Functional analysis of unfermented and fermented citrus peels and physical properties of citrus peel-added doughs for bread making

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Abstract Several studies have indicated citrus peels (CP) contain specific methoxy flavones, e.g. nobiletin and tangeretin, which have been shown to prevent numerous diseases. However, research reports regarding their application as food additive in healthy baked products is scarce. In our study, both unfermented (UF) and fermented (F) citrus peels were processed under different dry hot-air temperatures to make four citrus peel powders, UF-100 °C, UF-150 °C, F-100 °C, F-150 °C, respectively. The analysis of the basic components and nutraceuticals as well as antioxidant activity were conducted. Various percentages of CP were added to dough and toast bread for physical property and sensory evaluations. The results indicated the contents of crude proteins (3.3–4.3 mg/g) and fibers (10.9–14.9 %) among the four samples were similar. The UF extracts showed better antioxidant activities than F extracts. HPLC analysis indicated the contents of hesperidine, nobiletin and tangeretin in CP extracts were UF-150 °C > UF-100 °C. Farinograph analysis indicated a linear relation between CP powder content and the parameters of the physical properties of dough. A high percentage of fibrous CP powder in dough increases the water adsorption capacity of the dough, resulting in a decrease in its stability. The sensory evaluation

results indicated a greater acceptability of UF-added toast bread relative to the F-added one. Among these, according to the statistical analysis, the UF-150 °C 4 % and UF-100 °C 6 % groups were the best and F-150 °C 2 % group was the poorest in overall acceptability.

Keywords Citrus peels · Fermentation · Dough · Farinograph · Physical properties

Introduction

According to traditional Chinese medicine, citrus plants have the multiple effects on the regulation of the physiological functions of the human body. Besides producing essential oil, the citrus peel (CP) contains functional flavonoid components, especially the polymethoxylated flavone, including nobiletin and tangeretin, which have been proven to have multiple pharmacological actions against cancer, oxidation resistance, anti-inflammation and preventing cardiovascular diseases (Tripoli et al. 2007; Manthey et al. 2001; Murakami et al. 2000). However, most citrus peels are treated as waste. In recent years, the food industry has been paying increasing attention to the proper processing and the development of functional products to increase the utility value of citrus peel.

Many studies have indicated the extracts from vegetable and fruit peels have strong antioxidant activity, such as superoxide anion scavenging and DPPH radical scavenging ability (Kondo et al. 2002). In addition, some studies have explored the changes in polyphenolic substances, flavonoids and antioxidant activity during the fermentation process of vegetable and fruit peels. It has been found the antioxidant activity of glucoside form is weaker than that of phenolic compounds without the glucosyl groups (aglycone). In the fermentation process, the *Aspergillus*, *Lactobacillus* and

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Bacillus have hydrolytic enzyme cellulase and β -glucosidase activity removing glycosyl groups, and they can improve the antioxidant activity of natural foodstuff fermentation products (Kuo et al. 2006; Pyo et al. 2005). The preheating can generate different flavors, and many studies have found heating can enhance the phenolic compounds and antioxidant activity of foodstuff (Hayat et al. 2010; Francisco and Resurreccion 2009). In recent years, many studies have added natural foodstuff waste containing rich dietary fiber and functional components to bread making, with the aim of developing healthy functional bread (Sangnark and Noomhorm 2004).

However, many studies have shown this kind of additive in different proportions significantly affects the physical properties of dough and bread quality in the dough mixing process (Bohlin and Garlson 1980; Wang et al. 2002). Research indicated the added pectin and/or phenolic extract influenced the bread dough cross-linking microstructure and bread properties during dough development and bread baking (Sivam et al. 2011). The added bioactive ingredients may or may not promote the protein cross-links. Appropriate cross-links among wheat proteins, fiber polysaccharides, and phenolic antioxidants could be the most critical factor for bread dough (Sivam et al. 2010).

The objective of this study was to prepare both unfermented (UF) and fermented (F) citrus peels processed by different dry hot air temperatures, and the analysis of basic components and nutraceuticals as well as antioxidant activity were conducted. In addition, various percentages of CP were added to dough and toast-making for determining the physical properties of the CP-added doughs as well as sensory evaluation of the CP-added toast breads.

Materials and methods

Materials and chemicals

The Ponkan (*Citrus reticulata* Blanco) used in this study was obtained from the local fresh goods supply market of the Chiayi region of Taiwan from October to December 2009. *Lactobacillus* and *Bifidobacterium* for the 6-month fermentation of CP were supplied by Wu Sing Enzyme Industrial Co., Ltd. (Chiayi county, Taiwan). Bread flour (protein content 14.51 %) was provided by Uni-President Co. (Tainan City, Taiwan). The chemical reagents for general component measurement in this study were of analytical grade. The reagents for polyphenols and antioxidant measurements including Folin Ciocalteu reagent, 2,2-di (4-*tert*-octylphenyl)-1-picrylhydrazyl (DPPH) and horseradish peroxidase were obtained from Sigma-Aldrich Chemical Co. (St. Louis, MO). The standards hesperidine, tangeretin and nobiletin were purchased from Chromadex (Irvine, CA).

Preparation of citrus peel powders and extracts

The fresh and fermented citrus peels were dried by hot air at 100 °C and 150 °C, respectively, and the citrus peels were ground into powder and the particle sizes larger than 200 μ m were sieved out and stored at –20 °C. The general and functional composition of the processed citrus powder were analyzed. Then, 2 %, 4 % and 6 % citrus powder were added to the bread flour, respectively, to analyze the physical properties of the dough.

Next, 10 g citrus powder was extracted with 100 mL methanol at 25 °C and oscillation at 150 rpm for 24 h. The filtrate collected from two extractions was concentrated under reduced pressure at 40 °C until dryness. The obtained extract was stored at –20 °C for future use, or processed by freeze-drying and stored for future use.

General composition analysis of test citrus peel

The contents of water, crude protein, fat and fiber were measured according to AOAC 32.1.02, 4.2.03, 4.5.01 and 4.6.02 (Horwitz 2000), respectively. The water activities (A_w) of the test samples were measured with a water activity meter (Pawkit, Decagon, U.S.A.) via second-order correction.

Analysis of flavonoid in citrus peel extract

The quantitative citrus peel extract was dissolved in methanol and filtered with a 0.45 μ m filter membrane. A quantitative filtrate was diluted with HPLC grade solvent to a proper concentration. The contents of the major components were analyzed by HPLC. The analysis conditions are shown below: A sample (20 μ L) was filled in HPLC tubular column: Cosmosil 5C₁₈-AR-II, 4.6 I.D. $\times$ 25 cm (Nacalai Tesque, Japan), the mobile phase composition was 0.1 % H₃PO₄ (A) and acetonitrile (B) and gradient setting: 0–5 min, from 90 % A, 10 % B to 70 % A, 30 % B; 5–20 min, from 70 % A, 30 % B to 60 % A, 40 % B; 20–40 min, from 60 % A, 40 % B to 10 % A, 90 % B; 40–45 min, from 10 % A, 90 % B to 5 % A, 95 % B. The flow rate and detection wavelength were 1.0 mL/min and 254 nm respectively. The contents of the main flavonoids hesperidine, tangeretin and nobiletin in citrus peel were determined by interpolation according to the standard curve.

Determination of total polyphenols

The Folin-Ciocalteu method was used for measurement, and gallic acid was used as a standard. 1 mL of gallic acid at different concentrations (5–50 μ g/mL) was added in isometric Folin-Ciocalteu reagent, mixed uniformly and rested for 5 min, 2 mL 20 % Na₂CO₃ was added in, and rested for 5 min and centrifuged for 5 min. The upper clear solution

was measured with a UV-Vis spectrophotometer at 730 nm. The gallic acid equivalent (GAE) of the sample was then calculated.

Measurement of removing H₂O₂

The assay is based on the horseradish peroxidase (HRPO)-mediated oxidation of phenol red by H₂O₂, which results in the formation of a compound showing increased absorbance at 610 nm with a pH of 12.5 (Pick and Keisari 1980). A reaction mixture, containing 0.88 mL of phenol red solution (0.28 mM of phenol red in PBS), 0.1 mL of serially diluted vitamin C or CP extract and 0.01 mL of 1 mM H₂O₂, was mixed and allowed to stand for 5 min. 0.01 mL of 1 mg/mL HRPO was then added to the reaction mixture and 0.01 mL of 1 N NaOH was added after 5 min of incubation. The absorption was measured at 610 nm to determine the reduction of hydrogen peroxide free radicals. The Vit.C equivalent in each gram of CP extract was calculated.

Measurement of DPPH free radical scavenging ability

A series of citrus peel extracts (4 mL) at different diluted concentrations and freshly prepared 10 mM DPPH in methanol solution (1 mL) were mixed uniformly and stored in a dark place for 30 min. The absorbance value of the solution at 517 nm was measured with a spectrophotometer, and the standard vitamin E was used as the control group of the sample. A lower absorbance value indicated a stronger ability of the sample in scavenging DPPH free radical. The Vit.E equivalent in each gram of extract was calculated, and the extract scavenging power was calculated using the formula below.

$$\text{Scavenging power(\%)} = [(A_{517 \text{ nm of control}} - (A_{517 \text{ nm of sample}})/(A_{517 \text{ nm of control}})] \times 100$$

Formula and method for CP-added bread making

The CP powder bread was made using the formula for the direct white toast bread method from the Baking Technician Certification of Vocational Training Council (Taipei, Taiwan). The CP powder passing through a 200-mesh screen was added instead of 2 %, 4 % and 6 % flour. The formula for white toast bread (186 %, baker's percentage) contained 100 % bread flour, 1.5 % instant yeast, 10 % granulated sugar, 1.5 % salt, 63 % water and 10 % shortening.

The straight dough method was adopted. The dough (560 g) was fermented (28 °C, 75–80 % humidity) for 60 min and rounded into a ball shape. After 15 min intermediate fermentation (28 °C, 80 % humidity), the dough was shaped, placed into pan, further fermented (28 °C, 85 %

humidity) for 60 min, and baked (upper oven temperature 160 °C/lower oven temperature 200 °C) for 30 min. The breads were immediately taken out of the pan and cooled at room temperature.

Measurement of characteristics of bread doughs

The Brabender Farinograph (OHG, Duisburg, Germany) was used in the experiment. The flour weight was 300 g according to the constant flour weight method. The dough mixing quality was measured at a constant temperature of 30 °C, and the flour and water were mixed in the farinograph instrument to generate elasticity and extensibility. Then, each 300 g of dough containing 2 %, 4 % and 6 % of fermented or unfermented CP powder, which had been dried by hot air at 100 °C and 150 °C was sampled, and the dough quality curve was measured by dough quality tester (William 1989). The dough quality parameters of the above 12 groups of citrus powder-added doughs were analyzed, including water absorption, mixing tolerance (stability), mixing tolerance index (MTI), etc. The water absorption was measured as the percentage of water required to yield a dough consistency of 500 FU units.

Sensory quality

The hedonic test was used for sensory evaluation. The evaluation conditions include: the unfermented and fermented hot air dried citrus peel powder was used as raw material, 2, 4 and 6 % of it was added to the dough to make toast bread. The toast bread crust was removed and cut into cubes (3×3×3 cm) for the tasters to grade the crust feeling, hardness, fragrance, color, and overall acceptability. The 26 tasters were students of the Department of Food Science, China University of Science and Technology. The grading was based on a 5-point rating scale, where 1 point represented strong disapproval, and 5 points represented strong approval.

Statistical analysis method

The software package SPSS was to analyze the data variance (ANOVA) and Duncan's Multiple Range test was performed to determine the differences among various groups ($p < 0.05$). Each value is expressed as mean ± standard deviation ($n = 26$).

Results and discussion

Composition of fermented and unfermented citrus powders

Fermented and unfermented citrus peels dried by hot air at different temperatures were used in this study. Statistical

analysis shown in Table 1 indicated UF-100 °C, UF-150 °C, F-100 °C and F-150 °C samples were not significantly different in water activity ($p < 0.05$), but F-100 °C had higher water content, compared with the CNS flour standard in which the flour moisture content may not exceed 14 % (Xu et al. 1997). The other three kinds of citrus powder did not exceed the specified range of water content. It was found the crude fat and crude protein of the unfermented citrus powder was higher than that of the fermented citrus powder. This is possibly because the nonpolar components such as essential oil are converted into other polar molecules in the fermentation process. The fermented citrus powder contains more crude protein, possibly because of all the protein substances from the microbial itself in the fermentation process. It is interesting to note the crude fiber content was inversely proportional to the moisture content in dissimilarly processed citrus powder. In the other three samples, F-100 °C containing higher moisture content had significantly less crude fiber content (10.90 ± 0.37 %, calculated in dry weight proportion). The fiber is water retaining, expandable and adsorptive, and the digestive enzyme fails to decompose it. Fiber can promote the gastrointestinal peristalses and digestion *in vivo*, and reduce the incidence of intestinal cancer (Liu et al. 2001). The addition of fiber to bread can provide more dietary fiber to the body (Bonafaccia et al. 2003).

Functional components in extracts from fermented and unfermented citrus peels

HPLC analyzed the functional flavonoid components in dissimilarly processed unfermented and fermented citrus peel samples, including hesperidin, nobiletin and tangeretin contents. The HPLC analysis results are shown in Table 2. The hesperidin content is F-100 °C > UF-150 °C, F-150 °C > UF-100 °C. The fermented citrus peel is apparently higher in hesperidin than unfermented citrus peel. The content of nobiletin and tangeretin in unfermented citrus peel is UF-150 °C > UF-100 °C. The results

show after extraction of the citrus peel powder processed by hot air at higher temperature, the extract contains higher content of aglycone. This is because the tissue of the citrus powder dried by hot air at higher temperature is more damaged, which increases the extraction rate. In addition, the active components nobiletin and tangeretin, which are flavonoids without glycosyl groups, were not detected in the fermented citrus peel, but the content of hesperidin, a flavonoid glycoside was higher than that of the unfermented citrus peel. This finding suggests the biochemical transformations occurred in the fermentation process with microbials and the large amount of sucrose involved, resulting in the hesperidin content increasing and the aglycone converting into other unknown metabolites. A previous study indicated bio-transformation of nobiletin by *Aspergillus niger* led to 4'-hydroxy-5,6,7,8,3'-pentamethoxyflavone and the anti-inflammatory effects of hydroxylated polymethoxyflavones have been reported in recent years (Okuno and Miyazawa 2004; Li et al. 2009).

Antioxidant activity of citrus peel extracts

The total polyphenols and antioxidant activity of the extracts from dissimilarly hot air processed fermented and unfermented citrus peels were analyzed. The antioxidant activity was measured in terms of H_2O_2 scavenging (water phase system) and DPPH radical scavenging ability (alcohol phase system). Polyphenols content and antioxidant activity were expressed as gallic acid equiv., Vit.C equiv. and Vit.E equiv., respectively (Table 2). The GAE in citrus peel extracts is UF-150 °C > UF-100 °C > F-150 °C > F-100 °C. As for the H_2O_2 scavenging ability, Vit.C equiv. is UF-150 °C > UF-100 °C > F-150 °C > F-100 °C. As for the DPPH free radical scavenging ability, Vit.E equiv. is UF-150 °C > F-150 °C > UF-100 °C > F-100 °C. The above results indicate the unfermented citrus peel extract has a better antioxidant activity (DPPH and H_2O_2 test) and total polyphenols. In addition, the UF-150 °C processed citrus

Table 1 Physical and chemical quality characteristics of citrus peel (CP) powders

	Water content (%)	Water activity (Aw)	Crude fat* (%)	Crude protein* (%)	Crude fiber* (%)
UF-100 °C	10.5 ± 0.20^a	0.54 ± 0.13^a	3.3 ± 0.02^a	3.4 ± 0.81^a	13.1 ± 0.40^a
UF-150 °C	10.4 ± 0.10^a	0.68 ± 0.07^a	3.2 ± 0.42^a	3.3 ± 1.10^a	14.1 ± 0.31^a
F-100 °C	17.7 ± 0.30^b	0.58 ± 0.16^a	1.9 ± 0.12^b	4.3 ± 0.74^b	10.9 ± 0.37^b
F-150 °C	9.9 ± 0.10^c	0.52 ± 0.02^a	1.8 ± 0.83^b	4.0 ± 0.27^b	14.9 ± 0.88^a

Data are expressed as mean $\pm$ standard deviation ($n=3$)

Means within a column with different superscripts are significantly different ($p < 0.05$)

UF-100 °C unfermented CP powder under 100 °C of hot-air dry; UF-150 °C unfermented CP powder under 150 °C of hot-air dry; F-100 °C fermented CP powder under 100 °C of hot-air dry; F-150 °C fermented CP powder under 150 °C of hot-air dry

* The values are presented on dry-weight basis

Table 2 Total polyphenolic contents, antioxidant activities and functional flavones of citrus peel (CP) extracts

CP extract	Gallic acid equiv. (mg/g)	Vit.C equiv. (mg/g)	Vit.E equiv. (mg/g)	Hesperidin %	Nobiletin %	Tangeretin %
UF-100 °C	79.3±2.7 ^a	42.5±1.3 ^a	156.5±6.5 ^a	5.3±0.13 ^a	2.7±0.07 ^a	3.6±0.09 ^a
UF-150 °C	132.3±3.9 ^b	75.9±1.3 ^b	336.9±5.8 ^b	6.1±0.15 ^b	3.5±0.09 ^b	4.9±0.12 ^b
F-100 °C	47.1±0.70 ^c	11.7±1.4 ^c	125.9±8.1 ^c	7.8±0.20 ^c	N.D.	N.D.
F-150 °C	63.3±0.40 ^d	19.1±2.6 ^d	192.3±15.2 ^d	6.1±0.15 ^b	N.D.	N.D.

Gallic acid equivalent was determined by Folin-Ciocalteu method

Vitamin C equivalent (Vit.C equiv.) was determined by H₂O₂ reduction method

Vitamin E equivalent (Vit E equiv.) was determined by DPPH method

Data are expressed as mean ± standard deviation (*n*=3)

Means within a column with different superscripts are significantly different (*p*<0.05)

Refer Table 1 for UF-100 °C, UF-150 °C, F-100 °C and F-150 °C

N.D. not detected

extract has the highest antioxidant activity, whereas the F-100 °C processed one has the worst antioxidant activity. This result suggests the hot preprocessing can enhance the phenolic compounds and antioxidant activity of citrus peel extract.

Mixing properties analysis (Farinograph) of CP-added doughs

In this study, the curved graphs of various percentages of unfermented and fermented citrus powders-added doughs are shown in Figs. 1 and 2, respectively. The analytic results of several dough mixing parameters are shown in Fig. 3. In Fig. 3(a), it is observed the addition of UF-100 °C 6 % citrus powder needs a maximum water absorption of 74.8 %, and the F-100 °C 2 % and F-150 °C 2 % citrus powder needs a minimum water absorption of 63.8 %. It is interesting to note in the case of unfermented CP, higher citrus powder content in the dough requires a higher percentage of water absorption. However, in the fermented CP group, the required water absorption remains much lower and the dose-response effect is not observed. A previously published report using mango peel powder in dough biscuit also demonstrated the higher dietary fiber content requires more water absorption, which is consistent with this study (Ajila et al. 2008).

Next, the result in Fig. 3(b) shows a dose-dependent shortening of departure time in both unfermented and fermented doughs, while the control group had the longest departure time of 15.0 min. Departure time is usually considered as the point at which dough gluten starts to break down. It is proposed the high water retention of citrus powder fiber makes the citrus powder absorb a large amount of moisture within a relatively short time. Therefore, the flour particles cannot absorb water completely, and the gluten cannot easily form a continuous network structure, thus shortening the dough departure time.

In terms of stability shown in Fig. 3(c), the control group had the highest stability, of 22.2 min, while the group of UF-150 °C 6 % exhibited the lowest stability of 5.3 min. It is observed the stability decreased as the amount of citrus powder in dough increased for both the unfermented and fermented cases. A previous study also demonstrated when the flour is mixed with bran of grains, the stability as well as the strength of dough is reduced (Sudha et al. 2007).

The mixing tolerance index (MTI) represents the difference in FU between the peak time point on the graph and 5 min after peak time is reached. A smaller value usually represents stronger dough gluten elasticity. The results in Fig. 3(d) show the control group had the maximum MTI (0 F.U.), while UF-150 °C 6 % (84 F.U.) and F-100 °C 6 % had the minimum MTI (83 F.U.), suggesting a high percentage of CPs in the dough mixing process might result in relative intolerance to mechanical mixing, and the dough processing stability might be poor. Interestingly, much lower MTIs were observed in both the F-100 °C 2 % (9 F.U.) and F-150 °C 2 % (12 F.U.) groups, compared to those in the unfermented 2 % groups.

The development time indicates the point when the dough reaches the maximum viscosity as well the optimal gluten structure. As shown in Fig. 3(e), the control group had the maximum time of 15.0 min, and the F-100 °C 6 % group had the minimum time of 6.0 min, suggesting the control group has the highest dough gluten strength. The results also indicated a dose-response effect on the development time in both the unfermented and fermented groups. The dough strength decreases gradually as the added amount of citrus powder increases.

In summary, from the Farinograph graph analysis, F-150 °C 6 % had the shortest departure time, and F-100 °C 2 % and UF-100 °C 2 % had the longest departure time. It is observed when the dough departure time is longer, the stability is higher and the MTI is smaller. F-100 °C 6 % had the shortest and F-100 °C 2 % had the longest

Fig. 1 Farinographs of doughs containing various percentages of unfermented citrus peel (CP) powders. *FU* Farinograph units; *UF-100 °C* unfermented CP powder under 100 °C of hot-air dry; *UF-150 °C* unfermented CP powder under 150 °C of hot-air dry

Fig. 2 Farinographs of doughs containing various percentages of fermented citrus peel (CP) powders. *FU* Farinograph units; *F-100 °C* fermented CP powder under 100 °C of hot-air dry; *F-150 °C* fermented CP powder under 150°C of hot-air dry

development time. F-100 °C 6 % group displayed the shortest development time in maintaining maximum viscosity, resulting a much steeper decline after the peak time, as indicated by the lower MTI and it being the least tolerant of the mixing process. On the contrary, F-100 °C 2 % had the longest gluten development time and kept the viscosity longer than the other samples did. It is concluded when the departure time is longer and the mixing stability of dough is higher, the strength and elasticity of the dough gluten will be better.

Sensory quality

The sensory evaluation by the hedonic test was designed and conducted in this study (Stone and Sidel 1993). Unfermented and fermented hot air dried citrus peel powders under different temperatures were added to the dough at 2, 4 and 6 % respectively, to make toast bread for sensory evaluation. The results analyzed by statistical software indicated UF-150 °C 4 % had the best hedonic scale in flavor; UF-100 °C 6 % had the

Fig. 3 Effects of added citrus peel (CP) powders on the mixing properties of doughs. **a** water absorption; **b** departure time; **c** stability; **d** mixing tolerance index; **e** development time. UF-100 °C unfermented CP powder under 100 °C of hot-air dry;

UF-150 °C unfermented CP powder under 150 °C of hot-air dry; F-100 °C fermented CP powder under 100 °C of hot-air dry; F-150 °C fermented CP powder under 150 °C of hot-air dry

best hedonic scale in hardness and surface feeling. In addition, F-100 °C 2 % had the best hedonic scale in color, but the UF-150 °C 4 % and UF-100 °C 6 % performed the best in terms of overall acceptability, and

F-150 °C 2 % performed the worst. Interestingly, unfermented CP-added toast breads were much more acceptable in four of the five items, except for the color (Table 3).

Table 3 Sensory quality (Max score = 5) of bread containing citrus peel (CP) powders

Data are expressed as mean $\pm$ standard deviation ($n=26$)

Means within a column with different superscripts are significantly different ($p<0.05$)

UF-100 °C unfermented CP powder under 100 °C of hot-air dry; UF-150 °C unfermented CP powder under 150 °C of hot-air dry; F-100 °C fermented CP powder under 100 °C of hot-air dry; F-150 °C fermented CP powder under 150 °C of hot-air dry

	Surface feeling	Hardness max	Flavor max	Color max	Overall acceptability
UF-100 °C 2 %	3.2 $\pm$ 0.63 ^a	3.8 $\pm$ 0.51 ^a	2.8 $\pm$ 0.65 ^c	2.9 $\pm$ 0.69 ^b	2.4 $\pm$ 1.02 ^c
UF-100 °C 4 %	3.6 $\pm$ 0.70 ^b	4.0 $\pm$ 0.45 ^b	2.7 $\pm$ 0.78 ^c	3.2 $\pm$ 0.73 ^b	2.9 $\pm$ 0.84 ^c
UF-100 °C 6 %	4.0 $\pm$ 0.82 ^c	4.5 $\pm$ 0.51 ^c	3.1 $\pm$ 0.63 ^d	3.1 $\pm$ 0.71 ^b	3.4 $\pm$ 0.85 ^f
UF-150 °C 2 %	3.5 $\pm$ 0.81 ^a	4.1 $\pm$ 0.63 ^b	2.2 $\pm$ 0.7 ^a	2.7 $\pm$ 0.75 ^a	2.1 $\pm$ 0.65 ^b
UF-150 °C 4 %	3.0 $\pm$ 0.60 ^a	3.6 $\pm$ 0.64 ^a	3.2 $\pm$ 0.69 ^c	3.2 $\pm$ 0.83 ^b	3.5 $\pm$ 0.76 ^f
UF-150 °C 6 %	3.3 $\pm$ 0.67 ^a	3.8 $\pm$ 0.65 ^a	2.2 $\pm$ 0.82 ^a	2.7 $\pm$ 0.88 ^a	2.1 $\pm$ 0.82 ^b
F-100 °C 2 %	3.7 $\pm$ 0.89 ^b	3.9 $\pm$ 0.82 ^a	3.0 $\pm$ 0.87 ^d	3.5 $\pm$ 0.95 ^c	2.8 $\pm$ 0.98 ^d
F-100 °C 4 %	3.4 $\pm$ 0.64 ^b	3.9 $\pm$ 0.69 ^b	2.6 $\pm$ 0.57 ^c	3.1 $\pm$ 0.52 ^b	2.5 $\pm$ 0.76 ^c
F-100 °C 6 %	3.0 $\pm$ 0.66 ^a	3.5 $\pm$ 0.65 ^a	3.1 $\pm$ 0.93 ^d	2.9 $\pm$ 0.80 ^b	3.2 $\pm$ 0.97 ^e
F-150 °C 2 %	3.2 $\pm$ 0.61 ^a	3.4 $\pm$ 0.72 ^a	2.4 $\pm$ 0.64 ^b	2.8 $\pm$ 0.71 ^a	1.9 $\pm$ 0.69 ^a
F-150 °C 4 %	3.3 $\pm$ 0.53 ^a	3.8 $\pm$ 0.59 ^a	2.6 $\pm$ 0.08 ^c	2.8 $\pm$ 0.80 ^a	2.5 $\pm$ 0.99 ^c
F-150 °C 6 %	3.0 $\pm$ 0.60 ^a	3.7 $\pm$ 0.63 ^a	2.9 $\pm$ 0.93 ^c	3.3 $\pm$ 0.74 ^b	2.4 $\pm$ 0.90 ^c

Conclusions

In our study, the evaluation of the functionality of both fermented and unfermented citrus peels treated under different dry hot air processes indicated the unfermented citrus peel extract, especially the UF-150 °C extract, showed better antioxidant activity (DPPH and H₂O₂ test), containing more total polyphenols and functional flavonoid components, including nobiletin and tangeretin, among all of the CP extracts. In the aspect of the physical properties analyzed from Farinograph, the dose-response effects between added CP powder contents and the parameters of the physical properties of doughs were observed. It is expected high percentages of fibrous CP powders in dough increase the water adsorption capacity of the dough, resulting in decreased departure time as well as its stability. The sensory evaluation results indicated a greater acceptability of UF-added toast bread relative to the F-added one.

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