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ARTICLE

Comparison of Nanopowdered and Powdered Ginseng-added Yogurt on Its Physicochemical and Sensory Properties during Storage

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Abstract

This study was conducted to compare the physicochemical and sensory properties of yogurt added with nanopowdered ginseng (NPG) and powdered ginseng (PG) of different concentrations (0.1, 0.3, 0. 5, and 0.7%) (w/v) during the storage at 7°C for 20 d. The pH and viscosity values of yogurt added NPG or PG decreased during the storage. The pH values of the yogurt samples were ranged from 4.0 to 4.6 as a reflective of the fresh state. Viscosity values of yogurt with NPG at lower concentrations 0.1 and 0.3% (w/v) showed higher values during increased storage time. DPPH radical scavenging activity was significantly higher in the NPG-added yogurt than in the PG during the storage period (p<0.05). The lactic acid bacteria (LAB) counts ranged from 3.0×10^9 to 1.3×10^9 and 2.2×10^9 to 1.1×10^9 CFU/mL in 0.3% NPG and PG-added yogurts, respectively. Increased storage period showed decrease in LAB counts irrespective of the type of ginseng powder and storage period. In sensory test, 0.1 and 0.3% NPG-added yogurt showed similar results to control in yellowness, viscosity, and bitterness. Based on the data obtained from the present study, it was concluded that the concentrations 0.1 and 0.3% (w/v) of NPG could be used to produce NPG-added yogurt without significant adverse effects on physicochemical and sensory properties, and enhance functional value of yogurt.

Key words: yogurt, nanopowdered ginseng, viscosity, antioxidant activity

Introduction

Yogurt is an important fermented dairy products that contains all nutrients and probiotics which are consumed for many generations in various countries like India, China, Japan, South Korea and other asian countries (Ahn e*t al.,* 2012; Gobbetti *et al*., 2004). Addition of plant extract such as date, wheat bran, orange, and other fruits into yogurt were studied to increase functional and quality value of the yogurt (Aportela-Palacios *et al.,* 2005; Fernandez-Garcia *et al*., 1998; García-Perez *et al*. 2005). The quality of yogurt increased by serum retention in the addition of 0.5% barley β-glucan; retaining yellow green color by asparagus shoots (Brennan and Tudorica, 2008; Sanz *et al*., 2008). Further, the functional quality increased by the addition of plant polyphenols such as peanut sprouts extract rich in polyphenol like resveratrol (Ahn *et al*., 2012). However, the addition of certain pharmaceutical plant like ginseng to the dairy products is very limited. Recently, Jager *et al*. (2010) studied that pasteurization did not affect the functional value of the ginseng and it can be suitable for the supplementation of various dairy products.

Panax ginseng is widely seen in South Korea, China, America, and India, and has been used as a general tonic to increase vitality and health for old people in oriental medicine (Park, 1996). It has various other beneficial functions, such as prevention of cancer risk associated with smoking, can scavenge superoxide radicals (Keum *et al*., 2000), inhibit lipid peroxidation through transition metal chelation (Keum *et al*., 2000). The increase in the functional value of the ginseng mainly due to presence of various functional ingredients like ginsenosides, complex carbohydrates, phytosterols, and trace minerals. Nanosizing of various plant and animal foods increase the functional value in peanut sprouts and chitiosan (Ahn at al., 2012; Park *et al*., 2007; Seo *et al*., 2011). However, there are no informations on developing the functional yogurt which incorporates the nanopowdered or powdered ginseng. Due to the increase concern of health among consumers and to meet the demand of functional yogurt, a new functional yogurt should be developed using the appropriate functional ingredients, such as nanopowdered

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ginseng. Therefore, the objective of the present study was to compare the physicochemical and sensory properties of the yogurt added with nanopowdered and powdered ginseng during storage.

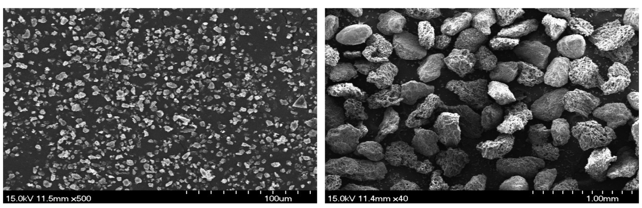
Materials and Methods

Materials

Commercial Korea white ginseng (four year old) was purchased from Kyoungdong market (Seoul, Korea). Ginseng roots were cut into 1 cm thickness, milled, passed through 250 μm sieve powdered ginseng (PG) by the dry milling method (Apexcel Co., Korea). Nanopowdered ginseng (NPG) was also produced by the drymilling method by Apexcel Co. (Korea). They were stored at 4°C until use. All chemicals were purchased from Sigma Chemical Co. (USA), and all solvents were of chromatographic grade.

Manufacture of yogurt added NPG or PG

Milk containing 3.6% fat and 13.4% total solids was added with 3.7% (w/v) skim milk powder, 0.2% of pectin and different concentrations (0.1, 0.3, 0. 5, and 0.7%) of NPG of the average particle size of 600-1,000 nm in Fig. 1A or PG with the average particle size of 300 to 500 μm in Fig. 1B are blended with Lab-blender (MS3040, MTops Misung, Korea) at 400 rpm for 5 min. Each batch was made with 10 L of milk (2 L per treatment) at lab-scale level. The milk added with NPG or PG was heated at 90°C for 10 min in water bath and cooled to approximately 42°C. 0.02% commercial starter culture (Chr. Hansen, Pty. Ltd, Australia) in freeze-dried direct-to-vat set form containing *Lactobacillus bulgaricus*, *Streptococcus thermophilus*, and *Bifidobacterium bifidum* was added and fermented at 43°C for 6 h until the final pH was reached at 4.5. After fermentation, each yogurt sample was stored for 0, 5, 10, 15, and 20 d at 7°C in a refrigerator to evaluate the physicochemical and sensory properties. Each batch of yogurt making was done in triplicate.



Nanopowdered ginseng Powdered ginseng

Fig. 1. Scanning electron microscope image of nanopowdered and powdered ginseng.

pH

The pH values of the NPG- or PG-enriched yogurt samples were measured using a glass electrode pH meter (Orion 900A, USA).

Viscosity

The viscosity of yogurt samples (100 mL) was measured after mixing of the sample for 5 min at room temperature using a Brookfield viscometer (Model LVDV I+, Version 3.0, USA) with a spindle no. 2 at 60 rpm. All samples were measured in triplicate.

Microbial analysis

MRS agar (Difco Laboratories, USA) was used for lactic acid bacteria counting. One milliliter of yogurt samples was diluted with 9 mL of sterile peptone and water diluents. Subsequent dilutions of each sample were plated in triplicate and incubated at 37°C for 48 h.

DPPH radical scavenging activity

The free radical scavenging activities of NPG- or PG-added yogurt were measured by the 2,2-diphenyl-1-picryl-hydrazil (DPPH) method proposed by Brand-Williams *et al.* (1995). Briefly, 0.1 mM solution of DPPH in ethanol was prepared and 1.0 mL of this solution was added to 0.5 mL of samples. After 20 min, the absorbance was measured at 525 nm. The DPPH radical scavenging activity was calculated according to the following equation:

$$\text{DPPH radical scavenging activity (\%)} = [(A_0 - A_1)/A_0] \times 100$$

Where A_0 was the absorbance of the control and A_1 was the absorbance in the presence of the NPG or PG supplemented yogurt.

Color measurement

Color values of yogurt sample added with NPG or PG were measured using a Hunter colorimeter (Minolta CT-310, Japan) after calibrating its original value with a standard plate (X=97.83, Y=81.58, Z=91.51). Measured *L**, *a**- and *b**- values were used as indicators of lightness, redness and yellowness, respectively.

Sensory analysis

The sensory evaluation was performed by 8-trained panelists, who were the graduate students (4 males and 4 females) in the Dairy Products Laboratory (Food Science and Technology Department, Sejong University, Korea), aged 25 to 33 yr, and familiar with yogurt consumption. Panelists were trained in 2 sessions using a 7-point scale, where 1 represented very weak peanut flavor, yellow color, and taste, and 7 represented very strong peanut flavor, yellow color, and taste. Reference samples prepared at the level of 0.1, 0.5, and 0.7% NPG or PG-added yogurt were kept in a closed cup for 0, 5, 10, 15, and 20 d. To test the flavor of samples, the panelists were asked to open the closed cup and sniff the headspace above the samples. The samples were then scored.

Statistical analysis

All statistical analyses were performed using SAS version 9.0 (SAS Institute, 2002). An ANOVA was performed using the general linear models procedure to determine significant differences among the samples. Means were compared by using Duncan's multiple range test ($p<0.05$).

Results and Discussion

NPG of the average particle size of 600-1,000 nm in Fig. 1A or PG with the average particle size of 300 to 500 μm in Fig. 1B are added in the yogurt and their effect on yogurt are discussed.

pH

The changes in pH values of yogurt samples added with various concentrations (0.1, 0.3, 0.5, and 0.7%) of NPG or PG during 20 d of storage at 7°C are shown in Fig. 2. The pH values of the yogurt samples were ranged from 4.0 to 4.6 as a reflective of the fresh state (Seo *et al.*, 2009). During storage pH value of all yogurt samples were in the normal range at 0 d. Increasing the storage period from 0 to 20 d significantly decreased the pH values from 4.6 to 4.15, indicating that the yogurt quality was acceptable during 20 d storage ($p<0.05$). Dramatic decrease of pH was observed during 20 d of storage irrespective of concentrations (0.1, 0.3, 0.5, and 0.7%) of NPG or PG addition. Lower pH was most likely due to the higher production of lactic acid during the storage period of 20 d (Ahn *et al.*, 2012; Kim *et al.*, 2011). Sugars like lactose in milk can be hydrolyzed by the enzymes of LAB, which can be further metabolized into lactic acid (Kim *et al.*, 2011). Ahn *et al.* (2012) also observed that addition of nanopowdered peanut sprouts decreased the pH values during the storage period. However, pH was significantly lower in PG than in NPG-added yogurt, irrespective of its concentrations and its storage time ($p<0.05$).

Viscosity

The viscosity values of yogurt samples added with various concentrations (0.1, 0.3, 0.5, and 0.7%) of NPG and PG during 20 d of storage at 7°C are shown in Fig. 3. At 0 d storage, viscosity values greatly differed by the addition of NPG and PG. Higher the concentration of NPG addition to the yogurt lowered the viscosity value during the storage time of 20 d. However, viscosity of NPG addition at lower concentrations (0.3 and 0.5%) was significantly higher than the PG addition to the yogurt, irrespective of its storage period ($p<0.05$). Increasing the viscosity was most likely due to the production of viscous exopolysaccharides along with the lactic acid by LAB during the storage (Vijayendra *et al.*, 2008). Further the viscosity values were greatly increased during 10 d and

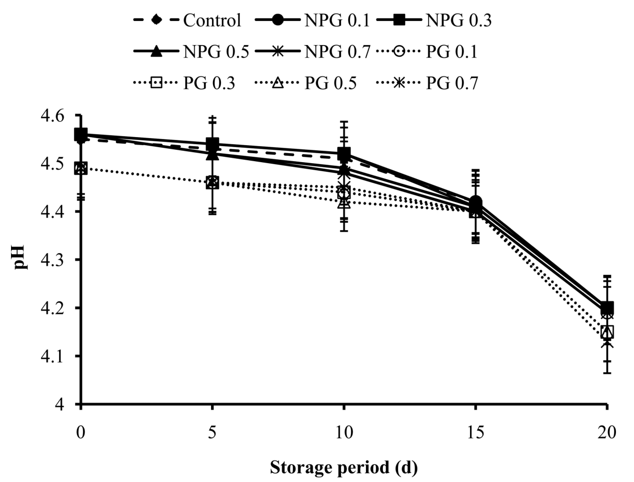


Fig. 2. Changes in pH of nanopowdered ginseng and powdered ginseng added yogurt stored at 7°C for 20 d. NPG, nanopowdered ginseng; PG, powdered ginseng

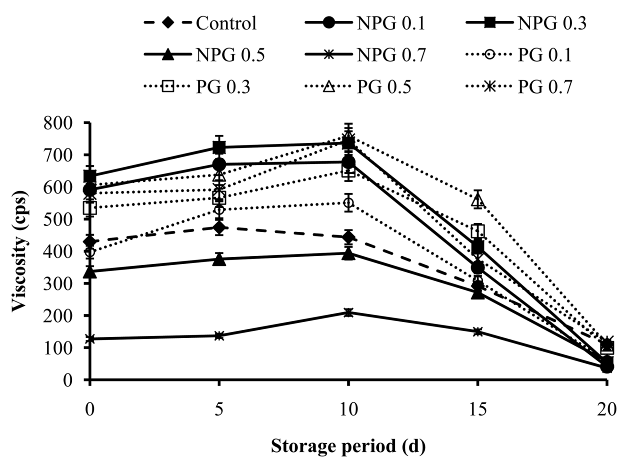


Fig. 3. Changes in viscosity of nanopowdered ginseng and powdered ginseng added yogurt stored at 7°C for 20 d. NPG, nanopowdered ginseng; PG, powdered ginseng

sharply decreased during the storage period of 20 d, irrespective of the type and concentrations of ginseng added to the yogurt. It was highly correlated with the pH of NPG- and PG-added yogurt.

DPPH

The changes in DPPH of NPG- and PG-added yogurts during storage at 7°C for 20 d are shown in Fig. 4. DPPH radical scavenging activity was found to be lower in the control (without addition of NPG or PG). However, increasing the concentrations of NPG or PG (0.1, 0.3, 0.5, and 0.7%) significantly increased the DPPH radical scavenging activity in NPG- or PG-added yogurt at 0 d of storage (p<0.05). NPG and PG are rich in bioactive compounds, such as terpenoids which has greater antioxidant activity (Kitts *et al*., 2000). However, the DPPH radical scavenging activity was found to be greater in NPG than PG irrespective of its concentrations added to yogurt. NPG provides greater surface area and more exposure of functional group, thus it leads to greater antiradical scavenging activity (Ahn *et al*., 2012; Park *et al.,* 2007). Higher the concentration of NPG-added yogurt (0.5 and 0.7%) was found to be higher radical scavenging activity during the storage of yogurt. Recently some researchers confirmed that addition of ginseng powder at a concentration of 0.1% (w/v) provides 10 to 12 mg of ginsenosides per 100 mL of milk which has various health beneficial functions.

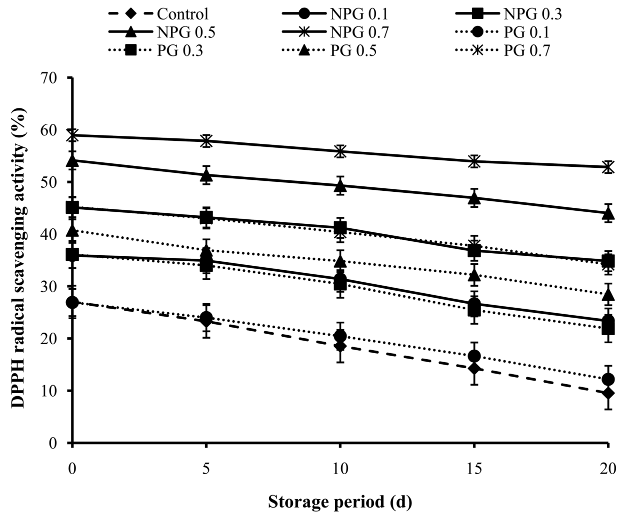


Fig. 4. Changes in DPPH radical scavenging of nanopowdered ginseng and powdered ginseng added yogurt stored at 7°C for 20 d. NPG, nanopowdered ginseng; PG, powdered ginseng

LAB counts

The changes in *L. bulgaricus, S. thermophilus*, and *B. bifidum* of NPG- and PG-added yogurt 0.7%) and types of ginseng (PG or NPG) added to the yogurt are shown in Table 1. Increasing the concentrations of NPG and PG greatly increase the microbial count at 0 d. Increasing the addition of ginseng provides nutrients for the growth of microbes. Ahn *et al*. (2012) also showed that nanopowder and powdered peanut sprouts provides greater surface area for the microbial growth in yogurt. The increased in the storage period of 20 d showed the decrease in the LAB counts in NPG- and PG-added yogurt. However, the decrease in LAB counts was not much in PG and NPG-added yogurt. Based on these data, PG or NPG does not affect the growth of LAB in ginseng added yogurt.

Color

The changes in color of NPG and PG-added yogurt

Table 1. Changes in viable cell counts of nanopowdered ginseng and powdered ginseng-added yogurt stored at 7°C for 20 d[1)]

(unit : CFU/mL)

Concentration (%, w/v) of sample	Storage period (d)				
	0	5	10	15	20
Control	$2.9{\pm}2.0{\times}10^{9c}$	$2.7{\pm}5.0{\times}10^{9cd}$	$2.3{\pm}4.5{\times}10^{9c}$	$2.1{\pm}2.6{\times}10^{9a}$	$1.8{\pm}4.4{\times}10^{9ab}$
NPG[2)] (0.1)	$2.9{\pm}1.5{\times}10^{9c}$	$2.6{\pm}2.0{\times}10^{9cd}$	$2.5{\pm}5.0{\times}10^{9abc}$	$1.7{\pm}2.5{\times}10^{9bc}$	$1.5{\pm}4.7{\times}10^{9bc}$
NPG (0.3)	$3.0{\pm}1.0{\times}10^{9bc}$	$3.3{\pm}3.1{\times}10^{9bc}$	$3.0{\pm}0.6{\times}10^{9ab}$	$1.9{\pm}1.5{\times}10^{9ab}$	$1.3{\pm}0.6{\times}10^{9cd}$
NPG (0.5)	$3.0{\pm}0.6{\times}10^{9bc}$	$2.2{\pm}1.0{\times}10^{9d}$	$2.3{\pm}3.2{\times}10^{9c}$	$2.0{\pm}1.5{\times}10^{9ab}$	$1.6{\pm}1.7{\times}10^{9bc}$
NPG (0.7)	$3.7{\pm}3.0{\times}10^{9a}$	$4.1{\pm}5.8{\times}10^{9ab}$	$2.5{\pm}2.0{\times}10^{9abc}$	$1.8{\pm}2.6{\times}10^{9abc}$	$1.6{\pm}1.5{\times}10^{9bc}$
PG[3)] (0.1)	$2.5{\pm}2.0{\times}10^{9d}$	$2.7{\pm}1.5{\times}10^{9cd}$	$2.3{\pm}2.6{\times}10^{9c}$	$1.5{\pm}2.6{\times}10^{9c}$	$0.9{\pm}1.5{\times}10^{9d}$
PG (0.3)	$2.2\ {\pm}2.3{\times}10^{9c}$	$2.8{\pm}0.6{\times}10^{9cd}$	$2.4{\pm}3.5{\times}10^{9bc}$	$1.7{\pm}1.0{\times}10^{9bc}$	$1.1{\pm}1.0{\times}10^{9d}$
PG (0.5)	$3.1{\pm}2.1{\times}10^{9bc}$	$3.8{\pm}5.6{\times}10^{9ab}$	$3.1{\pm}3.4{\times}10^{9a}$	$1.9{\pm}2.0{\times}10^{9ab}$	$1.8{\pm}2.1{\times}10^{9ab}$
PG (0.7)	$3.3{\pm}5.0{\times}10^{9ab}$	$4.4{\pm}3.0{\times}10^{9a}$	$3.0{\pm}1.5{\times}10^{9ab}$	$2.2{\pm}2.0{\times}10^{9a}$	$2.1{\pm}3.3{\times}10^{9a}$

[1)]Values within the same column with different superscripts are significantly different at p<0.05

[2)]NPG, nanopowdered ginseng with size 600-1000 nm

[3)]PG, powdered ginseng with size 300-500 μm samples stored at 7°C for 20 d are presented in Table 2. The L* values of the yogurt added with different concentrations (0.1, 0.3, 0.5, and 0.7%) of NPG were significantly differ at 0 d (p<0.05). However, L* values of the yogurt added with different concentrations (0.1, 0.3, 0.5, and 0.7%) of PG were not significantly different at 0 d (p>0.05). Increasing the concentration of NPG addition in yogurt was not increased the value at 0 d. Further a*-value was found to be higher in PG-added yogurt than in NPG. Increasing the concentrations of NPG- or PG-addition at 0 d markedly increased the b*-values, most likely due to the light yellow color of NPG or PG. Similarly Ahn *et al*. (2012) also reported that the addition of nanopowdered peanut sprouts in yogurt greatly increased the b*-values during the increase storage period due to the light yellow color of the peanut sprouts. Some other researchers also reported that addition of apple or orange fiber in the yogurt increased the yellow color in the yogurt (Garcia-Perez *et al*., 2005; Staffolo *et al*., 2004). Therefore, the results indicated that there were no considerable changes in color values of the NPG or PG-added yogurt samples at various concentrations during the 20 d storage.

Sensory evaluation

The sensory properties of NPG- and PG-added yogurt stored at 7°C for 20 d are shown in Table 3. Appearance, flavor, taste and texture properties were analyzed with increasing concentrations (0.1, 0.3, 0. 5, and 0.7%) of NPG and PG addition at the storage period of 20 d. The yellowness scores for the NPG- or PG-added yogurt at different concentrations and for the control were not significantly different at 0 d (p>0.05). However, during the extended storage period of 20 d, the yellowness score increased with increase concentrations of NPG or PG addition to the yogurt. Increase in earthy flavor was most likely due to the increase oxidation of ginseng at various concentrations of PG or NPG addition to the yogurt during the storage period of 20 d. However, PG favored greater oxidation than NPG during the storage period of 20 d. In the taste test, bitterness was found to be significantly increased during 0 to 20 d storage, irrespective of NPG or PG addition to the yogurt (p<0.05). However, at lower concentrations (0.1 and 0.3%) of NPG addition to the yogurt bitterness values did not significantly differed than control during its storage period. Ahn *et al*. (2012) are also reported that addition of nanopeanut sprout in yogurt greatly increased the bitterness score in yogurt during the storage periods. In the texture test, viscosity score increased with increase concentrations of PG addi-

Table 2. Changes in color of nanopowdered ginseng and powdered ginseng-added yogurt stored at 7°C for 20 d[1)]

Concentrations (%,w/v) of sample		Storage period (d)														
		0			5			10			15			20		
		L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Control		91.03±0.05^{c}	-3.41±0.01^{e}	6.91±0.01^{h}	90.35±0.01^{b}	-3.07±0.07^{ab}	6.82±0.09^{g}	89.98±0.02^{d}	-3.33±0.04^{e}	6.71±0.02^{h}	90.06±0.03^{d}	-3.29±0.02^{d}	6.73±0.01^{h}	89.4±0.7^{c}	-3.4±0.02^{cd}	7.08±0.01^{g}
NPG[2)]	0.1	89.48±0.05^{d}	-3.5± 0.03^{f}	7.44±0.02^{e}	86.68±0.05^{h}	-3.77±0.05^{b}	7.11±0.03^{f}	88.55±0.01^{e}	-3.64±0.01^{fg}	7.38±0.01^{c}	87.1±0.08^{g}	-3.86±0.02^{g}	7.63±0.01^{d}	88.17±0.01^{e}	-3.52±0.06^{cd}	7.55±0.03^{d}
	0.3	88.57±0.04^{e}	-3.48±0.02^{f}	7.62±0.01^{c}	86.95±0.05^{g}	-3.60±0.01^{b}	8.33±0.01^{b}	87.79±0.02^{g}	-3.42 ±0.00^{f}	8.06±0.03^{a}	87.67±0.10^{f}	-3.42±0.04^{e}	7.98±0.07^{c}	87.25±0.05^{g}	-3.53±0.02^{d}	8.08±0.01^{c}
	0.5	88.43±0.01^{f}	-3.39±0.03^{e}	8.05±0.00^{b}	87.27±0.10^{f}	-3.41±0.02^{b}	7.98±0.02^{c}	87.59±0.02^{h}	-3.43 ±0.05^{f}	7.91±0.02^{b}	87.01±0.14^{h}	-3.49±0.03^{f}	8.2±0.01^{b}	86.91±0.07^{h}	-3.17±0.01^{bcd}	8.44±0.05^{b}
	0.7	89.46±0.01^{d}	-3.16±0.02^{d}	8.11±0.03^{a}	87.9±0.02^{e}	-2.16±0.02^{a}	8.46±0.01^{a}	88.45±0.02^{f}	-3.09 ±0.02^{d}	8.05±0.02^{a}	86.73±0.16^{i}	-3.25±0.04^{c}	8.95±0.01^{a}	87.90±0.22^{f}	-3.05±0.01^{abc}	8.54±0.01^{a}
PG[3)]	0.1	91.73±0.02^{a}	-2.94±0.02^{b}	7.08±0.01^{g}	89.71±0.04^{d}	-3.17±0.02^{ab}	6.85±0.01^{g}	89.67±0.07^{d}	-3.35 ±0.02^{e}	7.14±0.13^{e}	89.35±0.05^{e}	-3.32±0.01^{d}	7.19±0.00^{e}	89.13±0.01^{d}	-3.31±0.01^{bcd}	7.46±0.01^{e}
	0.3	91.73±0.01^{a}	-2.94±0.04^{b}	7.08±0.01^{g}	90.79±0.01^{a}	-2.85±0.02^{ab}	6.83±0.01^{g}	90.07±0.01^{a}	-2.92 ±0.01^{b}	6.84±0.02^{g}	90.84±0.01^{a}	-2.92±0.01^{b}	6.83±0.01^{g}	90.23±0.06^{a}	-2.96±0.01^{ab}	7.33±0.00^{f}
	0.5	91.77±0.01$^{a a}$	-2.99±0.03^{c}	7.3±0.02^{f}	90.38±0.01^{b}	-2.86±0.01a^{b}	7.21±0.01^{e}	90.46±0.03^{b}	-2.96±0.02^{c}	7.03±0.01^{f}	90.41±0.05^{b}	-2.91±0.01^{b}	7.00±0.02^{f}	89.69±0.21^{b}	-3.27±0.51^{bcd}	7.51±0.06^{d}
	0.7	91.55±0.00^{b}	-2.8±0.01^{a}	7.44±0.01^{e}	90.18±0.01^{c}	-2.80±0.01^{ab}	7.33±0.01^{d}	90.47±0.02^{b}	-2.86"±0.01^{a}	7.26±0.02^{d}	90.26±0.03^{c}	-2.85±0.03^{a}	7.17±0.02^{e}	89.91±0.00^{b}	-2.8±0.01^{a}	7.59±0.02^{d}

[1)]Values within the same column with different superscripts are significantly different at p<0.05
[2)]NPG, nanopowdered ginseng with size 600-1000 nm
[3)]PG, powdered ginseng with size 300~500 μm

Table 3. Sensory characteristics of nanopowdered ginseng and powdered ginseng added yogurt stored at 7°C for 20 d[1)]

Concentrations (%, v/v) of sample		Storage period (d)	Appearance	Flavor	Taste	Texture	Over-all acceptability
			Yellowness	Earthy	Bitterness	Viscosity	
Control		0	1.0±0.50^{g}	1.0±0.02^{j}	1.0±0.05^{g}	3.5±0.29^{abc}	3.0±3.09^{def}
NPG[2)]	0.1		1.3±0.50^{efg}	1.5±0.53^{j}	1.4±0.53^{efg}	3.0±0.76^{bcdefg}	3.1±2.76^{cde}
	0.3		1.5±0.70^{defg}	1.8±0.37^{ij}	1.8±0.53^{bcdefg}	3.1±0.69^{abcdef}	3.5±2.16^{ab}
	0.5		1.8±0.53^{cdefg}	2.1±0.69^{ghij}	1.7±0.41^{cdefg}	3.0±0.57^{bcdefg}	3.0±2.28^{def}
	0.7		1.8±0.49^{cdefg}	2.0±0.69^{hij}	1.8±0.39^{cdefg}	2.8±0.69^{cdefgh}	2.6±3.31^{g}
PG[3)]	0.1		1.4±0.79^{fg}	1.8±0.68^{ij}	1.5±0.53^{defg}	4.0±0.81^{a}	3.2±1.97^{bcde}
	0.3		1.4±0.53^{fg}	2.0±0.57^{hij}	1.5±0.51^{defg}	4.0±0.82^{a}	3.0±2.73^{def}
	0.5		1.4±0.53^{fg}	2.8±0.89^{bcdefghi}	2.1±0.89^{abcde}	3.7±1.06^{ab}	3.6±2.13^{a}
	0.7		1.7±0.49^{cdefg}	3.0±0.84^{abcdefgh}	2.2±0.75^{abcde}	3.1±1.11^{abcdef}	3.4±1.64^{abc}
Control		5	0^{h}	0^{k}	1.0±0.03^{g}	3.0±0.28^{bcdefg}	3.0±3.46^{def}
NPG	0.1		1.5±0.49^{defg}	1.8±0.90^{ij}	1.1±0.38^{fg}	2.5±1.13^{defghi}	3.1±3.34^{cde}
	0.3		1.7±0.82^{cdefg}	1.8±0.69^{ij}	2.0±0.54^{abcdef}	2.5±0.53^{defghi}	3.6±1.73^{a}
	0.5		1.9±0.82^{abcdef}	2.2±0.90^{fghij}	2.0±0.79^{abcdef}	2.0±0.81^{ghijkl}	2.7±2.34^{fg}
	0.7		2.0±0.82^{abcdef}	2.2±0.27^{fghij}	2.2±0.95^{abcde}	2.4±0.98^{defghij}	2.1±1.57^{h}
PG	0.1		1.4±0.53^{fg}	2.0±0.82^{hij}	1.5±0.53^{defg}	3.4±1.13^{abcd}	3.0±1.34^{edf}
	0.3		1.5±0.53^{defg}	2.2±1.11^{ghij}	1.7±0.76^{cdefg}	3.8±1.07^{ab}	3.1±2.13^{ced}
	0.5		1.7±0.49^{cdefg}	3.0±0.81^{abcdefgh}	2.0±1.00^{abcdef}	3.2±0.76^{abcde}	3.5±3.18^{ab}
	0.7		1.8±0.69^{cdefg}	3.1±0.90^{abcdefg}	2.2±1.25^{abcde}	3.5±1.13^{abc}	3.2±3.36^{bcde}
Control		10	1.0±0.53^{g}	0.0^{k}	1.0±0.02^{g}	2.7±0.26^{cdefgh}	3.0±1.57^{def}
NPG	0.1		1.5±0.53^{defg}	2.0±0.01^{hij}	1.5±0.38^{defg}	1.8±0.69^{hijkl}	2.9±2.07^{efg}
	0.3		2.1±0.69^{abcde}	2.1±0.89^{ghij}	1.8±0.53^{bcdefg}	2.0±0.03^{ghijkl}	3.4±1.49^{abc}
	0.5		2.2±0.49^{abcde}	2.2±0.49^{ghij}	1.8±0.38^{bcdefg}	2.1±0.38^{fghijkl}	2.6±2.69^{g}
	0.7		2.2±0.49^{abcde}	2.2±0.48^{ghij}	1.8±0.38^{bcdefg}	2.0±0.37^{ghijkl}	2.1±2.15^{h}
PG	0.1		1.5±0.53^{defg}	1.4±0.53^{j}	1.4±0.49^{efg}	3.1±0.38^{abcdef}	2.0±1.57^{h}
	0.3		1.5±0.54^{defg}	2.1±0.79^{ghij}	1.4±0.69^{efg}	3.2±0.95^{abcde}	2.1±2.73^{h}
	0.5		1.7±0.76^{cdefg}	2.7±0.58^{cdefghi}	2.1±0.90^{abcde}	3.1±0.69^{abcdef}	3.3±2.27^{abcd}
	0.7		1.8±0.69^{cdefg}	3.2±1.25^{abcdef}	2.2±0.95^{abcde}	3.1±0.38^{abcdef}	3.6±2.67^{a}
Control		15	1.0±0.70^{g}	0^{k}	1.0±0.02^{g}	2.0±0.27^{ghijkl}	3±3.57^{def}
NPG	0.1		1.7±0.76^{cdefg}	2.0±0.02^{hij}	1.5±2.00^{defg}	1.5±0.76^{jkl}	2.7±3.86^{fg}
	0.3		2.2±0.24^{abcde}	2.1±0.69^{ghij}	1.8±1.86^{bcdefg}	1.8±0.69^{hijkl}	3.3±4.00^{abcd}
	0.5		2.3±0.39^{abcd}	2.1±0.79^{ghij}	1.8±1.86^{bcdefg}	1.2±0.57^{l}	2.0±4.43^{h}
	0.7		2.4±0.70^{abc}	2.5±0.78^{defghij}	2.0±2.00^{abcdef}	1.3±0.63^{kl}	1.7±3.71^{i}
PG	0.1		1.7±0.95^{cdefg}	3.5±0.79^{abcd}	2.2±2.29^{abcde}	2.5±0.65^{defghi}	2.9±6.71^{efg}
	0.3		2.2±0.98^{abcde}	3.5±0.98^{abcd}	2.2±2.28^{abcde}	2.8±0.90^{cdefgh}	3±6.00^{def}
	0.5		2.2±1.18^{abcde}	3.0±1.41^{abcdefgh}	2.1±2.14^{abcde}	2.4±0.53^{defghij}	3.1±5.14^{cde}
	0.7		2.2±0.76^{abcde}	3.6±1.31^{abc}	2.4±2.43^{abcd}	2.6±1.03^{cdefgh}	3.5±5.13^{ab}
Control		20	1.0±0.72^{g}	0^{k}	1.0±0.02^{g}	2.0±0.28^{ghijkl}	3.0±2.73^{def}
NPG	0.1		1.8±0.69^{cdefg}	2.2±1.50^{ghij}	1.8±0.69^{bcdefg}	1.3±0.85^{kl}	2.6±2.64^{g}
	0.3		2.1±0.83^{abcde}	2.7±0.95^{cdefghi}	2.5±0.79^{abc}	1.5±0.79^{jkl}	3±1.72^{edf}
	0.5		2.5±0.50^{abc}	2.8±0.90^{bcdefghi}	2.4±0.79^{abcd}	1.5±0.65^{jkl}	2.1±1.50^{h}
	0.7		2.7±0.61^{a}	3.0±1.01^{abcdefgh}	2.1±0.38^{abcde}	1.4±0.72^{kl}	1.6±1.91^{i}
PG	0.1		2.0±0.58^{abcdef}	3.4±0.79^{abcde}	2.7±0.76^{ab}	2.2±0.91^{efghijk}	2.9±2.23^{efg}
	0.3		2.2±0.38^{abcde}	3.2±1.11^{abcdef}	2.7±0.95^{ab}	2.8±1.07^{cdefgh}	3.0±2.38^{def}
	0.5		2.3±0.58^{abcd}	3.8±0.90^{ab}	2.7±1.38^{ab}	2.5±0.65^{defghi}	3.0±3.39^{def}
	0.7		2.4±0.49^{abc}	3.9±0.93^{a}	2.8±1.35^{a}	3.0±1.02^{bcdefg}	3.4±3.65^{abc}

[1)]Values within the same column with different superscripts are significantly different at $p<0.05$

[2)]NPG, nanopowdered ginseng with size 600-1000 nm

[3)]PG, powdered ginseng with size 300-500 μm tion to yogurt. However, at the lower concentrations (0.1 and 0.3%) of NPG addition to the yogurt, viscosity score was not much affected during the increased storage period of 20 d. Based on all the sensory data obtained from the current study, it is suggested that NPG concentrations (0.1 and 0.3%) could be used for the addition to the yogurt without affecting the sensory properties.

In conclusions, NPG addition markedly increased the yogurt quality than the PG with the higher radical scavenging activity. Further nanogrinding increased the greater exposure of its functional site and surface area of ginseng. In addition, the data on pH, viscosity, LAB, DPPH, color, and sensory analysis indicated that the lower concentrations (0.1 and 0.3%) of NPG could be applicable in the development of functional yogurt with higher antiradical scavenging activity. The production of the yogurt which incorporates the NPG can broaden the utilization of ginseng and the products can be regarded as possible health-promoting nutraceutical foods.

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