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Physicochemical and Sensory Properties of Yogurt Supplemented with *Corni fructus* during Storage

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ABSTRACT: This study was carried out to determine a possibility of adding *Corni fructus* extract (CFE) into yogurt for improving the neutraceutical properties of yogurt and the effects of adding CFE (2～6%, v/v) on the physicochemical and sensory properties of the products during a 15-day storage period at 4°C. Incorporation of CFE into the yogurt samples resulted in a significant pH reduction and a significant increase in titratable acidity. When evaluating the color of the yogurt, the *L**-values were not significantly influenced by CFE supplementation; however, the *a**- and *b**-values significantly increased with the addition of CFE during storage. The power law and Casson models were applied to assess the flow behavior of CFE-added yogurt samples. The magnitudes of apparent viscosity ($\eta_{a,100}$), consistency index (K), and yield stress (σ_{oc}) for 4～6% CFE yogurt samples were significantly greater than those for the control, indicating that CFE can be used as a thickening agent for yogurt. The sensory test revealed that addition of CFE (2～4%) to yogurt did not significantly affect the overall scores, but the overall preference score for 6% CFE yogurt was significantly decreased. Based on the data obtained from the present study, we concluded that the concentrations (2～4%) of CFE could be used to produce a CFE-added yogurt without the significantly adverse effects on the physicochemical and sensory properties.

Keywords: yogurt, *Corni fructus*, steady shear rheological properties

INTRODUCTION

Yogurt is one of the most popular fermented milk products in the world, and contains beneficial viable microorganisms that compete with pathogenic bacteria for nutrients and space. This property is responsible for the numerous health benefits of yogurt. Nowadays, the key to market growth of yogurt sales is continuous product evaluation and modification to match consumer expectations (1,2).

Corni fructus, the fruit of *Cornus officinalis Sieb. et Zucc.* (Family Cornaceae), has been frequently used in Korea, Japan, and China as traditional medicine, dietary supplements, and cosmetics because of its biological and pharmacological properties, such as anti-inflammation, antivirus, anti-diabetic, and anti-oxidation (3-7). Previously reported, the bioactive components of *Corni fructus* include gallic acid, morroniside, sweroside, loganin, and cornuside (8,9).

In recent years, many different food ingredients, including lentil flour (2), dietary fiber (1), nanopowdered chitosan (10), evening primrose oil (11), β-glucan (12,13), and green and black teas (14), have been included in yogurt formulations to improve nutritional value. So-called healthy foods, especially those with nutraceutical properties, are in great demand by our health conscious society. Nutraceutical yogurt could be a good vehicle in this respect if nutraceutical ingredients, such as *Corni fructus*, were to be fortified into yogurt. However, there is no report in the literature on the production of a *Corni fructus*-added yogurt. Therefore, the objectives of the present study were to investigate (1) a possibility of adding *Corni fructus* to yogurt and (2) the effects of adding *Corni fructus* on the physicochemical and sensory properties of the products during storage.

MATERIAS AND METHODS

Materials

Commercial milk (3.6% milk fat) and nonfat dry milk were purchased from Seoul Dairy Co-op. (Seoul, Korea). *Corni fructus* extract (CFE) and pectin were obtained from Chajeon (Seoul, Korea) and CP Kelco (Lille Skensved, Denmark), respectively. All other chemicals used in the present study were purchased from Sigma (St. Louis,

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MO, USA).

Production of CFE-supplemented yogurt

Milk was combined with different concentrations (0, 2, 4, and 6%, v/v) of CFE, and then mixed with nonfat dry milk (3.7%, w/v) and pectin (0.2%, w/v). The milk solution was heated at 90°C for 10 min and cooled to 42∼43°C. A 0.0012% (w/v) commercial starter culture (Chr. Hansen, Pty. Ltd., Bayswater, Australia) in a freeze-dried direct-to-vat set form containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus* was added to the milk solution, allowed to ferment at 43°C for 6 h, and stabilized at 10°C for 24 h (10). After stabilization, each yogurt sample was stored for 0, 5, 10, and 15 days at 4°C in a refrigerator to evaluate the physicochemical and sensory properties. Each batch of yogurt was made in duplicate.

Chemical analyses

The pH of each yogurt sample was measured using a pH meter (pH/Ion 510, Oakton Instruments, Vernon Hills, IL, USA). The titratable acidity values of each yogurt sample were determined after mixing the yogurt sample with 10 mL of hot distilled water (90°C) and titrating with 0.1 N NaOH containing 0.5% phenolphthalein as an indicator to an end point of faint pink color. All samples were measured in triplicate.

Color evaluation

The color of each yogurt sample was evaluated using a colorimeter (CM-600d, Minolta, Osaka, Japan) calibrated with a white calibration plate. Measured *L**-, *a**- and *b**-values were determined as indicators of lightness, redness and yellowness of the yogurt, respectively. All samples were measured in triplicate.

Steady shear rheological properties

The steady shear properties of each yogurt sample were determined with a concentric cylinder viscometer (Haake VT 550, Haake Inc., Karlsruhe, Germany) at 25°C using an MV I system. A constant temperature circulator (RW-0525G, Jeio Tech. Co. Ltd., Daejeon, Korea) was used to provide the working temperature of 25°C (±0.1°C). In order to describe the steady shear rheological properties of the samples, the data were fitted to the well-known power law (Eq. 1) and Casson (Eq. 2) models:

Eq. 1: $\sigma=K\gamma^n$

Eq. 2: $\sigma^{0.5}=K_{oc}+K_c\gamma^{0.5}$

where σ is the shear stress (Pa), γ is the shear rate (s^{-1}), K is the consistency index ($Pa{\cdot}s^n$), n is the flow behavior index (dimensionless), and $(K_c)^2$ is the Casson plastic viscosity (η_c). Casson yield stress (σ_{oc}) according to the Casson model (Eq. 2) was calculated as the square of the intercept (K_{oc}) obtained from the linear regression of the square roots of the shear rate-shear stress data. Using the magnitudes of K and n, apparent viscosity ($\eta_{a,100}$) at 100 s^{-1} was determined. All steady shear rheological properties were measured in triplicate.

Consumer acceptance test

To evaluate consumer acceptance of the yogurt supplemented with CFE, 40 untrained panelists, consisting of 15 males and 25 females aged from 20 to 29 years old, investigated randomly coded yogurt samples. Four samples were provided to panels at the same time. The color, flavor, softness, taste, and overall preference were determined using a 9-point hedonic scale (9=extremely like, 8=very much like, 7=moderately like, 6=slightly like, 5=neither like nor dislike, 4=slightly dislike, 3=moderately dislike, 2=very much dislike, and 1=extremely dislike).

Statistical analysis

All statistical analyses were performed using SAS version 9.0 (SAS Institute Inc., Cary, NC, USA). An analysis of variance (ANOVA) was performed using the general linear models (GLM) procedure to identify significant differences among the samples. Mean values were compared using Fisher's least significant difference (LSD) test. The significance was defined at the 5% level.

RESULTS AND DISCUSSION

Changes in pH and titratable acidity

Table 1 shows the changes in pH and titratable acidity of

Table 1. Changes in pH and titratable acidity of yogurt supplemented with *Corni fructus* extract stored at 4°C for 15 days[1)]

Storage period (day)	Concentration of sample (%)	pH	Titratable acidity
0	0	5.15±0.01[a]	0.80±0.01[k]
	2	5.12±0.01[b]	0.83±0.01[j]
	4	4.93±0.01[g]	0.92±0.01[d]
	6	5.00±0.01[e]	0.88±0.01[efg]
5	0	5.11±0.01[b]	0.85±0.02[ij]
	2	5.08±0.01[c]	0.86±0.01[gh]
	4	4.93±0.01[gh]	0.96±0.01[b]
	6	4.97±0.01[f]	0.93±0.02[cd]
10	0	5.08±0.01[c]	0.86±0.01[hi]
	2	5.05±0.01[d]	0.88±0.00[ef]
	4	4.92±0.02[h]	0.96±0.01[ab]
	6	4.92±0.01[gh]	0.94±0.01[c]
15	0	5.08±0.01[c]	0.87±0.00[fgh]
	2	5.04±0.01[d]	0.89±0.02[e]
	4	4.90±0.01[i]	0.98±0.01[a]
	6	4.85±0.01[j]	0.98±0.00[a]

[1)]Values with different letters within the same column differ significantly ($p<0.05$).

the yogurt supplemented with CFE and stored at 4°C for 15 days. The pH values significantly decreased during storage when CFE (2～6%) was incorporated into the yogurt samples. Also noted during the 15-day storage period, elevating the concentrations of CFE into the yogurt samples from 0 to 6% resulted in a significant reduction of the pH values from 5.08 to 4.85, respectively. The lower pH of CFE-supplemented yogurt samples could be related to the higher organic acid contents of CFE compared to milk.

Adding CFE (2～6%) into the yogurt samples significantly increased the values of titratable acidity (Table 1). Furthermore, the values of titratable acidity for all the samples studied were slightly increased when stored at 4°C for 15 days. Our findings (regarding the decrease in the pH values and the increase in the titratable acidity values for yogurt samples during 15-day storage at 4°C) obtained from the present study were consistent with those reported by Seo et al. (10) who showed that pH decreases and titratable acidity increases when nano-powdered chitosan-added and cholesterol-reduced yogurt samples are stored at 4°C for 15 days.

Color

Changes in the color of CFE-supplemented yogurt samples stored at 4°C for 15 days are presented in Table 2. The *L**-values for all the samples were not significantly affected by elevating the storage period from 0 to 15 days. However, increasing the concentration of CFE from 0 to 6% significantly decreased the *L**-values of the yogurt from 91.44 to 87.64, respectively. The *a**- and *b**-values of the control sample significantly increased from −1.95 to −1.35 and 7.46 to 8.58, respectively, when the storage period was increased from 0 to 15 days. The *a**-values of CFE-supplemented yogurt samples at 15-day storage were significantly higher than that of the control due to the red pigmentation of the CFE itself.

Steady shear rheological properties

The shear rate versus shear stress data (measured at 25°C) were well fitted to the power law (Eq. 1) and Casson (Eq. 2) models with high determination coefficients (R^2=0.96～0.99; data not shown). All the yogurt samples studied in the present study showed shear-thinning behavior with values of flow behavior indexes (n) as low as 0.37～0.46, as shown in Fig. 1 and Table 3. The n values of all the samples were independent of increases in the storage periods. However, the n value of the yogurt after 15 day storage was significantly decreased with the addition of 6% CFE, suggesting that 6% CFE-supplemented yogurt had a more pseudoplastic (i.e., shear thinning) behavior (15,16).

The apparent viscosity ($\eta_{a,100}$) values of all the sam-

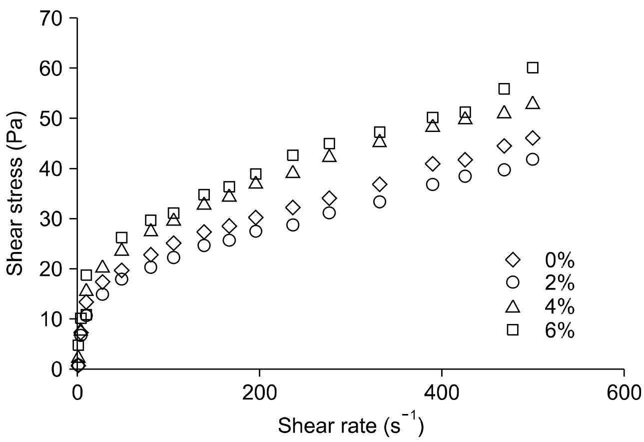

Fig. 1. Shear stress-shear rate plots for yogurt supplemented with *Corni fructus* extract after 15-day storage at 4°C.

Table 2. Changes in the color of yogurt supplemented with *Corni fructus* extract stored at 4°C for 15 days[1)]

Storage period (day)	Concentration of sample (%)	*L*	*a*	*b*
0	0	90.59±0.53^{b}	−1.95±0.05^{h}	7.46±0.46^{d}
	2	88.94±0.51^{cd}	−0.88±0.19^{f}	7.85±0.50^{c}
	4	87.85±0.43^{f}	−0.48±0.11^{e}	7.91±0.15^{cd}
	6	87.37±0.48^{fg}	−0.18±0.34^{c}	8.36±0.37^{b}
5	0	92.08±0.34^{a}	−1.37±0.04^{g}	8.72±0.08^{ab}
	2	89.55±0.33^{c}	−0.21±0.01^{d}	8.56±0.03^{ab}
	4	88.55±0.28^{de}	−0.32±0.06^{bc}	8.82±0.12^{a}
	6	87.90±0.40^{ef}	−0.67±0.16^{a}	8.52±0.27^{ab}
10	0	90.76±0.34^{b}	−1.37±0.06^{g}	8.57±0.06^{ab}
	2	89.17±0.34^{cd}	−0.26±0.01^{d}	8.53±0.22^{ab}
	4	87.75±0.18^{f}	−0.47±0.03^{b}	8.65±0.20^{ab}
	6	87.02±0.05^{g}	−0.69±0.01^{a}	8.80±0.17^{a}
15	0	91.44±0.88^{a}	−1.35±0.08^{g}	8.58±0.21^{ab}
	2	89.60±0.57^{c}	−0.24±0.04^{d}	8.67±0.13^{ab}
	4	88.52±0.45^{de}	−0.35±0.02^{b}	8.78±0.19^{a}
	6	87.64±0.77^{fg}	−0.67±0.16^{a}	8.87±0.11^{a}

[1)]Values with different letters within the same column differ significantly ($p<0.05$).

Table 3. Effects of *Corni fructus* extract on the steady shear rheological properties of yogurt stored at 4°C for 15 days[1)]

Storage period (day)	Concentration of sample (%)	Apparent viscosity $\eta_{a,100}$ (Pa·s)	Flow behavior index, n (−)	Consistency index K ($Pa \cdot s^n$)	Casson yield stress σ_{oc} (Pa)
0	0	0.19±0.01[hi]	0.46±0.02[a]	2.36±0.15[i]	2.46±0.14[i]
	2	0.19±0.00[i]	0.43±0.01[abc]	2.53±0.11[hi]	2.58±0.10[hi]
	4	0.26±0.01[e]	0.41±0.01[cd]	3.97±0.31[de]	3.10±0.99[ghi]
	6	0.25±0.01[ef]	0.38±0.00[de]	4.23±0.16[cd]	4.25±0.11[de]
5	0	0.23±0.01[fg]	0.45±0.01[ab]	2.95±0.23[gh]	3.12±0.23[gh]
	2	0.24±0.02[ef]	0.43±0.01[abc]	3.32±0.20[fg]	3.46±0.28[fg]
	4	0.32±0.02[cd]	0.42±0.01[bc]	4.62±0.48[c]	4.73±0.39[cd]
	6	0.38±0.00[a]	0.36±0.01[e]	7.16±0.49[a]	7.28±0.43[a]
10	0	0.25±0.01[ef]	0.42±0.01[bc]	3.63±0.34[ef]	3.86±0.27[ef]
	2	0.22±0.01[gh]	0.42±0.03[bc]	3.19±0.57[fg]	3.32±0.56[fg]
	4	0.33±0.02[bcd]	0.42±0.01[bc]	4.76±0.07[c]	5.08±0.12[c]
	6	0.35±0.01[b]	0.38±0.00[e]	6.05±0.28[b]	6.21±0.34[b]
15	0	0.27±0.01[e]	0.44±0.03[ab]	3.52±0.35[ef]	3.85±0.30[ef]
	2	0.23±0.01[fg]	0.43±0.03[abc]	3.13±0.34[fg]	3.21±0.25[fgh]
	4	0.31±0.01[d]	0.44±0.02[abc]	4.22±0.36[cd]	4.57±0.28[cd]
	6	0.34±0.02[bc]	0.37±0.03[e]	6.08±0.63[b]	6.25±0.51[b]

[1)]Values with different letters within the same column differ significantly ($p<0.05$).

Table 4. Sensory characteristics of *Corni fructus* extract-supplemented yogurt stored at 4°C for 15 days[1)]

Sensory characteristics	Concentration of sample (%)			
	0	2	4	6
Color	6.3±1.7[a]	5.4±1.4[b]	5.2±1.7[b]	4.1±1.7[c]
Aroma	5.1±2.1[a]	5.4±1.7[a]	5.3±1.8[a]	5.0±1.8[a]
Softness	4.3±1.9[a]	4.6±1.6[a]	4.5±1.7[a]	4.2±2.0[a]
Taste	4.0±1.8[a]	4.0±1.6[a]	3.6±1.8[a]	3.8±2.3[a]
Overall liking	4.4±1.7[ab]	4.7±1.6[a]	4.4±1.8[ab]	3.8±2.1[b]

[1)]Values with different letters within the same column differ significantly ($p<0.05$).

ples studied significantly increased during the 15-day storage period (Table 3). Increasing the values of viscosity has also been observed in concentrated (13,17), non-fat plain (18), and nanochitosan-supplemented yogurt (10). According to Sahan et al. (13), the increase in viscosity values of non-fat yogurt during 15-day storage may be associated with the rearrangement of protein molecules.

Values of the $\eta_{a,100}$, consistency index (K), and yield stress (σ_{oc}) for the 2% CFE-supplemented yogurt sample were not significantly altered after the 15-day storage period as compared to the control; however, adding 4∼6% CFE into the yogurt led to significant increases in these values (Table 3). Greater $\eta_{a,100}$, K, and σ_{oc} values for the 4∼6% CFE-supplemented yogurt samples could be associated with the lower pH (4.85∼4.90) of the CFE-supplemented yogurt compared to the control (5.08) (Table 1). In other words, the solubility of proteins (mainly casein) in the yogurt samples decreased and the thickening properties increased as the pH of casein approached its isoelectric point (pH 4∼5) (19). Therefore, in the present study, we speculated that CFE could be used not only to improve the nutraceutical properties of yogurt, but also act as a thickening agent.

Sensory evaluation

Sensory properties of the CFE-supplemented yogurt samples after 15-day storage at 4°C are listed in Table 4. The aroma, softness, and taste scores of the yogurt samples were not significantly influenced by the addition of CFE. The color score was significantly decreased when CFE (2∼6%) was incorporated into the yogurt samples, probably due to the inherent red color of *Corni fructus*. Incorporation (2∼4%) of CFE into the yogurt samples did not significantly influence the overall liking scores, but the score for 6% CFE-supplemented yogurt was significantly decreased. Based on all the sensory data obtained from the present study, it was suggested that the concentrations (2∼4%) of CFE could be used for the production of the CFE-added yogurt without the deterioration of sensory properties.

CONCLUSION

The present study was designed to develop a neutraceutical CFE-supplemented yogurt, and to evaluate the effects of adding CFE on the physicochemical and sensory properties of the final products during storage.

Data from the pH, titratable acidity, steady shear rheological, color and sensory analyses obtained from the present study indicated that a 2～4% concentration of CFE could be applicable in the CFE-supplemented yogurt development. Furthermore, it was found that CFE could also serve as a thickening agent for yogurt. The production of yogurt containing CFE can broaden the utilization of *Corni fructus*, and provide new nutraceutical foods that promote human health.

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