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Original article

Effects of roselle (*Hibiscus sabdariffa* L.) Calyx extract on the physicochemical characteristics, antioxidant activity and consumer preference of yogurt dressing

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Abstract. Roselle (*Hibiscus sabdariffa* L.) calyx is rich in anthocyanins, organic acids, and other phenolic compounds. In the present study, Roselle calyx extracts at varying concentrations were used as supplement in yogurt dressing, and physiochemical characteristics, antioxidant activity, and consumer preference were investigated. Control yogurt dressing was made with lemon juice, and four samples were prepared with different concentrations of Roselle calyx extracts (5 g/100 mL, 10 g/100 mL, 15 g/100 mL, and 20 g/100 mL). As the concentration of the Roselle calyx extract supplement increased, the pH of the dressing decreased. Higher concentration of Roselle calyx extract supplement resulted in increased total soluble solids content, viscosity, redness, and total polyphenol and flavonoid content of the dressing. ABTS and DPPH radical scavenging activity increased with increasing concentration of the added extract. Consumer preference test rated dressings made with 15 g/100 mL and 20 g/100 mL of Roselle calyx extracts with higher scores than control. Our results suggest 15 g/100 mL ~ 20 g/100 mL of Roselle calyx extract as the optimal concentration for preparation of yogurt dressing. Roselle calyx as a natural pigment and antioxidant is a useful ingredient in food industry.

Key words: antioxidant activity, consumer preference test, quality, roselle calyx extract, yogurt dressing

Introduction

Roselle (*Hibiscus sabdariffa* L.) is an annual herbaceous shrub that widely grows in tropical climate. It is a plant with manifold benefits. Most parts of the plant, including leaves, flowers, petals, and seeds, are used as ingredients in food formulations. However, it is primarily cultivated for its fleshy red calyx (1). Roselle calyces are frequently consumed in the form of cold and hot beverages. In East Africa, the infusion made from its calyces, known as 'Sudan tea,' is used as a medicament to relieve cough (2). Roselle calyx is rich in bioactive compounds such as organic acids, anthocyanins, minerals, and phenolic compounds (3). Owing to the presence of these bioactive compounds, Roselle calyces are known for their antioxidant, antimicrobial and anti-mutagenic activities. Roselle calyces are also reported to be helpful in treatment of hypertension, hypercholesterolemia, and obesity (4-9). Apart from being widely used for its medicinal properties, Roselle calyx finds widespread application in food industries. Previous study has reported the presence of high pigment content in Roselle calyces (1.5 g of anthocyanin/100 g of dry weight Roselle calyces) and due to widespread use of roselle, interests of roselle as food colorants has been increasing (10,11). Earlier studies have attempted to analyze the characteristics of food, such as wine, jam, low-fat yogurt, and cupcakes which were prepared with Roselle calyces (12-15). However, available data related to the analysis of Roselle calyx is insufficient to be considered as a base for its use in the food industry.

Yogurt, one of the best-known foods containing "probiotics," is a coagulated milk product fermented by *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (16). Compared to other dairy products, yogurt is more nutritious as it is enriched with higher levels of micronutrients, such as riboflavin, vitamin B_6, vitamin B_{12}, and calcium. In different parts of the world, yogurt consumption is considered as an indicator of a healthy diet and lifestyle (17). Therapeutically beneficial effects of yogurt have been reported related to the prevention and treatment of obesity, type II diabetes, and inflammatory bowel disease (18-20). Not only it is beneficial to health, but also it has the characteristics that can be produced in two forms, namely liquid form and curd form. To both these forms, different supplementary ingredients are added resulting in many types of yogurt that provide varying levels of nutritional benefit. Several research studies on the addition of supplementary ingredients to yogurt have been reported (21).

Yogurt serves as the principal ingredient of salad dressing. Recent research has focused on the development of functional yogurt dressing with bioactive substances such as ginger and wild grapes to mention a few (22, 23). In the present study, Roselle calyx extract and yogurt, both with diverse bioactive functions were used to develop a functional dressing. The possibility of using Roselle calyx extract as a natural food coloring agent for dressing was also analyzed. Four different Roselle calyx extract concentrates were prepared and used for yogurt dressing and their effect on the physicochemical characteristics, antioxidant activities and consumer preferences were investigated. The ideal Roselle calyx extract concentrate was identified as a basic reference data for various applications in food industries.

Materials and Methods

Materials

Dried Roselle (*Hibiscus sabdariffa* L.) calyces were obtained from Chongmyeong Food (Chongmyeong Food Co., Ltd, Seoul, Korea). Additional ingredients required for the preparation of yogurt dressing were purchased from the local market: plain yogurt (Maeil Dairies Co., Ltd, Seoul, Korea), lemon juice (Elmac Agro Co., Ltd, Kalachara, India), honey (Chong Kun Dang Healthcare, Seoul, Korea), salt (Daesang Group Co., Ltd, Seoul, Korea), and white pepper (Shinsegae Group Co., Ltd, Seoul, Korea).

Preparation of Roselle calyx extract

The concentration of Roselle calyx extract for preparing the dressing was fixed based on the amount of soluble solids present in lemon juice. More than 15 g of Roselle calyces extracted in 100 mL of distilled water had greater amounts of soluble solids than that in lemon juice. Accordingly, experimental concentrations of Roselle calyx extract were set at 5 g/100 mL, 10 g/100 mL, 15 g/100 mL, and 20 g/100 mL. Roselle calyces were ground in a blender (HMF-630WG, Hanil Electric Co., Ltd, Seoul, Korea) for 20 sec. The following amounts of ground Roselle calyces were weighed: 5, 10, 15 and 20 g, mixed with 100 mL of distilled water, and extracted at 90 ˚C and 185 rpm for 20 min using a shaking water bath (BS-20, Jeio Tech, Gimpo, Korea).

Preparation of yogurt dressing with Roselle calyx extract

The ratio of ingredients used for preparing the dressing was as published previously (24). Table 1 summarizes the formulas used for yogurt dressing with Roselle calyx extract. Control (Con) was prepared by mixing 20 g of lemon juice with 200 g of yogurt, 30 g of honey, 1 g of salt, and 0.5 g of white pepper in a mixing bowl. The contents were stirred for 1 min with a hand blender (HHM-610HK, Hanil Electric Co., Ltd, Seoul, Korea). Four different types of yogurt dressing (S5, S10, S15 and S20) were prepared with four different concentrations of Roselle calyx extract in distilled water (E5, 5 g/100 mL; E10, 10 g/100 mL; E15, 15 g/100 mL; and E20, 20 g/100 mL) mixed with 200 g of yogurt, 30 g of honey, 1 g of salt, and 0.5 g of white pepper in a mixing bowl, and the contents were stirred for 1 min with a hand blender.

Table 1. Formulae for yogurt dressing made with Roselle calyx extract

Ingredients (g)	Con[1)]	S5	S10	S15	S20
Yogurt	200	200	200	200	200
Lemon juice	20	-	-	-	-
E5	-	20	-	-	-
E10	-	-	20	-	-
E15	-	-	-	20	-
E20	-	-	-	-	20
Honey	30	30	30	30	30
Salt	1	1	1	1	1
White pepper	0.5	0.5	0.5	0.5	0.5

[1)] E5: Extract of 5 g of Roselle calyx /100 mL of distilled water. E10: Extract of 10 g of Roselle calyx /100 mL of distilled water. E15: Extract of 15 g of Roselle calyx /100 mL of distilled water. E20: Extract of 20 g of Roselle calyx /100 mL of distilled water. Con: Dressing made with lemon juice. S5: Dressing made with E5. S10: Dressing made with E10. S15: Dressing made with E15. S20: Dressing made with E20.

pH

The pH of the samples (10 mL): Roselle calyx extracts E5, E10, E15, and E20; Con; dressing S5, S10, S15, and S20 were measured with a pH meter (SP-701, Suntex instruments Co., Ltd, Taipei, Taiwan). All the measurements were carried out in triplicate and the average value was recorded.

Total soluble solids content

The amount of total soluble solids in Roselle calyx extracts (E5, E10, E15, and E20), Con, and dressing (S5, S10, S15, and S20) were measured using a digital refractometer (PR-201α, Atago Co., Ltd, Tokyo, Japan). All the measurements were carried out in triplicate and the average value was recorded.

Viscosity

The prepared dressings Con, S5, S10, S15, and S20 were stored at 4 °C for 1 h. An LV2 spindle at 10 rpm recorded the viscosity after 1 min using a viscometer (DV-I Prime, AMETEK Brookfield, Middleboro, USA). All the measurements were carried out in triplicate and the average value was recorded.

Color

Samples from dressings Con, S5, S10, S15, and S20 were taken into cells of a 10 × 10 × 30 mm size and the lightness (*L*), redness (*a*) and yellowness (*b*) were measured using a spectrophotometer (CR-400, Konica Minolta, Osaka, Japan). All the measurements were carried out in triplicate and the average value was recorded.

Total polyphenol content

The dressings Con, S5, S10, S15, and S20 were filtered using Whatman filter paper no. 4. The filtered dressings weighing 5 g each were diluted with 10 mL of ethanol. Total polyphenol content was determined according to the Folin-Dennis method (25) with some modifications. The extracts were diluted 1:80 with distilled water and used as samples. Accordingly, 10 μL of each extract was diluted to a total volume of 800 μL. Eight hundred microliters of the sample was mixed with 50 μL of 0.9 N Folin-Ciocalteu's reagent (Junsei Chemistry, Tokyo, Japan), 150 μL of 20 % sodium carbonate solution (Merck kGaA, Darmstadt, Germany), mixed, and incubated for 2 h in dark at 25 °C. Absorbance was measured at 700 nm using a Microplate reader (Apollo11LB913, Berthold Co., Ltd, Bad Wildbad, Germany). Gallic acid (Merck kGaA, Darmstadt, Germany) was used as a standard. Total polyphenol contents were expressed as gallic acid equivalents (μg GAE/mg).

Flavonoid content

Sample preparation method for the evaluation of flavonoid content was same as that described for the measurement of total polyphenol content. Flavonoid content was determined according to the method published by Lee and Hong (26). To 1 mL of the sample, 150 μL of 5 % sodium nitrite (Junsei Chemistry, Tokyo, Japan) was added and incubated for 6 min in dark at 25 °C. After incubation, 300 μL of 10 % aluminum chloride (Junsei Chemistry, Tokyo, Japan) was added, mixed, and incubated for 5 min in dark at 25 °C. Finally, 1 mL of 1 N sodium hydroxide (Deajung chemicals & metals Co., Ltd, Gyeonggi, Korea) was added and the absorbance was measured at 520 nm using a Microplate reader (Apollo11LB913). Quercetin (Sigma-Aldrich Co., Ltd, MO, USA) was used as a standard and the flavonoid content was expressed as quercetin equivalents (μg QE/mg).

2,2-azinobis(3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS)

ABTS radical scavenging activity was measured as described by Choi et al. (27). The dressings Con, S5, S10, S15, and S20 were filtered using Whatman filter paper no. 4. The filtrates were diluted with ethanol and the following concentrations were prepared: 50, 100, 150, 300, and 500 mg/mL, and used as samples. To 10 μL of the diluted sample, 200 μL of ABTS reagent was added and allowed to react for 60 min in dark at 25 °C. Absorbance was measured at 405 nm using a Microplate reader (Apollo11LB913). ABTS IC50, which indicates the concentration of the extract required to scavenge 50% of the ABTS radicals, was derived from a trend line.

2.2-diphenyl-1-1-picrylhydrazyl (DPPH)

Sample preparation method and dilution used for the analysis of DPPH radical scavenging activity were same as those used for the measurement of ABTS radical scavenging activity. DPPH radical scavenging activity was measured according to the method described by Molyneux (28). To 0.1 mL of the sample, 0.1 mL of 200 μM DPPH reagent (Sigma Aldrich Co., Ltd., MO, USA) was added and the reaction was allowed to proceed for 30 min in dark at 25 °C. Absorbance was measured at 520 nm and the DPPH IC50 values (mg/mL) were obtained.

Consumer preference test

Consumer preference test was conducted with 22 graduate students majoring in food and nutrition (Korea University). Each of the dressing Con, S5, S10, S15, and S20 was taken in a transparent cup and five of these cups were placed on a white plate and served to the panels along with water. Color, thickness, flavor, sourness, sweetness, mouth feel, and the overall acceptability of the dressings were evaluated using the 9-point hedonic scale (from 1 = strongly dislike to 9 = strongly like).

Statistical analysis

Data from the measurements were analyzed using the SPSS program (IBM SPSS Statistics 23, International Business Machines Corporation, New York, USA). Significant differences between data were determined by the one-way analysis of variance (ANOVA). A $p < 0.05$ was considered to indicate statistical significance. Where $p < 0.05$, ANOVA was followed by the Duncan's multiple range tests.

Results and Discussion

Physicochemical characteristics

Table 2 shows the physicochemical characteristics of yogurt dressing containing Roselle calyx extracts. Lemon juice used in this study had a pH of 1.51. The pH of Roselle calyx extracts showed a decrease from 2.18 to 1.98 with an increase in the concentration of the extracts. Accordingly, the pH value of the dressing decreased from 4.07 to 3.75 as the concentration of the added Roselle calyx extracts increased from E5 to

Table 2. Physicochemical characteristics of yogurt dressing containing Roselle calyx extract

Contents		Con$^{1)}$	S5	S10	S15	S20
pH value		3.62±0.00$^{2)e}$	4.07±0.00^{a}	3.94±0.00^{b}	3.83±0.00^{c}	3.75±0.00^{d}
Total soluble solids content (°Brix)		20.67±0.15^{b}	18.33±0.25^{c}	20.20±0.35^{b}	20.53±0.15^{b}	21.60±0.72^{a}
Viscosity (cP)		486.90±7.55$^{1)}$ c	444.90±16.52^{d}	457.90±4.58^{d}	508.90±6.24^{b}	533.90±6.00^{a}
Hunter's color value	*L*$^{3)}$	81.98±0.47$^{3)a}$	76.17±0.18^{b}	76.09±0.11^{b}	73.49±0.01^{c}	71.27±0.08^{d}
	a	-1.75±0.03^{e}	1.72±0.02^{d}	3.55±0.00^{c}	4.81±0.01^{b}	6.31±0.02^{a}
	b	4.96±0.14^{a}	3.97±0.03^{b}	3.27±0.01^{c}	3.25±0.01^{c}	3.21±0.02^{c}

[1)]Con: Dressing made with lemon juice. S5: Dressing made with 5 g/100 mL for Roselle calyx extract. S10: Dressing made with 10 g/100 mL for Roselle calyx extract. S15: Dressing made with 15 g/100 mL for Roselle calyx extract. S20: Dressing made with 20 g/100 mL for Roselle calyx extract.

[2)]Each value is mean ± standard deviation.

[3)] L: lightness, a: redness, b: yellowness.

[a~e]Different superscripts indicate significant differences between values in the same row according to Duncan's multiple range test ($p < 0.05$).

E20. The presence of a high content of organic acids such as oxalic acid, malic acid, and citric acid in Roselle has been reported (1.23 g of organic acids/100 g of Roselle). Especially its calyces contain a high percentage of organic acids including malic acid and citric acid and is also rich in ascorbic acid (29-31). In this study, the presence of such large quantities of organic acids in Roselle calyx extracts might have affected the pH values of dressing (S5, S10, S15 and S20) that were all acidic (3.75~4.07). Also these results can be analyzed that the organic acids in Roselle calyx were well extracted in water at 90 ℃. Similar studies characterizing the quality of yogurt dressing made with blueberries and aronia juice, both containing large amounts of organic acid and hence with lower pH, indicated an overall decrease in the pH of the dressing (24, 32).

The total soluble solids contents of Roselle calyx extracts showed an increase from 2.87 ° Brix to 9.23 ° Brix (E5 ~ E20). Lemon juice used in this study had a total soluble solids content of 7.33 ° Brix and it was the most similar with that value of E15. As a result, with the increasing concentration of added Roselle calyx extracts, the total soluble solids content in the dressing increased from 18.33 ° Brix to 21.60 ° Brix. The total soluble solids contents of S10 and S15 had no significant differences with that of Con ($p < 0.05$). It is reported that total sugar content in Roselle is 4.80 % and is comprised of glucose, fructose, and sucrose (3). This sugar content affected on the total soluble solids contents of Roselle calyx extracts and use of larger quantities of Roselle calyx for extraction resulted in increased total solids content in the dressing.

Addition of Roselle calyx extract significantly increased the viscosity of yogurt dressings and the increase was directly proportional to the concentration of the extract. Viscosity of Con was significantly higher than that of S5 and S10 but lower than that of S15 and S20 ($p < 0.05$). Viscosity is defined as the flow rate per unit load (33). Generally, increase in carbohydrate content lead to an increase in viscosity (34). According to an earlier study (35, 36), increase in the viscosity of vanilla sauce and vanilla yogurt was accompanied with an increase in the sugar content of sauce and yogurt. Thus, the total soluble solids content in Roselle calyx was effective in increasing the viscosity of the yogurt dressing made with the extract.

Results of color evaluation indicated the lightness of Con to be the highest at 81.98 followed by the yogurt dressings containing Roselle calyx extract that showed a decrease with increasing concentration of the extracts (76.17~71.27). The yellowness of Con was also the highest. Among the dressings, yellowness of S5 was the highest ($p < 0.05$), while no significant difference was detected between the other samples. In contrast, redness of Con was found to be the lowest. Among the dressings, an increase in the concentration of Roselle calyx extract resulted in an increase in redness. Previous studies reported the presence of anthocyanins in bokbunja and mulberry that decreased the lightness and increased the redness accordingly upon addition to the respective and bokbunja and mulberry juice (37, 38). Thus, in line with these studies, the higher anthocyanin content present in Roselle calyx (10) might have propelled the tendency seen in the color values of the dressings. Anthocyanins which are rich in Roselle calyces are one of the water soluble pigments visible to the human eye. They are responsible for many of the attractive colors, from scarlet to blue. Under low pH, the anthocyanins exists in the form of red (39, 40). The color of anthocyanin is susceptible to changes in pH. Anthocyanins are most stable and reddish in an acidic medium. However, they are generally unstable and decompose during processing and storage (41). The acidic condition of Roselle calyx extract and yogurt dressing in this study will give positive effects on the stability of anthocyanin pigments in the dressings.

Antioxidant activities

To investigate the antioxidant activity, the total polyphenol content, flavonoid content, ABTS IC50, and DPPH IC50 were measured and the results are summarized in Table 3. Polyphenols and flavonoids are dietary antioxidants known to have diverse physiological functions. Plant polyphenols are potent primary antioxidants acting as free radical terminators (42, 43). Roselle calyces are rich in polyphenols and flavonoids that enhanced the nutritive value of Roselle calyx. Roselle calyx extract is a rich source of anthocyanin, a water-soluble flavonoid pigment possessing antioxidant activities, and anthocyanin is a main phenolic compound of roselle calyx (29, 44, 45). Total polyphenol content in raw Roselle was reported as 37.42 mg/g dry weight and corresponds to the total polyphenol content present in fruits such as strawberries and currants (31). In this study, the total polyphenol content was the lowest in Con, and increased significantly in the dressings with increasing concentration of Roselle calyx extract ($p < 0.05$). A significant increase was detected in the flavonoid content of the dressing with increasing concentration of Roselle calyx extract. Although

Table 3. Summary of evaluation of total polyphenol content, flavonoid content, ABTS IC50, and DPPH IC50 of yogurt dressing containing Roselle calyx extract

Contents	Con[1)]	S5	S10	S15	S20
Total polyphenol content (μg GAE/mg)	0.33±0.102)[e]	0.59±0.00[d]	0.80±0.02[c]	1.25±0.01[b]	2.27±0.01[a]
Flavonoid content (μg QE/mg)	0.49±0.07[c]	0.39±0.03[d]	0.55±0.04[c]	0.76±0.04[b]	0.89±0.05[a]
ABTS IC50 (mg/mL)	658.56±23.24[b]	733.73±12.91[a]	626.49±16.29[b]	542.59±8.66[c]	456.60±33.42[d]
DPPH IC50 (mg/mL)	441.77±92.91[a]	233.15±15.29[b]	194.90±11.76b[c]	143.94±35.07[cd]	76.18±14.77[d]

[1)]*Con: Dressing made with lemon juice. S5: Dressing made with 5 g/100 mL for Roselle calyx extract. S10: Dressing made with 10 g/100 mL for Roselle calyx extract. S15: Dressing made with 15 g/100 mL for Roselle calyx extract. S20: Dressing made with 20 g/100 mL for Roselle calyx extract.*

[2)]*Each value is mean ± standard deviation.*

a~eDifferent superscripts indicate significant differences between values in the same row according to Duncan's multiple range test ($p < 0.05$).

no significant difference was detected in the flavonoid content between Con and S10, significantly higher flavonoid content was detected in S15 and S20 compared to that in Con ($p < 0.05$). The increase of total polyphenol and flavonoid content in the dressings was attributed to the polyphenols and flavonoids present in Roselle calyx extract, which increased with increasing concentrations of the added extract. Thus, S15 and S20 having significantly higher total polyphenol and flavonoid content than Con could have contributed to the higher antioxidant activities and physiological effects.

Antioxidants are typical defense compounds that neutralizes the effect of free radicals in body. ABTS and DPPH are spectrophotometry-based analysis methods for measuring antioxidant activity. These methods measure the antioxidant-induced reduction of ABTS and DPPH radicals and are widely used as convenient methods despite the limitation that they use non-physiological radicals (46, 47). In the present study, ABTS IC50 and DPPH IC50 of the dressings decreased with increasing concentration of Roselle calyx extract, indicating enhanced ABTS and DPPH radical scavenging activity. ABTS radical scavenging activity was significantly higher in S15 and S20 than that of Con. DPPH radical scavenging activity was significantly higher in all the Roselle calyx-containing yogurt dressing samples compared to that of Con ($p < 0.05$). It has been reported earlier that the addition of wild grape powder to dressings significantly enhanced the ABTS radical scavenging activity (23). DPPH radical scavenging activity of yogurt dressing containing bokbunja and mulberry were higher than that of the control group (37, 38). In a study related to yogurt dressing, significantly higher DPPH radical scavenging activity was seen in the aronia juice-added group than that of the control group, attributing the effect to the presence of anthocyanin and polyphenol in aronia (32). Together with these results, our results confirmed that Roselle calyx extract could play a part as an antioxidant in yogurt dressing due to the organic acids, flavonoids and polyphenols in it. The radical scavenging activity was higher in S15 and S20 compared to that in Con. Thus, these results are consistent with the results of total polyphenol and flavonoid content described above.

Consumer preference test

Table 4 shows the results of the consumer preference test for yogurt dressings containing Roselle calyx extract. Consumer preference for color significantly increased with increasing concentration of Roselle calyx extract ($p < 0.05$). The color preference score of S20 was the highest among samples. The color preference

Table 4. Consumer preference scores of yogurt dressing containing Roselle calyx extract

Sensory property	Con[1])	S5	S10	S15	S20
Color	6.32±1.492)[bc]	5.36±1.22[d]	6.09±1.44[cd]	6.95±1.13[b]	7.77±1.34[a]
Thickness	5.59±1.22[NS]	6.05±1.33	5.73±1.24	6.00±1.27	5.91±1.23
Flavor	5.55±1.79[NS]	5.00±1.57	5.64±1.40	6.27±1.61	5.95±1.68
Sourness	4.32±1.76[b]	5.50±1.37[a]	5.32±1.43[a]	5.77±1.57[a]	5.41±1.47[a]
Sweetness	5.32±1.62[NS]	5.95±1.25	5.41±1.22	5.86±1.52	6.00±1.41
Mouth feel	5.27±1.42[NS]	5.59±0.85	5.55±1.10	5.73±1.42	5.68±1.13
Overall acceptability	5.00±1.95[c]	5.55±1.50b[c]	5.32±1.39[c]	5.82±1.50[bc]	6.45±1.65[a]

1)Con: Dressing made with lemon juice. S5: Dressing made with 5 g/100 mL for Roselle calyx extract. S10: Dressing made with 10 g/100 mL for Roselle calyx extract. S15: Dressing made with 15 g/100 mL for Roselle calyx extract. S20: Dressing made with 20 g/100 mL for Roselle calyx extract.
2)Each value is mean ± standard deviation.
a~dDifferent superscripts indicate significant differences between values in the same row according to Duncan's multiple range test (p<0.05).
NSNot significant.

score of Con was higher than that of S5 but lower than that of S15. The preference for sourness of yogurt dressings made with Roselle calyx extract was significantly higher than that for Con ($p < 0.05$). The score for overall acceptability was the highest for S20, followed by S5 and S15 ($p < 0.05$). Con and S10 had the lowest score for overall acceptability among all the samples ($p < 0.05$). Significant differences were not seen in preferences for thickness, flavor, sweetness, and mouth feel. Preference for color, sourness, and overall acceptability of S15 and S20 was the highest when compared to preference for S5, S10, and Con ($p < 0.05$).

Results of sensory evaluation of yogurt dressing supplemented with blueberry and bokbunja juice, both having their own color and physiological activity, revealed greater preference for color. Furthermore, addition of blueberry juice increased the preference for flavor, taste, texture, and overall acceptability. The highest overall acceptability score was seen in the yogurt dressing supplemented with bokbunja juice compared to that of the control group. However, more than 40% addition of bokbunja juice halved the preference for the dressing because of the dark-red color of bokbunja (24, 37). Thus, it can be concluded that appropriate addition of natural ingredients in yogurt dressing could increase the preference score.

Sensory evaluation of cupcakes prepared with Roselle calyx extracts showed higher color, appearance, and texture than those of controls (15). Addition of Roselle calyx powder to *Sulgidduck* did not affect the preference for color but decreased the preference for sourness (addition of 2 % Roselle calyx powder) (48). Supplementation with Roselle calyx had a good effect on the preference for color but excess amounts could lower the preference because of the sour taste. In the present study, S15 and S20 were not significantly different in the preference for sourness, but the average value decreased from 5.77 (S15) to 5.41 (S20). Thus, it can be concluded that addition of 15 g/100 mL ~ 20 g/100 mL of Roselle calyx extract to yogurt dressing during production might positively affect consumer preference.

Conclusion

Roselle calyx extract at different concentrations was used in the preparation of yogurt dressing and their effects on the physicochemical characteristics, antioxidant activity, and consumer preference were investigated. The presence of organic acids in Roselle calyx extract decreased the pH of the dressing and this condition will positively affect the stability of anthocyanins in Roselle calyx. In addition, greater amounts of anthocyanins in the extract increased the redness of the dressing, thereby increasing the consumer preference score for color. Supplementation of yogurt dressing with Roselle calyx extract significantly increased its antioxidant activity. Addition of 15 g/100 mL and 20 g/100 mL of Roselle calyx extract to the dressing, significantly increased the total polyphenol and flavonoid content, and ABTS and DPPH radical scavenging activities compared to that of the control. Consumer preference test rated S15 and S20 with higher scores than controls. Our results confirm that supplementation of Roselle calyx in food production could be useful in satisfying consumers who prefer healthy food. We optimized the concentration of Roselle calyx extract supplement that produced the highest antioxidant activity and overall acceptability by the consumer to be 15 g/100 mL ~ 20 g/100 mL. These results serve as valuable basic data for the food industry. In this study, survey of consumer preference test was limited to students majoring in food and nutrition. Further research is needed to reflect the preferences of various age groups.

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