

Evaluation of Physicochemical Properties of Muffins Made With Ultrafiltered *Sunmul* Powder

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Abstract

This study was conducted to investigate the quality characteristics of muffins with added ultrafiltered (UF) *sunmul* powder. Muffins were prepared with four different levels of UF powder (0%, 3%, 5% and 7%) and the physicochemical properties were examined. The volume and specific volume were lower in muffins prepared with UF powder than the control. The incorporation of UF powder in muffin lowered the lightness values but increased the redness values. Rheology testing showed that hardness increased with increasing UF powder and gumminess and brittleness were the highest in the control group and decreased with increasing UF powder. Initial isoflavone content was 2.39~5.57 mg%, and decreased to 1.81~4.09 mg% after baking, resulting in 24~37% reduction in muffin formulations. Scanning electron microscopy showed that the size of the air cells increased with increasing UF powder levels. In sensory evaluation, overall acceptability score was the highest in muffins with 3% added UF powder and no significant difference was observed between control and 7% addition. Therefore, muffins prepared with up to 7% addition of UF powder would be at least as acceptable as control muffins.

Key words: *sunmul*, ultrafiltered powder, muffin, isoflavone

INTRODUCTION

Tofu, the most popular processed food of soybean in Asian countries, is prepared by coagulating the protein component by heating. This process generates a liquid by-product, which is called *sunmul* (tofu whey). *Sunmul* has been regarded as a waste product in the tofu industry and its disposal causes a serious environmental problem. However, *sunmul* contains various low molecular weight substances such as isoflavones, oligosaccharides, phytic acids, and saponins, which possess diverse physiological activities (1,2), and thus should not be considered as a waste. Isoflavones, a class of phytoestrogens, have been demonstrated to prevent some types of cancer, cardiovascular diseases, osteoporosis, and diabetes (3-5). The major isoflavones in soybean are genistin, daidzin, and glycitin as glycosides and genistein, daidzein, and glycitein as aglycones (6). Among them, genistein, genistin, daidzein and daidzin are the principal isoflavones showing diverse biological activities (7-9). Oligosaccharides have been reported to stimulate the growth of endogenous bacteria such as *bifidobacteria* and *lactobacilli* in the intestine (10). Phytic acid has been shown to help prevent cancer development as well as lower serum cholesterol

(11). With the discovery of functional compounds present in the *sunmul*, much effort has been made to separate these substances from the *sunmul* and utilize them (12-15). Kim et al. reported that a sequential membrane filtration process was useful for separation of isoflavones and oligosaccharides (12,13) and some food products were developed with these concentrates (16,17).

In the present study, muffins were prepared with ultrafiltered (UF) *sunmul* powder which was substituted for 0, 3, 5 or 7% of the wheat flour and the physicochemical properties were investigated to examine the feasibility of developing value-added product.

MATERIALS AND METHODS

Materials

Sunmul (Doosol Corporation, Yeisan-Gun, Korea) and *sunmul* powder were prepared according to the method described previously (12,13). In brief, separation and concentration was performed using an ultrafiltration membrane filter (Millipore Corporation, Bedford, MA, USA) with a molecular weight cut-off of 10 K dalton and surface area of 0.1 m², followed by spray drying. Proximate composition analysis indicated that UF *sun-*

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mul powder contained 10.08% moisture, 12.88% ash, 0.94% crude fat, 30.06% crude protein. It also contained 1.008 mg/g isoflavones and 0.185 mg/g oligosaccharides (13). Ingredients for muffins, such as flour, milk, sugar, butter, egg, salt and baking powder were purchased from a local market. Isoflavone standards (daidzin, daidzein, genistin, genistein, glycitin and glycitein) were purchased from Sigma Chemical Corporation (St. Louis, MO, USA).

Muffin preparation

The ingredients used in the formulations are shown in Table 1. UF powder was used to replace part of the wheat flour (0%, 3%, 5%, 7%) in a standard muffin recipe. Milk, egg, sugar and butter were creamed in a mixer. Flour, baking powder and salt were sifted and then added to the liquid ingredients and mixed for 30 seconds. Batter was weighed out in aliquots of 35 g into muffin cases and placed into a muffin tin. The muffins were baked in an oven (FDO-7103, Daeyoung Co., Korea) at upper heating temperature of 190°C and lower temperature of 190°C for 20 min. Muffins were immediately removed from the pan and cooled on a wire rack for 1 hr before analyses.

Volume, weight and specific volume measurement

Muffin volume was measured using the seed replacement method, weight was determined with the aid of a precision scale and specific volume was calculated from the ratio of weight (g) to volume (mL) of the muffin.

Color measurement

Interior colors of muffins were determined by measuring tristimulus L (lightness), a (redness), b (yellowness) values with a colorimeter (JX 777, Juki, Japan).

Texture profile analysis

The textural characteristics of the muffins were determined using a texture profile analysis using a rheometer (Compac-100, Sun Scientific Co., Japan). Muffins were cut into cubes of 4×4×4 cm and evaluated by compressing twice to 50% of their original height. The textural variables were hardness, cohesiveness, springiness, gumminess and brittleness. Operating conditions

were as follows: test type, mastication; load cell, 2 kg; adaptor type, circle (diameter 10 mm); table speed, 120 mm/min.

Isoflavone contents of muffin

One gram of dried muffin was extracted with 20 mL of 80% ethanol for 1 hr using an ultrasonicator. The extract was centrifuged at 10,000×g for 15 min, and the supernatant was filtered through a syringe filter (0.22 µm, Waters Co., Milford, MA, USA). Analysis of isoflavone was performed by HPLC (Waters Co.) using a Waters 486 absorbance UV detector at 254 nm, and an XTerra™ RP18 column (5 mm, 4.6×250 mm, Waters Co.). The mobile phases for HPLC consisted of solvent (A), 0.1% (v/v) acetic acid in water, and (B), 0.1% (v/v) acetic acid in acetonitrile. The solvent gradient was as follows: the fraction of solvent B increased linearly from 15 to 23% over the initial 40-min period, followed by a 27% increase up to 30 min, to 35% up to the following 15 min, and finally to 40% during the last 5 min at a flow rate of 1 mL/min. A standard curve was obtained from the peak areas of known concentrations of the standards (daidzin, daidzein, genistin, genistein, glycitin, and glycitein) in HPLC chromatograms. The amount of each isoflavone in the samples was determined using the standard curves.

Microstructure of muffin by scanning electron microscopy

Scanning electron microscopy (SEM) was used to examine the microstructure of muffins. Raw samples were viewed directly on a scanning electron microscope (Philips, XL30 ESEM, Netherlands) without any coating treatment at an accelerating voltage of 30 kV.

Sensory evaluation

Sensory evaluation was conducted after cooling the muffins for 1 hr at room temperature. Muffins were cut in half, placed on a plastic dish coded by a three-digit random number and offered to 8 panelists in an individual booth with lighting. Color, flavor, sweet taste, air cell size, aftertaste and overall desirability of each muffin were evaluated using the nine-point scale with

Table 1. Formula for muffins with different levels of added UF powder

(%)

Groups ¹⁾	Ingredient							
	Flour	UF powder	Milk	Sugar	Butter	Egg	Salt	Baking powder
UF-0	100	0	50	50	50	50	2.2	3.3
UF-3	97	3	50	50	50	50	2.2	3.3
UF-5	95	5	50	50	50	50	2.2	3.3
UF-7	93	7	50	50	50	50	2.2	3.3

¹⁾UF-0: ultrafiltered powder-0%, UF-3: ultrafiltered powder-3%, UF-5: ultrafiltered powder-5%, UF-7: ultrafiltered powder-7%.

9 indicating strong attributes.

Statistical analysis

All data were expressed as means \pm standard deviation of at least triplicate measurements. Data were analyzed using SAS version 8.12 ANOVA and Duncan's multiple range test were used to determine the difference among means at $\alpha=0.05$.

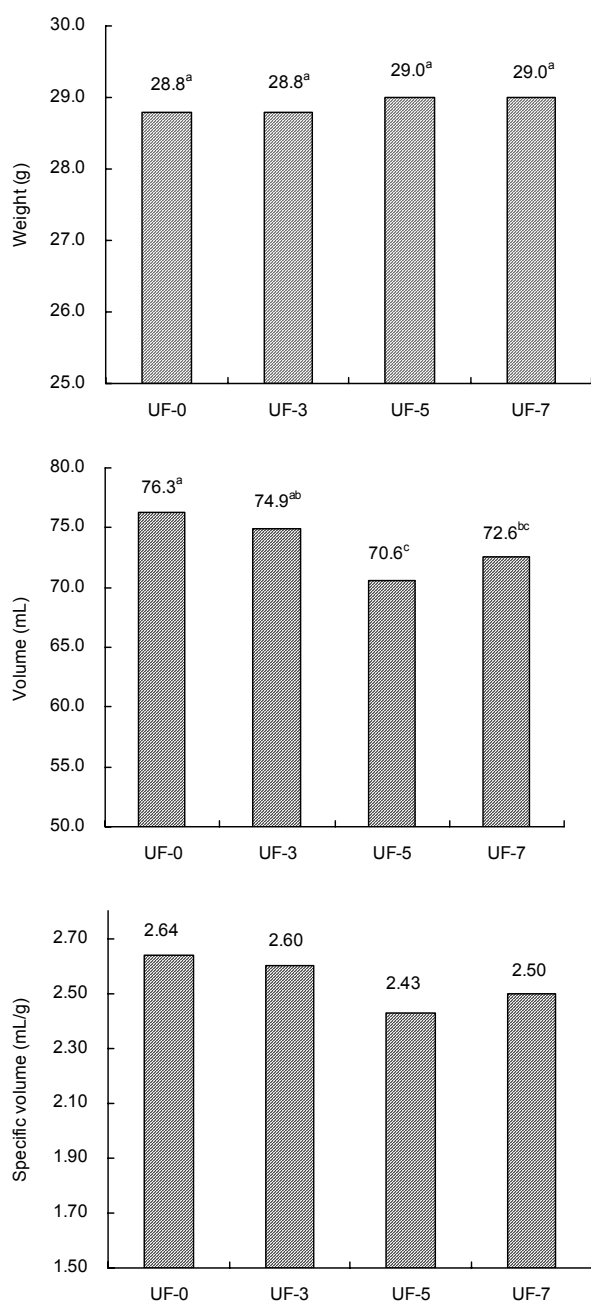


Fig. 1. Weight, volume and specific volume of muffins with different levels of added UF powder. Groups are the same as in Table 1. Means with different letters are significantly different from each other at $p < 0.05$ as determined by Duncan's multiple range test.

RESULTS AND DISCUSSION

Volume, weight and specific volume

Weight, volume and specific volume of muffins are presented in Fig. 1. The weight of muffins ranged from 28.0 g to 29.0 g, showing no significant difference between the control and the three treatments. The volume of control muffin was 76.3 mL and the UF powder groups were 70.6~74.9 mL, resulting in a decrease of 1.8~7.5%. Specific volume showed a similar trend to volume as the UF powder addition level increased. These results might be attributed to the dilution of gluten by the substitution of wheat flour with UF powder (18). In addition, UF powder could cleave gluten strands and impair gas retention, resulting in easy disruption of gluten network during baking, and reduce the volume of muffins (18). This is in agreement with the results of other researchers, who reported reduced volume with the replacement of wheat flour with other food materials. For example, Lee et al. (19) reported that increasing sugaring puree content reduced the volume and specific volume in muffins. Chang (20) reported that the volume of sponge cake prepared with millet flour was decreased as the addition level increased.

Color measurement

The results of Hunter L, a and b color values of muffins are shown in Table 2. The L value (lightness) of control muffin was 69.22 and those of UF powder muffins ranged from 64.58 to 68.49. The lightness of the UF powder muffins decreased with the reduction in the proportion of wheat flour because of the loss of white color of the flour. Therefore, it could be expected that muffins would become darker with increasing amount of UF powder level. Similar results were obtained in Jeung-Pyun made with UF powder (21) and bread supplemented with soy flour (22), curry powder (23), and muffins formulated with potato peel (24). The a value (redness) of the control muffin was 0.44 and those of UF powder groups were 0.46~0.75, showing more red-

Table 2. Hunter L, a and b values of muffins with different levels of added UF powder

Group ¹⁾	L	a	b
UF-0	69.22 \pm 2.94 ^{2)a3)}	0.44 \pm 0.37 ^a	26.14 \pm 0.28 ^a
UF-3	68.49 \pm 0.64 ^a	0.75 \pm 0.18 ^a	27.48 \pm 0.45 ^b
UF-5	67.96 \pm 2.46 ^a	0.61 \pm 0.23 ^a	26.63 \pm 0.21 ^a
UF-7	64.58 \pm 1.81 ^b	0.46 \pm 0.28 ^a	26.35 \pm 0.50 ^a

¹⁾ See the legend of Table 1.

²⁾ Each value is mean \pm standard deviation (SD).

³⁾ Means with different letters within a column are significantly different from each other at $p < 0.05$ as determined by Duncan's multiple range test.

Table 3. Texture value of muffins with different levels of added UF powder

Group ¹⁾	Hardness (g/cm ²)	Cohesiveness (%)	Springiness (%)	Gumminess (g)	Brittleness (g)
UF-0	551.65 ± 82.39 ^{2)a3)}	43.29 ± 3.23 ^a	77.39 ± 3.31 ^a	62.90 ± 10.01 ^a	48.93 ± 9.42 ^a
UF-3	838.31 ± 91.91 ^b	41.48 ± 5.39 ^a	77.95 ± 8.93 ^a	89.62 ± 11.12 ^b	70.53 ± 16.04 ^b
UF-5	786.85 ± 95.41 ^b	41.83 ± 6.27 ^a	76.63 ± 9.45 ^a	83.00 ± 20.39 ^b	65.22 ± 24.14 ^b
UF-7	781.90 ± 89.58 ^b	39.81 ± 4.82 ^a	75.67 ± 7.94 ^a	77.19 ± 15.45 ^b	59.00 ± 16.48 ^b

¹⁾See the legend of Table 1.

²⁾Each value is mean ± SD.

³⁾Means with different letters within a column are significantly different from each other at p<0.05 as determined by Duncan's multiple range test.

dish color than control. The b value (yellowness) ranged from 26.14 to 27.48 and no significant differences were observed among treatments.

Texture profile analysis

The result of textural properties of muffins including hardness, cohesiveness, springiness, gumminess and brittleness are shown in Table 3. Hardness value was lowest in the control muffin and increased with increasing UF powder amount. The result is consistent with that of Ahn and Song (25) who reported that cake with added sea tangle and sea mustard exhibited harder texture than control. Joo et al. (26) also reported that the incorporation of grape seed extract into muffin increased hardness. Texture is an important aspect of muffin quality and affects the consumer acceptance. Replacing wheat flour by UF powder increased muffin density and reduced the number of air pockets, thereby increasing the force needed for compression (27). Cohesiveness and springiness are not affected by the UF powder addition. Springiness is related to muffin weight, which remained relatively constant in all formulations. Gumminess and brittleness values were much lower in control than in muffins with UF powder. A number of studies have been reported on the texture profile of baked products in which wheat flour was substituted with other substances. For example, the addition of up to 20% sorghum flour did not influence the texture parameters such as hardness, adhesiveness, gumminess and chewiness (28). Bread prepared with oak mushroom powder exhibited increased firmness (29), whereas hardness of cookies added with barely germ decreased with increasing substitution levels (30). These results suggested that the incorporation of different ingredients into baked products results in different texture profile.

Changes in isoflavone contents

Total isoflavone contents of muffin are summarized in Table 4. Initial isoflavone contents were 2.39~5.57 mg%, and decreased to 1.81~4.09 mg% after baking,

Table 4. Changes in isoflavone content of muffins with different levels of added UF powder after baking (unit : mg%)

		Groups ¹⁾			
		UF-3	UF-5	UF-7	
Before baking	glycosides	Daidzin	1.11	1.85	2.59
		Genistin	0.21	0.35	0.49
		Glycitin	0.36	0.60	0.84
		Subtotal	1.68	2.80	3.92
	aglycones	Daidzein	0.54	0.90	1.26
Genistein		0.15	0.25	0.35	
Glycitein		0.02	0.03	0.04	
Subtotal		0.71	1.18	1.65	
Total		2.39	3.98	5.57	
After baking	glycosides	Daidzin	0.39	0.59	0.91
		Genistin	0.44	0.60	0.98
		Glycitin	0.07	0.09	0.17
		Subtotal	0.90	1.28	2.09
	aglycones	Daidzein	0.33	0.55	0.80
Genistein		0.41	0.41	0.91	
Glycitein		0.17	0.26	0.29	
Subtotal		0.91	1.22	2.00	
Total		1.81	2.50	4.09	

¹⁾See the legend of Table 1.

resulting in a 24~37% reduction in muffin formulations. It is notable that the total amount of aglycones increased from 0.71~1.65 mg% to 0.91~2.00 mg% in all muffin formulations, corresponding to an increase from 30% to 50% after baking. Daidzin and daidzein were the most abundant isoflavones and accounted for about 69% of total isoflavones before baking, but decreased to 40~45% after baking. Genistin and genistein increased from 15% to 45% after baking, resulting in a 3 fold increase. The isoflavones and isomers are unstable under heat treatment. Therefore, isomers are converted to glycosides or aglycones of isoflavones, and glycosides are converted to aglycones during heating, which would possibly account for the increased amount of aglycones in the data.

It has been known that genistin, genistein, daidzin and dadizein are the major isoflavones showing biological effects such as preventing carcinogenicity, osteoporosis, and cardiovascular disease. Our data show that these four types of isoflavones accounted for 86~88% of total isoflavone contents and therefore, muffins prepared with UF powder would be a good source of bioavailable isoflavones.

Microstructure of muffin

The internal microstructure of muffins as revealed by SEM is shown in Fig. 2. The control muffin was observed to have quite small, uniform air cells, showing a consistent sponge-like appearance. In contrast, muffins with added UF powder exhibited rough crumb structures and the air cells decreased but the cell size remarkably increased as the proportion of UF powder to wheat flour increased. The existence of UF powder diluted the protein and interfered with optimal gluten network formation during mixing. The dilution also changed the

crumb structure and impaired the CO₂ retention, resulting in easy disruption of the gluten network during baking, and reduced the volume of the muffin (18). This result is in good agreement with other observations obtained in bread supplemented with oak mushroom powder (29) and sponge cake with added laver powder (31).

Sensory evaluation

Results of sensory evaluation for muffins are shown in Table 5. The interior color was evaluated to become darker as the UF powder level increased, which is due to the browning reactions caused by oligosaccharides and amino acids present in UF powder as well as the yellow color of UF powder. The flavor and aftertaste scores of muffins increased with increasing UF powder level, which could be attributed to the beany or tofu flavor present in UF powder. Sweet taste scores were higher in muffins with UF powder than in the control muffin, probably due to the presence of oligosaccharides and free

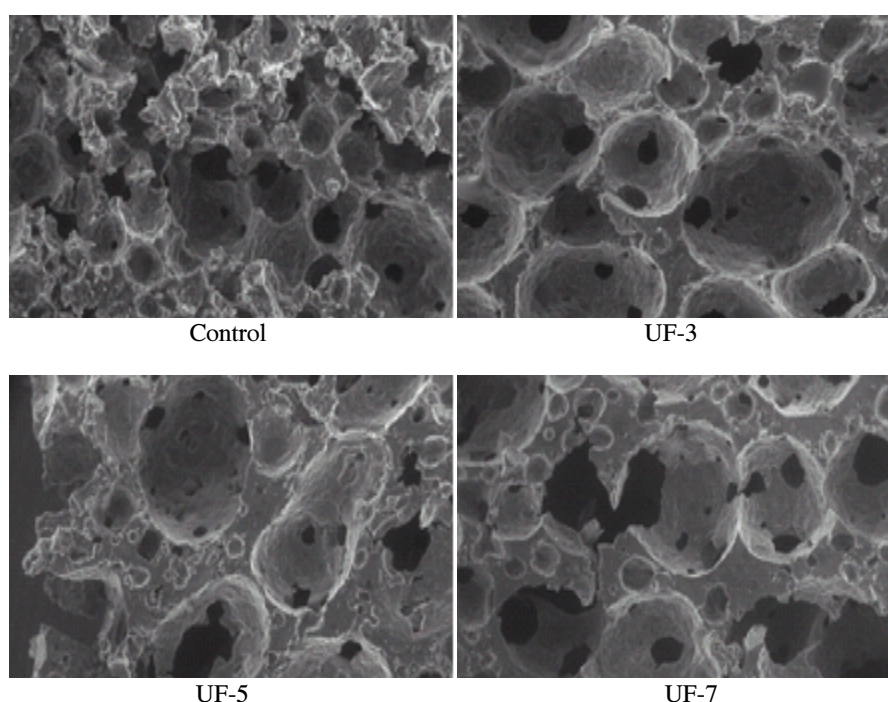


Fig. 2. Scanning electron micrographs (SEM) of muffins with different levels of added UF powder.

Table 5. Sensory scores of muffins with different levels of added UF powder

Group ¹⁾	Color	Flavor	Sweet taste	Air cell size	Aftertaste	Overall desirability
UF-0	4.00 ± 0.80 ^{2)a3)}	3.75 ± 1.10 ^a	4.69 ± 1.10 ^a	3.63 ± 1.07 ^a	1.81 ± 1.00 ^a	5.19 ± 1.39 ^a
UF-3	4.44 ± 0.83 ^a	4.56 ± 1.13 ^b	5.25 ± 1.13 ^b	4.75 ± 0.77 ^b	2.19 ± 0.88 ^{ab}	6.25 ± 0.96 ^b
UF-5	5.50 ± 0.79 ^b	4.75 ± 0.97 ^b	4.81 ± 0.97 ^{ab}	4.81 ± 1.12 ^b	2.19 ± 0.97 ^{ab}	5.69 ± 0.77 ^{ab}
UF-7	5.69 ± 0.98 ^b	4.94 ± 0.92 ^b	5.19 ± 0.92 ^b	5.19 ± 1.22 ^b	2.63 ± 1.37 ^b	5.63 ± 0.98 ^{ab}

¹⁾See the legend of Table 1.

²⁾Each value is mean ± SD.

³⁾Means with different letters within a column are significantly different from each other at p < 0.05 as determined by Duncan's multiple range test.

amino acids in UF powder. The score for air cell size was lower in control muffin than those of muffins with UF powder, indicating that air cell size increased with increasing UF powder level. This is consistent with the result of SEM shown in Fig. 2. Overall desirability of muffins showed that 3% addition of UF powder gave the highest score and no significant difference was observed between the control muffin and 7% UF muffin. Therefore, our results showed the feasibility of replacing up to 7% flour with UF powder in muffins with no significant change in the acceptability.

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REFERENCES

1. Kwon HJ. 1999. Bioactive compounds of soybean and their activity in angiogenesis regulation. *Korea Soybean Digest* 16: 63-68.
2. Kim JS. 1996. Current research trends on bioactive function of soybean. *Korea Soybean Digest* 13: 17-24.
3. McVeigh BL, Dillingham BL, Lampe JW, Duncan AM. 2006. Effect of soy protein varying in isoflavone content on serum lipids in healthy young men. *Am J Clin Nutr* 83: 244-251.
4. Lee KH, Chung HK, Han JH, Sohn HS. 2003. Soy isoflavone: current usage and production. *Korean Soybean Digest* 20: 28-36.
5. Hutchins AM, Slavin JL, Lampe JW. 1995. Urinary isoflavonoid phytoestrogen and lignan excretion after consumption of fermented and unfermented soy products. *J Am Diet Assoc* 95: 545-551.
6. Ryoo SH, Kim SR, Kim KT, Kim SS. 2004. Isoflavone, phytic acid and oligosaccharide contents of domestic and imported soybean cultivars in Korea. *Korean J Food Nutr* 17: 229-235.
7. Birt DF, Hendrich S, Wang W. 2001. Dietary agents in cancer prevention: flavonoids and isoflavonoids. *Pharmacol Ther* 90: 157-177.
8. Izumi T, Piskula MK, Osawa S, Obata A, Tobe K, Saito M, Kataoka S, Kubota Y, Kikuchi M. 2000. Soy isoflavone aglycones are absorbed faster and in higher amounts than their glucosides in humans. *J Nutr* 130: 1695-1699.
9. Kennedy AR. 1995. The evidence for soybean products as cancer preventive agents. *J Nutr* 125: 733-743.
10. Hoover DG. 1993. Bifidobacteria activity and potential benefits. *Food Technol* 47: 120-128.
11. Thompson LU, Zhang L. 1991. Phytic acid and minerals: effect on early markers for mammary and colon carcinogenesis. *Carcinogenesis* 12: 2041-2045.
12. Kim WJ, Kim HH, Yoo SH. 2005. Ultra- and nano-filtration process optimization of isoflavones and oligosaccharides from *sunmul*. *Food Sci Biotechnol* 14: 380-386.
13. Kim HH, Eom KY, Kim JS, Kim WJ. 2005. Drying of isoflavone and oligosaccharides retentates separated by membrane filtration from tofu *sunmul*. *Food Engineering Progress* 9: 81-87.
14. Kim DM, Baek HH, Jin JS, Lee SE, Kim KH. 1992. Physicochemical properties of soybean curd whey concentrated by reverse osmosis. *Korean J Food Sci Technol* 24: 311-314.
15. Seo SH, Hwang IK. 1997. Ultrafiltration of soybean curd whey for the separation of functional components. *Korean J Food Cookery Sci* 13: 597-513.
16. Chung HJ, Choi MH, Kim WJ. 2006. Effects of membrane-filtered powder of *sunmul* on the quality characteristics of noodles. *J Korean Soc Food Sci Nutr* 35: 199-204.
17. Chung HJ, Jung JY, Kim WJ. 2005. Influence of addition of membrane-filtered powder of *sunmul* on the quality characteristics of yogurt. *J Korean Soc Food Sci Nutr* 34: 1579-1585.
18. Pomeranz Y, Shogren MD, Finney KF, Bechtel DB. 1977. Fiber in breadmaking-effects on functional properties. *Cereal Chem* 54: 25-41.
19. Lee EH, Choi OJ, Shim KH. 2004. Properties on the quality characteristics of muffin added with sugaring ume puree. *Food Industry and Nutrition* 9(1): 58-65.
20. Chang HG. 2004. Quality characteristics of sponge cakes containing various levels of millet flour. *Korean J Food Sci Technol* 36: 952-958.
21. Chung HJ, Joo SY, Kim WJ. 2005. Preparation of Jeung-Pyun added with ultrafiltered powder of *sunmul*. *Korean J Food Cookery Sci* 21: 647-654.
22. Kim IH, Ha SC, Rhee IK. 2002. Rheological changes of dough and breadmaking qualities of wheat flour with additions of soy flour. *Korean J Food Preservation* 9: 418-424.
23. Woo IA, Nam HW, Pyun JW. 2003. Quality characteristics of bread prepared with the addition of curry powder. *Korean J Soc Food Cookery Sci* 19: 447-450.
24. Arora A, Camire ME. 1994. Performance of potato peels in muffins and cookies. *Food Res Intern* 27: 15-22.
25. Ahn JM, Song YS. 1999. Physicochemical and sensory characteristics of cakes added sea mustard and sea tangle powder. *J Korean Soc Food Sci Nutr* 28: 534-541.
26. Joo SY, Choi MH, Chung HJ. 2004. Studies on the quality characteristics of function, muffin prepared with different levels of grape seed extract. *J Korean Soc Food Culture* 19: 267-272.
27. Grigelmo-Miguel N, Carreras-Boladeras E, Martin-Belloso O. 1999. Development of high-fruit-dietary-fiber muffins. *Eur Food Res Technol* 210: 123-128.
28. Im JG, Kim YS, Ha TY. 1998. Effect of sorghum flour addition on the quality characteristics of muffin. *Korean J Food Sci Technol* 30: 1158-1162.
29. Hong GH, Song GS, Kim YS. 2003. Quality of bread prepared with wheat flour and oak mushroom powder. *Food Sci Biotechnol* 12: 146-150.
30. Kim IS, Lee YT, Song HM. 2002. Effect of barely germ on sugar snap cookie quality. *Food Sci Biotechnol* 11: 515-519.
31. Kwon BM, Jeon SW, Kim DS. 2003. Quality characteristics of sponge cake with addition of laver powder. *J Korean Soc Food Sci Nutr* 32: 1278-1284.

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