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Polyphenols Profile and Antioxidant Activity of Either Peels or Nanomilled Peels of Sour Orange (*Citrus aurantium* L.) used in Cookies Processing

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Abstract

This study was carried out to prepare functional cookies using sour orange peels powder and nano-particle sour orange peels as a rich source of phytochemicals. The phytochemicals in wheat flour, sour orange peels powder, nano-particle sour orange peels and the produced cookies were determined, and polyphenols compounds in sour orange peels and nano-particle sour orange peels were identified by HPLC. Also, the chemical composition of wheat flour, sour orange peels powder and the prepared cookies were carried out. Whereas physical properties, color measurements and sensory evaluation were determined in wheat flour cookies and sour orange peels powder cookies. The results showed that sour orange peels cookies contained the highest ash content. The nano-particle sour orange peels had the highest total phenolic content, total flavonoid content and antioxidant activity being 9.05 mg GAE / g, 2.10 mg QE / g and 90.13 %, respectively. The addition of sour orange peels powder to wheat flour up to 7.5 % was accepted by the panelists. From the results, it could be indicated that the nano peels particles are a good source of phytochemicals and minerals which improves the quality of cookies. Therefore, it could be recommended that using sour orange peels up to 7.5% enhanced the antioxidant properties and nutritional value of the prepared cookies.

Key words: Sour orange peels; Nano-particles peels; Phytochemicals; Antioxidant activity.

1. Introduction

Food processing produces large quantities of by-products rich in valuable components that can be used as functional ingredients, such as antioxidants, using these substances in food would be advantageous for giving consumers healthier options [1], due to greater knowledge of the effects that current food choices are having on people's health, there is an increase in consumer demand for functional foods enhanced with by-products [2]. Cookies are commonly produced from wheat flour, fat and sucrose, also cookies contain less than 20% moisture [3]. Due to their reasonable price, delicious flavor and comparatively longer shelf life, cookies are one of the most well-known and commonly consumed bakery goods globally [4]. Cookies are the most popular snack due to they can be kept without spoilage for a long time, they have many flavors, in addition to can be eaten between the main meals that don't provide adequate nutrients [5]. The wheat flour that is used in producing cookies, considered as the main source of total carbohydrates, but it has lacking in some important metals and bioactive components, as antioxidants, that are necessary for customers' satisfaction [6].

Citrus agriculture is the primary fruit production around the world, also technology has allowed for the conversion of excess citrus fruit into other food products like jams and juices. The waste generated by these citrus fruits through industries worldwide each year is close to 120 million tonnes [7, 8]. These wastes include seeds ranged from 20 to 40%, peels ranged from 50 to 55%, pomace and wastewater [9]. Bitter orange or sour orange *(Citrus aurantium* L.), also, called as the Seville orange was grown in Syria and Eastern Africa, and then introduced to North America, Spain and Italy [10]. Bitter orange provides

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a variety of health benefits, including antioxidant, antibacterial, anti-inflammatory, antihypertensive, neuroprotective, antimutagenic, and antiallergic qualities, in addition to their abundance in bioactive compounds [11]. Sour orange processors consider peels as a waste [12]. Such wastes can provide significant and important nutrients (bioactive compounds), furthermore, their cheap cost and availability [13]. Phenolic compounds and flavonoids are the most biologically active compounds found in bitter oranges [14].

Sour orange peel is a rich source of total polyphenols compounds such as, *o*-coumaric acid, benzoic acid, ellagic acid, *p*-hydroxybenzoic acid, chlorogenic acid, caffeic acid, cinnamic acid, gallic acid, vanillic acid, syringic acid, ferulic acid, rosmarinic acid, myricetin, quercetin, kaempferol, naringin and catechin. These polyphenols compounds are responsible for the antioxidant properties of sour orange peels in addition to total antioxidant activity values. Also, the sour orange peels can be used in increasing the shelf life of food and improving its quality [15]. Also, Dried citrus peel is rich in carbohydrates and minerals; the fat content, however, is low [16].

The word "nano" means a billionth of a physical unit. The field of nanotechnology works with materials that have at least one dimension between 1 and 100 nm [17]. In the last two decades nanofoods (food related nano- particles) have led to the most debate on nanotechnology and food. Increased interest in improving nanosized substances to enhance nutritional value, absorption, bioavailability and smart delivery of biomolecules is very clear [18]. Based on the above-mentioned considerations, therefore, the objective of this study was to evaluate and use the sour orange peels powder and nano-particle sour orange peels as a rich source for bioactive components in cookies processing.

2. Materials and Methods

2.1. Materials

Sour orange, weak wheat flour (72%), shortening, sugar, NaCl, and baking powder were bought from a local market in Cairo, Egypt. Folin-Ciocalteu reagent and 2,2-Di Phenyl-1-Picryl Hydrazyl (DPPH) reagent were purchased from Sigma Co. (USA), while other chemicals used in this research were bought from EL-Gomhoria Company for Chemicals trade, Egypt.

2.2. Methods

2.2.1. Sour orange peels powder preparation

The fruits were washed with water to remove dirt, then manually peeled with a sharp knife. Peels were dried in oven (Astell Hearson, England) at 50 °C for 24 hours. The dried pieces were grounded, and powder was sieved using a sieve of 425 µm (USA Standard Testing Sieve) to obtain a fine powder and preserved in freezer at -18°C till used.

2.2.2. Preparation of nano-particles sour orange peels

Conventional particle size reduction techniques as ball milling process (Ball milling Model: PQ-N2 Planetary Ball Mill, Gear Drive 4 station (New Jersey, USA) was used for reducing sour orange peels to nano- particles according to Al-Okbi *et al.* [19].

2.2.3. Flour blends preparation

Wheat flour (72%) was partially replaced by 0, 5 and 7.5% Sour Orange peels powder.

2.2.4. Cookies preparation

Along with the control sample, cookies samples were made using the flour mixtures according to A.A.C.C. [20] with some modifications. The ingredients used for cookies processing were 100 g flour, 58 g sucrose, 28 g shortening, 1.1 g baking powder, 0.9 g sodium chloride and 22 ml water. The prepared dough was sheeted to a 1.1 cm thickness and then cut into a circle with a 4.1 cm diameter. Cookies were baked for 25 minutes at 180°C in a preheated oven. The baked cookies were cooled to room temperature before being placed in airtight polythene bags.

2.2.5. Proximate chemical composition

Raw materials and the produced cookies were chemically analyzed. Moisture, ash, total lipids and total protein contents were determined according to A.O.A.C. [21]. Total carbohydrates were calculated by difference.

2.2.6. Physical characteristics of cookies

Weight (g), height (cm), volume (cm^3), specific volume (cm^3 /g), diameter (cm), and spread ratio (diameter/height) were measured according to Nadir *et al*. [22].

2.2.7. Color measurement of cookies

The color parameters of the cookies was determined based on the L^* a^* and b^* uniform color space; Chroma (C) represents color saturation or purity was calculated from $C = (a^{*2} + b^{*2})^{1/2}$; Hue angle (θ) is defined as a color wheel, with red-purple at angle of 0° and 360°, yellow at 90°, bluish-green at 180° and blue at 270°. Hue angles (θ) were calculated from: $\theta = \tan^{-1} (b^*/a^*)$ according to CIE [23] using a colorimeter (Model CR-410, Konica Minolta, JAPAN).

2.2.8. Transmission electron microscope (TEM)

TEM was used to confirm the size of the particles produced by nanomilling. About 50 mg of the powdered sour orange peels (both before and after nanomilling) were diluted in 1 ml of distilled water in an Eppendorf tube, vortexed for 5 minutes, and then one drop was pipetted onto a carbon-coated grid [24]. The specimens were examined directly with a Jeol TEM (JEM 1400, Japan) after being air dried at ambient temperature.

2.2.9. Samples Extraction

Samples were extracted according to Khanavi *et al*. [25] with some modifications. About 0.2 g of powdered sour orange peels with 50 ml of methanol was mixed by magnetic stirrer (IKA- Combimag RCT, Germany) at 1100 rpm in a flask at room temperature for 1 hour then filtered through Whatman No.5 filter paper. Determination of total phenolic contents, total flavonoid contents and antioxidant activity of each extract were performed.

2.2.10. Total phenolic content

Total phenolic was determined according to the Folin-Ciocalteu method described by Cheung *et al*. [26]. Gallic acid was used a standard and total phenolic content of samples were expressed as mg of gallic acid per gm dry sample.

2.2.11. Total flavonoid content

Total flavonoid was determined according to the colorimetric aluminium chloride method described by Zhishen *et al.* [27]. Quercetin acid was used as standard and total flavonoid contents of samples were expressed as mg of quercetin acid per gm dry sample.

2.2.12. Identification of polyphenols

Samples were prepared according to Kim *et al*. [28]. Determination of polyphenols compounds of sour orange peels powder and nano-particle sour orange peels were carried out using HPLC Agilent 1100 series. The used column was an Eclipse XDB-C18 (150 X 4.6 µm; 5 µm) with a C18 guard column (Phenomenex, Torrance, CA). The mobile phase contained solvent A (acetonitrile) and solvent B (2% acetic acid in water (v/v). The flow rate was kept at 0.8 ml/min for a total run period of 70 min. The gradient program was as follows: (100% B to 85% B) in 30 min, (85% B to 50% B) in 20 min, (50% B to 0% B) in 5 min, and (0% B to 100% B) in 5 min. The injection volume was 50 µl and peaks were measured simultaneously at 280 and 320 nm for the benzoic acid and cinnamic acid derivatives, respectively. Prior to injection, each sample was filtered via a 0.45 µm Acrodisc syringe filter (Gelman Laboratory, MI). Peaks were identified by congruent retention times and UV spectra, also, it was compared with those of the standards.

2.2.13. Antioxidant activity

The radical scavenging activity was examined using previously published method Platat *et al*. [29]. The percentage of radical scavenging activity was calculated using the following equation:

% inhibition= {(Absorbance of the control – Absorbance of the sample) / Absorbance of the control} x 100.

2.2.14. Sensory evaluation of cookies

Cookies samples were organoleptically evaluated by ten semi trained panelists from staff members and students of Food Science Department, Faculty of Agriculture, Cairo University. All samples were evaluated for appearance, color, texture, flavor, taste and overall acceptability on ten-point hedonic scale, where a score of 10 reflected the traits that were most liked, a score of 5 represented the attributes at an unacceptable margin, and a score of 1 the attributes that were most disliked [30].

2.2.15. Statistical analysis

Each measurement was conducted in triplicate, except for sensory evaluation (n=10). The data were subjected to analysis of variance (ANOVA). The significance level was set at < 0.05.

3. Results and Discussion

3.1. Proximate chemical compositions of wheat flour and sour orange peels

The average values of proximate chemical composition (moisture, fat, protein, ash and total carbohydrates) of wheat flour and sour orange peel powders are presented in Table (1). Data in Table (1) show that the sour orange peels had higher ash and total carbohydrates contents being 5.50 and 79.13%, respectively as compared to wheat flour, furthermore, the sour orange peels had lower protein contents (7.65 %) than wheat flour (10.15%). The previous results also indicate that sour orange peels had minerals, total lipids and total carbohydrates contents higher than wheat flour [31] meanwhile, wheat flour had higher protein content.

Table 1: Proximate chemical compositions (%) of wheat flour and sour orange peels

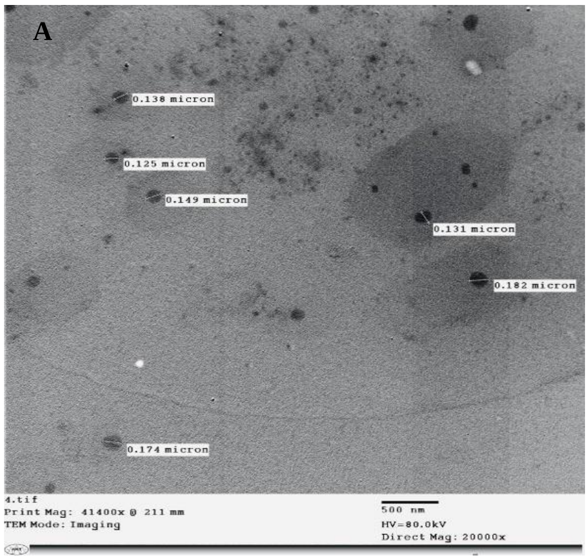
Constituent (%)	Wheat flour	Sour orange peels
Moisture	$11.63^{a} \pm 0.38$	$6.62^{b} \pm 0.21$
Ash	$0.57^{b} \pm 0.00$	$5.50^{a} \pm 0.00$
Total lipids	$1.00^{a} \pm 0.00$	$1.10^{a} \pm 0.14$
Total protein	$10.00^{a} \pm 0.00$	$7.65^{b} \pm 0.21$
Total carbohydrates*	$76.80^{b} \pm 0.38$	$79.13^{a} \pm 0.27$

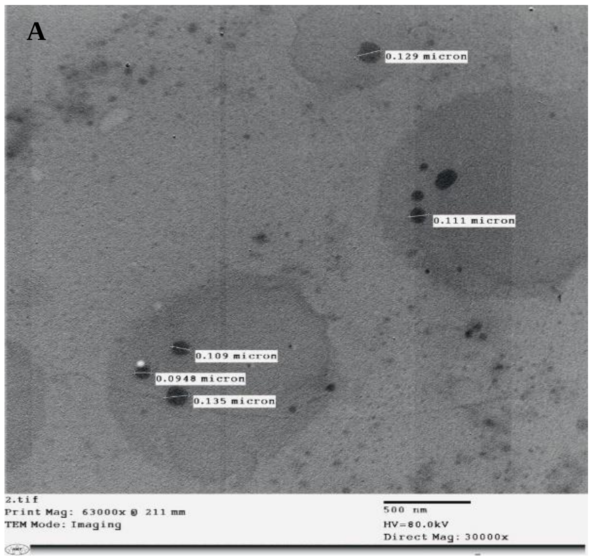
*Total carbohydrates were calculated by difference. Means ± (SD) followed by different superscripts within rows are significantly different ($p < .05$).

3.2. Nano-particles sour orange peels (NPSOP)

Nanotechnology is the process of breaking down macromolecules into smaller particles with a size range of 1-100 nm to create new materials with enhanced properties [24].

Figure (1) shows TEM images of sour orange peels powder (SOPP) before (A) and (B) after nanomilling.





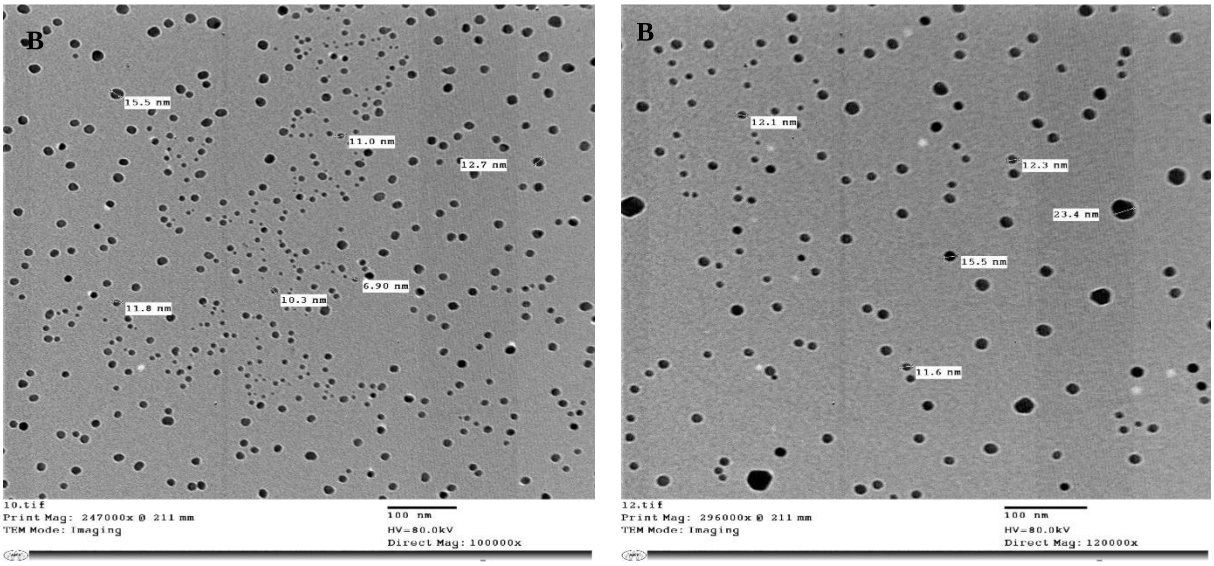


Fig. 1: TEM images of SOPP particles before nanomilling (A) and after nanomilling (B).

3.3. Phytochemical compounds and antioxidant activity of raw materials

The antioxidant activity and the phytochemicals as phenolic and flavonoid compounds were determined in Wheat flour (WF), Sour orange peel powder (SOPP) and Nano-particle sour orange peel (NPSOP) and the results were recorded in Table (2). Phenolic compounds contents in WF, SOPP and NPSOP were 0.16, 8.42 and 9.05 mg GAE/g, respectively. Flavonoid compounds contents in WF, SOPP and NPSOP were 0, 1.32 and 2.10 mg QE /g, respectively. Moreover, antioxidant activity as DPPH radical scavenging activity in WF, SOPP and NPSOP were 4.79, 69.61 and 90.13 %, respectively. Results of total phenolic and antioxidant activity in SOPP are in agreement with results reported by Ana *et al*. [32], while results of total flavonoid in SOPP are in line with those mentioned by Bendaha *et al*. [33]. In fact, several studies performed by Ersus and Cam [34] and Wang *et al*. [35] identified the presence of phenolic chemicals in citrus as the source of its antioxidant properties. Citrus fruits have high nutritional and antioxidant qualities [36]. NPSOP showed the highest contents of phenolic compounds, flavonoid compounds and antioxidant activity and this perhaps because nanoparticles had a large surface area, which increased chemical activity [37] and the solvents' greater penetration of the sample matrices [38] consequently, Phyto-nano particles showed higher antioxidant activity than macromolecules [18]. The breakdown of plant cell walls may be accelerated using ball milling technology and consequently enhancing the release of components attached to cell walls [39].

Table 2: Phytochemical compounds and antioxidant activity of raw materials

Phytochemical analysis	Wheat flour	Sour orange peels	Nano- particle sour orange peels
Total phenolic content (mg GAE / g)	$0.16^{c} \pm 0.01$	$8.42^{b} \pm 0.03$	$9.05^{a} \pm 0.07$
Total flavonoid content (mg QE / g)	$0.00^{c} \pm 0.00$	$1.32^{b} \pm 0.11$	$2.10^{a} \pm 0.02$
Antioxidant activity DPPH (%)	$4.79^{c} \pm 0.00$	$69.61^{b} \pm 0.55$	$90.13^{a} \pm 0.55$

Means ± (SD) followed by different superscripts within rows are significantly different ($p < .05$).

3.4. Profiles of polyphenolic compounds by HPLC

The polyphenols contents were identified in SOPP and NPSOP by using HPLC. The chromatograms (Figure 2) A and B show that there were different compounds, consisting of two classes of polyphenols as phenolic acids and flavonoids in the used sour orange peels and nano-particle sour orange peels (Table 3). Fourteen components were identified in sour orange peel, they include gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, caffeic acid, vanillic acid, ferulic acid, sinapic acid, *p*-coumaric acid, naringin, hesperidin, cinnamic acid, quercetin, apigenin and kaempferol .The results were agreement with the previous reports by Ana *et al*. [32] & Fathy *et al*. [15]. The amount in the NPSOP of protocatechuic acid (8.495 µg/g), *p*-hydroxybenzoic acid (31.307 µg/g), caffeic acid (120.939 µg/g), vanillic acid (28.088 µg/g), ferulic acid (573.209 µg/g), sinapic acid (84.088 µg/g), naringin (315.902 µg/g) and cinnamic acid (5.309 µg/g) were higher than in the SOPP. These results are in agreement with Dawi *et al*. [40], it was found that when the peels are reduced to nanoparticles, polyphenols compounds are increased. Gómez-Mejía *et al.* [41] identified ferulic acid, *p*-coumaric acid and naringin in all analyzed citrus peel extracts and proposed that citrus peels considered a rich source of polyphenols for adding value to food products.

Table 3: Profile of polyphenolic compounds (µg/g DW) in sour orange peels and nano- particle sour orange peels

Compounds	**SOPP (µg/g)**	**NPSOP (µg/g)**
Gallic acid	10.329	6.792
Protocatechuic acid	7.407	8.495
p-hydroxybenzoic acid	30.570	31.307
Caffeic acid	116.300	120.939
Vanillic acid	16.790	28.088
Ferulic acid	548.616	573.209
Sinapic acid	78.443	84.088
Cinnamic acid	4.766	5.309
p-coumaric acid	27.896	27.180
Naringin	223.302	315.902
Hesperidin	508.806	448.273
Quercetin	95.369	93.979
Kaempferol	4.917	4.023
Apigenin	108.767	101.222

SOPP = sour orange peels powder, NPSOP= nano- particle sour orange peels.

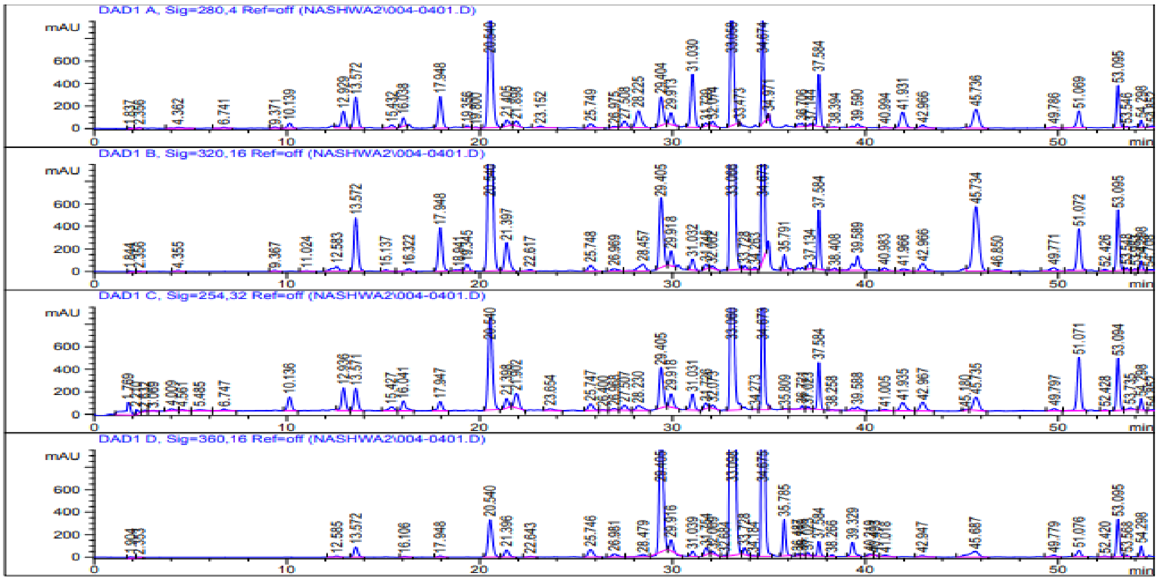


Fig.2 (A): Polyphenols compounds identified in sour orange peels powder by HPLC.

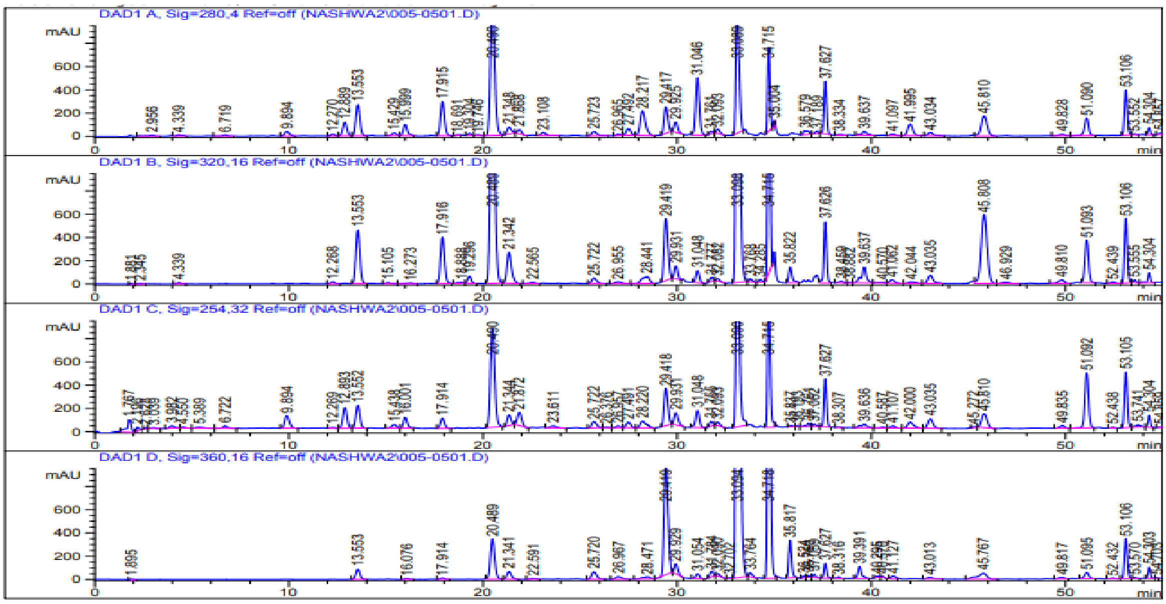


Fig.2 (B): Polyphenols compounds identified in nano-particle sour orange peels by HPLC.

3.5. Proximate chemical compositions of Wheat flour Cookies (WFC) and Sour Orange Peels Powder Cookies (SOPPC)

The addition of powdered sour orange peels to cookies had an impact on their chemical composition, as shown in Table (4). When sour orange peel powder was added, the ash content of the cookies samples increased compared to the control.

Meanwhile, protein levels in cookies made with sour orange peels showed a modest decline.

Generally, these findings suggest that adding sour orange peels to cookies led to improve their mineral content. Results are in agreement of those reported by Nassar *et al*. [42].

Table 4: Proximate chemical compositions (%) of WFC and SOPPC

Samples	WFC	SOPPC 5%	SOPPC 7.5%
Moisture	5.40 ^{a} ± 0.14	5.40^{a} ± 0.00	5.40^{a} ± 0.42
Ash	1.07^{b} ± 0.02	1.22^{a} ± 0.00	1.23^{a} ±0.00
Total lipids	13.70^{a} ± 0.24	13.70^{a} ± 0.14	14.07^{a} ± 0.03
Total protein	6.15^{a} ± 0.07	5.58^{b} ± 0.04	5.10^{c} ± 0.14
Total carbohydrates*	73.68^{a} ± 0.14	74.10^{a} ± 0.09	74.20^{a} ± 0.31

WFC = wheat flour cookies, SOPPC = sour orange peels powder cookies. Means ± (SD) followed by different superscripts within rows are significantly different (p < .05). *Total carbohydrates were calculated by difference.

3.6. Physical characteristics of WFC and SOPPC

The physical properties of the cookies prepared either from wheat flour (WFC) or sour orange peels powder (SOPPC) are shown in Table (5). Data show that supplemented cookies with sour orange peel exhibited significantly (p< 0.05) lower values of Height, volume and diameter than control cookies. There were no significant (P<0.05) differences between the values obtained for weight, specific volume and spread ratio of cookies enriched with (5 & 7.5% SOPP) and the control (100% wheat flour) cookies [43, 44].

Table 5: Physical characteristics of WFC and SOPPC

Samples	WFC	SOPPC 5%	SOPPC 7.5%
Weight (g)	16.28^{a} ± 0.54	15.27^{a} ± 0.10	15.11^{a} ± 0.46
Height (cm)	1.30^{a} ± 0.00	1.15^{b} ± 0.07	1.10^{b} ± 0.00
Volume (cm^3)	29.50^{a} ± 0.70	27.80^{ab} ± 0.28	27.50^{b} ± 0.70
Specific volume (cm^3 /g)	1.81^{a} ± 0.10	1.82^{a} ± 0.03	1.82^{a} ± 0.00
Diameter (cm)	4.60^{a} ± 0.14	4.25^{b} ± 0.07	4.25^{b} ± 0.07
Spread ratio (diameter/height)	3.53^{a} ± 0.10	3.70^{a} ± 0.28	3.86^{a} ± 0.06

WFC = wheat flour cookies, SOPPC = sour orange peels powder cookies. Means ± (SD) followed by different superscripts within rows are significantly different (p < .05).

3.7. Color measurement of WFC and SOPPC

The choice of food products is influenced by several aspects, including color [45]. Browning is the term used to describe the color development that takes place during the baking of bakery products. When the cookies color was evaluated (Table 6), Lightness, redness, yellowness, chroma and hue values are represented by the variables $L*$, $a*$ $b*$, C and H, respectively. It was observed that the $L*$ values of the cookies ranged from 64.69 to 70.45. In comparison to the control sample, the addition of SOPP resulted in a significant browning of the cookies surface and by increasing SOPP content, cookies browning increased. The highest *a** and *b** values of the cookies were found in the sample with SOPP 7.5 % (4.36 and 20.06, respectively) and the lowest in the control sample (1.55 and 18.67, respectively). The color of the SOPP varied from light yellow to dark yellow because the existence of carotenoids and flavonoids [46]. Hue (H) is a term used to express the pure spectrum of color without tint or shade [47]. The increased level of substitution of sour orange peel powder reduced the hue value. Chroma (C) indicates the saturation or intensity of the color [48] and the highest values were found in the sample with SOPP 7.5 %.

Table 6: Color measurement of WFC and SOPPC

Samples	*L**	*a**	*b**	C	H
WFC	$70.45^{a} \pm 0.53$	$1.55^{c} \pm 0.06$	$18.67^{c} \pm 0.02$	$18.73^{c} \pm 0.08$	$85.25^{a} \pm 0.33$
SOPPC 5%	$66.25^{b} \pm 0.97$	$3.57^{b} \pm 0.09$	$19.49^{b} \pm 0.00$	$19.81^{b} \pm 0.09$	$79.62^{b} \pm 0.21$
SOPPC7.5%	$64.69^{c} \pm 0.31$	$4.36^{a} \pm 0.26$	$20.06^{a} \pm 0.08$	$20.52^{a} \pm 0.34$	$77.73^{c} \pm 0.36$

WFC = wheat flour cookies, SOPPC = sour orange peels powder cookies, *L** = lightness, *a** = redness, *b** = yellowness, C = Chroma, H = hue. Means ± (SD) followed by different superscripts within columns are significantly different ($p < .05$).

3.8. Total phenolic, total flavonoid contents and antioxidant activity of cookies

Antioxidant substances can shield the human body from oxidative damage and are well known for delaying, retarding and preventing rancidity and other flavor deterioration in foods [49]. Table (7) shows the total phenolic, total flavonoid contents and antioxidant activity in WFC, SOPPC and NPSOPC. The NPSOP cookies (7.5%) showed significant ($p<0.05$) and the highest phenolic content, flavonoid content and antioxidant activity followed by NPSOP cookies (5%) then SOPP cookies (7.5%) and (5%). By increasing SOPP concentrations in cookies, the phenolic content, flavonoid content and antioxidant activity increased. Increasing antioxidant activity in cookies may be due to the high levels of polyphenols that are present in SOPP. The nanomilled sour orange peels (NPSOP) had the highest phenolic content and flavonoid content. The breakdown of plant cell walls may be accelerated and enhancing the release of compounds attached to cell walls through using of ball milling technology [39]. Moreover, the nanomilled sour orange peels (NPSOP) exhibited the highest antioxidant activity perhaps because nanoparticles had a large surface area, which increased chemical activity [37] and the solvents' greater penetration of the sample matrices [38].

Table 7: Total phenolic, total flavonoid contents and antioxidant activity of cookies

Samples	Total phenolic content (mg GAE /g)	Total flavonoid content (mg QE /g)	Antioxidant activity DPPH (%)
WFC	$0.01^{e} \pm 0.00$	$0.00^{e} \pm 0.00$	$6.55^{e} \pm 0.42$
SOPPC 5%	$0.34^{d} \pm 0.11$	$0.22^{d} \pm 0.02$	$41.86^{d} \pm 0.19$
SOPPC 7.5%	$0.80^{c} \pm 0.18$	$0.47^{b} \pm 0.00$	$44.77^{c} \pm 0.40$
NPSOPC 5%	$1.22^{b} \pm 0.10$	$0.30^{c} \pm 0.02$	$54.31^{b} \pm 0.40$
NPSOPC 7.5%	$2.09^{a} \pm 0.07$	$0.55^{a} \pm 0.01$	$75.25^{a} \pm 0.35$

WFC = wheat flour cookies, SOPPC = sour orange peels powder cookies, NPSOPC= nano- particle sour orange peels cookies. Means ± (SD) followed by different superscripts within columns are significantly different ($p < .05$).

3.9. Sensory evaluation of WFC and SOPPC

Sensory evaluation values of WFC and SOPPC are shown in Table (8). All samples were evaluated for appearance, color, texture, flavor, taste and overall acceptability. Addition of SOPP led to low scores of cookies appearance. Color, texture and flavor had no significant differences (p<0.05) among the cookies samples. When the samples taste was evaluated, it was noticed that cookies with 7.5% SOPP were the least accepted cookies while cookies with 5% SOPP had no significant difference compared with the control. Further supplementation decreased the taste score of cookies attributed to slight bitterness after taste due to the high polyphenol content of SOPP [50]. Overall acceptability refers to how customers or panelists accept the product in general. In this study, control and cookies with 5% addition SOPP were liked by evaluators.

Table 8: Sensory evaluation of WFC and SOPPC

Samples	Appearance (10)	Color (10)	Texture (10)	Flavor (10)	Taste (10)	Overall acceptability (10)
WFC	$9.80^{a}\pm 0.44$	$9.60^{a}\pm 0.89$	$9.20^{a}\pm 0.83$	$9.80^{a}\pm 0.44$	$9.60^{a}\pm 0.54$	$9.80^{a}\pm 0.44$
SOPPC 5%	$8.30^{b}\pm 0.67$	$9.70^{a}\pm 0.67$	$9.50^{a}\pm 0.70$	$9.40^{a}\pm 0.89$	$9.40^{a}\pm 0.89$	$9.20^{a}\pm 0.83$
SOPPC 7.5%	$8.30^{b}\pm 0.67$	$9.30^{a}\pm 0.83$	$8.90^{a}\pm 0.74$	$9.40^{a}\pm 0.54$	$6.80^{b}\pm 0.70$	$7.40^{b}\pm 0.70$

WFC = wheat flour cookies, SOPPC = sour orange peels powder cookies. Means ± (SD) followed by different superscripts within columns are significantly different (p < .05).

4. Conclusions

The present study confirmed that sour orange peels are rich in several nutrients and an excellent source of phenolic compounds such as ferulic acid, caffeic acid, sinapic acid and *p*-hydroxybenzoic acid, and rich source of flavonoids such as hesperidin, naringin, quercetin and Kaempferol. Furthermore, sour orange peels exhibited high natural antioxidant activity. Due to their high mineral content, sour orange peel flour can be utilized as a recipe in a variety of local foods such as bakery products (cookies). Sour orange peels were found to have an important effect, when added to cookies in limited amounts (7.5%) on phytochemical properties: higher polyphenolic compounds compared to the control cookies (without SOPP addition). The cookies enriched with 7.5% SOPP had similar specific volume with the control cookies. Also, a difference on the cookies color was observed compared to the control cookies. When reducing sour orange peels to nano- particles lead to enhanced antioxidant properties. Nanoparticles of sour orange peels need further studies.

5. References

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