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Effect of Okara and Vital Gluten on Physico-Chemical Properties of Noodle

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Abstract

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Okara, a by-product during processing of soymilk or tofu, is rich in dietary fiber, protein and phytochemicals. Therefore, it can be useful as a functional ingredient with health-promoting attributes. This study was to investigate the effects of addition of dried okara powder (DOP) and vital gluten (VG) on rheological, antioxidative and sensory properties of noodle. Results showed that high DOP amount (10–15%) significantly reduced optimum cooking time, extensibility, tensile strength and elasticity of noodle. Increasing DOP amount led to the increase in total phenolics and flavonoids, as well as radical-scavenging activity of noodle. Supplement of 6% vital gluten could improve the quality of 10%-DOP noodle, including cooking loss, tensile property, elasticity and sensory acceptability. Therefore, we suggest that enriched noodle can be prepared with 5% DOP or 10% DOP plus 6% VG in order to increase the intake of phytochemicals and maintain the sensory acceptability of consumers.

Keywords: antioxidant; flavonoid; gluten; soybean residue; polyphenol; rheology

Okara or soybean residue, a by-product of soymilk and tofu production processes, is used as fertilizer and feed, but most of okara is dumped as waste. Okara is rich in dietary fiber, protein, lipid and phytochemicals, such as isoflavone, lignan and phytosterol (Li *et al.* 2012; Jankowiak *et al.* 2014; Zhong & Zhao 2015). Hence, it can be useful as a health-promoting functional ingredient of food products, such as bread, steamed bread and cookie (Lu *et al.* 2013; Park *et al.* 2015).

Dietary fiber (DF) intake offers health benefits including lower risk for coronary heart diseases, cancer and diabetes (Fuller *et al.* 2016). Many DFs derived from plant processing by-products had good antioxidant capacity (Eskicioglu *et al.* 2015). Hence DF has been paid tremendous attention by food scientists and industry. Noodle or pasta is a popular and important staple food in the world, and can be enriched with various DFs, such as wheat straw (Ugarcic-Hardi 2007), wheat bran (Shiau *et al.* 2012) and tomato peel (Padalino *et al.* 2017). Okara noodle had lower glycemic index than control (Lu *et al.* 2013). To the best of our knowledge, there are few reports on the use of okara as a source of DF in noodle 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 noodle (Chen *et al.* 2011; Shiau *et al.* 2012) or spaghetti (Basman *et al.* 2006). However, recent studies showed that total phenolic compounds and carotenoids of noodle or pasta could be enhanced by the addition of fibers, such as watermelon rind powder and tomato peel flour (Ho & Dahri 2016; Padalino *et al.* 2017).

Both quantity and quality of gluten protein are crucial for wheat products. Addition of VG could improve the quality of noodle prepared with moderately

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sprouted wheats (Sekhon *et al*. 1994) and bread with low-protein soft wheat flour or high-protein hard wheat flour (90%) plus wheat bran (10%) (Czuchajowska & Pomeranz 1993). Hence, the aim of this study was to investigate the physico-chemical and sensory properties of noodle enriched with various levels of DOP and VG.

MATERIAL AND METHODS

Materials. Wheat flour with 11.74% crude protein was obtained from Chia-Fha Enterprise Co., Ltd. (Taiwan). Fresh okara was obtained from a soymilk production line of Ming Hua Food Co., Ltd. (Taiwan). Duo to easy spoilage of wet okara, DOP was prepared by drying at 50°C, grinding and sieving with 40-mesh screen. VG was from Roquette (France). All the chemicals used in food analysis were of reagent grade.

The proximate compositions (AACC 2000) and total, insoluble and soluble dietary fibers (AOAC 2000) of DOP produced were determined.

Preparation of dough. Noodle dough was prepared with slight modifications according to our previous method (Shiau *et al*. 2012). Briefly, wheat dough was prepared by mixing wheat flour, DOP, VG and distilled water in a mixer (Model TS-108; Tian Shuai Food Machine Co., Taiwan) using slow and medium speeds, respectively, for 2 minutes. Basic okara dough recipe on flour weight basis was: wheat flour (100%), DOP (0–15%) and water (36–53%). Increasing DOP amounts led to the increase of water absorption in dough mixing. By preliminary test, we found that suitable water absorption for the dough with 0–15% DOP was 36, 41.2, 47 and 53%, respectively. Moisture contents of the dough made were 35.61, 37.2, 38.49 and 39.84%, respectively. Apart from the basic okara dough, 10% DOP-dough added 3–9% VG was prepared at constant dough moisture (38.49%).

Preparation of noodle. Noodle was prepared according to the method (Shiau *et al*. 2012) with slight modifications. In brief, the dough was sheeted and rolled several times by a dough sheeter (Model CM-450B; Chanmag Bakery Machine, Taiwan), and finally cut into raw noodle with 25 cm long and 3 mm wide. Parts of raw noodle were dried at 50°C for 3 h in an air oven, and the dried noodles were stored in sealable plastic bags before testing.

About 70 g of raw noodles were cooked in boiling water (700 ml) until the white core disappeared. The cooked noodles were collected by a 20-mesh screen and cooled for 8 min at ambient temperature. The cool cooked noodles were stored in sealable plastic bags, and their rheological properties were measured as soon as possible.

Tensile strength (TS) and extensibility (E) of noodle. Tensile test of cooked noodles was measured according to the method (Shiau *et al*. 2012).

Stress relaxation of noodle. The stress relaxation of cooked noodle was measured according to the method (Shiau *et al*. 2012) with slight modifications. The cooked noodle sample was deformed in compression to a constant strain of 20% with test speed of 0.5 mm/s. The residual force was continuously recorded as a function of time for 240 seconds. The measurement of stress relaxation for each treatment was performed three times.

The stress relaxation data were analyzed by using a Peleg-Normand model (Peleg & Normand 1983).

$$(F_0 t/F_0 - F(t)) = k_1 + k_2 t \quad (1)$$

where: F_0 – initial force; $F(t)$ – momentary force at time (t); k_1 and k_2 – constants. The percent stress relaxation (%SR) was calculated from the following equation (Bellido & Hatcher 2009).

$$\%SR = (F_0 - F_{t=20})/F_0 \times 100 \quad (2)$$

where: F_0 – initial force; $F_{t=20}$ – force at 20 s after the initial strain was achieved.

Cooking properties of noodle. The cooking properties of noodle were determined using the method (Shiau *et al*. 2012) with slight modifications. As stated above, raw noodle was cooked until white core of center disappeared. The optimum time for cooking noodle was recorded. Cooking loss of noodle was analysed by gravimetric methods from the calculation of weighing raw noodle and solids in cooking water.

Antioxidant properties of noodles

Extraction of total phenolics and flavonoids. Total phenolic compounds (TPC) and flavonoids (TFC) of noodle were extracted according to the method of Chang *et al*. (2015) with slight modifications. Briefly, ground dried noodle sample (500 mg) was placed in a 50-ml centrifuge tube and 10 ml of 80% ethanol was added. The mixture was agitated for 30 min using a platform shaker and centrifuged at

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6000 *g* for 10 minutes. The supernatant was removed, and the extraction was repeated once. The combined supernatants of 80% ethanol solvents were used to measure the TPC, TFC and antioxidant capacity.

Determination of total phenolic content (TPC). TPC was determined by Folin-Ciocalteau method (Cilliers *et al*. 1990; Chang *et al*. 2015) using ferulic acid as a standard. Briefly, samples (1 ml) were introduced into test cuvettes, and 0.25 ml of Folin-Ciocalteu'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. Results were expressed as μg ferulic acid equivalent per g noodle (dry weight basis; DB).

Determination of total flavonoid content (TFC). TFC was measured according to the method (Jia *et al*. 1999) using rutin as a standard. Its value was expressed as μg rutin equivalent per gram noodle (DB).

Determination of antioxidant activity as DPPH scavenging capacity. Radical DPPH scavenging capacity of the extract of total phenolic compounds was measured according to the method of Liyana-Pathlrana and Shahidi (2007) with some modifications. Briefly, an aliquot of 1 ml of the test sample was mixed with 1 ml 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 ethanol blank. Results were expressed as μg Trolox equivalent per g noodle (DB).

Sensory evaluation. The sensory evaluation of cooked noodles with 0–15% DOP or 0–9% vital gluten was separately performed according to the method reported by Chang *et al*. (2015). The cooled noodles were served at room temperature (26 ± 2°C) under normal lighting conditions. Consumers' sensory evaluation of cooked noodle was performed by 30 panelists consisting of students, teachers and employees in Tajen University. Colour, odour, texture and overall preference of the noodle samples were evaluated by a 7-point hedonic scale (1 – very unacceptable, 4 – neither unacceptable nor acceptable, and 7 – very acceptable).

Statistical analysis. 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 among the values by using of the SPSS software 13.0 (Chicago, USA).

RESULTS AND DISCUSSION

Proximate composition. Proximate compositions of DOP prepared were 9.96% moisture (wet basis), 26.1% crude protein, 12.3% crude fat, and 52.6% total dietary fiber contents (dry basis). The contents of insoluble and soluble dietary fibers (IDF and SDF) were 51 and 1.6%, respectively. This indicated that insoluble DF was the major constituents in the DOP. It was consistent with the report of Li *et al*. (2012) that okara contained about 50% dietary fiber, 25% protein, 10% lipid on a dry weight basis. Lu *et al*. (2013) reported okara contained 55.6% IDF and 1.9% SDF.

Tensile properties. Figure 1 shows tensile strength (TS), extensibility (E) and TS/E ratio of noodle with various amounts of DOP and VG. Results showed that 15% DOP-noodle had significantly lower TS than noodles with 0–10% DOP. Increasing DOP amount resulted in an increase of TS/E ratio and a decrease of *E* value. Hence excessive DOP resulted in a weaker and less extensible cooked noodle.

For 10%-DOP noodles, addition of VG could increase TS and E values but decrease TS/E ratio (Figure 1B). The noodle with 6% VG had the highest TS and E among all treatments tested. Therefore,

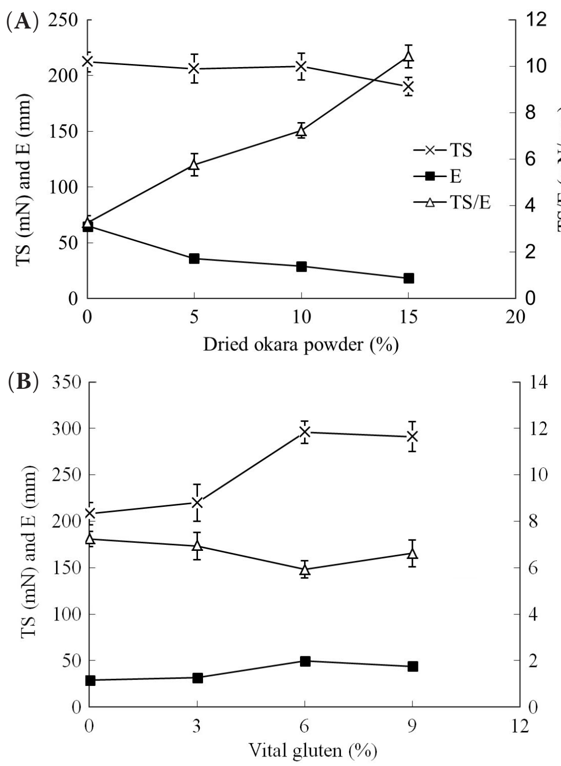

Figure 1. Effect of amounts of dried okara powder (**A**) and vital gluten (**B**) on tensile properties of noodle

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adequate supplement of VG could improve tensile properties of 10%-DOP noodle.

Cooking properties. The optimum cooking time of noodle with 0–15% DOP is 3, 3, 2.5, and 2 min, respectively. The result implied that high DOP-substituted noodle needed less time for adequate cooking. However, 10% DOP-noodle with 3–9% VG had higher optimum cooking time (3 min) than that without VG (2.5 min). Therefore, the optimum cooking time of noodle was affected by adding DOP and VG, due to the change of gluten network by adding the ingredients.

Cooking loss of noodles with 0–15% DOP and 10% DOP-noodle added 3–9% VG is 2.42, 2.76, 2.78, and 2.77%, as well as 2.78, 2.44, 2.17 and 2.04%, respectively. Addition of DOP and VG led to a mild increase and decrease in cooking loss of the noodle, respectively. It could relate to the weak gluten network of okara noodle, due to the presence of fiber in DOP. Inversely, supplement of VG could improve gluten network of noodle with 10% DOP. However, cooking loss (2.04–2.78%) of noodle in this study was low and acceptable. The result was in agreement with the reports that cooking loss was increased by incorporation of wheat bran into spaghetti and noodle (Basman *et al.* 2006; Shiau *et al.* 2012).

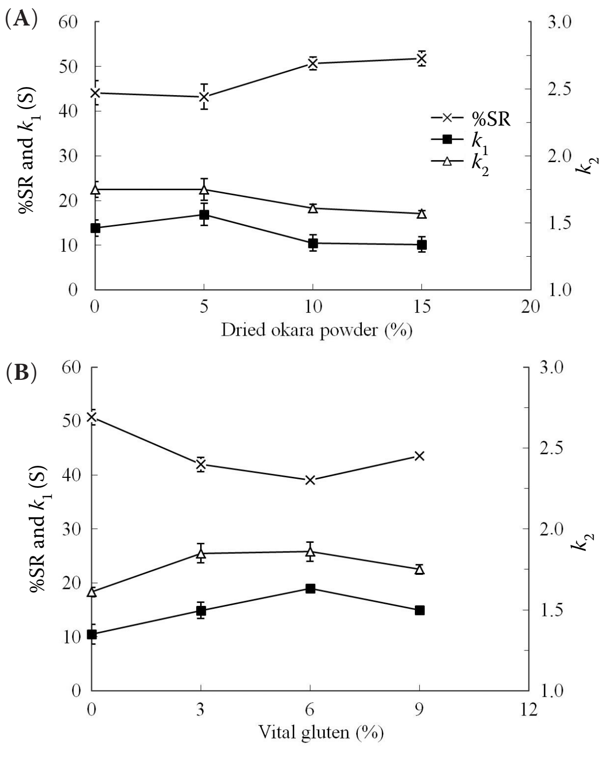

Figure 2. Effect of amounts of dried okara powder (DOP) and vital gluten (VG) on stress relaxation parameters of noodle

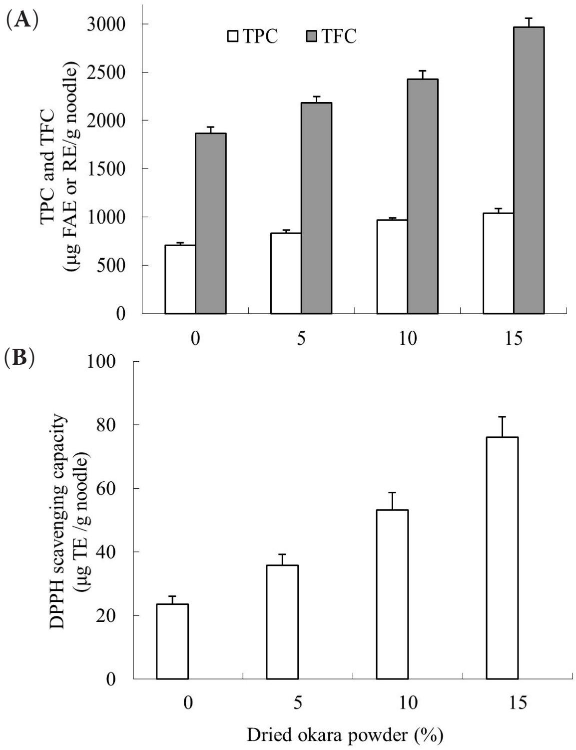

Figure 3. Effect of dried okara powder on TPC, TFC and DPPH scavenging capacity of noodle

Stress relaxation. Fundamental viscoelastic properties of foods can be measured by stress relaxation. Stress relaxation data of cooked noodle fitted well ($R^2 > 0.99$) to the Peleg-Normand model. In Figure 2A, both k_1 and k_2 parameters of noodle enriched with 10–15% DOP were significantly lower than those with 0–5% DOP. Inversely, noodles with 10–15% DOP had relatively higher %SR. Thus, the noodle enriched with high level of DOP had less elastic than control, due to the adverse effect on the formation of gluten network by fiber. The result of stress relaxation in this study is consistent with the reports of Sozer and Dalgic (2007) and Shiau *et al.* (2012) that substitution of flour by wheat bran resulted in less elasticity of noodle and spaghetti.

At 10% DOP level, cooked noodles added VG had significantly higher k_1 and k_2 values as well as lower %SR than control (Figure 2B). The noodle with 6% VG had the highest k_1 and lowest %SR among all treatments tested. Therefore, supplement of 6% VG could improve the elasticity of the high-okara noodle.

TPC, TFC and antioxidant capacity. Okara was rich in isoflavone and phenolic acids, which contributed to good antioxidant capacity (Li *et al.* 2012; Zhong & Zhao 2015). Result in Figure 3A indicated that both TPC and TFC of noodle increased with the

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Table 1. Effect of amount of dried okara powder (DOP) and vital gluten (VG) on sensory evaluation of noodle

DOP (%)	VG (%)	Colour	Flavour	Texture	Overall
0	0	5.61 ± 1.31[a]	5.10 ± 1.27[a]	5.32 ± 1.25[a]	5.39 ± 1.31[a]
5	0	5.29 ± 1.04[a]	4.77 ± 0.95[a]	5.29 ± 1.24[a]	5.26 ± 1.09[a]
10	0	4.65 ± 1.37[b]	3.84 ± 1.32[b]	3.94 ± 1.55[b]	4.06 ± 1.34[b]
15	0	4.26 ± 1.36[b]	3.32 ± 1.33[b]	3.23 ± 1.36[c]	3.13 ± 1.26[c]
10	0	4.52 ± 0.98[a]	4.07 ± 1.11[a]	3.67 ± 1.11[b]	4.00 ± 0.73[b]
10	3	4.78 ± 0.89[a]	4.11 ± 1.25[a]	4.33 ± 1.11[ab]	4.48 ± 1.16[ab]
10	6	4.52 ± 1.01[a]	4.63 ± 1.24[a]	4.41 ± 1.05[a]	4.78 ± 0.93[a]
10	9	4.52 ± 0.98[a]	4.19 ± 1.44[a]	4.44 ± 1.60[a]	4.44 ± 1.34[ab]

All data are the means ± SD (n = 30); means with different letters within a column and same section are significantly different (P < 0.05)

increase of DOP amount. When DOP amount was increased from 0 to 15%, TPC and TFC of the noodle was improved by 18.2–16.9, 37.2–30, and 47–58.9%, respectively. Ho and Dahri (2016) reported that increasing replacement of flour by watermelon rind powder led to higher TPC in yellow noodle.

In Figure 3B, noodles enriched with 5–15% DOP had significantly higher DPPH scavenging capacity than control noodle. The antioxidant activity of TPC extract from DOP-enriched noodle was increased by 51.9% to 223.8% as compared to the control noodle. The correlation coefficients between TPC and TFC and DPPH scavenging capacity were 0.966 and 0.995, respectively. This showed TPC and TFC of noodle had good linear relationships with DPPH scavenging capacity.

Sensory evaluation of noodle. Table 1 shows the results of consumers' sensory evaluation of noodles with various DOP and VG levels. The noodle enriched with high DOP (10 and 15%) had significantly low sensory scores in colour, flavour, texture and overall acceptability (Table 1). But none sensory scores of 5% DOP-enriched noodle showed any significant difference between those of the control noodle. Moreover, 10% DOP-enriched noodle added 6% VG had better texture and overall acceptability than that without VG. Therefore we suggest fiber-enriched noodle can be prepared with 5% DOP or 10% DOP plus 6% VG in order to increase the intake of phytochemicals and maintain sensory acceptability for the consumers.

CONCLUSIONS

Okara can be supplied as a potential functional food ingredient containing abundant dietary fiber and phytochemicals. Both DOP and VG amounts significantly affects rheological and antioxidant properties of noodle. Peleg-Normand model fitted well to the stress relaxation data of noodle. High DOP level would result in adverse effect on the formation of gluten network, and led to the less optimum cooking time, extensibility and elasticity of the DOP-enriched noodle. However, addition of DOP could elevate TPC, TFC and antioxidant capacity of the fiber-enriched noodle. Adequate supplement of vital gluten could improve cooking loss, tensile and elastic properties, and sensory score of 10%-DOP noodle. In conclusion, this study demonstrated fiber-enriched noodle with good sensory quality, phytochemicals and antioxidant capacity could be produced by the addition of 5% DOP or 10% DOP plus 6% VG.

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