Research Article

Quality Characteristics and Antioxidant Activity of Yogurt Containing Raw Omija and Sugared Omija during Storage

Won-Young Cho , Sung-Hyun Hwa, Fengqi Yang, and Chi-Ho Lee

Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 05029, Republic of Korea

Correspondence should be addressed to Chi-Ho Lee; leech@konkuk.ac.kr

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This study was conducted to determine the quality characteristics and antioxidant properties of yogurt containing omija extract (control, raw omija, and sugared omija) stored at 4°C for 14 days. The pH of all groups decreased, while the titratable acidity increased as the storage period increased. The viscosity of the sugared omija sample was high, while in the syneresis test, the sugared omija sample showed a low value. The total polyphenol content was the highest in the raw omija sample on day 0. DPPH activity was the highest in the raw omija sample for all storage periods; this sample also showed high Fe²⁺ chelating activity, which did not significantly differ from the sugared omija sample. In sensory evaluation, the sugared omija sample showed the highest overall score. Based on these results, it can be concluded that yogurt containing sugared omija shows improved quality and antioxidant activity.

1. Introduction

The nutritional characteristics and health advantages of yogurt have gained attention among consumers [1]. The health effects of yogurt can be improved by adding probiotic strains of lactic acid bacteria (LAB) [2]. Yogurt is consumed worldwide as a fermented dairy food and has beneficial effects on the immune system and digestive system, as well as anticancer properties [3]. Farvin et al. reported that the high oxidative stability of yogurt is related to the antioxidant peptides released during milk fermentation by LAB [4]. According to a recent study, as interest in the functional properties and quality of foods has increased, the number of studies examining the fortification of dairy foods with natural ingredients has also increased. Thus, the addition of natural components such as olive leaf extract [5], green, white, and black tea [6], and wine grape pomace [7] can elevate the nutritional value of yogurt and potentially enhance its biological activities.

Omija (*Schisandra chinensis*) is a Korean fruit with five flavors, sweet, salty, bitter, sour, and hot [8], and is used in food and medicinal applications [9]. It has been traditionally used as a natural medicine for fatigue, antipyretic action, and

improving visual activity and as a food material for beverages, fruit punches, and sugared omija [10]. Omija has functional effects exerted by its lignan compounds, such as schizandrins and gomisins [11]. Accordingly, omija exhibits antioxidant [12], cancer inhibition [13], and liver protection activities [14]. Lee et al. reported that the main lignan of omija is schizandrin, with the seed containing the highest schizandrin content [11]. However, the seed and peel of omija are discarded after sugared omija is prepared, or juice is extracted from the fruit [11]. To utilize the lignan compound, it is considered necessary to use the omija seed portion separated from the sugared omija. Thus, this study was performed to determine the effects of adding sugared omija, a byproduct of juice extraction processing, and raw omija extract to yogurt for the quality characteristics and antioxidant properties of yogurt, during storage.

2. Materials and Methods

Raw omija and sugared omija were purchased in dry form from Mungyoung Mall (Mungyeong-si, Gyeongsangbuk-do, Korea) and ground using a blender (NFM-9960, NUC. Co.,

Ltd., Daegu, Korea). LAB used as a yogurt fermentation starter (Lyofast YAB 450 AB, Sacco srl., Codarago, Italy) consisted of *Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Lactobacillus acidophilus*, and *Bifidobacterium animalis* ssp. *lactis*.

2.1. Raw Omija and Sugared Omija Extract. Raw omija powder (50 g) and sugared omija powder (50 g) were each diluted by 10-fold with distilled water. Extraction was performed at 60°C and 150 rpm in a shaking incubator for 6 h, followed by centrifugation (3000 g, 5 min) and then filtration through Whatman filter paper No. 4 (Whatman plc, Maidstone, UK).

2.2. Preparation of Yogurt. Milk samples containing skim milk powder, pectin, white sugar, and omija extract (0%; CON, 0.5% raw omija extract; RO or 0.5% sugared omija extract; SO) were homogenized with a homogenizer for 5 min (HG-15A, Daihan Scientific Co., Wonju, Korea). After homogenization, the samples were pasteurized by heating for 30 min at 85°C, cooled to 42°C in a water bath, and incubated with LAB until the pH reached 4.5 at 37°C after 8 h. These samples were stored overnight at 4°C. Samples were collected after 1, 7, and 14 days for analysis.

2.3. pH and Titratable Acidity. pH was measured using a pH meter (pH 900, Precisa Co., Dietikon, Switzerland). Titratable acidity (TA) was determined for all groups through neutralization titration until the pH reached 8.3 using distilled water (3 g of stored yogurt sample in 27 mL of distilled water). Next, 0.1 N NaOH was used to estimate the amount of lactic acid (%) using the following equation:

$$\text{LA\%} = \left[\frac{(10 \times V_{\text{NaOH}} \times 0.009 \times 0.1)}{W} \right] \times 100, \quad (1)$$

where 10 = dilution factor; W = weight of sample (g) for titration; V_{NaOH} = volume of NaOH used to neutralize the lactic acid; 0.1 = normality of NaOH.

2.4. LAB. The number of LAB was determined using the streak plate method with MRS agar (Oxoid Ltd., Hampshire, UK). To measure the number of LAB, each sample (100 μL) was serially diluted with 0.85% NaCl solution (900 μL). After spreading the diluted solution (100 μL) onto MRS agar plates, they were cultured at 37°C for 24 h. The total number of viable cells was expressed as a log value.

2.5. Viscosity and Syneresis. The viscosity of the yogurt samples stored at 4°C was determined using a viscometer (Model LVDV-E, Brookfield Engineering Laboratories, Inc., Middleboro, MA, USA). Measurements were performed at 30 rpm every minute using Spindle No. 3 on the instrument for 5–8 min. Syneresis of the yogurt was measured as described by Keogh and O’Kennedy with some modifications. In brief, the yogurt (20 g) was centrifuged at 3000 g for

10 min at 4°C [15]. The difference in weight between the residue and supernatant was calculated as follows:

$$\text{syneresis} = \frac{\text{weight of supernatant (g)}}{\text{weight of sample (g)}} \times 100\%. \quad (2)$$

2.6. Color Measurement. Color was measured using a colorimeter (NR-300, Nippon Denshoku, Tokyo, Japan), which was calibrated before measurements using a standard white plate supplied with the instrument. Lightness (CIE L^*), redness (CIE a^*), and yellowness (CIE b^*) values were measured three times for each treatment group.

2.7. Total Polyphenol Content (TPC). TPC was measured as described by Wei et al. with slight modifications [16]. In brief, after mixing 100 mL of sample that had been diluted by 10-fold and 100 mL of Folin–Ciocalteu phenol reagent (1 N solution), the mixture was allowed to react at room temperature for 3 min. Next, 1 N Na_2CO_3 solution (300 mL) was added to the mixture and incubated at room temperature for 90 min, after which 1 mL of distilled water was added to complete the reaction. The absorbance of the mixture was measured at a wavelength of 725 nm with a spectrophotometer (OPTIZEN 2120 UV, Mecasys Co., Ltd., Seoul, Korea).

2.8. DPPH Radical Scavenging Activity and Fe^{2+} Chelating Activity Iron Assay. DPPH free radical scavenging activities (1,1-diphenyl-2-picrylhydrazyl) in the 10-fold diluted sample solutions were measured as described by Blois [17]. In brief, 100 mL of the sample extract and 100 mL of 0.15 mM DPPH solution were reacted in the dark at room temperature for 30 min. The absorbance was then measured at a wavelength of 517 nm on a microplate spectrophotometer (Bio-tek, Winooski, VT, USA).

Fe^{2+} chelating activity was determined as described by Dinis et al. [18]. Fe^{2+} was analyzed by measuring the formation of ferrous iron-ferrozine complex. The mixture consisted of 184 mL distilled water, ferrous chloride (4 mL and 2 mM), ferrozine (8 mL and 5 mM), and 4 mL of sample in a 96-well plate. After incubation at room temperature for 10 min, the absorbance of the mixture was measured at a wavelength of 562 nm.

2.9. Organoleptic Evaluation. Organoleptic evaluation of the CON, RO, and SO samples was performed at 1 day after production (stored at 4°C). Samples were evaluated by 10 untrained panelists (4 males and 6 females; age range, 24–31 years) who are members of Konkuk University (Seoul, Korea). Each evaluated item was given a score on a 7-point hedonic scale: liked extremely = 7, liked very much = 6, liked moderately = 5, neither liked nor disliked = 4, disliked moderately = 3, disliked very much = 2, and disliked extremely = 1. The evaluation items included color, flavor, sweet, sour, texture, and overall.

2.10. Statistical Analysis. All data from three replicate measurements were analyzed by one-way analysis of variance using SPSS/PC Statistics 23.0 software (SPSS, Inc., Chicago, IL, USA). Data are presented as the means and standard deviation. All experiments were performed in three replicates. Tukey's multiple range tests were used to determine the significance of differences among the reported mean values; statistical significance was considered when the P value was less than 0.05 ($P < 0.05$).

3. Results and Discussion

3.1. pH, TA, and LAB. The changes in pH, TA, and total LAB counts of yogurts during storage are shown in Table 1. The sample pH at the beginning of storage was 4.55–4.57, which decreased to pH 4.22–4.38 after 14 days of storage. pH decreased in all groups as the storage time increased but did not show significant differences until day 7 ($P > 0.05$), after which significant differences were observed ($P < 0.05$). Lactose fermentation decreased the pH during the storage period [19]. This may be because the conversion of lactose to lactic acid is increased by the metabolic activity of bacteria [7]. According to Lee and Hwang⁹, the range of optimum pH of coming into the market thick fermented milk is 3.27–4.59 [20]. In this study, yogurt stored for 14 days showed a pH within this range, indicating no difference in quality compared to fermented milk available on the market.

The initial TA of yogurt was 0.94–1.01%. After 15 days, the value increased to 0.99–1.05%. The titratable acidity value increased as the storage period was prolonged, but only the CON showed a significant difference compared to the experimental group ($P > 0.05$). TA is influenced by the level of nonfat solid substances such as citrates, proteins, and phosphates [21]. Davis found that the TA of market thick fermented milk can reach 0.72–1.20%, which is similar to the range of TA determined in this study [22]. LAB counts in the CON sample increased as the storage period increased ($P < 0.05$), but there was no significant difference after day 7. The number of LAB in the RO and SO samples increased until day 7 ($P < 0.05$) and then decreased slightly, but the difference was not significant. LAB counts in all yogurt groups were over 7.0 log CFU/g, which is the minimum requirements of Codex. The RO and SO did not adversely affect the growth of LAB on yogurt.

3.2. Viscosity and Syneresis. The values for viscosity and syneresis of yogurt stored at 4°C for 14 days are shown in Table 2. The viscosity of all samples decreased over a longer storage period, but with no significant difference ($P > 0.05$). The SO and CON groups showed higher viscosities than the RO group ($P < 0.05$). The higher viscosity of the SO sample than the RO sample suggests that stickiness remained in the SO group, which may have also affected the extract. Syneresis tended to increase in all groups as the storage period was prolonged ($P < 0.05$). Additionally, the SO sample showed the lowest syneresis ($P < 0.05$). Syneresis is directly affected by acidity and inversely proportional to pH [23]. Acidification reduces the net negative electric charge of

casein micelles by steadily dissolving calcium and inorganic phosphate. When the pH was decreased (particularly below 4.6), casein approaches the isoelectric point and electrostatic repulsions are minimized through the promotion of protein-protein interactions [24, 25]. Even a slight reduction in pH reduces the electric charge, which reduces colloid stability [26]. Whey separation is generally influenced by physical properties during storage and can be prevented by increasing the total solid content of the added stabilizer [27].

3.3. Color Measurements. The values of color L^* , a^* , and b^* of the yogurt stored at 4°C for 14 days are presented in Table 3. The L^* value was highest in the order of $CON > SO > RO$, and the a^* value was highest in the RO group, which was considered to be an effect of the anthocyanin red pigment of the omija extract. As storage periods increased, the values for L^* , a^* , and b^* decreased. Peker and Arslan found that the L^* and b^* values of yogurt were consistently decreased during storage, which agrees with the results with our study [28]. Coggins et al. showed that yogurt had a very light cream color early in the storage period and became darker with increasing storage periods and temperatures [29]. It was shown that the a^* values of RO and SO decreased during the storage period. Samples demonstrated this parameter, indicating that the color changed from red to orange during storage mostly due to the decomposition of anthocyanins or the formation of yellow and brown polymeric compounds [30].

3.4. TPC. The TPC of the yogurts is shown in Figure 1. On day 1, the total phenolic content of yogurt was 25.89 mg GAE/100 g for the RO sample and 25.29 mg GAE/100 g for the SO sample. The CON sample exhibited a significantly lower value of 22.43 mg GAE/100 g ($P < 0.05$). The TPC of all groups tended to decrease as the storage period increased. The Folin–Ciocalteu reactivity of plain yogurts is derived from milk components such as free amino acids, peptides, proteins, and low-molecular-weight antioxidants, as well as polyphenols [3]. This is consistent with the results of a previous study showing that the TPC values of yogurt containing grape and callus extracts were decreased when the storage period was prolonged [31]. A temporary decrease in the TPC of yogurt may result from decomposition of polymeric phenolics in the presence of LAB during refrigerated storage [32].

3.5. DPPH Radical Scavenging Activity and Fe^{2+} Chelating Activity. To investigate the antioxidant activity of the yogurts, DPPH radical scavenging activity and Fe^{2+} chelating activity were examined (Table 4). DPPH analysis was primarily used to measure the free radical scavenging activity of natural antioxidants. When DPPH radicals are reduced to stable diamagnetism molecules, the color of the sample becomes violet to yellow. The DPPH value of the RO sample was highest during all storage periods ($P < 0.05$). There was no significant difference between the SO and CON samples

TABLE 1: pH, titratable acidity, and lactic acid bacteria during the storage of yogurt.

	Storage period (d)	CON	RO	SO
pH	0	4.57 ± 0.11 ^{ns,A}	4.55 ± 0.03 ^A	4.56 ± 0.01 ^A
	7	4.45 ± 0.00 ^{b,A}	4.47 ± 0.05 ^{ab,A}	4.55 ± 0.04 ^{a,A}
	14	4.22 ± 0.07 ^{ns,B}	4.29 ± 0.08 ^B	4.38 ± 0.02 ^B
Titratable acidity (%)	0	0.94 ± 0.01 ^{b,B}	1.01 ± 0.01 ^{a,NS}	0.97 ± 0.01 ^{b,NS}
	7	0.97 ± 0.02 ^{ns,AB}	1.03 ± 0.07	0.98 ± 0.01
	14	0.99 ± 0.02 ^{ns,A}	1.05 ± 0.08	0.99 ± 0.01
Lactic acid bacteria (log CFU/mL)	0	7.28 ± 0.19 ^{ns,B}	7.46 ± 0.15 ^B	7.50 ± 0.17 ^B
	7	7.86 ± 0.09 ^{ns,A}	8.03 ± 0.07 ^A	8.03 ± 0.11 ^A
	14	7.95 ± 0.05 ^{ns,A}	7.86 ± 0.08 ^A	7.87 ± 0.07 ^A

CON: control; RO: raw omija; SO: sugared omija. Means with different superscripts (^{A,B} in the same column and ^{a,b} in the same row) differ significantly ($P < 0.05$). All values are represented as mean ± standard deviation for three replicates. NS: not significant.

TABLE 2: Viscosity and syneresis during the storage of yogurts.

	Storage period (d)	CON	RO	SO
Viscosity (cp)	0	123.03 ± 6.60 ^{a,NS}	75.30 ± 5.14 ^{b,NS}	145.38 ± 16.19 ^{a,NS}
	7	120.01 ± 15.78 ^a	71.66 ± 4.64 ^b	134.81 ± 13.19 ^a
	14	102.73 ± 5.26 ^a	68.13 ± 9.48 ^b	113.70 ± 15.42 ^a
Syneresis (%)	0	45.58 ± 1.56 ^{b,A}	57.74 ± 2.02 ^{a,A}	40.45 ± 0.86 ^{c,A}
	7	57.38 ± 1.77 ^{b,B}	66.20 ± 2.81 ^{a,B}	51.48 ± 3.51 ^{b,B}
	14	72.86 ± 2.39 ^{a,C}	72.67 ± 2.28 ^{a,C}	58.85 ± 2.71 ^{b,C}

CON: control; RO: raw omija; SO: sugared omija. Means with different superscripts (^{A-C} in the same column and ^{a,b} in the same row) differ significantly ($P < 0.05$). All values are represented as mean ± standard deviation for three replicates. NS: not significant.

TABLE 3: Color during the storage of yogurts.

Color value	Storage period (d)	Treatment		
		CON	RO	SO
L* value	0	85.01 ± 1.35 ^{a,NS}	80.28 ± 0.43 ^{b,NS}	83.76 ± 0.95 ^{a,A}
	7	84.50 ± 1.19 ^a	80.17 ± 0.65 ^b	82.22 ± 0.77 ^{b,A}
	14	83.34 ± 2.50 ^{ns}	79.71 ± 1.01	79.93 ± 0.61 ^B
a* value	0	-2.96 ± 0.19 ^{b,NS}	-0.53 ± 0.01 ^{a,A}	-2.80 ± 0.04 ^{b,A}
	7	-2.97 ± 0.20 ^b	-0.61 ± 0.03 ^{a,B}	-2.85 ± 0.07 ^{b,A}
	14	-3.35 ± 0.03 ^c	-0.86 ± 0.02 ^{a,C}	-3.02 ± 0.05 ^{b,B}
b* value	0	6.61 ± 0.08 ^{b,A}	9.26 ± 0.24 ^{a,A}	6.74 ± 0.13 ^{b,A}
	7	6.47 ± 0.05 ^{b,A}	8.96 ± 0.09 ^{a,AB}	6.66 ± 0.08 ^{b,A}
	14	6.23 ± 0.10 ^{b,B}	8.63 ± 0.07 ^{a,B}	5.60 ± 0.19 ^{c,B}

CON: control; RO: raw omija; SO: sugared omija. Means with different superscripts (^{A-C} in the same column and ^{a,b} in the same row) differ significantly ($P < 0.05$). All values are represented as means ± standard deviation for three replicates. NS: not significant.

until day 7 ($P > 0.05$); the SO sample showed a higher value than the CON sample on day 14 ($P < 0.05$).

Fe²⁺ chelating activity resulted in the formation of a complex, and the sample turned to purple. The chelating activity of the sample can inhibit formation of Fe²⁺-ferrozine complexes. In all groups, Fe²⁺ chelating activity tended to decrease with increasing storage periods ($P < 0.05$). There was no significant difference between the RO and SO samples during the storage period ($P < 0.05$). The antioxidant activities of phenolic compounds of internal plants are highly correlated [33]. Protein degradation by lactic acid bacteria can release bioactive peptides with antioxidant activity in fermented milk products [4]. Additionally, the hydrolysis of milk protein or organic acid production may explain the antioxidant activity, which occurs because of

microbial metabolic activity during fermentation and refrigerated storage. Decreased antioxidant activity of samples during storage may be related to milk-polyphenol interactions, which may lead to decreased antioxidant capacity [34]. Thus, proline rich casein may lead to precipitation of phenolic compounds and reduce the antioxidant potential [35].

3.6. Sensory Evaluation. The results of sensory evaluation of yogurt containing RO and SO are shown in Figure 2. The color of the CON sample was highest with a value of 5.80 and that of the SO sample was 5.60. Flavor showed the highest score in the SO sample with a value of 5.30, and the CON and RO samples showed the same score of 4.30. Sweet flavor in

FIGURE 1: Changes in total polyphenol content (TPC) during storage of yogurt. CON: control; RO: raw omija; SO: sugared omija. Means with different superscripts (A, B in the same column and a, b in the same row) differ significantly ($P < 0.05$). All values are represented as mean $\pm$ standard deviation for three replicates. NS: not significant.

TABLE 4: Antioxidant activities during the storage of yogurts.

	Storage period (d)	CON	RO	SO
DPPH (%)	0	56.52 $\pm$ 2.40 ^{b,A}	64.69 $\pm$ 0.91 ^{a,A}	58.23 $\pm$ 1.14 ^{b,A}
	7	56.13 $\pm$ 0.40 ^{b,A}	62.71 $\pm$ 0.23 ^{a,B}	55.47 $\pm$ 1.27 ^{b,B}
	14	46.64 $\pm$ 1.19 ^{c,B}	62.71 $\pm$ 0.60 ^{a,B}	53.89 $\pm$ 0.60 ^{b,B}
Fe ²⁺ chelating activity (%)	0	36.38 $\pm$ 1.87 ^{b,NS}	43.09 $\pm$ 1.28 ^{a,NS}	41.04 $\pm$ 2.57 ^{ab,NS}
	7	35.62 $\pm$ 0.76 ^b	43.00 $\pm$ 3.09 ^a	39.51 $\pm$ 0.85 ^{ab}
	14	34.87 $\pm$ 0.66 ^b	38.77 $\pm$ 0.22 ^a	38.79 $\pm$ 1.53 ^a

CON: control; RO: raw omija; SO: sugared omija. Means with different superscripts (^{A,B} in the same column and ^{a-c} in the same row) differ significantly ($P < 0.05$). All values are represented as mean $\pm$ standard deviation for three replicates. NS: not significant.

FIGURE 2: Sensory test results of yogurts. CON: control; RO: raw omija; SO: sugared omija.

the SO group exhibited a value of 4.40, and the CON and RO samples had values of 4.30. The SO sample showed a value of 4.80 for sour and 5.7 for texture. Overall, the value for the SO

sample was the highest at 5.50, CON sample was 5.20, and RO sample was 4.70. Except for the color score, the SO sample showed the highest value in all groups, but the difference was not significant ($P > 0.05$). Sweetness can influence sensory characteristics, and the overall value of the SO sample was highest.

4. Conclusions

All yogurts containing omija showed reasonable ranges for pH, TA, and LAB counts during storage. Viscosity and syneresis were improved by adding SO to the yogurt. In sensory evaluation, the SO sample showed the highest overall value of 5.50. The phenolic compounds in the RO and SO samples increased the antioxidant activity and total phenolic compounds in the yogurt. In conclusion, we confirmed that adding sugared omija to yogurt improves its quality, antioxidant activity, and sensory properties.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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