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Research Article

The Effect of Okara on the Qualities of Noodle and Steamed Bread

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Abstract: Okara is a byproduct of tofu or soymilk production process, which contains rich dietary fibre and protein. To estimate the feasibility of okara's application in noodle and steamed bread, the effect of okara addition on the qualities of these foods were investigated. The results showed that the optimal ingredient for okara noodle was: wheat flour 75%, okara powder 25%, gluten 3%, carboxymethyl cellulose sodium 0.4%, konjac flour 0.2%, NaCl 1%; the optimal ingredient for okara steamed bread was: wheat flour 85%, okara powder 15%, gluten 1%. The noodle and steamed bread made from above ingredients had almost similar qualities to those made from 100% wheat flour. Okara addition produces some negative influences on dough mixing and food making, which can be remedied by various additives. This study suggests that replacing part wheat flour with okara powder to make noodle and steamed bread is a potential method for okara application.

Keywords: Noodle, okara, steamed bread, wheat flour

INTRODUCTION

Okara is the residue left from ground soybean after extraction of the water extractable fraction used to produce bean curd (tofu) or soy milk. About 1.2 kg of fresh okara is produced from 1 kg of soybean processed for tofu (Li *et al*., 2008). Huge quantities of okara are produced with the increase of soybean consumption, e.g., in China about 2,800,000 tons of okara are produced from the tofu production industry every year (Ahn *et al*., 2010; Mateos-Aparicio *et al*., 2010a). The huge quantities of okara produced annually pose a significant disposal problem. Okara is sometimes used as animal feed but most is dumped and burned as waste.

Dry okara contains about 50% fibre, 25% protein and 10% lipid (Van der Riet *et al*., 1989; Redondo-Cuenca *et al*., 2008; Mateos-Aparicio *et al*., 2010b). Other components of soy products which are also likely present in okara include isoflavones, lignans, phytosterols, coumestans, saponins and phytates (Head, 1997). It is well known that dietary fibre plays an important role in many physiological processes and in the prevention of diseases of different origin. Okara may be considered a good source of dietary fibre because it is the major constituent. Furthermore, okara contains much protein and considerable isoflavone and mineral elements, so it possesses high nutritional value and various prebiotic effects. Studies showed okara had the functions of preventing diabetes (Xu *et al*., 2000), hyperlipidemia (Villanueva *et al*., 2011; Préstamo *et al*., 2007; Wang and Li, 1996) and obesity (Matsumoto *et al*., 2007) and present antioxidant activity (Amin and Mukhrizah, 2006; Yokomizo *et al*., 2002; Zhu *et al*., 2008; Ge *et al*., 2010; Huang *et al*., 2006, 2004). Therefore, it could be useful as a functional ingredient with health-promoting attributes.

In the past decades incidence of diabetes, particularly type 2 diabetes which accounts for>90% of cases, has increased quickly (151 million in 2000 to 285 million in 2010). By 2030 the global prevalence of diabetes will be 7.8%, with diabetes affecting 438 million adults (International Diabetes Federation, 2009). Daily food is one of the most important factors for diabetes to control blood sugar level. It has been reported that the nutritional characteristics of high dietary fibre and high protein is beneficial for diabetes as the daily food. Okara contains about 50% dietary fibre and 25% protein, plus it is cheap and wide source, so it could be used as a daily food ingredient for diabetes. However, fresh okara is difficult to storage and has weak taste. Therefore, it is necessary to prolong the storage period and improve the taste before okara could be used widely as a food ingredient. Drying fresh okara, grinding it to powder and adding okara powder to suitable foods could be an ideal solution to this problem. Noodle and steamed bread are the principal foods for many Chinese and Asian. Replacing part wheat flour with okara powder to make noodle and steamed bread could improve their nutritional value and be profitable for diabetes. The objective of this study was to investigate the effects of okara addition on the qualities of noodle and steamed bread, so as to estimate the feasibility of applying okara in these foods.

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MATERIALS AND METHODS

Materials: Fresh okara was obtained from a tofu production line of Henan Xiaobao Douye Co. Ltd., Xinxiang, China. Soybean (*Glycine max* L.), north-east variety (China) was soaked, rinsed and ground and the okara was filtered off according to guidelines for the Chinese method. Okara was freeze-dried (LGJ-18 freeze-dryer, Beijing Sihuan Co., China) and ground to fine powder (80 mesh). Wheat flour, gluten, Carboxymethyl Cellulose sodium (CMC) and konjac flour were purchased from local market. Other chemicals and reagents used were of analytical grade.

Determination of chemical composition of Okara: Moisture, ash, protein, lipid, reducing sugar and dietary fibre contents were determined by the standard Approved methods 44-15, 08-01, 46-11, 30-10, 80-68 and 32-05 (AACC International, 2000). Mineral elements were determined by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP, Optima 2100DV, PE Co. Ltd., USA). Flavone was extracted with methanol and measured by colorimetric method at OD_{260nm}.

Preparation of okara noodle: Wheat flour, okara, gluten, CMC, konjac flour, NaCl and water were mixed and kneaded to make dough at 25~30°C for 15~20 min. The dough was proofed at 25~30°C for 30 min, then it was pressed and cut into noodle of 3 mm width. The wet noodle was dried at room temperature and cut into 18~20 cm length.

Quality evaluation of noodle:
Water absorption: Twenty strips of noodle were cooked in 300 mL boiling water for 8 min. The cooked noodles were taken out and weighed. Water absorption = (mass of cooked noodles-mass of noodles before cooking)/mass of noodles before cooking ×100%.

Elongation: Twenty strips of noodle were cooked in 300 mL boiling water for 8 min and soaked in 70°C hot water for 10 min. Elongation = (length of cooked noodles-length of noodles before cooking)/length of noodles before cooking×100%.

Cooking loss: Ten strips of noodle were cooked in 300 mL boiling water for 8 min and washed with distilled water for 10 s. The washing liquid and noodle soap were combined and boiled to 50 mL, then dried at 105℃. Cooking loss = dry material of noodle soap/dry material of noodle before cooking×100%.

Sensory evaluation: Twenty strips of noodle were cooked in 300 mL boiling water for 8 min and tasted by ten trained assessors. The evaluation standard was shown in Table 1.

Texture Profile Analysis (TPA): Three strips of noodle were cooked, washed with cold water and checked with P 50 probe of TA-XT PLUS textural analyser (SMS Co., UK). The test parameters were that velocity: 1.00 mm·/s; mode: compression ratio; initial distance: 30 cm; strain displacement: 70%; time interval: 3 s; induction force: 5 g; point per second: 400 pps.

Table 1: Sensory evaluation standard for okara noodle

Items	Evaluation standard
Color (10 score)	White and bright.
Appearance (10 score)	Fine and smooth structure.
Palatability (20 score)	The force of biting a noodle is moderate.
Tenacity (25 score)	Chewy and elastic.
Viscidity (25 score)	Refreshing and not stick to teeth when chewing.
Smooth (5 score)	Taste smooth.
Flavor (5 score)	Have soybean flavor.

Table 2: Sensory evaluation standard for okara steamed bread

Item	Evaluation standard
Appearance (15 score)	Smooth, symmetrical and upright.
Structure (15 score)	The pore of longitudinal section is small and even.
Elasticity and tenacity (20 score)	Nice reconstitution after finger compression and nice chewy.
Viscidity (15 score)	Refreshing and not stick to teeth when chewing.
Flavor (5 score)	Have soybean flavor.
Color (10 score)	Light yellow.
Specific volume (20 score)	Full score is ≥2.30 mL/g, and min 1 score per 0.1 mL/g reduction.

Shearing experiment: Three strips of noodle were cooked, washed with cold water and checked with A/LKB-F probe of TA-XT PLUS textural analyser. The test parameters were that velocity before test: 0.5 mm·/s; velocity during test: 0.1 mm·/s; velocity after test: 10 mm·/s; mode: compression ratio; strain displacement: 90%; time interval: 3 s; induction force: 5 g; point per second: 200 pps.

Environmental scanning electron microscope (ESEM) observation: Dried noodle was stuck on sample stage with silver conductive adhesive. The powder on sample surface was blown away and observed with Quanta 200 ESEM (FEI Co., USA).

Preparation of okara steamed bread: Wheat four, okara, gluten, yeast and water were mixed to make dough. The dough was fermented at 37°C for 2 h, then it was kneaded to bread mould. The mould was proofed at 37°C for 10 min and steamed for 25 min.

Quality evaluation of steamed bread:
Specific volume: After cooling 1 h, the steamed bread was weighed and its volume was determined by the method of millet substitution (Hu, 2000). Specific volume (mL/g) = volume of steamed bread (mL)/mass of steamed bread (g).

Sensory evaluation: The steamed bread was tasted by ten trained assessors. The evaluation standard was shown in Table 2.

TPA: The center part of steamed bread cooled for 24 h at room temperature was cut into three cubes (25×25×25 mm). The cubes were tested by compression experiment with P50 probe at TPA mode. The test parameters were that falling velocity before test: 2 $mm \cdot s^{-1}$; falling velocity during test: 1 $mm \cdot s^{-1}$; back velocity after test: 1 $mm \cdot s^{-1}$; compression degree: 30%; induction force: 10 g; point per second: 400 pps; time interval: 5 s.

ESEM observation: The center part of cooled steamed bread was cut into the slice of 1 mm thickness. The slice was stuck on sample stage with silver conductive adhesive. The powder on sample surface was blown away and observed with ESEM.

Statistical analysis: All the experimental results for quality evaluation were the mean (±standard deviation) of three parallel measurements. The data was analysed by statistical software DPS (ver9.5).

RESULTS AND DISCUSSION

Chemical composition of Okara: Moisture content of okara flour was 6.7%. Chemical composition of okara flour were shown in Table 3. It can be seen that okara contains 58.6% dietary fibre and 15.3% protein, suggesting its nutritional value is high. Moreover, the nutritional property of high fibre and protein and low fat and reducing sugar is beneficial for diabetes. Some flavone of soybean was remained in okara, which has the function of antioxidant and scanvenging free radicals. High potassium and low sodium were found in okara (Table 4). Okara also contained trace chrome, which was the important component of glucose tolerance factor.

The effect of okara on noodle quality:

Effect of okara addition on noodle quality: Substituting part wheat flour with okara powder to make noodle can improve its nutritional value. However, adding okara will influence the taste and quality of noodle. So the optimum addition of okara should be selected. The effect of okara powder addition on sensory quality and texture of noodle was shown in Table 5 and 6.

Table 5 showed that elongation of noodle decreased significantly with the raise of okara addition. This probably because okara contained much dietary fibre, which had strong capacity of water absorption. So the water combined with gluten protein reduced and gluten network could not expanded fully, which resulted in the shorten of elongation of noodle. The cooking loss of noodle decreased markedly at 5% okara addition, then raised when more okara was added. This was perhaps due to a small quantity of dietary fibre can reduce the loss of noodle components for its high viscidity, but gluten network can't hold too much dietary fibre particles, leading to some fibre dissolved in water during noodle cooking. Because okara noodle contained more water than normal noodle owing to the stronger water absorption capacity of dietary fibre, the amount of noodle absorbing water decreased during cooking. In addition, noodle color became

Table 3: Chemical composition of okara (% dry matter)

Item	Moisture	Protein	Lipid	Ash	Reducing sugar	Dietary fibre	Flavone
Content	6.7	15.3	5.9	3.9	2.6	58.6	0.22

Table 4: Mineral elements of okara (mg/g dry matter)

Item	K	Ca	Na	Mg	Mn	Zn	Fe	Cr	Cu
Content	9.36	4.19	0.96	2.57	0.019	0.026	0.11	0.0018	0.0067

Table 5: Effect of okara powder addition on noodle quality

Okara addition	Elongation/ %	Cooking loss/%	Water absorption/%	Sensory quality							
				Color	Appearance	Palatability	Tenacity	Viscidity	Smooth	Flavor	Total score
0%	48.32±1.04	11.34±0.02	260.36±7.01	9.20±0.67	8.80±1.13	16.70±2.62	19.60±4.9	22.60±1.51	4.36±0.73	4.45±0.64	85.71±10.85
5%	30.73±1.18	7.71±0.02	237.74±1.51	8.77±0.70	8.45±1.01	16.40±2.33	19.90±3.25	21.55±1.86	4.31±0.64	4.33±0.57	83.71±8.05
10%	29.70±1.93	8.42±0.00	209.75±3.20	8.14±0.91	7.95±1.04	16.55±1.17	19.35±3.27	20.60±1.90	4.01±0.62	4.11±0.60	80.71±5.91
15%	19.47±1.10	9.24±0.01	153.48±4.01	7.40±1.31	7.45±1.32	14.90±1.97	17.55±2.75	19.10±2.38	3.31±0.84	3.65±0.63	73.36±6.60
20%	19.46±1.24	10.14±0.01	146.06±6.68	6.75±1.14	7.10±1.43	14.60±1.78	15.80±2.93	18.30±2.49	3.00±0.71	3.33±0.71	68.88±5.83
25%	21.63±0.84	10.18±0.02	175.40±8.69	6.20±1.25	6.62±1.34	13.90±1.51	14.50±3.47	17.50±3.80	2.86±0.73	3.32±0.66	64.90±8.70
30%	19.66±1.66	10.91±0.03	178.96±13.29	5.75±1.34	6.29±1.28	13.10±2.18	14.15±2.83	16.50±4.69	2.69±0.79	3.21±0.77	61.69±9.62
35%	18.15±1.14	10.08±0.03	170.63±4.53	4.90±1.63	6.15±1.75	12.00±2.62	12.40±3.43	15.50±4.48	2.53±0.78	2.91±0.89	56.39±12.75

Table 6: Effect of okara powder addition on TPA and shear stress of noodle

Okara addition	Hardness /g	Adhesiveness /gs	Springiness	Cohesiveness	Gumminess /g	Chewiness /g	Resilience	Maximum shear stress/g
0%	5897±348	69±6	0.88±0.04	0.75±0.01	4411±307	3880±436	0.51±0.01	152±15
5%	7288±325	88±10	0.88±0.03	0.71±0.01	5198±212	4578±328	0.47±0.01	151±6
10%	9084±449	110±10	0.92±0.01	0.72±0.01	6528±377	6004±327	0.48±0.01	148±4
15%	12004±841	133±47	0.92±0.01	0.70±0.01	8389±643	7690±638	0.47±0.02	183±8
20%	14149±797	169±43	0.88±0.03	0.68±0.02	9588±748	8460±640	0.48±0.03	185±5
25%	12686±524	131±35	0.87±0.02	0.65±0.01	8186±462	7165±501	0.46±0.02	167±8
30%	12497±604	119±35	0.86±0.04	0.65±0.02	8081±561	6935±557	0.47±0.03	155±4
35%	13987±284	100±12	0.90±0.02	0.67±0.01	8917±195	8049±191	0.46±0.01	185±17

Table 7: Effect of gluten addition on okara noodle quality

Gluten addition	Elongation/ %	Cooking loss/%	Water absorption/%	Sensory quality Color	Appearance	Palatability	Tenacity	Viscidity	Smooth	Flavor	Total score
CK*	21.63±0.84	10.18±0.02	175.40±8.69	6.20±1.25	6.62±1.34	13.90±1.51	14.50±3.47	17.50±3.80	2.86±0.73	3.32±0.66	64.90±8.70
1%	18.70±0.69	10.91±0.11	185.65±6.12	7.94±0.69	7.41±0.71	13.80±2.99	15.60±3.43	16.70±3.71	3.55±0.58	3.47±0.57	68.47±8.64
2%	19.07±0.45	8.20±0.09	191.61±7.24	7.79±0.72	6.85±1.06	13.40±3.29	15.40±3.80	16.80±4.22	3.50±0.59	3.25±0.78	66.99±11.54
3%	20.44±0.56	8.21±0.06	197.74±2.49	7.30±0.78	6.91±1.45	12.70±3.66	14.70±3.86	16.10±4.64	3.23±0.56	3.22±1.05	64.16±13.12
4%	20.54±1.39	8.14±0.06	206.24±2.26	7.35±0.71	6.78±1.69	12.50±3.37	14.80±4.42	16.20±4.88	3.27±0.72	3.28±0.97	64.18±13.85
5%	20.91±1.78	8.01±0.05	217.24±4.38	7.40±1.00	6.01±2.03	13.50±3.37	15.70±4.26	17.00±4.52	3.75±0.85	3.63±1.15	66.99±14.14

*CK was the noodle made from 75% wheat flour and 25% okara powder, and the same for Table 9

Table 8: Effect of gluten addition on TPA and shear stress of okara noodle

Gluten addition	Hardness /g	Adhesiveness /gs	Springiness	Cohesiveness	Gumminess /g	Chewiness /g	Resilience	Maximum shear stress/g
CK	12686±524	131±35	0.87±0.02	0.65±0.01	8186±462	7165±501	0.46±0.02	167±8
1%	12209±285	182±9	0.90±0.02	0.55±0.01	6701±236	5998±123	0.36±0.02	120±4
2%	13673±527	167±34	0.90±0.02	0.57±0.02	7802±418	7056±376	0.39±0.01	153±9
3%	11771±282	126±10	0.86±0.04	0.55±0.01	6454±292	5576±328	0.37±0.01	148±5
4%	13573±327	122±10	0.90±0.02	0.57±0.01	7721±355	6909±294	0.39±0.01	188±7
5%	13295±609	137±20	0.88±0.02	0.58±0.02	7745±544	6815±582	0.40±0.02	154±7

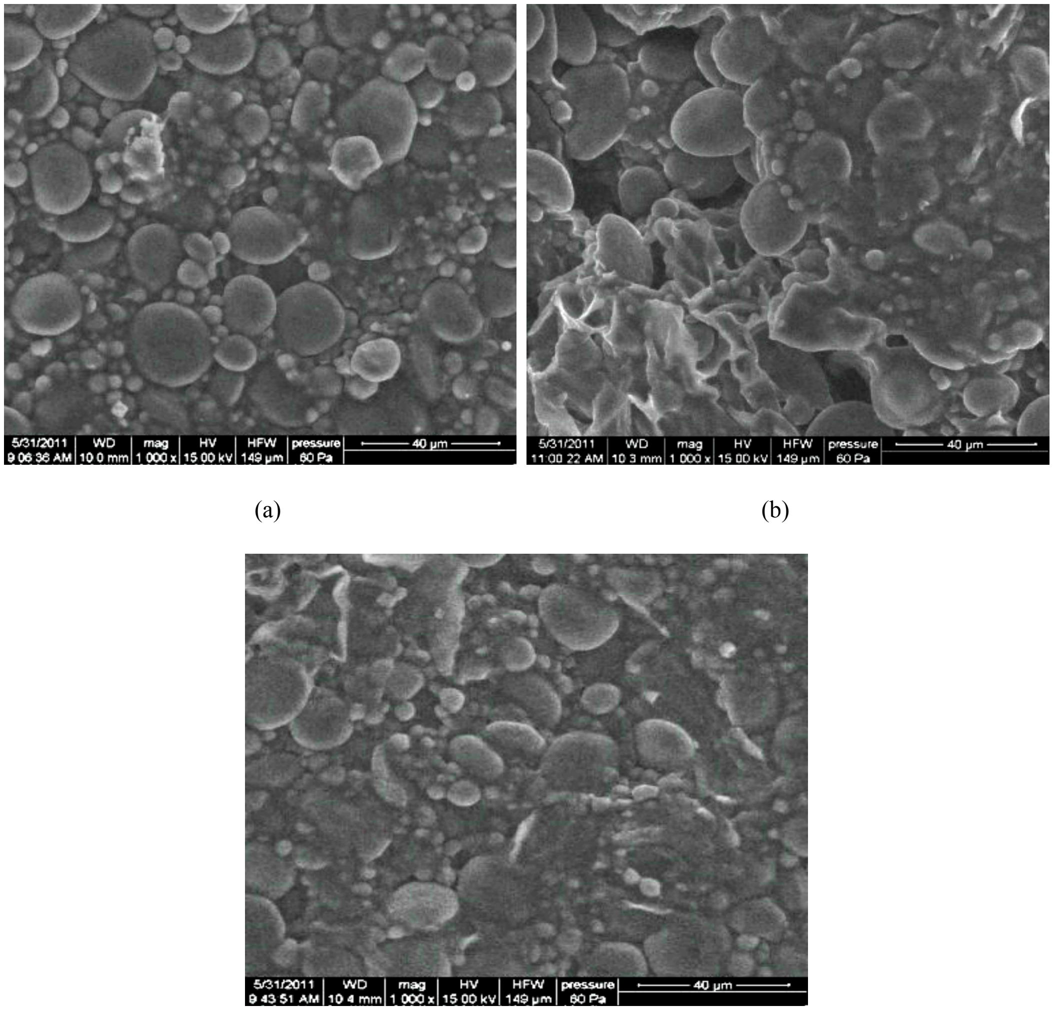
dark, palatability became weak and soybean flavor enhanced with the addition of okara powder. The tenacity, viscidity and smooth of noodle had no remarkable changes with okara addition. Comprehensive consideration, replacing 25% wheat flour with okara powder to make noodle is appropriate and the product can be accepted by eaters.

Texture Profile Analysis (TPA) can simulate masticatory movement of human, so it can be used to test physical properties of food. Hardness, gumminess and chewiness have negative correlation with noodle quality, i.e. the higher of these values, the worse of noodle quality is. Springness and cohesiveness have positive correlation with noodle quality. For shearing experiment, there is a remarkable positive correlation between maximum shear stress and chewiness, hardness and elasticity of noodle. Table 6 showed that hardness, gumminess, chewiness and maximum shear stress increased with the addition of okara powder. These values are biggest at 20% okara addition, then decreased. Replacing part wheat flour with okara exhibited two influences for dough. On the one hand, the reduction of gluten protein caused the worse of rheological characteristics of dough. On the other hand, dietary fibre had some improvement to rheological characteristics of dough. The result of two influences led to noodle quality parameters showing wave change trend with the addition of okara. Considering the results of sensory evaluation and textural analysis, the optimal addition for okara powder was 25%.

Effect of gluten addition on noodle quality: Because the amount of gluten protein decreased with okara addition, gluten network became weak and noodle broke easily. Gluten is the natural gluten protein extracted from wheat. Adding gluten to okara noodle can compensate the shortage. Table 7 showed that with the addition of gluten, water absorption and elongation of okara noodle increased, cooking loss decreased and the quality of okara noodle was improved significantly. Table 8 revealed that hardness, gumminess, chewiness and maximum shear stress presented the similar change trend of wave with the addition of gluten. When gluten addition was 3%, the hardness of okara noodle was Moderate, gumminess, chewiness and maximum shear stress were close to that of normal noodle. Considering textural analysis and sensory evaluation, the optimal addition of gluten was 3%.

Effects of CMC, konjac flour and NaCl on noodle quality: CMC and konjac glucomannan, the main content of konjac flour, are water-soluble polysaccharides. They form hydrophilic colloid with high viscosity, which can connect with wheat protein to constitute the compact network. As a result, the elasticity and tenacity of noodle enhance and the dissolution loss of noodle contents reduces. Suitable amount of NaCl favours gluten protein absorbing water and forming perfect network and the anion of NaCl can combine the polar amino acid residues to stabilize protein structure and heighten dough strength and elongation. The effects of CMC, konjac flour and NaCl additions on the quality of okara noodle (25% wheat flour replaced by okara powder) were determined and the results showed that the optimal additions for CMC, konjac flour and NaCl were 0.4, 0.2 and 1%, respectively.

Microstructure of Okara noodle: To investigate the effect of Okara addition on noodle microstructure, three noodle samples prepared from 100% wheat flour, 75% wheat flour and 25% okara powder, 75% wheat flour, 25% okara powder, 3% gluten, 0.4% CMC, 0.2% konjac flour and 1% NaCl, respectively, were observed by ESEM. It can be seen that the noodle made from 100% wheat flour had an extensible gluten matrix which covered all starch granules (Fig. 1a). For noodle sample of 25% okara addition, dietary fibre combined with protein to form a discontinuous and irregular matrix around the starch granules (Fig. 1b). Thus, the existence of dietary fibre diluted the protein and interfered with optimal gluten matrix formation during dough mixing. CMC and konjac glucomannan



(a) (b)

(c)

Fig. 1: ESEM photographs of (a) noodle made from 100% wheat flour; (b) noodle made from 75% wheat flour and 25% okara powder; (c) noodle made from 75% wheat flour, 25% okara powder, 3% gluten, 0.4% CMC, 0.2% konjac flour and 1% NaCl (×1000)

combined with protein to form gel network, which embedded the starch granules and fibre fragments to improve the noodle quality (Fig. 1c).

The effect of okara on steamed bread quality:

Effect of okara addition on sensory quality of steamed bread: Table 9 showed that the quality of steamed bread declined to some degree when part of wheat flour was replaced by okara powder to make steamed bread. When okara addition exceeded 25%, the total score of sensory quality of the steamed bread decreased markedly, representing low specific volume, rough skin, uneven gas pore, weak elasticity and unacceptable for eaters. Table 10 also revealed that with the addition of okara, springiness, cohesiveness and resilience of steamed bread reduced gradually, the adhesiveness raised, the hardness, gumminess and chewiness exhibited wave change trend. Considering the results of sensory evaluation and TPA analysis, the optimal addition for okara powder was 15%.

Effect of gluten addition on the quality of okara steamed bread: Because part wheat flour was substituted by okara, the gluten protein content was not enough for the formation of optimal network during dough mixing, resulting in easy disruption of gluten network and low loaf volume of bread during steaming. This can be remedied by adding suitable gluten. Table 11 showed that specific volume, elasticity and tenacity, flavor and structure of okara steamed bread increased after adding gluten. During the range of 0.5%~1.5% gluten addition, the okara steamed bread had even gas pore and soft mouth feel, meanwhile the wrinkle of bread skin was improved. However, when gluten addition exceeded 2%, the gluten network became too compact, resulting in the hard dough during

Table 9: The effect of okara powder addition on sensory quality of steamed bread

Okara addition	Specific volume	Appearance	Structure	Elasticity and tenacity	Viscidity	Flavor	Color	Total score
0%	20.0±0.1	12.0±2.0	12.0±1.3	17.0±2.6	11.0±1.8	3.0±1.0	9.0±0.4	84.0±1.9
5%	20.0±0.1	12.8±1.3	11.8±1.0	16.0±2.0	13.0±1.3	3.5±0.9	7.9±1.0	85.0±4.6
10%	19.0±0.2	13.3±1.4	12.8±1.3	15.5±2.6	12.3±1.4	3.0±0.4	7.7±1.0	83.6±6.1
15%	18.0±0.1	12.3±1.7	12.5±1.9	15.5±2.6	12.3±1.3	3.2±0.21	7.8±1.4	81.6±6.4
20%	17.0±0.0	12.0±1.8	13.0±2.1	14.8±2.8	12.8±2.3	3.0±0.1	8.1±1.5	80.7±5.8
25%	17.0±0.2	12.0±2.4	12.5±1.9	14.0±3.0	11.8±1.8	3.3±0.3	7.9±1.2	78.5±5.8
30%	13.0±0.1	10.0±1.8	11.3±2.7	12.0±4.0	11.0±2.4	3.1±0.4	7.1±0.8	67.6±7.5
35%	11.0±0.1	9.0±2.1	9.0±1.5	10.0±4.2	8.0±2.4	2.5±0.9	6.0±1.6	55.5±6.1
40%	10.0±0.2	9.0±2.6	7.0±3.1	9.0±4.3	8.0±3.1	2.5±0.9	6.0±1.7	51.5±9.4

Table 10: The effect of okara powder addition on TPA of steamed bread

Okara addition	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
0%	3436±180	0.79±0.14	0.73±0.04	0.48±0.06	1988±200	1435±176	0.18±0.03
5%	2361±196	0.90±0.12	0.80±0.05	0.35±0.19	858±328	695±250	0.13±0.08
10%	3605±186	1.22±0.13	0.76±0.03	0.34±0.05	1209±209	919±172	0.13±0.02
15%	3606±109	1.52±0.12	0.75±0.02	0.38±0.05	1404±61	1047±81	0.15±0.02
20%	5514±307	1.13±0.19	0.67±0.02	0.30±0.02	1701±163	1143±112	0.12±0.01
25%	4402±433	2.38±0.20	0.60±0.01	0.33±0.01	1437±187	870±126	0.12±0.00
30%	4564±434	14.6±0.25	0.49±0.12	0.28±0.02	1260±184	610±143	0.09±0.01
35%	4013±445	47.3±1.26	0.39±0.08	0.27±0.02	1098±170	428±125	0.08±0.02
40%	3740±471	100±5.65	0.38±0.01	0.22±0.01	825±57	314±28	0.06±0.06

Table 11: The effect of gluten addition on the quality of okara steamed bread

Gluten addition	Specific volume	Appearance	Structure	Elasticity and tenacity	Viscidity	Flavor	Color	Total score
CK*	17.0±0.2	12.0±2.4	12.5±1.9	14.0±3.0	11.8±1.8	3.3±0.3	7.9±1.2	78.5±5.8
0.5%	17.0±0.1	12.8±1.3	12.5±2.7	15.0±3.2	11.3±1.9	3.6±0.8	7.5±1.6	79.7±8.1
1.0%	17.3±0.1	11.8±1.4	12.8±2.4	15.9±3.4	11.6±2.0	3.5±0.6	7.8±1.5	80.5±8.1
1.5%	17.2±0.1	10.9±0.7	11.9±2.3	15.8±2.2	11.3±2.0	3.8±0.8	7.9±1.4	79.0±6.4
2.0%	16.9±0.1	10.8±2.6	11.0±3.5	13.0±3.9	11.5±3.3	4.6±1.1	7.8±2.3	75.5±5.7
2.5%	16.8±0.0	11.3±1.5	10.5±2.8	12.3±2.5	11.0±2.3	4.2±0.8	7.4±1.6	73.5±7.5

*: CK was steamed bread made from 85% wheat flour and 15% okara powder, the same for Table 12

Table 12: The effect of gluten addition on TPA of okara steamed bread

Gluten addition	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
CK	5514±307	1.13±0.19	0.67±0.02	0.30±0.02	1701±163	1143±112	0.12±0.01
0.5%	5028±541	0.99±0.20	0.62±0.02	0.35±0.02	1745±62	1087±78	0.13±0.01
1.0%	5171±472	1.23±0.12	0.62±0.03	0.33±0.01	1688±222	1048±93	0.12±0.01
1.5%	3505±672	13.99±0.15	0.62±0.02	0.33±0.04	1168±338	716±188	0.12±0.02
2.0%	4417±716	16.65±0.27	0.62±0.02	0.34±0.01	1497±300	930±161	0.12±0.01
2.5%	4276±628	23.04±0.52	0.68±0.03	0.32±0.04	1401±492	940±307	0.13±0.02

fermentation and low loaf volume after steaming. Table 12 revealed that with the addition of gluten, hardness, springiness, cohesiveness, gumminess, chewiness and resilience of steamed bread exhibited the trend of up first and then down. Considering the results of sensory evaluation and TPA analysis, the optimal addition of gluten was 1%.

Microstructure of okara steamed bread: To investigate the effect of okara addition on the microstructure of steamed bread, three steamed bread samples prepared from 100% wheat flour, 75% wheat flour and 25% okara powder, 85% wheat flour, 15% okara powder and 1% gluten, respectively, were observed by ESEM. Figure 2a showed that the steamed bread made from pure wheat flour had bigger, more and even gas pores, the pore wall was thin and the honeycomb structure led to the soft and elastic property of bread. When 25% wheat flour was replaced by okara powder, the steamed bread had little pores and the pore wall was thick, resulting in low specific volume and weak elasticity (Fig. 2b). The steamed bread made from 85% wheat flour, 15% okara powder and 1% gluten had bigger and uneven pores, some pore walls were thick and others were thin (Fig. 2c). The specific volume of bread was enhanced to some extent and the elasticity was improved markedly. The ESEM photographs showed that the gluten network structure of steamed bread made from pure wheat flour was uniform and loose (Fig. 2d), the network of bread prepared from 75% wheat flour and 25% okara was very dense with little gap (Fig. 2e), whereas those from 85% wheat flour, 15% okara and 1% gluten had bigger pores and gaps (Fig. 2f). The ESEM results showed that okara addition produced some negative effects on gluten network. Moreover, okara fibre absorbed water faster and stronger than starch during dough mixing, which influenced the starch to absorb enough water for

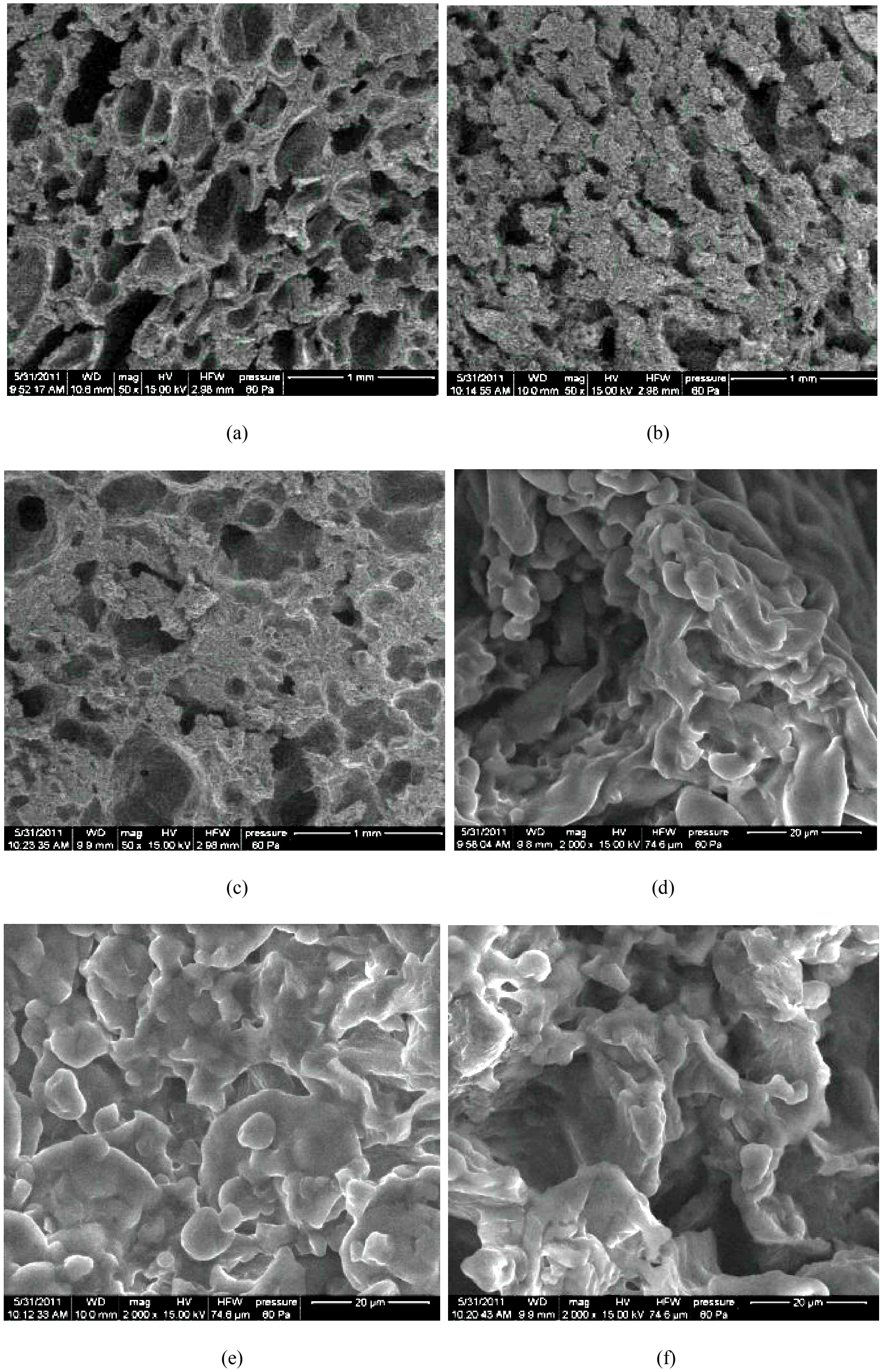


Fig. 2: ESEM photographs of (a, d) steamed bread made from 100% wheat flour, (b, e) steamed bread made from 75% wheat flour and 25% okara powder, (c, f) steamed bread made from 85% wheat flour, 15% okara powder and 1% gluten. The magnification rate for a, b, c was 50, for d, e, f was 2000

swelling and affected the gelatinization during bread steaming. As a result, the gluten network was not perfect, starch gelitinization was not enough and the gas-keeping capacity of steamed bread decreased. The addition of gluten improved the network structure and enhanced gas-keeping capacity, so the steamed bread formed a lot of bigger pores.

CONCLUSION

This study studied the effects of okara powder addition on the qualities of noodle and steamed bread to estimate the possibility of okara used in these foods. Okara powder contains 58.6% dietary fibre and 15.3% protein, plus considerable amounts of flavone, potassium, calcium, ferrum and zinc. The substitution of okara powder for part wheat flour to make noodle and steamed bread can improve their nutritional values, especially beneficial for diabetes who are required dietary pattern of high fibre and high protein. However, okara dose not contain gluten protein and its dietary fibre absorbs water stronger and faster than starch, so adding okara will affect the formation of gluten network and the hydroscopicity of starch during dough mixing and the gas-keeping capacity and starch gelitinization during bread steaming. Therefore, some suitable additives are necessary to improve the quality of okara noodle and okara steamed bread. The sensory evaluation and TPA analysis results showed that the optimal ingredient for okara noodle was: wheat flour 75%, okara powder 25%, gluten 3%, CMC 0.4%, konjac flour 0.2%, NaCl 1%; the optimal ingredient for okara steamed bread was: wheat flour 85%, okara powder 15%, gluten 1%. The noodle and steamed bread made from above ingredients have almost similar qualities to normal noodle and steamed bread. Okara is the by-product of tofu and soy milk. Its low cost, huge quantity and high fibre content endow it competitive advantages as a dietary fibre source. This study shows that drying fresh okara and grinding it to fine powder, then replacing okara powder for part wheat flour to make foods is a potential method for okara application.

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REFERENCES

AACC International, 2000. Approved Methods of the American Association of Cereal Chemists. 10th Edn., American Association of Cereal Chemists, St. Paul, MN.

Ahn, S.H., S.C. Oh, I. Choi, G. Han, H. Jeong, K. Kim, Y. Yoon and I. Yang, 2010. Environmentally friendly wood preservatives formulated with enzymatic-hydrolyzed Okara, Copper and/or Boron Salts. J. Hazard. Mater., 178: 604-611.

Amin, I. and O. Mukhrizah, 2006. Antioxidant capacity of methanolic and water extracts prepared from food-processing by-products. J. Sci. Food Agric., 86(5): 778-784.

Ge, F., L. Gui, Y. Tao, L. Zhu and Y. Huang, 2010. DPPH radical scavenging activity of extract from soybean residue and coordination effect. Soybean Sci., 29(1): 113-117.

Head, K.A., 1997. Isoflavones and other soy constituents in human health and disease. Altern. Med. Rev., 2(6): 433-450.

Hu, B.Q., 2000. Determination of bread specific volume. Metrol. Meas. Technol., 6: 10-12.

Huang, X., L. Chen and H. Hu, 2004. Study on the antioxidative properties of the extracts from soybean residue. Sci. Technol. Food Ind., 25(3): 109-110.

Huang, X., L. Wang, S. Li, X. Gao and L. Zhu, 2006. Study on the antioxidative stability of soybean residue extract. China Brewing, 4: 42-43.

International Diabetes Federation, 2009. IDF Diabetes Atlas. 4th Edn., International Diabetes Federation, Brussels, pp: 7-104.

Li, B., Y. Zhang, H. Yang and R. Li, 2008. Effect of drying methods on functional properties of bean curd dregs. J. Henan Inst. Sci. Technol. , 36(3): 64-66.

Mateos-Aparicio, I., A. Redondo-Cuenca, M.J. Villanueva-Suárez, M. Zapata-Revilla and M. Tenorio-Sanz, 2010a. Pea pod, broad bean pod and okara, potential sources of functional compounds. LWT-Food Sci. Technol., 43(9): 1467-1470.

Mateos-Aparicio, I., C. Mateos-Peinado and P. Rupérez, 2010b. High hydrostatic pressure improves the functionality of dietary Fibre in Okara byproduct from soybean. Innov. Food Sci. Emerg. Technol., 11(3): 445-450.

Matsumoto, K., Y. Watanabe and S. Yokoyama, 2007. Prevents obesity in a diet-induced Murine obesity model. Biosci. Biotech. Biochem., 71(3): 720-727.

Préstamo, G., P. Rupérez, I. Espinosa-Martos, M.J. Villanueva and M.A. Lasunción, 2007. The effects of Okara on rat growth, Cecal fermentation and serum lipid. Eur. Food Res. Technol., 225: 925-928.

Redondo-Cuenca, A., M.J. Villanueva-Suárez and I. Mateos-Aparicioet, 2008. Soybean seeds and its by-product Okara as sources of dietary fibre. Measurement by AOAC and Nglyst methods. Food Chem., 108: 1099-1105.

Van der Riet, W.B., A.W. Wight, J.J.L. Cilliers and J.M. Datel, 1989. Food chemical investigation of tofu and its byproduct Okara. Food Chem., 34: 193-202.

Villanueva, M.J., W. Yokoyama, Y.J. Hong, G.E. Barttley and P. Rupérez, 2011. Effect of high-fat diets supplemented with Okara soybean by-product on lipid profiles of plasma, liver and faeces in Syrian hamsters. Food Chem., 124: 72-79.

Wang, C. and S. Li, 1996. Influence of Okara fibre on lipid metabolism and hemorheology of rats. Acta Nutr. Sinica, 18(2): 168-174.

Xu, H., Y. Wang, H. Liu, J. Zheng and Y. Xin, 2000. Influence of soybean fibers on blood sugar and blood lipid metabolism and hepatic-nephritic histomorphology of Mich with STZ-induced diabetes. Acta Nutr. Sinica, 22(2): 171-174.

Yokomizo, A., Y. Takenaka and T. Takenaka, 2002. Antioxidative activity of peptides prepared from Okara protein. Food Sci. Technol. Res., 8(4): 357-359.

Zhu, Y.P., J.F. Fan, Y.Q. Cheng and L.T. Li, 2008. Improvement of the antioxidant activity of Chinese traditional fermented Okara (Meitauza) using bacillus subtilis B2. Food Control, 19: 654-661.