Physico-chemical and Sensory Properties of Bread Enriched with Lemon Pomace Fiber

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Abstract


Lemon fiber (LF) was extracted from lemon pomace and incorporated into bread. The results showed that the hardness of bread increased with the increase of LF substitution (0–9%), but the cohesiveness, springiness, and specific volume decreased with the fiber substitution. Both Peleg-Normand and Wiechert models fitted well the stress relaxation data of bread. The parameters (k₁ and k₂, as well as P₀–P₂ and λ₂) in two models were followed significantly affected by the amount of LF. The breads enriched with LF revealed higher total phenolic contents and DPPH radical scavenging capacities than the control bread. Compared with water, methanol was a better solvent for extracting total phenolic compounds of bread. These results suggest that the addition of 3% LF can produce healthy and acceptable bread with higher phytochemicals and antioxidant capacities.

Keywords: texture; rheology; stress relaxation; polyphenol; antioxidant

The consumption of dietary fiber (DF) offers health benefits including lower risk of coronary heart diseases, cancer, and diabetes (Anderson et al. 2009). Hence DF has received tremendous attention from the food scientists and industry. Bread is a popular and important staple food in the world, and can be enriched with various DFs sources, such as wheat bran (Ugarčić-Hardi et al. 2009), apple pomace (Masoodi & Chauhan 1998), and pomegranate peel powder (Altunkaya et al. 2013). To the best of our knowledge, there are no reports on the use of lemon pomace fiber as a source of DF in bread making.

DF incorporated into wheat flour interacts directly with gluten proteins and affects the formation of gluten-starch matrix. Excess amounts of insoluble dietary fibers had an adverse effect on the formation of gluten network and reduced the quality of bread due to the gluten dilution effect or gluten-fiber interaction (Masoodi & Chauhan 1998; Wang et al. 2003; Kaack et al. 2006). Potato fiber containing a high level of insoluble DF led to increases in the hardness and gumminess of bread (Kaack et al. 2006). However, recent studies showed that both total phenolic and antioxidant content of bread could be enhanced by the addition of fibers, such as grape seed flour (Hoye & Ross 2011) and pomegranate peel powder (Altunkaya et al. 2013).

Lemon is the third most important Citrus species in the world and is mainly processed into fruit juice and tea drinks. Since its pomace accounts for 50–65% of the whole fruit mass, there is a great interest in utilising the biomass, instead of discarding it. The pomace contains many phytochemicals, such as fiber, phenolics, flavonoids, and carotenoids (Marin et al. 2007; Wang et al. 2008). Hence, lemon pomace is a good phytochemical source for the food enrichment. The aim of this study was to investigate the rheological, antioxidative, and sensory properties of bread enriched with lemon pomace fiber.

MATERIAL AND METHODS

Materials. Wheat flour containing 13.64% of crude protein was obtained from Chia-Fha Enterprise Co. Ltd. (Taichung, Taiwan). Commercial instant dried
Preparation of bread. Basic dough formula on 340 g flour basis consisted of water (187 g), instant dried yeast (4.04 g), sucrose (20.4 g), shortening (17.0 g), and salt (5.1 g). Bread was produced by using an automatic Kaiser breadmaker (Model BM-812; Wilson Sources Inc., Kowloon, China). Identical baking program (menu 1) was performed for all the breads in this study. The ending point of baking was set as “Light Crust”. The total baking time was 3 h and 11 min, including two-stage kneading (25 min), rest (5 min), shaping (20 s), three-stage fermentation (115 min), and baking (46 min). Apart from the basic dough, 3–9% fiber-enriched breads were prepared with wheat flour partially substituted by 10.2–30.6 g LF, respectively. After the production, the breads were cooled for 90 min at room temperature.

Stress relaxation of bread. Stress relaxation of bread was measured by a texture analyser (TA) (TA-XT2i; Stable Micro Systems, Surrey, UK) according to the method reported by Wu et al. (2012) with some modifications. In brief, the cool bread was cut into slices (12 mm in thickness) by toast slicer machine. One of the central slices was taken and the determination of the stress relaxation (SR) was performed using the TA equipped with a cylindrical probe of P20 (20 mm diameter). The residual force of the sliced bread sample was continuously recorded for 240 s at 20% strain.

The stress relaxation data were analysed using a Peleg-Normand model (Eq. 1), proposed by Peleg and Normand (1983).

\[
\frac{F(t)}{F_0} - F(t) = k_1 + k_2 t
\]

where: \(F_0\) – initial force; \(F(t)\) – momentary force at time \(t\); \(k_1, k_2\) – constants

Extraction of total phenolic compounds. Total phenolic compounds of bread were extracted according to the method reported by Ragaee et al. (2011) with slight modifications. Briefly, ground freeze-dried bread (500 mg) was placed in a 50-ml centrifuge tube and 10 ml of 80% methanol or distilled water solvent was added. The mixture was agitated for 30 min using a platform shaker and subsequently centrifuged at 6000 g for 10 minutes. The supernatant was removed, and the extraction was repeated once. The combined supernatants of both 80% methanol
and distilled water solvents were individually used to measure the TPC and antioxidant capacity.

**Determination of TPC.** TPC was determined by Folin-Ciocalteau method (Cilliers et al. 1990) using ferulic acid as a standard. Briefly, samples (1.0 ml) were introduced into test cuvettes, and 0.25 ml of Folin-Ciocalteau's reagent, 0.25 ml of sodium carbonate (20% w/v), and 2.5 ml distilled water were added. After standing for 60 min at room temperature, the absorbance at 725 nm was measured. The results were expressed as mg ferulic acid equivalent per g bread.

**Determination of antioxidant activity as DPPH scavenging capacity.** Radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging capacity of the extract of total phenolic compounds was measured according to the method of Liyana-Pathirana and Shahidi (2007) with some modifications, and by using Trolox or ascorbic acid as a standard for 80% methanol or water extracts, respectively. Briefly, an aliquot of 1ml of the test sample was mixed with 1ml of 0.1 mM DPPH in methanol. The mixture was shaken vigorously and left to stand for 30 min at 25°C. The absorbance of the resulting solution was determined at 517 nm against methanol or water blank. The results were expressed as mg Trolox equivalent or ascorbic acid equivalent per g bread.

**Sensory evaluation.** The sensory evaluation of cooled breads with 0–9% LF substitutions was performed according to the method reported by Fu et al. (2014). The colour, odour, texture, and overall preference of the bread samples were evaluated by a 7-point hedonic scale; which was 1 – very unacceptable, 2 – unacceptable, 3 – mildly unacceptable, 4 – neither unacceptable nor acceptable, 5 – mildly acceptable, 6 – acceptable, and 7 – very acceptable. The data in triplicate, unless stated otherwise, for different treatments were analysed by one-way ANOVA and Duncan’s new multiple range tests to determine the statistical significance of differences between the values by using the SPSS v. 13.0 software (SPSS, Chicago, USA).

**RESULTS AND DISCUSSION**

**Proximate composition and water holding capacity.** Proximate composition of the LF powder prepared was 8.32% moisture (wet basis), 4.41% ash, 6.90% crude protein, 0.55% crude fat, and 63.85% total dietary fiber content (dry basis). The contents of insoluble and soluble dietary fibers were 51.44 and 12.41%, respectively. This indicated that the insoluble and soluble DFs were the major constituents in the LF powder. Marin et al. (2007) reported that dried lemon juice by-product contained 17.1–23.3% soluble DF and 54.0–64.5% insoluble DF, depending on the method of preparation. Water holding capacity (WHC) of wheat flour and LF was 1.2 ± 0.1 and 11.04 ± 0.9 ml/g, respectively. The results indicated that LF had obviously a higher WHC than wheat flour.

**Stress relaxation of bread.** The fundamental viscoelastic properties of foods can be measured by stress relaxation. In Table 1, the stress relaxation data of bread fitted well ($R^2 > 0.99$) to the Peleg-
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**Normand model.** $F_0$ (initial force) values of breads increased with the increasing the LF substitution. However, both $k_1$ and $k_2$ parameters of bread enriched with 3–9% LF were significantly lower than those of control bread. Thus, the bread enriched with a high level of LF was more rigid and less elastic than the control bread, due to the adverse effect of LF on the formation of gluten network by fiber. The result of stress relaxation in this study is consistent with the report of Wu et al. (2012) stating that increasing the substitution of flour by wheat bran resulted in a lower elasticity of the steamed bread.

Since bread is a typical viscoelastic solid food, we found that the stress relaxation data of bread could be fitted well ($R^2 > 0.99$) to the Wiechert model with two-Maxwell elements (Eq. (2)). Wiechert models with three-Maxwell elements were found adequate for demonstrating the stress relaxation data of noodle (Bellido & Hatcher 2009). In Table 1, relaxation moduli ($P_0$, $P_1$, and $P_2$) of bread significantly increased with the increasing substitution of LF. Although $\lambda_1$ value (relaxation time) of bread was not significantly affected by LF, breads enriched with 3–9% LF had obviously lower $\lambda_2$ values than the control bread. The higher relaxation modulus and shorter relaxation time of bread with a high LF content indicated that the bread had a more rigid and less elastic behaviour, corresponding to the results from the Peleg-Normand model. Figueroa et al. (2013) reported that a slower (longer) relaxation time of wheat dough and gluten was associated with good baking quality.

**Texture and specific volume of bread.** The hardness of bread generally increased with increasing LF substitution, but the cohesiveness, springiness, and specific volume decreased with the substitution (Figure 2). However, no significant difference was observed in hardness, springiness, and specific volume between 3% LF-enriched and control breads.

In this study water absorption in dough making was fixed at 55%, while wheat flour would compete with LF for the water uptake during the preparation of dough. Since LF had obviously a higher WHC than wheat flour, it was not easy for wheat flour to absorb sufficient water for the full development of the gluten protein network, especially at a high LF level. Hence, the LF-enriched bread had a higher hardness due to the rigid nature of fiber or the competition for water absorption between LF and flour components. Since insoluble DF is the major DF in LF, LF added may interfere with the formation of gluten network. This led to the lower cohesiveness, springiness and specific volume of the LF-enriched bread. The results shown in Figure 2 are comparable to those in the studies of Hoye and Ross

**Figure 2.** Effect of lemon fiber (LF) amount on the texture and specific volume of bread

**Figure 3.** Effect of lemon fiber (LF) amount on total phenolic content (A) and DPPH radical scavenging capacity (B) of bread

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who reported that the replacement with above 5% grape seed flour significantly increased the bread
hardness and decreased the bread loaf volume.

**TPC and antioxidant capacity of bread.** Lemon
peel was rich in phenolic acids, flavonoids, and
carotenoids, which contributed to a good antioxi-
dant capacity (Wang *et al.* 2008). The result given
in Figure 3A indicated that TPC of bread in both
80% methanol and water extracts increased with
the increase of LF level. When LF substitution was
increased from 0% to 9%, TPC of the bread was im-
proved by 25.9–47.3, 36.7–77.9, and 62.2–111.9%,
respectively. Moreover, TPC of methanol extract
was higher than that of water extract at the same
LF level. This showed that methanol was a better
solvent for extracting total phenolic compounds
of bread.

In Figure 3B, breads enriched with 3–9% LF had
significantly higher DPPH scavenging capacity than
the control bread. The antioxidant activity of TPC
extract from LF-enriched bread was increased by
10.0% to 42.0% as compared to the control bread.
The correlation coefficients between TPC and DPPH
scavenging capacity for methanol and water extracts
were 0.890 and 0.938, respectively. This showed that
TPC of bread had a good linear relationship with
DPPH scavenging capacity.

Hoye and Ross (2011) indicated that breads with
10% grape seed flour had a higher TPC than the con-
trol bread. Altunkaya *et al.* (2013) reported that
the increasing replacement of flour by pomegranate
peel powder (0–10%) led to higher antioxidant levels
in ethanolic extracts.

**Sensory evaluation of bread.** The bread enriched
by a high substitution (6 and 9% LF) had significantly
low sensory scores in the flavour, texture, and overall
acceptability (Table 2). But none sensory score of 3%
LF-enriched bread showed any significant difference
between those of the control bread. Therefore, we
suggest that the fiber-enriched bread can be prepared
with 3% LF in order to increase the intake of phy-
tochemicals and maintain the sensory acceptability
for the consumers.

**CONCLUSIONS**

LF can be supplied as a potential functional food
ingredient containing abundant dietary fiber and
phytochemicals. The amount of LF significantly
affects the rheology, total phenolic content, and
antioxidant capacity of bread. The increases in the
hardness of bread enriched with LF may relate to
the decrease of free water in dough or the rigid
nature of fiber. Both Peleg-Normand and Wiechert
models fitted well the stress relaxation data of bread.
High substitution of LF would result in an adverse
effect on the formation of gluten network, and a
led to lower cohesiveness, elasticity, and specific
volume of the LF-enriched bread. The addition of
LF could elevate TPC and antioxidant capacity of
the fiber-enriched bread. In conclusion, this study
demonstrated that the fiber-enriched bread with
good sensory quality, phytochemicals, and antioxi-
dant capacity could be produced by the substitution
of wheat flour by 3% LF.

**Table 2. Effect of lemon fibre (LF) amount on the sensory evaluation of bread**

<table>
<thead>
<tr>
<th>LF (%)</th>
<th>Colour</th>
<th>Flavour</th>
<th>Texture</th>
<th>Overall</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>5.20 ± 1.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.67 ± 1.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.20 ± 1.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.10 ± 1.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>5.13 ± 0.79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.67 ± 1.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.93 ± 1.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.00 ± 1.29&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>5.03 ± 0.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.77 ± 1.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.23 ± 1.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.13 ± 1.11&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>9</td>
<td>4.90 ± 1.47&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.17 ± 1.46&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.57 ± 1.41&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.40 ± 1.19&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
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All data are the means ± SD (n = 30); means with the different letters within a column are significantly different (P < 0.05)

(2011), who reported that the replacement with above
5% grape seed flour significantly increased the bread
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**References**

AACC (2000): Approved Methods of the AACC. 10<sup>th</sup> Ed.
St. Paul, AACC International.

Altunkaya A., Hedegaard R.V., Brimer L., Gokmen V., Skib-
sted L.H. (2013): Antioxidant capacity versus chemical
safety of wheat bread enriched with pomegranate peel

Anderson J.W., Baird P., Davis R.H., Ferreri S., Knudtson

AOAC (2000): Approved Methods of the AOAC. 17<sup>th</sup> Ed.
Washington, AOAC International.

AACC (2000): Approved Methods of the AACC. 10<sup>th</sup> Ed.
St. Paul, AACC International.

Altunkaya A., Hedegaard R.V., Brimer L., Gokmen V., Skib-
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AOAC (2000): Approved Methods of the AOAC. 17<sup>th</sup> Ed.
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