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Research Note

Physicochemical and Sensory Evaluation of Whole Soybean Curd Supplemented with Pine Needle Powder

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ABSTRACT: To develop functionally and nutritionally improved whole soybean curd (WSC), the effects of partial (0～4%) replacement with pine needle powder (PNP) on the quality characteristics of WSC were investigated. The moisture content and pH ranged from 76.96～77.80% (wet basis) and 6.69～6.74, respectively, with no considerable differences. Lightness significantly decreased with higher PNP content in the formulation ($P<0.05$), as indicated by visual observation that the color of WSC became darker. Redness and yellowness also significantly decreased ($P<0.05$). The texture profile analysis indicated that WSC containing PNP was softer and less cohesive than control WSC. 2,2-Diphenyl-1-picrylhydrazyl and 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) radical scavenging activities significantly increased ($P<0.05$) with higher substitution of PNP, and they were well correlated. Results from the consumer test revealed that WSC with 1% PLP received the most favorable acceptance scores for sensory attributes, including overall acceptability. The present study indicated that the characteristics of PNP may play a role in improving WSC quality in terms of physicochemical, sensorial, and antioxidant characteristics.

Keywords: whole soybean curd, pine needle powder, physicochemical, sensory, antioxidant

INTRODUCTION

Soybean curd (tofu), a traditional soybean product composed mainly of protein and fat, is a prime component of Asian food culture (1). The consumption and popularity of tofu continues to grow due to its status as a healthy vegetable protein. On the other hand, soybean curd residue (SCR), a byproduct of soybean food processing, is discarded as agro-industrial waste and has raised concerns over severe environmental pollution (2). Nevertheless, SCR is rich in fat, starch, protein, and sugar and has been recognized as a valuable ingredient due to its plentiful dietary fiber content and various bioactive compounds (3). Whole soy bean curd (WSC) is made from soymilk after removal of SCR, and WSC includes SCR along with a curdling agent added to the coagulation. WSC can be made in a relatively short period of time compared to soybean curd, and losses of soluble and insoluble proteins, dietary fibers, and other nutritional components can be lessened (4).

Korean pine (*Pinus koraiensis*), a large conifer with important economic value, is found across Korea, Japan, and the Northeastern part of China (5). *P. koraiensis* has long been used in Oriental fork medicine due to its anti-fatigue, anti-aging, and anti-inflammatory effects as well as a food supplement (6). Its leaves (called pine needles) contain large amounts of protein, vitamins, and minerals (7) and are utilized extensively as an important food ingredient (8). Therefore, the development of a novel functional food containing pine needles would be beneficial owing to its physiological activities and therapeutic effects. Pine needle powder (PNP) has been successfully used in noodles (9), meat (10), rice cupcakes (11), rice madeleine (12), and tofu (13).

Rapidly growing concerns about healthy diets and increased demand for the use of novel food ingredients, especially soybean products, have led to investigations of WSC with value-added ingredients, such as PNP. To the best of our knowledge, little to no information is available on the effect of PNP on the physicochemical and sensory properties of WSC. Pine needles contain antioxidants and other nutritional components, and if added to foods as a supplement, it can provide beneficial effects on nutrition and health. Therefore, it would be beneficial to develop a novel formulation of WSC products with PNP.

In this study, PNP was supplemented to soybean milk in order to improve its functional and nutritional qual-

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ities. The aim of this research was to determine the effects of PNP addition (0～4%) on the physicochemical and sensory characteristics of WSC. The antioxidant properties of WSC were also determined.

MATERIALS AND METHODS

Materials

PNP was procured from Garunara (Seoul, Korea), and soybeans were purchased from a local market. Microbial transglutaminase (TGase) and silicon defoamer were purchased from Ajinomoto Co. (Tokyo, Japan) and Dow Corning Korea Ltd. (LS-303, Seoul, Korea), respectively.

WSC preparation

TGase-treated WSC was produced according to the method used by Jin and Lee (14) with slight modifications. Briefly, an appropriate amount of yellow soybeans (57.6～60.0 g), PNP (0.0～2.4 g), distilled water (240 mL), and defoamer (1.2 mL) were mixed and homogenized (ULTRA-TURRAX, IKA, Staufen, Germany) at 10,000 rpm for 2 min. The mixture was partially heated to 80°C for 10 min to produce the soybean milk, which was then cooled down to 50°C at room temperature and homogenized again at 10,000 rpm for 5 min after adding TGase (3 g). Subsequently, the soybean milk was incubated at 50°C for 1 h, followed by heat treatment at 80°C for 20 min. WSC (0～4% depending on the amount of replacement) was then stored in a 4°C refrigerator until use.

Physicochemical analyses

A sample (5 g) of WSC was mixed with 45 mL of distilled water and homogenized for 10 min. The mixture was held at ambient temperature for 3 h to separate the solid and liquid phases. The pH of the supernatant was measured using a pH meter (pH/Ion 510, Oakton Instruments, Vernon Hills, IL, USA). Moisture content was obtained by drying a specific amount (5 g) of WSC sample to a constant weight at 50°C in an oven (FOL-2, Jeio Tech Co., Daejeon, Korea), and the results were reported on a wet basis (w.b.).

Texture profile analysis (TPA) of WSC samples (3×3×3 cm) was performed using a computer-controlled Advanced Universal Testing System (model LRX*Plus*, Lloyd Instrument Limited, Fareham, Hampshire, UK) at room temperature. Each sample was compressed twice to 30% of its original height using a cylindrical-shaped probe (12.45 mm in diameter) at 3 mm/s speed, and the trigger was set at 0.4 $\mathrm{kg_f}$. Hardness is expressed as the peak height of the force on the first bite, whereas cohesiveness quantifies the internal resistance of food structure (9). Color determination was measured using a Chromameter (model CM-600d, Minolta Co., Osaka, Japan) set for CIELAB color space, and reported as CIE L^*-value (lightness), a^*-value (redness), and b^*-value (yellowness).

Determination of free radical scavenging activity

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activities of the samples were measured based on their hydrogen-donating or radical scavenging activity using a stable DPPH radical. The assay was performed as previously described by Blois (10) with some modifications. Briefly, 0.2 mM solution of DPPH radical in ethanol was prepared, after which 5 mL of this solution was added to 1 mL of sample solution in ethanol at different concentrations and then shaken and left to stand for 10 min. Decolorization of DPPH-donated protons was determined by measuring the absorbance at 517 nm using a spectrophotometer (Optizen 2020 UV Plus, Mecasys Co., Ltd., Daejeon, Korea). The scavenging activity of DPPH radical was calculated using the following equation:

$$\text{Radical scavenging activity (\%)} = \frac{\text{Absorbance}_{\text{control}} - \text{Absorbance}_{\text{sample}}}{\text{Absorbance}_{\text{control}}} \times 100$$

The spectrophotometric analysis of 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging activity was measured according to the method used by Re et al. (11) with slight modifications. The $\mathrm{ABTS^{+}\cdot}$ was produced by the reaction between 7.4 mM ABTS in H_2O and 2.6 mM potassium persulfate during storage in the dark at room temperature for 12～16 h. Before use, $\mathrm{ABTS^{+}\cdot}$ solution was diluted with methanol to obtain an absorbance of 1.1±0.02 at 734 nm. Subsequently, 3 mL of $\mathrm{ABTS^{+}\cdot}$ solution was added to 0.1 mL of sample. After 10 min, the percent inhibition at 734 nm was calculated for each concentration relative to the blank absorbance.

Sensory evaluation

The Hedonic test was used to determine the degree of overall preference scores for WSC. For this study, 30 untrained volunteer consumers were recruited from the University and informed that they would be evaluating WSC. Five samples (3×3×3 cm) were presented in random order, and panelists were asked to evaluate the acceptability of color, flavor, taste, chewiness, and overall acceptability. Consumer participants were asked to evaluate preference levels using a seven-point hedonic scale (7=like extremely, 6=like moderately, 5=like slightly, 4=neither like nor dislike, 3=dislike slightly, 2=dislike moderately, and 1=dislike extremely). Panelists received a tray containing the samples at room temperature (ran-

Table 1. Physicochemical properties of WSC supplemented with different levels of PNP

Properties	PNP level (%)				
	0	1	2	3	4
Moisture content (%)	77.80±0.32^a	77.40±0.14^a	77.32±0.23^a	77.64±0.26^{ab}	76.96±0.62^b
pH	6.74±0.01^a	6.72±0.01^b	6.72±0.00^b	6.71±0.01^b	6.69±0.01^c
Color					
L^*	81.81±0.18^a	78.60±0.12^b	74.39±0.18^c	73.70±0.15^d	71.79±0.11^e
a^*	1.87±0.07^a	1.19±0.09^b	1.16±0.07^b	1.16±0.08^b	1.10±0.07^c
b^*	20.79±0.43^a	18.29±0.29^b	17.29±0.17^c	17.00±0.32^c	16.98±0.20^c
Texture					
Hardness (N)	2.42±0.08^a	2.38±0.07^a	2.22±0.11^b	1.74±0.07^c	1.22±0.06^c
Cohesiveness (−)	0.34±0.04^a	0.30±0.03^b	0.31±0.01^b	0.29±0.02^b	0.24±0.04^c

Means with different letters (a-e) in the same row are significantly different according to Duncan's multiple range test ($P<0.05$).

domly coded using a three-digit number), a glass of water, and an evaluation sheet. Participants were instructed on how to evaluate the samples and were not required to expectorate or consume the entire volume served. Overall acceptance was evaluated first, and another session was held to evaluate the rest of the attributes. There was an inter-stimulus interval of 30 s imposed between samples, to allow time to recover from adaptation. Participants were advised to rinse their palates between samples. Enough space was given to handle the samples and questionnaire, and evaluation time was not constrained. No specific compensation was given to the participants.

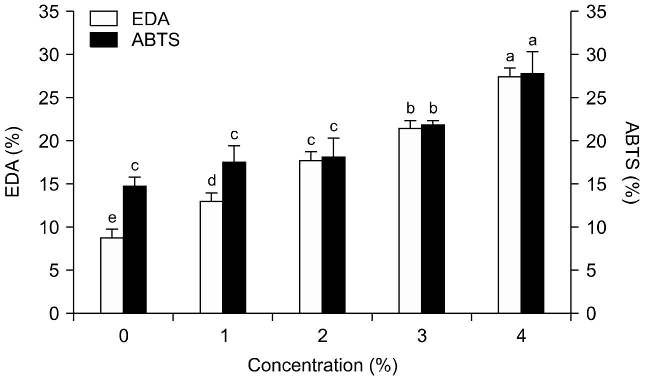

Fig. 1. DPPH and ABTS radical scavenging activities of WSC supplemented with different levels of PNP. Means within the same activity without a common letter (a-e) are significantly different ($P<0.05$).

Statistical analysis

Each measurement was conducted five times, except for hardness ($n=15$), antioxidant activities ($n=3$), and sensory evaluation ($n=30$). The experimental data were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure. Mean values were compared using Duncan's multiple range test. The significance was defined at the 5% level.

RESULTS AND DISCUSSION

Physicochemical characteristics

Table 1 describes the physicochemical characterization of WSC supplemented with different levels of PNP. Moisture of the samples ranged from 76.96 to 77.80% (w.b.), and the control samples exhibited the highest moisture content. The pH values of WSC ranged from 6.69 to 6.74, and decreased upon addition of increasing amounts of PNP but the changes were little. Thus, it seems that PNP supplementation resulted in WSC of slightly lower moisture content and pH.

Surface color, together with texture, is a very important element for consumers' initial acceptability (12). WSCs made with PNP were significantly different from the control ($P<0.05$). The L^*-value for the control (81.81±0.18) was higher than any of the values seen for WSCs containing PNP. This was also true for a^*- and b^*-values. L^*-values decreased significantly upon addition of increased amounts of PNP ($P<0.05$). a^*- and b^*-values showed similar trends but no significant differences were found among the 1~3% samples in a^*-values and the 2~4% samples in b^*-values. Similar color changes were reported for cookies (13) and tofu (14) supplemented with PNP.

The TPA results presented in Table 1 show that addition of an increasing amount of PNP from 0 to 4% resulted in a reduction of WSC hardness from 2.42 to 1.22 N as well as a reduction of cohesiveness values from 0.24 to 0.34. Cohesiveness is a dimensionless value used to define the internal resistance of WSC structure, and it an indicator of the ability of a material to stick together (9,15). These results show that the WSC containing PNP is softer and less cohesive when compared to the control WSC. Woo et al. (16) also reported a reduced hardness of tofu with added roasted sorghum powder.

Free radical scavenging activities

Antioxidant activities were investigated based on DPPH radical-scavenging activity and ABTS radical cation assay. The usage of PNP in the WSC formulation enhanced the levels of antioxidant activity (Fig. 1). This can be attributed to the inherent rich antioxidant capacities of PNP as compared to soybean powder. There were significant increases in electron donating ability (EDA) values of bound phenolic extracts in the samples with PNP as compared to those of the control sample ($P<0.05$). EDA values increased significantly with increased levels of PNP ($P<0.05$). ABTS values also significantly increased after addition of 3% PNP compared to the control samples ($P<0.05$), whereas no significant differences were found in ABTS values among the control, 1, and 2% samples ($P>0.05$). Samples enriched with 4% PNP showed the highest antioxidant potential. Data also showed a positive correlation between the antioxidant capacities of the various samples. EDA increased as ABTS increased. A similar trend was reported by Kilci and Gocmen (17) for tarhana (Turkish fermented cereal food) supplemented with oat flour. The antioxidant capacities of various extracts are mainly due to the total phenolic content and total phenolic acids (18).

Sensory findings

Color, flavor, taste, chewiness, and overall acceptance of control WSC and PNP-supplemented WSC were evaluated, and the results are presented in a radar plot (Fig. 2). The highest flavor, taste, and overall acceptance scores were obtained for samples supplemented with 1% PNP (5.19, 5.16, and 5.87, respectively). Color values obtained by the consumer acceptability test of PNP-supplemented WSC varied between 3.63 and 6.47. The control received the highest score, and the values decreased with increased levels of PNP. Excessive addition of PNP seemed to have a detrimental effect on this property. Similarly, the highest chewiness value of 4.61 was obtained in the control samples, but it was not significantly different from that of the 1% samples ($P>0.05$). Overall acceptability scores of WSC containing PNP were the highest for the 1% samples as mentioned above. The results of the sensory analysis showed that supplementation WSC with 1% PNP improved most of the sensory attributes evaluated. However, further increasing the levels of PNP seemed to have some undesirable sensorial effects.

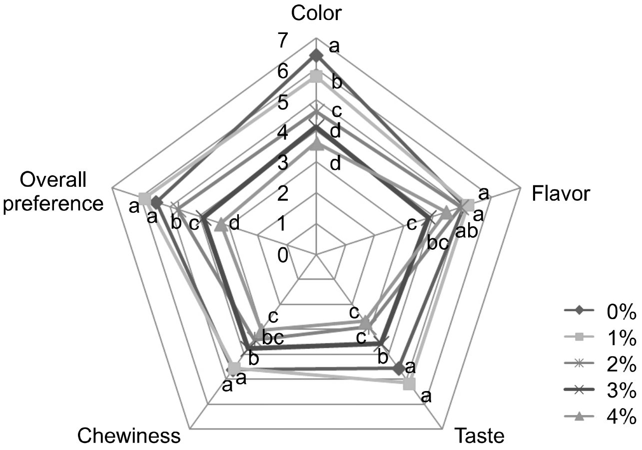

Fig. 2. Radar plot of sensory results of WSC supplemented with different levels of PNP. Means within the same attribute without a common letter (a-d) are significantly different ($P<0.05$).

In conclusion, the present study established the feasibility of using PNP as a supplement for enhancing the nutritional quality of WSC. The results of this study showed that nutritious WSC can be prepared by supplementing 1% PNP, with increased physicochemical, sensorial, and antioxidant characteristics.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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