored cookies. The moisture content of cookie samples before storage was 6.04% and 5.08% for control and cookies containing 4% PPP. The moisture content of cookies containing 4% PPP significantly decreased as compared with control cookies. That may be attributed to the water retention created by fibers. Further storage for 3 months significantly decreased the moisture content of the control and cookies containing 4% PPP to 4.31% and 4.29%, respectively.

The decrease in the moisture content during storage is attributed to water loss during the storage of cookies, and the lower moisture content of 4% PPP cookies may be due to the fiber content of pomegranate peel powder in the 4% PPP cookies that can bind water. The results of the present research agree with those reported by Incoronato *et al.* (2021), who indicated that the low moisture content can be attributed to water retention associated with a high dietary fiber content and the presence of hydrocolloids, like the pectin present in pomegranate peel powder.

On the other hand, Ranjitha *et al*. (2018) found that the moisture content increased significantly with the increase of PPP replacement (2.5% and 5%) in cookies. The moisture content varied from 2.43% to 2.50%, compared with the control. The increase in moisture content of cookies might be due to the increased water absorption of dietary fiber present in pomegranate peel powder when compared to refined wheat flour. The high water absorption capacity of fiber present in PPP is due to more hydroxyl groups of cellulose in the fiber, able to bind free water molecules through hydrogen bonding and thus resulting in greater water holding capacity. Also, Rajiv *et al*. (2012) their results demonstrated that there was no significant change in the moisture content of cookies for control and those containing ground flaxseed powder (RGF).

In general, the hygroscopic nature of dried products, storage conditions which involves temperature and relative humidity, and the nature of the product itself may all contribute to an elevation in moisture content, according to Nagi *et al*. (2012).

pH of cookies product:

As shown in Table (7) the pH values of cookies containing 4% PPP significantly decreased compared with control at zero time of storage. The pH values of control and cookies containing 4% PPP significantly decreased after 3 months of storage. The results are in agreement with Urganci and Isik (2021), who measured the pH values of biscuits substituted with pomegranate peel powder. They found that pH values significantly decreased from 5.03 to 4.39 with increasing the ratio of PPP from 6% to 18% respectively, compared with control (6.26). Also, according to Loza *et al*. (2017), cookies elaborated with the formulation of 20% of banana flour and 8% of sesame seeds were evaluated during storage of 3 months. The pH values were significantly different during storage.

Table 7. **Moisture content, pH and TBA values of cookies containing PPP after storage at room temperature for 3 months**

Property	Type of Cookies	Storage (month)		Mean
		0	3	
Moisture (%)	Control,0%PPP	6.04 ± 0	4.31 ± 0.11	5.18[a]
	4% PPP	5.08 ± 0.10	4.29 ± 0.03	4.69[b]
Mean		5.56 [a]	4.30 [b]	
pH values	Control,0%PPP	8.08 ± 0.23	8.06 ± 0.03	8.02 [a]
	4% PPP	6.94 ± 0.04	6.79 ± 0.01	6.75 [b]
Mean		7.51 [a]	7.12 b	
TBA (mg malonaldehyde /Kg sample) on dry weight basis	Control,0%PPP	1.19 ± 0.19	0.08 ± 0	0.63[a]
	4% PPP	1.28 ± 0.25	0.26 ± 0.04	0.77[a]
Mean	1.23 [a]	0.17 [b]	Mean	1.23 [a]

The difference in letters in rows and columns demonstrates a significant difference at $p \leq 0.05$.

Oxidative stability:

Air accelerates lipid oxidation and hence contributes to deterioration during the storage of cookies (Sharma and Riar, 2020). Results of thiobarbituric (TBA) of the present study are shown in Table (7) where the TBA values of cookies containing 4% PPP are slightly higher as compared to the control. The TBA values of the control and 4% PPP cookies markedly decreased after 3 months of storage at room temperature.

Ismail *et al*. (2016) found that pomegranate peel reduces oxidative degradation of cookies during storage for 90 days. Pomegranate peel extract, featured with their vital phenolic profile, imparts characteristic inhibition of lipid oxidation in systems; therefore; it has gained popularity as a natural preservative in high lipid carrying food preparations.

Total phenolic content:

The results in Table (8) show that the total phenolic content (TPC) of cookies containing 4% PPP was 1.58 mg GAE/g, which was higher than the total phenolic content of the control sample, which was 0.46 mg GAE/g at the beginning of storage. Such increment of total phenolic content in cookies containing PPP represents a percentage of 243.48% as compared with control, due to the TPC of the PPP.

The storage of samples for 3 months at room temperature demonstrated that the TPC of the cookies containing 4% PPP markedly decreased to 1.44 mg GAE/g. That can be explained by the fact that total phenols act as antioxidants. Table (8) also indicated that the mean TPC of PPP containing cookies is significantly higher than that of the control cookies. The total phenolic content of biscuit samples was increased significantly by increasing of pomegranate peel ratio in the biscuit formulation (Ismail *et al*., 2014; Jandal & Naji, 2021 and Urganci & Isik, 2021).

Antioxidant activity:

The antioxidant activity of cookie samples at the beginning and after 3 months of storage at room temperature was determined by DPPH radical scavenging ability (%), mg ascorbic acid equivalent/ g sample and IC_{50} (mg/ml). Also, the antioxidant activity was determined by Ferric reducing antioxidant power (FRAP) assay and all the results are shown in Table (8).

The results indicated that at zero time of storage, the 4% PPP cookies showed significant increase in DPPH radical scavenging ability (68.70%), ascorbic acid equivalent (0.89 mg/g sample), IC_{50} value (93.53 mg/ml) and FRAP value 1434.32 mmol potassium ferrocyanide equivalent (Fe^{+2})/ 100 g dried sample), compared with control sample that showed significant.

Lower DPPH radical scavenging ability (21.30%), ascorbic acid equivalent (0.29 mg/ g sample), IC_{50} value (297.17 mg/ml) and FRAP value (121.52 mmol potassium ferrocyanide equivalent (Fe^{+2})/ 100 g dried sample). This indicates that pomegranate peel powder substitution in cookie samples is a potential source of polyphenols, which have a high antioxidant activity.

Moreover, the effect of storage on the antioxidant activity of samples is shown in Table (8) since the results showed significant difference at ($p \leq 0.05$) in antioxidant activity of samples between zero time and after storage at room temperature for 3 months.

After storage for 3 months, the results showed significant decrease in DPPH scavenging ability, ascorbic acid equivalent and FRAP assay to 64.59%, 0.83 mg/g and 844.90 mmol Fe^{+2} equivalent/ 100g dried sample, respectively compared with control which their results showed significant increase to 36.49 %, 0.49

mg/g and 286.27 mmol potassium ferrocyanide equivalent (Fe^{+2})/ 100 g dried sample, respectively.

Generally, still, the values of antioxidant activity for cookies containing 4% PPP are more than those of the control, except IC_{50}.

IC_{50} of control sample showed significant decrease after storage (168.72 mg/ml) compared with these values for 4% PPP cookies which significantly increased to (98.29 mg/ml), generally IC_{50} is considered for 50% inhibition of DPPH free radicals so, still the cookies containing 4% PPP was higher than control sample regarding antioxidant activities after 3 months.

The results are in agreement with Ismail *et al*. (2014) and Jandal & Naji (2021), who demonstrated that the DPPH radical scavenging ability of cookies containing PPP increased significantly compared with the control.

Msaddak *et al*. (2015) and Loza *et al*. (2017) found that the antioxidant capacity against the radical DPPH, expressed as IC_{50}, presented statistical difference through storage. They found that cookies containing added fiber sources showed a higher antioxidant capacity.

Microbial quality:

As shown in Table (9) the total viable count (TVC) and the yeast and mould count (YMC) were followed for control and cookies containing 4% PPP during storage at room temperature up to 3 months. The statistical analysis revealed that there is a significant difference in CFU between treatments for both TVC and YMC and before and after storage. The TVC significantly increased during storage for the control and cookies containing 4% PPP. YMC was 0.89 $\log_{10}$ CFU/g and 0.33 $\log_{10}$ CFU/g for control and cookies containing 4% PPP, respectively and by storage, it reached 0.67 $\log_{10}$ CFU/g and 0.43 $\log_{10}$ CFU/g, respectively. Generally, cookies with PPP substitution showed antimicrobial properties during 3 months' storage period.

Ismail *et al*. (2016) detected that pomegranate peel extract supplemented cookies showed relatively good microbial stability during storage for 3 months as a significant reduction in microbial load was noticed.

Table 8. Total phenolic content and antioxidant activity of cookies containing 4% PPP compared with control after storage at room temperature for 3 months

Property	Type of cookies	Storage time (month)		Mean
		0	3	
Total phenolic content (mg GAE/g)	Control,0%PPP	0.46 ± 0.13	0.88 ± 0.13	0.67 [b]
	4% PPP	1.58 ± 0.15	1.44 ± 0.18	1.51 [a]
	Mean	1.02 [a]	1.16 [a]	
DPPH scavenging ability (%)	Control,0%PPP	21.30 ± 1.61	36.49 ± 1.53	28.89 [b]
	4% PPP	68.70 ± 3.21	64.59 ± 0	66.65 [a]
	Mean	45.0 [b]	50.54 [a]	
Ascorbic acid equivalent (mg/ g)	Control,0%PPP	0.29 ± 0.01	0.49 ± 0.02	0.39 [b]
	4% PPP	0.89 ± 0.02	0.83 ± 0	0.86 [a]
	Mean	0.59 b	0.66 a	
IC_{50} (mg/ml)	Control,0%PPP	297.17 ± 11.36	168.72 ± 7.88	232.94 [a]
	4% PPP	93.53 ± 1.72	98.29 ± 0	95.91 [b]
	Mean	195.35 [a]	133.51 [b]	
FRAP * mmol Fe^{+2} equivalent /100 g	Control,0%PPP	121.52 ± 0	286.27 ± 20.64	203.90 [b]
	4% PPP	1434.32 ± 30.08	844.90 ± 186.77	1139.61 [a]
	Mean	777.92 [a]	565.59 [b]	

*FRAP: Ferric reducing antioxidant power.

The difference in letters in rows and columns demonstrates a significant difference at $p \leq 0.05$

Table 9. **Microbial count (log CFU/g) of cookies containing PPP during storage at room temperature for 3 months**

Microbial count	Type of Cookies	Storage time (month)				Mean
		0	1	2	3	
Total viable count (TVC)	Control, 0% PPP	0 ± 0	1.0 ± 0	0.35 ±0.56	2 ± 0	0.88 [a]
	4% PPP	0 ± 0	1.0 ± 0	0.33 ±0.58	0.77 ±0.68	0.53 [b]
Mean		0[b]	0.42 [b]	1.0 [a]	1.38 [a]	
Yeast and mould count (YMC)	Control, 0% PPP	0.89 ±0.85	1.20 ±0.17	3.04 ±0.43	0.67 ±1.15	1.45 [a]
	4% PPP	0.33 ±0.58	0.33 ±0.58	0.33 ±0.58	0.43 ±0.75	0.36 [b]
Mean		0.62 [b]	0.77 [b]	1.69 [a]	0.55 [b]	

The difference in letters in rows and columns demonstrates a significant difference at $p \leq 0.05$.

Table 10. **Sensory evaluation of cookies containing PPP during storage at room temperature for 3 months**

Property	Type of cookies	Storage time (month)				Mean
		0	1	2	3	
Colour	Control, 0% PPP	8.70 ± 0.67	9.0 ± 0	8.70 ± 0.48	8.60 ± 0.69	8.75 [a]
	4% PPP	7.70 ± 1.16	7.70 ± 0.95	7.85 ± 0.82	8.10 ± 1.02	7.84 [b]
Mean		8.20 [a]	8.35 [a]	8.28 [a]	8.35 [a]	
Odour	Control, 0% PPP	8.30 ± 0.95	8.80 ± 0.42	8.45 ± 0.69	8.30 ± 0.67	8.46 [a]
	4% PPP	8.50 ± 0.97	8.50 ± 0.53	8.35 ± 0.75	8.30 ± 0.82	8.41 [a]
Mean		8.40 [a]	8.65 [a]	8.40 [a]	8.30 [a]	
Taste	Control, 0% PPP	8.30 ± 0.95	8.50 ± 0.71	8.25 ± 0.79	7.70 ± 0.82	8.19 [a]
	4% PPP	8.20 ± 1.32	7.80 ± 1.03	8.05 ± 0.89	7.90 ± 0.88	7.99 [a]
Mean		8.25 [a]	8.15 [a]	8.15 [a]	7.80 [a]	
Texture	Control, 0% PPP	8.10 ± 0.88	7.80 ± 0.92	7.80 ± 0.63	7.20 ± 1.23	7.79 [a]
	4% PPP	8.30 ± 1.06	7.60 ± 0.97	7.80 ± 1.14	7.45 ± 1.34	7.73 [a]
Mean		8.20 [a]	7.80 [ab]	7.70 [ab]	7.33[b]	
Crispiness	Control, 0% PPP	7.80 ± 1.32	8.0 ± 0.82	7.80 ± 0.63	7.40 ± 1.17	7.75 [a]
	4% PPP	7.80 ± 1.03	7.80 ± 1.03	7.70 ± 1.16	7.70 ± 1.25	7.75 [a]
Mean		7.80 [a]	7.90 [a]	7.75 [a]	7.55 [a]	
Overall acceptability	Control, 0% PPP	8.38 ± 0.68	8.40 ± 0.52	8.20 ± 0.59	7.65 ± 0.75	8.16 [a]
	4% PPP	8.30 ± 0.98	8.10 ± 0.77	8.0 ± 0.91	7.75 ± 0.92	8.04 [a]
Mean		8.34 [a]	8.25 [a]	8.10 [ab]	7.70 [b]	

The difference in letters in rows and columns demonstrates a significant difference at $p \leq 0.05$.

Sensory evaluation of stored samples:

According to the results of sensory evaluation (Table 1), an addition of PPP at a proportion of 4% was suggested for further study to investigate the effect of adding PPP as a functional ingredient in cookies formulation.

The results of the organoleptic evaluation of control and cookies containing 4% PPP during storage are demonstrated in Table (10). The results revealed that there was no significant difference between control and cookies containing 4% PPP in odour, taste, texture, crispiness and overall acceptability, while there was significant difference between colour of control and

cookies containing 4% PPP, since the control samples had significantly ($p \leq 0.05$) the highest scores given by panelists for colour compared with cookies containing 4% PPP which were slightly darker in colour, as compared to control.

The storage of cookies for 3 months at room temperature didn't significantly affect the scores of colour, odour, taste and crispiness, while the scores of texture and overall acceptability showed a significant change by storage. Yet, all the cookies' sensory parameters still indicate good acceptability during storage. Also, after 3 months of storage, the cookies containing 4% PPP scored 7.9 for taste and 8.3 for odour, and the control samples scored 7.7 for taste and 8.3 for odour on a 9-point hedonic scale. Generally, the cookies containing 4% PPP showed high organoleptic stability. According to Ismail *et al*. (2014), the improvement of crude fiber contents in PPP-supplemented cookies, might have a featured product hardening property.

CONCLUSION

This study recommends using dried pomegranate peel powder at a ratio of 4% for producing cookies for the utilization of its content of fibers, minerals and bioactive components, which can be stored for 3 months.

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الملخص العربي

قشور الرمان كمكون وظيفي في الكوكيز: كتطبيق لتعظيم الإستفادة من المخلفات

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في الآونه الأخيرة، تهدف صناعة الأغذية إلي تقليل تأثير معالجة النفايات علي صحة الإنسان. تم استخدام قشور الرمان المجففة كمكون وظيفي يحتوي علي مكونات نشطه حيوياً، مثل عديدات الفينول ومضادات الأكسدة في منتج الكوكيز. تمت إضافة قشور الرمان المجففة في الكوكيز بنسبة 4% ونسب إستبدال أخري. تشير النتائج إلي عدم وجود فرق معنوي بين عينة الكنترول الخالية من قشور الرمان المجففة والعينة المحتوية علي 4% من مسحوق قشر الرمان في درجات الخصائص الحسية مع عدم وجود تأثير ملحوظ علي قيمة السعرات الحرارية للمنتج. زاد محتوي الألياف الذائبة في العينة التي تحتوي علي 4% قشور الرمان المجففة بنسبة 234,5% مقارنة بعينة الكنترول. لم يظهر فرق كبير بين عينات (0 و 4% قشور رمان مجففة) في السماكة والقطر ونسبة الإنتشار بعد التخزين. أدي التخزين لمدة 3 أشهر إلي انخفاض في محتوي الرطوبة في عينة الكنترول وكذلك العينة التي تحتوي علي 4% قشور الرمان مجففه يعادل 4,31 % و 4,29% علي التوالي. أظهرت النتائج انخفاضاً في قدرة كسح الأصول أو الشوارد الحره (DPPH) ومكافيء حمض الأسكوربيك وقيم FRAP إلي 64,59 % ، 0,83% مجم/جم و 844,90 ملي مول Fe^{+2} مكافيء / 100 جم عينة مجففة، علي التوالي مقارنة مع الكنترول التي أظهرت نتائجها زيادة معنوية بلغت 36,49% ، 0,49% مجم/جم و 286,27 مل مول مكافيء فيروسيانيد البوتاسيوم/ 100 جم عينة مجففة، علي التوالي. أظهرت العينات المحتوية علي قشور الرمان المجفف ثباتا ميكروبيا جيدا نسبيا أثناء التخزين لمدة 3 أشهر حيث لوحظ إنخفاض كبير في الحمل الميكروبي. كما أظهرت العينات قبولا حسيا جيدا أثناء التخزين.

الكلمات المفتاحية: قشور الرمان، المخلفات، النشاط المضاد للأكسدة، الكوكيز.