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Development and quality evaluation of cookies enriched with various levels of grapefruit pomace powder

Tusneem Kausar[1] · Esha Saeed[1] · Ashiq Hussain[1] · Nida Firdous[2] · Barira Bibi[3] · Khurram Kabir[3] · Qurat Ul An[1] · Muhammad Qasim Ali[4] · Ayesha Najam[5] · Adnan Ahmed[6] · Shazia Yaqub[1] · Abdeen Elsiddig Elkhedir[7]

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Abstract

Grapefruit pomace, has been considered a valuable waste byproduct and a rich source of health promoting and functional components. The present work aims to prepare a flour by hot air drying of grapefruit pomace, in order to explore and incorporate it into the formulation of cookies at a level of 0, 5, 10 and 15% replacement with the straight grade wheat flour. The effect of grapefruit pomace powder on the physical, bioactive, chemical, textural and organoleptic properties of the cookies was assessed. Results showed the presence of 8.25% fibre, 9.63% ash, 8.96 mg/GAE g total phenolic content, 3.64 mg QE/g total flavonoid content, 2.05 mg/g total carotenoid contents and 42.12% antioxidant activity (DPPH assay) in the grapefruit pomace powder. The addition of pomace powder at varying amount in the cookies resulted in significant ($p < 0.05$) change in the chemical and bioactive composition. A significant increase in the fibre (1.58–3.10%), ash content (0.58–1.25%) and fat (20.19–22.05%) and significant decrease in crude protein content (6.79–5.20%) was observed in the cookies having 0–15% grapefruit pomace powder. Similarly, bioactive contents and antioxidant activity of the cookies was also significantly ($p < 0.05$) increased as the level of incorporation of grapefruit pomace powder was increased. Significant changes in the physical properties of the cookies were also observed, as diameter and thickness were decreased and hardness of the cookies was increased. Cookies containing 10% grapefruit pomace powder got significantly high scores in terms of taste and overall acceptability. It could be concluded that the use of grapefruit pomace powder has potential to enhance the nutritional and antioxidant potential of the cookies.

Highlights

- Grapefruit pomace powder could be used as a bioactive rich functional ingredient to develop cookies
- Grapefruit pomace powder incorporated cookies were high in ash, fiber, phenolics, flavonoids and carotenoids
- High antioxidant activity was exhibited by the cookies having higher levels of grapefruit pomace powder
- Significant variations in physicals features of cookies were observed, still 10% level of grapefruit pomace powder produced acceptable cookies

✉ Ashiq Hussain, ashiqft@gmail.com; ✉ Abdeen Elsiddig Elkhedir, abdeenkhider@gmail.com | [1]Institute of Food Science and Nutrition, University of Sargodha, Sargodha 40100, Pakistan. [2]Department of Food Science and Technology, MNS-University of Agriculture Multan, Multan 66000, Pakistan. [3]PMAS Arid Agriculture University, Rawalpindi 10370, Punjab, Pakistan. [4]Faculty of Chemical and Process Engineering Technology, University Malaysia Pahang, Gambang, 26300 Kuantan, Pahang, Malaysia. [5]Punjab Food Authority Lahore, Lahore 54000, Pakistan. [6]Department of Zoology, University of Sargodha, Sargodha 40100, Pakistan. [7]Sudan University of Science & Technology, Khartoum, Sudan.

Keywords Fruits waste · Valorization · Functional cookies · Nutritional aspects · Organoleptic acceptability

1 Introduction

Food processing industry has been growing continuously across the globe with innovations. These industries create large amount of waste and by-products which are mostly exploited as animal feed and yet a large quantity is disposed as landfill creating pollution problem after degradation and cost finance to manage it [1–3]. By-products obtained from processing of fruits and vegetables are rich in bioactive compounds like polyphenols, proteins, peptides, dietary fibre, and other antioxidants compounds [4, 5]. These bioactive compounds can be valorized from food processing wastes, and could be used as health promoter, dietary supplements, nutraceuticals and natural food additives [6].

Fruits from the elite class of 'citrus', are known for their healthful sources of bioactive compounds specially fibers, vitamins and phenolics, which have been found largely associated with medicinal roles [7–9]. Almost one third of citrus fruits produced in the world are used for the production of fresh juice and citrus-based drinks, leaving behind peels, leaves, seeds and pomace as by products, and while these by-products when are not treated effectively create a lot of environmental issue [2, 10, 11]. Among citrus fruits, grapefruit (*Citrus paradise* M.) is a unique fruit due to sweet and tart taste and is a hybrid of two pomelos; *Cucurbita maxima* and *Cucurbita sinensis*, first discovered in eighteenth century [12]. Grapefruits are well known for their phenolics and flavonoids, which posse anti-inflammatory, antiproliferative, anticarcinogenic, and antimicrobial properties, and play imperative role in anticipation of certain cardiovascular impairments and cancers [13–15]. Grapefruit by-products such as peel and pomace are also reported to prevent metabolic disorders, diabetes, obesity and hypercholesterolemia, hypertension, gastrointestinal diseases and osteoporosis [12, 16, 17].

Bakery products are best choice for consumer all over the world as a snack food prepared from the flour of staple foods, due to their versatility, nutritional value, low cost and availability. Usually, most of these commercially available products are based on various types of flours and need to be supplemented with other functional and nutritional ingredients to uplift their nutritional value while conserving their appeal to the consumers. The relationship of food with health has been creating an impact to provide innovation in food products, giving popularity to the functional foods [4, 18]. Various researches have indicated that a limited replacement of wheat flour by flours developed from waste of fruits a valuable strategy to improve the nutrition value of bakery products [19, 20]. Various parts (peel, seed and flesh) were used for the preparation of biscuits, which increased the important macro and micro nutrients in them [5, 21]. Salehi et al. [22] investigated the potential of carrot pomace for the production of fibre-rich sponge cake, and positive effects on the texture of cakes were noted. Bertagnolli et al. [23] prepared the cookies by using guava peel flour with partial replacement of wheat flour, and observed increased bioactive compounds.

Among bakery products, cookies are widely accepted and eaten by all age groups and a good vehicle to incorporate ingredients from other sources to boost their nutritional value and consumer attention [20]. Teke et al. [24] reported that wheat cookies fortified with 4% citrus peel powder proved to be nutritious, functional and healthful food. Qureshi et al. [25] used grapefruit albedo powder as a fat replacer in fruit cake and 8% replacement did not show any considerable negative change in the organoleptic properties. Hassan and Ali [26] successfully prepared the toast bread by replacing white flour with different levels of white grapefruit albedo layer flour and recommend it for obese persons due to the low-calorie contents. Theagarajan et al. [27] recommend the use of 6% grape pomace in the cookies having enhanced taste and better texture during the storage, as compared to the control sample. Keeping these studies in mind, while exploring and comparing the nutritional and bioactive contents of grapefruit pomace powder, this study was planned to analyze the incorporation of grapefruit pomace powder at relatively higher levels (up to 15%) in straight grade wheat flour to develop cookies, which were analyzed for their physico-chemical, bioactive and antioxidant contents, and sensory characteristics. Further, this study investigated the suitability of various combinations of grapefruit pomace powder and wheat flour for cookies development without compromising the organoleptic properties.

2 Materials and methods

2.1 Materials

The current study was led at IFSN, University of Sargodha, Sargodha during the year 2023. Raw material including grapefruit, wheat flour, hydrogenated vegetable fat, sugar, baking powder and egg were procured from the local market of district Sargodha, Pakistan. While various chemicals used for analysis of flour and develop product were purchased from Sigma Aldrich (Germany). Collection of the plant materials (grapefruit) used in this study complied with local or national guidelines.

2.2 Preparation of grapefruit pomace powder

Grapefruits, after thorough washing and cleaning were cut into halves and after juice extraction; the leftover pomace was collected and handled carefully. The pomace was dried using hot air oven (Hitachi MRO-A V100, Japan) at 60 °C for 24 h. The dried pomace was powdered using common spice grinder (Hitachi CS-B50A, Japan), to get acceptable quality powder by following the guidelines described by Zhang et al. [2] and Hussain et al. [28]. The obtained powder was sieved to get fine powder with 80 µm size, and was properly packed in polyethylene bags, which were stored at 20 °C, inside a laboratory shelf, for further use.

2.3 Preparation of cookies

In the light of method used by Hussain et al. [29], cookies were developed using blends of straight grade wheat flour and grapefruit pomace powder, in the ratios of; 100:0, 95:5, 90:10, 85:15, w/w. First of all, fat was beaten to form a creamy paste, then sugar was added and the mixture was thoroughly mixed for 3 min. Then other ingredients were added and again the mixture was mixed consistently for another 3 min. The dough obtained was sheeted and cut by cookie cutter, baked at 150 °C for 10 min in a heating oven, cooled and stored in air tight containers for further analysis. Formulation of cookies along with treatment plan has been shown in Table 1.

2.4 Chemical analysis of grapefruit pomace powder and developed cookies

The grapefruit pomace powder, wheat flour and cookie samples were analyzed for moisture, ash, fat, protein, fibre and NFE (nitrogen free extract) contents, using the AACC standard method [30]. According to Frary et al. [31], the gross energy value of the cookies was calculated using standard values of 3.75, 9.0, and 3.75 kcal/g for protein, fat, and carbohydrate, respectively.

2.5 Physical analysis of cookies

The physical properties i.e., thickness, diameter and spread ratio of the cookies was measured as was previously reported by Arun et al. [32]. Cookies (six) were arranged and their diameter was measured by plane ruler, and thickness was calculated by using a Vernier caliper in triplicate. By dividing diameter with thickness, the spread ratio was calculated.

2.6 Total phenolic content of raw materials and cookies

Grapefruit pomace powder, straight grade flour and cookies prepared by incorporation of grapefruit pomace powder at various concentration were subjected to analyze the total phenolic content, utilizing the Folin-Ciocalteu reagent test, in accordance with Shen et al.'s [33] methodology. The results were represented as mg GAE/g.

Table 1 Formulation of cookies (treatment plan)

Sample	Flour (g)	Grapefruit pomace powder (g)	Sugar (g)	Shortening (g)	Baking powder (g)	Egg (g)
T_0	100	0	75	75	0.25	0.5
T_1	95	5	75	75	0.25	0.5
T_2	90	10	75	75	0.25	0.5
T_3	85	15	75	75	0.25	0.5

2.7 Total flavonoid content of raw materials and cookies

As previously, Shen et al. [33] used the aluminium chloride colorimetric assay method, we also did to determine the total flavonoid content of wheat flour, grapefruit pomace powder, and created cookies. At 510 nm, the absorbance was measured using spectrophotometer (UNICO SQ2802S, UNICO Co. Suite E Dayton, New Jersey, USA), and quercetin was used to create a standard diagram. The results were expressed as mg of quercetin equivalents (QE) per gram of samples (mg QE/g). To determine the mean values, each experiment was conducted three times.

2.8 Total carotenoid content of raw materials and cookies

The methodology described by Priyadarshi et al. [34] was used to evaluate total carotenoids. In summary, two grams of every sample were ground up, two mg of *α*-tocopherol and two grams of the anhydrous form of sodium sulphate were then included, and the pigments were extracted using ice-cold acetone. The residue was repeatedly removed until all colour was gone. The solvent was extracted in a rotavapor at 40 °C and 40 m bar at low pressure. Absorbance was detected at 450 nm after the purified extract samples were suitably diluted with 50 mL of methanol. The carotenoid concentration on a dry weight basis was expressed as mg/g dw.

2.9 Antioxidant activity (DPPH assay) of raw materials and cookies

The ability of wheat flour, grapefruit powder, and created cookies to scavenge DPPH free radical was assessed as antioxidant activity using the previously described methods by Shen et al. [33]. To summarize, the test entails mixing 50 µL of the sample at different concentrations and adding 250 µL of DPPH to each well. The microplate is then left in the dark for 30 min to acquire the absorbance reading at 517 nm. Each sample's antioxidant activity was expressed as a percentage.

2.10 Texture analysis of cookies

Texture analysis of the cookies was performed by using a texture analyzer (TA. XT. plus, Stable Microsystems, Surrye, UK) conferring to the way described by Nadeem et al. [35]. Hardness of the cookies was calculated using data regarding force (g) and distance (mm) from texture analyzer.

2.11 Sensory evaluation of cookies

Cookies developed by incorporation of grapefruit pomace powder in wheat flour were evaluated for their sensory characteristics by semi-trained 25 panelists from the IFSN, University of Sargodha, following the guidelines and protocols provided by the ethical committee of the University (details provided in the declarations). The evaluation was done with normal lights at room temperature on 9-points hedonic scale as has been conducted recently by Rafique et al. [36]. In brief, the experiment was initially explained to the semi-trained sensory panel, which consisted of 10 female participants and 15 male participants, ages ranging from 30 to 45. The judges graded the various cookie samples using a 9-point hedonic scale that included five sensory parameters: colour, taste, texture, flavour, and overall acceptability. A score of 1 represented extremely poor, 2 very poor, 3 poor, 4 below fair and above fair, 5 fair, 6 below fair and below poor, 7 good, 8 very good, and 9 excellent. Panelists were given distilled water bottles to rinse and neutralize, and code numbers were assigned to the cookie samples so they could be evaluated.

2.12 Statistical analysis

The analysis of variance technique (ANOVA) was used to statistically analyze the analysis's results. The Least Significant Design was used to assess the mean difference. The USA-sourced software SPS.8.1 was employed for these analyses.

3 Results and discussion

3.1 Chemical and bioactive composition of wheat flour and grapefruit pomace powder

Proximate and bioactive composition of wheat flour and grapefruit pomace powder is given in Table 2. Results revealed that grapefruit pomace powder contained 10.35% moisture, 9.63% ash, 8.25% fibre, 5.97% crude proteins, 4.51% crude fat and 68.29% NFE. It is clear from the results that grapefruit pomace powder contained a considerable amount of fibre and ash, as compared to the wheat flour, as usually peels of fruits are considered as good source of ash and fibers. While the moisture content of both flours was also under the limit, as a moisture content below 14 is acceptable for storage of flours. From the results (Table 2), higher protein content in wheat flour can be observed, as compared to grapefruit pomace powder, because wheat flour is a good source of protein as compared to the fruits pomace. Ali et al. [37] found 8.9% moisture, 7.69% crude protein, 50.33% carbohydrates, 6.13% crude fat, 2.16% ash and 24.79% ash in their results regarding the grapefruit pomace, while their findings were supportive enough to validate the current results. In another similar study, Ali et al. [38] studied the proximate composition of grapefruit byproducts and found the amount of moisture, crude fat and ash as 6.8, 2.5 and 6.9%, respectively. Chemical composition results of straight grade flour were in line with the recent findings of Rafique et al. [36] and Hussain et al. [39], as they both analyzed the straight grade wheat flour before being utilized to develop cakes rusks and biscuits, respectively.

Total phenolic, flavonoid, and carotenoid content and antioxidant activity of wheat flour and grapefruit pomace powder were found to be 2.23 and 8.96 mg GAE/g, 0.36 and 3.64 mg QE/g, 0.21 and 2.05 mg/g, and 6.36 and 42.12%, respectively, as shown in Table 2. From these results it was evident that grapefruit pomace powder was found to be a comparatively high source of bioactive compounds and antioxidant activity, as compared to the wheat flour. Presence of phenolics, flavonoids, carotenoids and other antioxidant compounds in the pomace of citrus fruits has also been confirmed from Asif et al. [9], when the phenolic and flavonoid contents and antioxidant activities of citrus pomace enriched corn extrudates were increased significantly. The total phenolic content (78.5 mg GAE/g dw), total flavonoid content (53.5 mg naringin/g dw), and total antioxidant activities by DPPH assay (25.5 mM Trolox/g dw) of grapefruit pomace powder dried through hot air oven were found to be the respective optimum phytochemicals and antioxidant activity in a similar fashion study by Islam et al. [17]. Grapefruit possess high antioxidant activity due to presence of different bioactive compounds including phenolics, flavonoids and vitamin C [15]. The study carried out by Multari et al. [40] aims to undertake a thorough examination of the volatile organic compounds, carotenoids, and phenolic compounds present in the juices and pomaces of four citrus fruits. Citrus pomaces were found to contain high levels of phytochemicals, and they proposed that these waste streams could have new uses in the food. Although the wheat flour is a staple food and main ingredient of bakery products, but not a good source of these discussed bioactive components, as compared to grapefruit pomace flour. Relatively low amounts of antioxidants in wheat flour, just as has been confirmed in this work has also been previously reported by Hussain et al. [29].

Table 2 Chemical and bioactive composition of wheat flour and grapefruit pomace powder

Chemical and bioactive composition	Wheat flour	Grapefruit pomace powder
Moisture (%)	12.01 ± 0.30^{a}	10.35 ± 0.20^{b}
Ash (%)	2.63 ± 0.25^{b}	9.63 ± 0.15^{b}
Fiber (%)	0.63 ± 0.05^{b}	8.25 ± 0.30^{b}
Proteins (%)	10.02 ± 0.40^{a}	5.97 ± 0.20^{b}
Fats (%)	1.25 ± 0.10^{b}	4.51 ± 0.10^{a}
NFE (%)	33.54 ± 0.50^{b}	68.29 ± 0.70^{a}
Total phenolic content (mg GAE/g)	2.23 ± 0.03^{b}	8.96 ± 0.15^{a}
Total flavonoid content (mg QE/g)	0.36 ± 0.02^{b}	3.64 ± 0.03^{b}
Total carotenoid contents (mg/g)	0.21 ± 0.03^{b}	2.05 ± 0.05^{a}
Antioxidant activity (%)	6.36 ± 0.20^{a}	42.12 ± 0.50^{b}

Values are presented means along with standard deviations (n = 3), whereas values with different alphabetical letters in a column are statistically significant, where, NFE = nitrogen free extract, GAE = gallic acid equivalent, QE = quercetin equivalent

3.2 Effect of grapefruit pomace powder on the physical properties of cookies

Regarding the physical properties of the grapefruit pomace powder added cookies, results for diameter, thickness and spread factor were found significantly different among different samples (Table 3). Diameter values of cookies were found to be ranging from 53.26 to 55.53 mm in different samples. It was observed that T_0 (cookies without grapefruit pomace powder) had the highest diameter value and T_3 (having 15% grapefruit pomace powder) had lowest diameter value. Thickness of cookies ranged from 1.41 to 1.63 mm having same trend as the diameter, i.e., highest value for control and lowest value for T_3. Spread factor was also significantly affected by the addition of grapefruit pomace powder in the cookies, which was highest for T_3 and lowest for T_0. Addition of grapefruit pomace powder increases the fibre, which causes the dilution of gluten protein, and significantly affect the physical properties of the bakery products, by reducing their diameter [41]. These findings are in accordance to a previous study, which found that the addition of apple pomace powder decreased the thickness of baked cookies [42]. In another similar work, with in line findings, Kohajdova et al. [43] found a decrease in the volume of biscuits by incorporation of grapefruit powder, rich in dietary fiber. Usually, the diameter or volume of the cookies is dependent upon the amount and quality of flour proteins, especially gluten, and whenever other flours from fruit are added in wheat flour, a decrease in protein content of composite flour results in decrease volume of cookies, and same is the case for spread ratio. Recently Rafique et al. [36] reported that addition of non-wheat flour from fruits and vegetables had undesirable effects on the physical features of bakery products, possibly due to the disturbance of the gluten concentration and network, therefore it is vital to select the optimum level of replacement of these flours, so that minimum undesired changes may occur while aiming to develop the nutritional products.

3.3 Effect of grapefruit pomace powder on the texture of cookies

The hardness of the cookies was measured using texture analyzer. The hardness of the cookies developed with and without grapefruit pomace powder differ in samples from 1800 to 2370 g (Fig. 1). This indicates that T_3, prepared with 15% grapefruit pomace powder had significantly high ($p < 0.05$) hardness than other samples. This increase in the hardness of cookies might be due to the reason that addition of fibre rich flour reduces the aeration, and lowers the protein contents in the batter prepared for cookie manufacturing, resultantly developing dense structure, which cause decrease in the volume and increase in the hardness of final product [25]. Results for hardness of grapefruit pomace incorporated cookies are in accordance to the findings of Lim et al. [44], when they studied the effect citrus pectin as fat replacer in the bakery products, and observed increased hardness of the cookies. Similarly, when Larrea et al. [45] looked into how adding orange pulp affected the cookies' quality, they discovered that they were quite hard. According to Spinei and Oroian [10], pectin present in high amount in grapefruit pomace powder (almost 20% of dry weight of grapefruit peel) might be responsible for high hardness of the food products incorporated with it. The addition of grapefruit pomace powder, which is high in pectin and other fibres, to cookies causes them to become harder having dense structure. This can be explained by the fact that dietary fibres compete with starch and gluten for water during thermal processing, which lowers lubrication and increases viscosity because dietary fibre also fills the matrix [46, 47].

Table 3 Physical properties of the cookies

Sample	Diameter (mm)	Thickness (mm)	Spread factor
T_0	55.53 ± 1.63^a	1.63 ± 0.06^a	34.09 ± 1.25^b
T_1	54.90 ± 0.88^{ab}	1.54 ± 0.04^{ab}	35.59 ± 1.12^{ab}
T_2	54.20 ± 0.3^{ab}	1.48 ± 0.02^{bc}	36.46 ± 0.76^{ab}
T_3	53.26 ± 1.04^b	1.41 ± 0.05^c	37.82 ± 2.05^a

Values are presented means along with standard deviations (n = 3)

$^{a–c}$Mean values in column with different superscript are significantly different (p < 0.05). Where, T_0 = control, T_1 = cookies having 5% grapefruit pomace powder, T_2 = cookies having 10% grapefruit pomace powder, T_3 = cookies having 15% grapefruit pomace powder

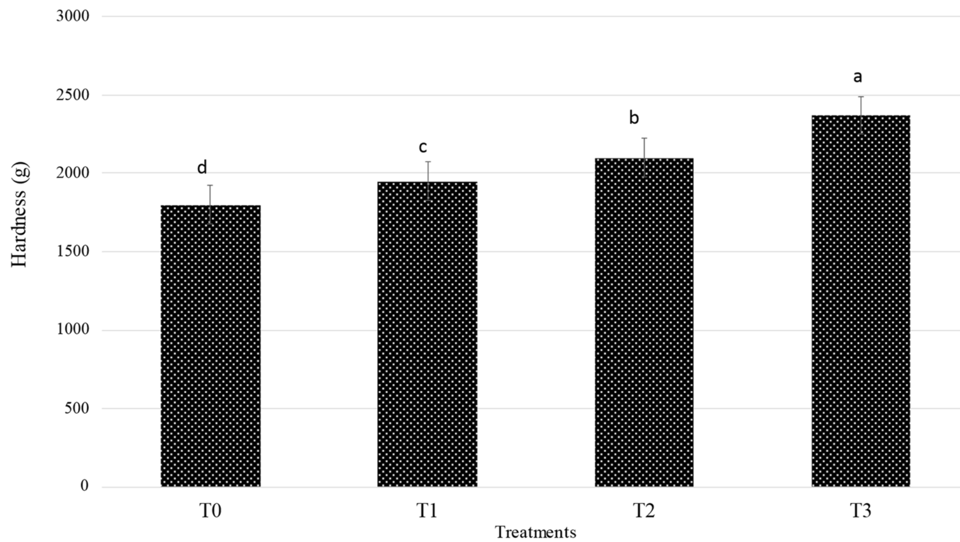

Fig. 1 Effect of different treatments on hardness of cookies. Values are presented means along with standard deviations (n = 3), whereas values with different alphabetical letters in the bars are statistically significant. Where, T_0 = control, T_1 = cookies having 5% grapefruit pomace powder, T_2 = cookies having 10% grapefruit pomace powder, T_3 = cookies having 15% grapefruit pomace powder

3.4 Effect of grapefruit pomace powder on the chemical composition of cookies

The results regarding the proximate composition of cookies are shown in Table 3. It is confirmed that moisture content differs significantly ($p < 0.05$) among different samples of cookies. High moisture contents were found in T_3 (4.87%) and minimum moisture contents found in T_0 (2.66%). Increase in the moisture content was found in the samples with incorporation of grapefruit pomace powder. Presence of fibre in grapefruit pomace might be the reason of water retention in the cookies. Because soluble dietary fibre content increased with increased fibre intake, batter's ability to absorb water increased as well [48]. Similar findings were also reported by Qureshi et al. [25], as they also observed an increase in the moisture content of the cakes after addition of grapefruit albedo powder. Similarly, increase in the moisture in the bread prepared by using white grapefruit albedo layer flour was found [26]. The fat contents also differed significantly in the samples. Highest fat contents were found in T_3 (22.05%) and lowest in T_0 (20.19%). Use of grapefruit pomace powder resulted in a gradual increase in the fat contents. A similar increase in fat contents from 18.60% (control) to 29.60% (biscuits having 15% lemon pomace powder) of the biscuits was also witnessed when Hussain et al. [39], replaced wheat flour with lemon pomace powder. Regarding the proteins, high protein contents were found in T_0 (6.79%) and decrease in the protein content was found with the increase of grapefruit pomace powder. The level of protein content decreased with the addition of grapefruit pomace powder because of lower protein content (Table 1). Reduction in the protein content was also reported by Hassan and Ali, [26] in bread and by Qureshi et al. [25], in the cakes by addition of different fruit powders, as most of the fruits are low in protein as compared to the wheat flour. Significant changes in the fiber contents were also observed, as the fiber contents ranged from 0.86 to 3.10%, having maximum value for T_3 and minimum value for T_0. This increment in fiber could be related to the results presented in Table 1, as the grapefruit pomace powder was significantly high in fiber, as compared to the wheat flour, and replacement of wheat flour with grapefruit pomace powder caused an increase in fiber contents of the biscuits. These results are in line with those given by Qureshi et al. [25], who used grapefruit albedo powder for preparation of cakes, and observed high fiber contents in the cakes having higher levels of grapefruit albedo powder. In comparison to maize extrudates used as control samples, the inclusion of 15% citrus pomace raised fibre content by 58.33% and dietary fibre contents increased 2.12 times, according to the results of the Asif et al. [9] study. The ash contents of cookies were ranging from 0.86 to 1.25%, having highest score for T_4 and lowest for T_0, and the reason behind this was high ash contents in grapefruit pomace powder, as compared to wheat flour (Table 1) These results are similar to the earlier results of a study when the cake supplemented with banana peel fiber showed increase in ash contents [49]. Results of NFE content for all samples were also significantly different, as the NFE content found in T_0 were 67.90% and in T4 were 68.90%. These results could be justified from the NFE results presented in Table 2, and also from the findings of Rafique et al. [36]. Another similar previous research has also showed an increase in NFE, after the addition of grapefruit powder [26]. Energy calculated from the data obtained from proximate composition also showed significantly different results, and there was a decrease in the energy value of cookies, with an increase

Table 4 Chemical composition of the cookies

Sample	Moisture (%)	Fat (%)	Protein (%)	Fibre (%)	Ash (%)	NFE (%)	Energy (kcal)
T_0	2.66 ± 0.21^d	20.19 ± 0.40^d	6.79 ± 0.19^a	1.58 ± 0.25^d	0.86 ± 0.10^d	67.90 ± 0.88^d	461.69 ± 0.72^a
T_1	3.24 ± 0.33^c	20.65 ± 0.31^c	6.32 ± 0.12^b	2.12 ± 0.10^c	1.02 ± 0.03^c	68.28 ± 0.40^c	450.86 ± 2.87^b
T_2	4.15 ± 0.19^b	21.34 ± 0.41^b	5.82 ± 0.30^c	2.79 ± 0.15^b	1.13 ± 0.02^b	68.49 ± 0.50^b	441.45 ± 3.13^c
T_3	4.87 ± 0.20^a	22.05 ± 0.2^a	5.20 ± 0.21^d	3.10 ± 0.09^a	1.25 ± 0.03^a	68.90 ± 0.18^a	427.82 ± 2.61^d

Values are presented means along with standard deviations (n = 3)

[a–d]Mean values in column with different superscript are significantly different ($p < 0.05$), where, NFE = nitrogen free extract. Where, T_0 = control, T_1 = cookies having 5% grapefruit pomace powder, T_2 = cookies having 10% grapefruit pomace powder, T_3 = cookies having 15% grapefruit pomace powder

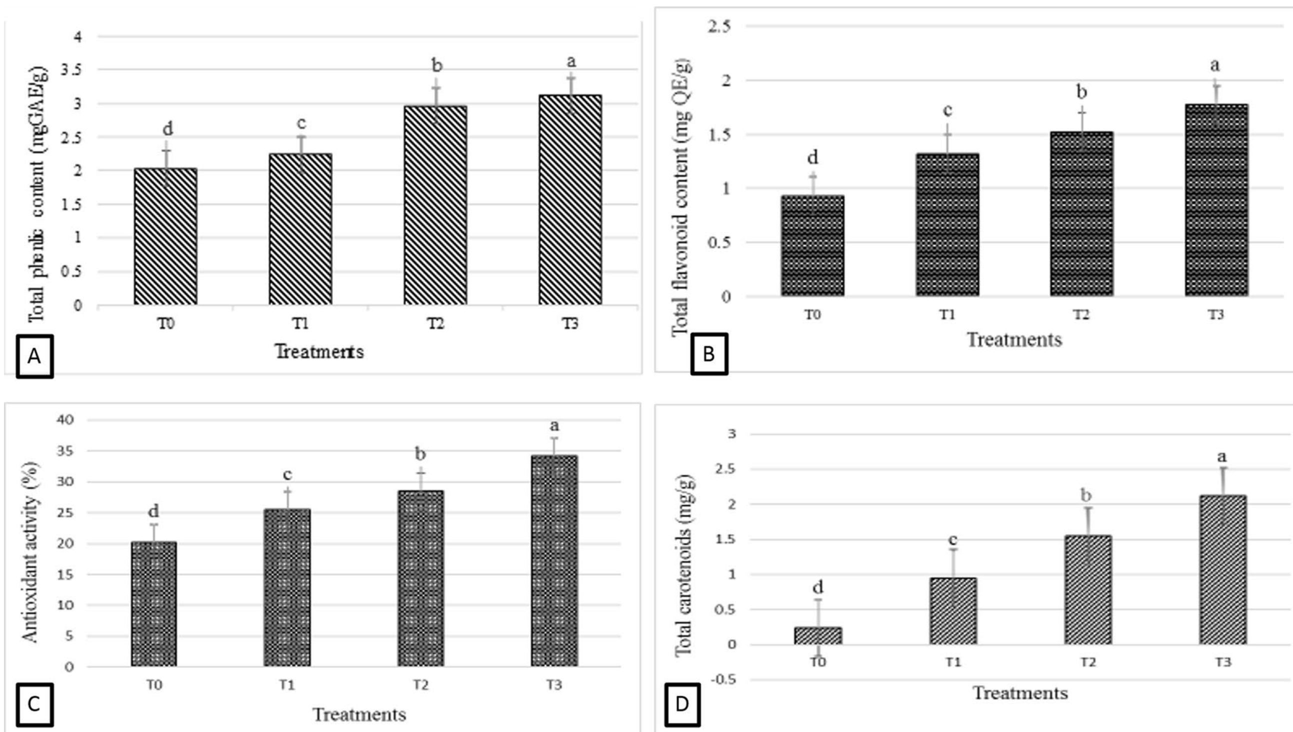

Fig. 2 Effect of treatments on the total phenolic contents (**A**), total flavonoid contents (**B**), antioxidant activity (**C**), total carotenoid content (**D**) of the cookies. Values are presented means along with standard deviations (n = 3), whereas values with different alphabetical letters in the bars are statistically significant. Where, T_0 = control, T_1 = cookies having 5% grapefruit pomace powder, T_2 = cookies having 10% grapefruit pomace powder, T_3 = cookies having 15% grapefruit pomace powder

of the grapefruit pomace powder, which was due to decreased fat and protein contents, and these findings were also confirmed by Rafique et al. [36] (Table 4).

3.5 Effect of grapefruit pomace powder on the different bioactive contents and antioxidant activity of the cookies

Food items enriched with grapefruit pomace powder may be regarded as nutritious foods with a wealth of useful bioactives [14]. Total phenolic, flavonoid and carotenoid contents, and antioxidant activity were measured in the cookies prepared by using various concentrations of wheat flour and grapefruit pomace powder, and results are shown in Fig. 2. Addition of grapefruit pomace powder significantly improved the total phenolic, flavonoid, and carotenoid contents, and antioxidant activity of the cookies, and these results could be related with the results shown in Table 2, where grapefruit pomace powder presented significantly high values of all these parameters as compared to the wheat flour. Similar increase in the total phenolic and flavonoid contents was also reported by Usman et al. [42] in the cookies developed by adding apple pomace powder. Ali et al. [37] also reported the presence of total phenolic and flavonoid content in the grapefruit peel and pomace, when working on the functional drinks. Increase in the bioactive contents and antioxidant capacity of bakery product (cake) was also witnessed by Abdelwahab and Abouelyazeed [50], when citrus peel powder was used with wheat flour.

Kohajdová et al. [43] have also reported that grapefruit pomace powder has the ability to increase the bioactive contents and antioxidant capacity of the biscuits. Based on the majority of prior research, fruit pomace powders add high-capacity antioxidant phenolic and flavonoid components, which greatly increases the bakery goods' nutraceutical potential [20]. High antioxidant power of grapefruit waste bioactive components has also been confirmed by Kaanin-Boudraa et al. [51] validating the present findings. In another similar study, Nuzzo et al. [52] have also reported that biscuits dough, which was enriched with pomegranate peel powder, showed high values of phenolics, flavonoids, carotenoids and antioxidant activity. Thus, these discussed could strongly be related with the current ones, explaining fruits peels and pomace as nutritional ingredients of bakery products, with high of bioactive and antioxidant compounds.

3.6 Effect of grapefruit pomace powder on the sensory properties of cookies

Cookies prepared by incorporating grapefruit pomace powder were assessed for their sensory attributes and results are found to be significantly different ($p < 0.05$) within the samples, as shown in Table 5. Mean values for color ranged from 6.4 to 7.1. Maximum scores were received by T_1 (with 5% grapefruit pomace powder) while lowest scores were secured by T_0 (control). A decrease in color scores for the cookies having more than 5% level of grapefruit pomace powder might be due to high carotenoid contents of grapefruit pomace powder (Table 2), imparting darker color to the cookies. Results regarding the taste of cookies also showed significant statistics, as first an increase and then a decrease in the values were observed by the addition of grapefruit pomace powder. The reason behind low taste scores of T3 might be the high polyphenols transferred from grapefruit pomace powder (Table 2), in those samples. In case of flavor, T_3 (6.9) received maximum score and T_0 (5.4) received minimum score by the panelists, and these high flavor scores in cookies with 15% grapefruit pomace powder might be due to the aromatic and flavoring compounds of the grapefruit. Score for texture of cookies increased with the 5% addition of grapefruit pomace powder, and then decreased as were highest in T_1 and lowest in T_3, and this decrease in texture scores with the increase in grapefruit pomace powder could be related with increased hardness of the cookies (Fig. 2). However, results for texture of cookies revealed the increase in hardness by addition of grapefruit pomace powder. Over all acceptability of the cookies received highest score for T_2 (with 10% grapefruit pomace powder) than other sample, but all the samples were in the range of acceptability by the consumers, as very comparable scores were given on hedonic scale testing. Kohajdova et al. [43] found that biscuits containing powdered grapefruit at 5% level were the most acceptable for assessors, and these findings were supportive enough to be compared with the present results. Current findings were also very comparable to the results of Hussain et al. [21] and Hussain et al. [39], when orange seed powder and lemon pomace powder, respectively, were replaced with wheat flour to develop nutritional biscuits, which were equally liked by the consumers. The study by Asif et al. [9] revealed that citrus pomace could be employed at appropriate levels to make food items and that the sensory qualities of extrudates developed through incorporation of up to 5% citrus pomace powder were acceptable in sensory evaluation. From the current findings, cookie samples in T_2 were found most acceptable, therefore a 10% level of grapefruit pomace powder could be a suitable level of replacement with wheat flour to develop acceptable bakery items.

Table 5 Sensory properties of the cookies

Sample	Color	Taste	Flavor	Texture	Overall acceptability
T_0	6.4 ± 0.84^{b}	6.2 ± 1.68^{b}	5.4 ± 0.84^{c}	6.4 ± 0.85^{b}	5.8 ± 0.7^{b}
T_1	7.1 ± 0.73^{a}	6.3 ± 1.05^{ab}	6.1 ± 0.74^{bc}	6.6 ± 0.74^{a}	6.1 ± 0.73^{ab}
T_2	7.0 ± 0.66^{ab}	6.4 ± 1.34^{a}	6.4 ± 0.69^{ab}	6.2 ± 0.84^{c}	6.6 ± 0.52^{a}
T_3	6.9 ± 0.73^{ab}	5.8 ± 0.63^{c}	6.9 ± 0.99^{a}	5.5 ± 0.52^{d}	5.7 ± 0.67^{c}

Values are presented means along with standard deviations (n = 3)

$^{a–e}$Mean values in column with different superscript are significantly different (p < 0.05). Where, T_0 = control, T_1 = cookies having 5% grapefruit pomace powder, T_2 = cookies having 10% grapefruit pomace powder, T_3 = cookies having 15% grapefruit pomace powder

4 Conclusion

Grapefruit pomace are a plentiful source of antioxidants such as phenolics, flavonoids and carotenoids, which have huge potential as a functional ingredient in different food products. The present research concluded that grapefruit pomace powder is a good source of fibre, ash and bioactive compounds, as compared to straight grade wheat flour, and its incorporation in the cookies improve their nutritional value. Increase in fibre, ash, fat and NFE content and decrease in protein, and energy (kcal) value of cookies was found, as a result of replacement of wheat flour with grapefruit pomace powder. Total phenolic, flavonoid, and carotenoid contents, antioxidant activity and hardness of the cookies was also found to be increased in grapefruit pomace powder added cookies. Furthermore, according to sensory evaluation, color and texture of the cookies having 5% grapefruit pomace powder, while taste and overall acceptability of cookies having 10% grapefruit pomace powder was liked by evaluators. Hence, grapefruit pomace powder can be successfully used for preparation of cookies with better nutritional properties without affecting the consumer acceptability. Grapefruit pomace powder is suggested to use in different other food products of various classes.

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Data availability All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate No animal or human study was involved in this work, however for sensory evaluation study, the participants (all above 16 years age) gave their consent to participate. Proper protocols approved by the ethical committee were followed during the sensory evaluation. Further, the research was carried out following the guidelines provided by the departmental ethics committee (Dr. Anjum Murtaza, Dr. Tusneem Kausar, Dr. Ghulam Mohiuddin) constituted by the University of Sargodha, Pakistan.

Competing interests The authors declare no competing interests.

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