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A Study of the Physicochemical, Functional, and Sensory Properties of Farm Produced and Commercially Produced Grape Juice in the Korean Market

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Abstract Fruit juices such as grape juice are associated with healthy products by consumers because of the many health benefits they provide. Farm produced (FPGJ) and commercially produced grape juice (CPGJ) in South Korea were compared and studied through the evaluation of their physicochemical, functional, and sensory properties. The results of this study show that FPGJ's physicochemical properties are more varied than CPGJ. The pH, titratable acidity, and total soluble solids of FPGJ were higher than CPGJ. FPGJ had a higher mean value for total phenolics (2,558.20±50.06 mg/L GAE), total flavonoid (3,236.80±56.11 mg/L), total anthocyanin (559.88±3.51 mg/L), and radical scavenging activity (86.48%) than CPGJ, although the differences were significant only with regard to total flavonoid and total anthocyanin. This study also demonstrates that CPGJ is preferred in terms of sensory evaluation. These properties may be used as a basis for the optimization of processing to produce a higher quality grape juice.

Keywords: grape juice, total phenolics, radical scavenging activity, anthocyanin, quality

Introduction

The demand for high-quality and nutritious foods for the health-conscious consumers is increasing and as a result fruit juices have become very popular commodities. Consumers associate the fruit juices such as grape juice with healthy products, thus their commercialization has increased in the last years (1). Grape juice, which is extracted from suitably ripened grapes, is one of the most important juices because it can be consumed directly or as material used in wine making.

In order to retain or even increase the popularity of grape juice, manufacturers must produce a high quality juice. Processing can affect the quality of the grape juice and Huckleberry (2) found that the less heat used in juice processing, the more acceptable the flavor. However, the color of heat processed juice was preferred, especially with the red cultivars. Morris *et al.* (3) noted the effects of grape maturity, extraction temperature, storage temperature, and storage time on color extraction and degradation, quality changes, and argol or tartrate formation in grape juice.

The color of grape juice is due to a complex mixture of anthocyanins which are mainly water soluble diglucosides (4), and their changes during processing and storage are very important in the juice industry because the consumer preference depends greatly on the visual appearance of the product. Anthocyanin is a pigment known to have a beneficial health effects, potent antioxidant properties, and can be considered as a potential replacement for synthetic dyes because of its bright and attractive color (5, 6). The color stability of the anthocyanins is significantly influenced by pH, temperature, and the presence of light (7). These results are in agreement with those reported by Dyrby *et al.* (8) regarding the thermal stability of anthocyanins from *Vitis vinifera* L. grape skins in which an increase in temperature caused a significant increase in the color degradation of anthocyanins.

Fruits and vegetables are reported to have a phenolic compounds that include flavonoids and phenolic acids, carotenoids, and vitamins (9-12) and have multiple biological effects including antioxidant activity (6, 13), lowering the rates of cardiovascular disease (14), and antitumor and antimutagenic activities (15). It has also been found that fruits can contribute to the prevention of degenerative processes caused by oxidative stress (9).

Vinson *et al.* (14) found that grape juice possesses antioxidant properties and is an excellent nonalcoholic alternative to red wine. This is supported by the recent report that grape juice indeed has the highest antioxidant capacity of common commercial fruit juices including grape, grapefruit, orange, tomato, and apple (16).

Singleton and Esau (17) recognized the complexity of the phenolic composition and the importance of phenolic constituents to the color, flavor, and stability characteristics of grape juices and wines. Among the antioxidant phytochemicals, polyphenols deserve special mention due to their free radical scavenging properties and to their contribution to pungency, bitterness, color, and the flavor of foods (18).

The aim of this study was to evaluate the physicochemical, functional, and sensory properties of farm produced and commercially produced grape juices in South Korea.

Materials and Methods

Fourteen farm produced grape juices (FPGJ, processed on a small scale typically with a temperature of approximately 100°C and packed in pouches) and 7 commercially produced

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grape juices (CPGJ, processed on an industrial scale typically in processing plants at a temperature not exceeding 65°C and packed in plastic or glass bottles) (19) were obtained from the South Korean market on 2006. Ethanol and sodium hydroxide were purchased from Duksan Pure Chemical Co., Ltd. (Gyeonggi, Korea). All the juices were stored at 0°C and analyzed within 2 weeks after purchase. The results were expressed as means ± standard error (SE) of the mean which corresponds for the 3 analytical replicates.

Chemical analyses The pH of the commercial grape juice was measured using a pH meter (Delta 320; Metler Toledo, China). The total soluble solids (°Bx) were measured using an Atago hand refractometer (model N-1E; Kyoto, Japan). Titratable acidity as modified by Haight and Gump (20) was measured by adding 10 mL of grape juice sample to 100 mL of distilled water and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2. The results were expressed as mg per 100 g tartaric acid.

Color measurement Color of the grape juice was determined using a Commision Internationale de l'Eclairge illuminant (CIE), L^* (lightness), a^* (green to red), and b^* (blue to yellow) tristimulus values obtained by using a Hunter colorimeter (CR-200; Minolta, Osaka, Japan). These values were used to calculate chroma ($C=[(a^*)^2+(b^*)^2]^{0.5}$), which indicates the intensity or color saturation and hue angle ($h=\arctan(b^*/a^*)$).

Sensory evaluation The sensory evaluation of the 14 FPGJ and 7 CPGJ grape juice samples was conducted with 20 judges randomly selected from the Department of Food Science at Kyungpook National University, Korea. Grape juices were presented in glasses with 3-digit numbers. The judges scored each attribute on a scale of 1-9, in which 1 denotes like extremely and 9 denotes dislike extremely.

Total phenolics The total phenolic content was determined by the Folin-Ciocalteu method (20) previously modified by Yildirim *et al.* (22) to reduce the assay volume. To 3.90 mL of H_2O, 0.1 mL of the sample (10%, v/v grape juice) was added followed by 0.5 mL of Folin-Ciocalteu reagent (Junsei Chemical Co., Ltd., Tokyo, Japan). After 3-6 min 0.5 mL of saturated sodium carbonate (20 g of Na_2CO_3 in 100 mL of H_2O) (Yukuri Pure Chemicals Co., Ltd., Kyoto, Japan) was added. After 30 min of vigorous mixing with a vortex mixer the absorbance was measured at 725 nm (2120UV spectrophotometer; Optizen, Korea). The results were expressed as gallic acid equivalents (GAE) using a calibration curve with gallic acid (Sigma-Aldrich Chemical Co., Taufkirchen, Germany) as the standard (mg/L).

Total flavonoid analysis Total flavonoid concentrations were determined using procedures outlined by Zhishen *et al.* (23). One mL of diluted grape juice (1 mL juice/5 mL distilled H_2O) was placed in a 10 mL flask. Four mL of distilled water was added followed by 0.3 mL of $NaNO_2$ (5 g/100 mL distilled water) was also added. After 5 min, 0.3 mL of $AlCl_3$ (10 g/100 mL distilled H_2O) was added. After another 6 min, 2 mL of 1 N NaOH was added and then the solution was diluted to a total volume of 10 mL with distilled water. The absorbance of the solution was measured at 510 nm and the flavonoid concentration was determined by using a routine standard curve.

Free radical scavenging The antioxidant activity of FPGJ and CPGJ was measured in terms of hydrogen donating or radical scavenging ability, using the stable radical, 1,1-diphenyl-2-picrylhydrazyl (DPPH) (24). One mL of diluted sample (10%, v/v grape juice) was placed in a test tube and 4 mL of 6×10^{-5} mol/L ethanolic solution of DPPH (Sigma-Aldrich Chemical Co.) was added. The mixture was shaken vigorously for 40 sec and then absorbance measurements were taken immediately. The decrease in absorbance at 517 nm was determined with an Optizen 2120UV spectrophotometer. Ethanol was used to zero the spectrophotometer. The absorbance of the DPPH radical ethanolic solution was measured daily. All evaluations were made in triplicate. The % DPPH radical scavenging activity of the sample was calculated according to the formula of Blois (25).

Anthocyanin analysis The total anthocyanin contents of the FPGJ and CPGJ samples were determined using the pH-differential method previously described by Gusti and Wrolstad (26). Grape juices were diluted with potassium chloride buffer solution, pH 1.0, so that the absorbance reading at 520 nm, which is the wavelength of maximum absorption for anthocyanins, was less than 1.0 absorption units. Two dilutions of the grape juice samples, one with potassium chloride buffer, pH 1.0 and the other with sodium acetate buffer, were allowed to equilibrate for 15 min. The absorbance of each equilibrated solution was then measured at the wavelength of maximum absorption (λ_{max}) and 700 nm for haze correction, against a blank cell filled with distilled water. Malvidin-3-glucose was used as a reference compound with a molar absorbance of 28,000 and molecular weight of the pigment (493.2 g) used to calculate the concentration of monomeric anthocyanin pigments (mg/L) in the juices.

Statistical analysis Analysis of variance and Duncan's multiple range tests were performed using the SAS program to determine the differences between variables of the FPGJ and CPGJ. The level of significance was set at $p < 0.05$.

Results and Discussion

Figure 1 and 2 show the physicochemical properties and color composition of the FPGJ and CPGJ in South Korea. The total soluble solids (°Bx) range from 11.40±0.0 to 20.60±0.0 for the FPGJ, and 13.00±0.0 to 15.21±0.0 for CPGJ. The FPGJ has a wide range of total soluble solids as compared to the CPGJ. In the grape juice industry, the percent soluble solids are used to determine the optimum maturity of the grape fruit. Morris and Striegler (28) reported that ideal flavor, acid, and color levels occur in 'Concord' grapes when soluble solids value is between 16 and 17%. The total soluble solids obtained from both

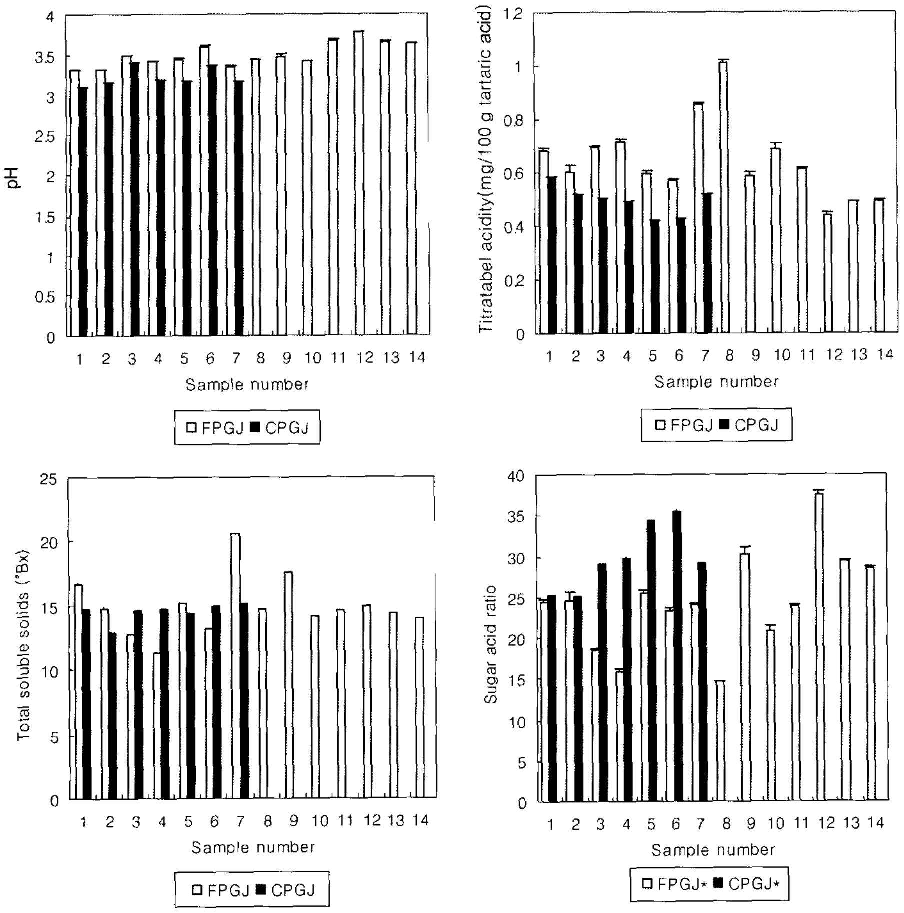

Fig. 1. The physicochemical properties of farm produced (FPGJ) and commercially produced (CPGJ) grape juices. The results are expressed as means±SEM (n=3).

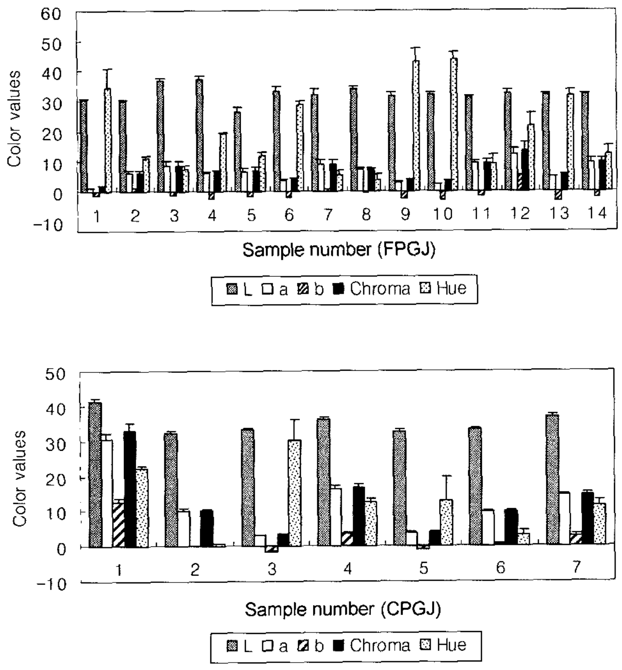

Fig. 2. Color property values of farm produced (FPGJ) and commercially produced (CPGJ) grape juices. The results are expressed as means±SEM (n=3).

FPGJ and CPGJ fall both below and above the reported ideal values. The pH values of the grape juice samples ranged from 3.30±0.0 to 3.78±0.0 for FPGJ and 3.10±0.0 to 3.41±0.0 for CPGJ. All the pH levels were below pH 4.0.

The titratable acidity ranged from 0.44±0.01 to 1.01± 0.01 mg/100 g tartaric acid and 0.42±0.0 to 0.59±0.0 mg/ 100 g tartaric acid for FPGJ and CPGJ, respectively. Titratable acidity was higher in the FPGJ as compared to CPGJ which indicates that FPGJ is more acidic than CPGJ. The sugar/acid ratios ranged from 14.61±0.11 to 33.77±0.44 for FPGJ, and 25.12±0.0 to 35.30±0.21 for CPGJ, which shows that CPGJ has a higher sugar/acid ratio than FPGJ. In a previous study conducted by Morris and Striegler (28) it was observed that as fruit matures, the sugar increases and the titratable acidity decreases. This is in line with the studies reported by Robinson *et al.* (29) and Cash *et al.* (30) which reported that the decrease in total acid is due to a decrease in malic acid and they also observed a decrease in tartaric acid.

Product color is one of the most significant quality factors of grape juice. Changes in the color of fruit juice during processing and storage are very important in the fruit juice industry. The color of the grape juice samples used in this study ranged from natural purple-red to a duller brownish color. The CPGJ samples in general are lighter in color than the FPGJ samples (Fig. 2). The FPGJ a* values (1.46±0.04 to 12.17±2.08) were lower than the a* values for CPGJ (3.04±0.22 to 16.27±1.01), and thus were less red. These results indicate that the samples in this study have a variable range of color values. These differences can be due to the variety of grape fruit used, the method of processing, and the conditions of storage. It was observed from the gathered data that the FPGJ samples have a more brownish color than the CPGJ. Browning reactions in grape products such as fresh juice may pose a great problem for producers because the consumers might perceive the juice as a defective product.

It can be seen in Fig. 3-5 that FPGJ and CPGJ differ in the total content of phenolics, flavonoid, and antioxidant radical scavenging activity, however the differences between the functional property values of FPGJ and CPGJ were not significant except with regard to total flavonoids . Amerine and Ough (31) have reported that grape variety, processing practices and storage conditions among other factors can affect the phenolic component of grape juices. The total phenolics content of grape juice ranged from 1,338.50±4.01 to 2,558.20±50.06 mg/L GAE for FPGJ and 809.67±3.04 to 1,929.40±148.68 mg/L GAE for CPGJ. The total flavonoid content of grape juice ranged from 1,198.14±24.72 to 3,236.80±56.11 mg/L for FPGJ and 634.14±29.37 to 2,115.46±46.77 mg/L for CPGJ. There is a broad distribution of phenolic compounds that are present in grapes. The concentration of total phenolics in grapes is one of the important factors that affect the content of these compounds in grapes, pomace, juice, must, and wine (22). Thus it can be inferred that perhaps the grape juice samples from different varieties of grapes will contain different amount of phenolics. Another factor that may contribute to this finding is the processing method used in the juice production. Revilla *et al.* (32) reported that in maceration processes the phenols are extracted from the seed and can increase the phenolic content of the grape juice. Accordingly, Auw *et al.* (33) determined the effect of several presses, hot presses and skin fermentation on the phenolic composition of some red wines and juices. They also noted that high pressure during pressing and skin fermentation promoted the extraction of some phenols.

The results presented here also show that the total phenol mean value was higher in FPGJ sample 7 (2,558.20±50.06 mg/L GAE) and CPGJ sample 3 (1,929.40±148.68 mg/L GAE), while the total flavonoid mean value was higher in FPGJ sample 12 (3,236.80±56.11 mg/L) and CPGJ sample 2 (2,115.46±46.77 mg/L). The radical scavenging activity mean value was higher in sample 14 (86.48%) and sample 7 (85.77%) for FPGJ and CPGJ, respectively. Although, FPGJ and CPGJ are not significantly different in terms of functional property values except for total flavonoids, the results of this study show that the highest mean value for total phenolics, total flavonoids, and radical scavenging activity were found in farm produced grape juice samples.

It can be inferred that the high temperature used in the processing of FPGJ relative to CPGJ might help in the extraction of phenolic compounds from grapes, although elevated processing temperatures can also lead to the degradation of their functional properties (3, 34, 35). It should also be noted that FPGJ samples were processed using a variety of methods, thus some samples had high

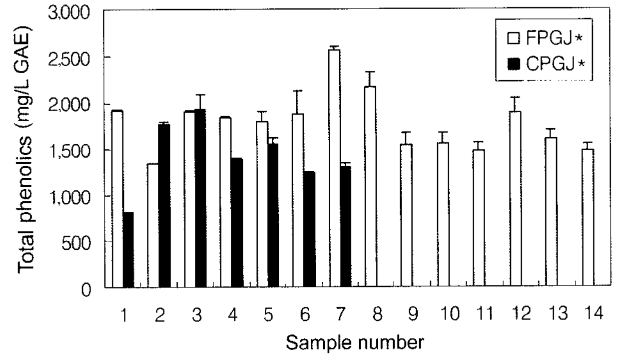

Fig. 3. The total phenolic contents of farm produced (FPGJ) and commercially produced (CPGJ) grape juices. FPGJ and CPGJ samples are not significantly different at $p<0.05$ by Duncan's multiple range tests. The results are expressed as means±SEM (n =3).

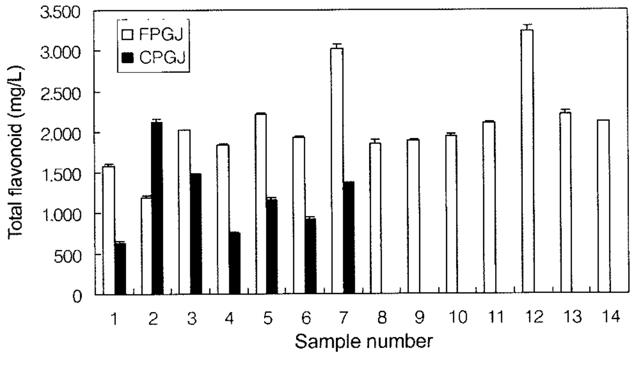

Fig. 4. The total flavonoid contents of farm produced (FPGJ) and commercially produced (CPGJ) grape juices. FPGJ and CPGJ samples are significantly different at $p<0.05$ by Duncan's multiple range tests. The results are expressed as means±SEM (n=3).

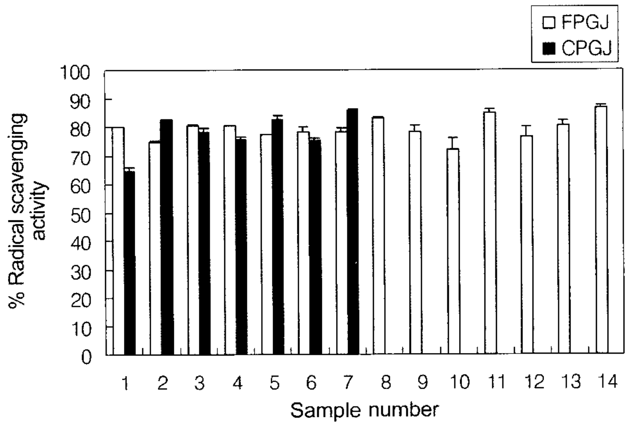

Fig. 5. The percent radical scavenging activities of farm produced (FPGJ) and commercially produced (CPGJ) grape juices. FPGJ and CPGJ samples are not significantly different at $p<0.05$ by Duncan's multiple range tests. The results are expressed as the means±SEM (n=3).

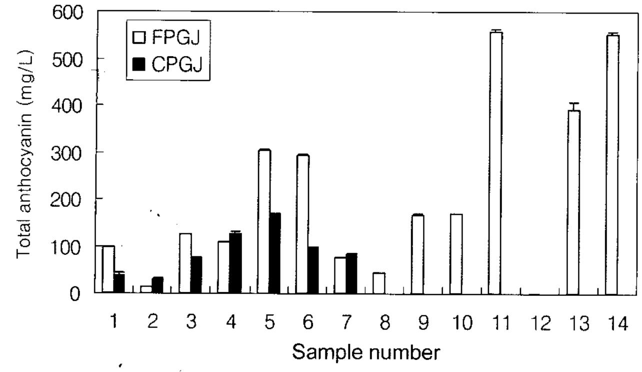

Fig. 6. The total anthocyanin contents of farm produced (FPGJ) and commercially produced (CPGJ) grape juices. FPGJ and CPGJ samples are significantly different at $p<0.05$ by Duncan's multiple range tests. The results are expressed as the means±SEM (n=3).

Table 1. Mean scores of the sensory evaluation of farm produced (FPGJ) and commercially produced (CPGJ) grape juices[1)]

	Sensory properties			
Sample number	Color	Aroma	Taste	Overall acceptability
FPGJ				
1	3.75^{cbd}	2.65^{a}	3.30^{a}	3.15^{a}
2	5.00^{efg}	6.05^{a}	5.80^{dc}	5.25^{def}
3	5.45^{g}	4.75^{a}	4.45^{ab}	4.90^{cde}
4	4.25^{cdef}	4.30^{a}	5.85^{dc}	4.90^{cde}
5	3.20^{ab}	4.05^{a}	3.85^{ab}	3.80^{ab}
6	3.10^{ab}	3.50^{a}	4.85^{bc}	3.95^{abc}
7	7.25^{h}	6.00^{a}	5.80^{cd}	6.25^{fg}
8	6.90^{h}	$5 .95^{a}$	6.95^{de}	6.60^{g}
9	3.45^{bc}	4.40^{a}	4.55^{bc}	4.10^{abc}
10	5.20^{fg}	4.50^{a}	6.00^{dc}	5.40^{ef}
11	2.25^{a}	4.15^{a}	4.75^{bc}	4.25^{bcd}
12	8.35^{i}	8.00^{a}	7.50^{e}	8.05^{h}
13	4.00^{bcde}	3.70^{a}	4.25^{ab}	3.60^{ab}
14	4.55^{defg}	4.70^{a}	5.35^{bc}	4.65^{bcde}
CPGJ				
1	$4 .75^{dc}$	4.80^{ab}	4.65^{bc}	5.05^{dc}
2	4.15^{bc}	3.55^{a}	5.60^{dc}	4.90^{ab}
3	4.35^{bcd}	4.50^{a}	4.40^{bc}	4.65^{bcd}
4	4.00^{bc}	4.35^{a}	4.35^{bc}	3.70^{abc}
5	2.70^{a}	4.30^{a}	4.05^{ab}	3.75^{ab}
6	3.30^{ab}	3.80^{a}	2.95^{a}	3.20^{a}
7	5.25^{d}	5.90^{b}	6.05^{d}	5.85^{d}

[1)] Values with different letters within the same column are significantly different at $p<0.05$ by Duncan's multiple range test.

mean functional values and other samples had low mean functional values. However, the overall mean value is still higher in FPGJ than CPGJ, although the differences were not significant. Dávalos *et al.* (36) also reported that differences in the antioxidant activities of grape juice can be attributed to differences in their phenolic contents and compositions, and to other non-phenolic antioxidant present in the juice samples. Yildirim *et al.* (21) noted that some individual phenolic compounds have a particularly high antioxidant activity. Bors *et al.* (37) and Larrauri *et al.* (35) demonstrated that free radical scavenging activity depends on the structural conformation of phenolic compounds, thus free radical scavenging activity is greatly influenced by the phenolic composition of the sample. Accordingly, Duh (38), Maisuthisakul *et al.* (39), and Park *et al.* (40) reported that there is a correlation between the phenolic content and antioxidant activity since phenolic compounds contribute directly to antioxidant activity. Su and Silva (41) also reported that antioxidant activity is highly correlated to the anthocyanin and total phenolic levels of the sample.

The results in Fig. 6 demonstrate that the total monomeric anthocyanin values of the FPGJ vary greatly, much more than CPGJ. The differences between FPGJ and CPGJ were significant and it can be seen that the total monomeric anthocyanin of the CPGJ is lower than FPGJ. Pressed juices contain 700-800 mg/L anthocyanin (42), which is comparable to the total monomeric anthocyanin of the grape juice samples. Sample 11 of FPGJ has the highest total monomeric anthocyanin concentration (559.88 ±3.51 mg/L), but sample 12 of FPGJ also has the lowest total monomeric anthocyanin concentration (0.6577±0.12 mg/L) which is far below the literature value. The total monomeric anthocyanin value for CPGJ ranged from 30.33±5.23 to 168.50±5.54 mg/L for sample 1 and 4, respectively. Pazmiño-Durán *et al.* (43) observed that the overall decomposition rate of monomeric anthocyanins is significantly dependent on the time and temperature of storage. Also, Monagas (44) reported that during extraction and processing polymeric pigments are formed due to the degradation of monomeric anthocyanins and are condensed with other flavonoid material. They also suggest that certain processing conditions may induce the degradation of individual anthocyanins and the formation of polymeric pigments. Thus, for the juice samples with very low total anthocyanin content it can be assumed that the processing temperature was too high. These juice samples might also have suffered from storage abuse. Morris and Striegler (28) reported that the juices that containing higher total solids, tannin, and pigments were obtained by the hot press method, however Sistrunk (45) and Morris *et al.* (3) reported that to preserve the good quality of the juice, temperature above 65°C must be avoided.

Table 1 shows the sensory properties of different grape juice samples. It should be noted that there was a significant difference in the panelist's preferences between FPGJ samples in terms of color, taste, and overall acceptability while there was no significant difference in the panelist's preferences between FPGJ in terms of aroma. CPGJ samples also showed significant differences in terms of color, aroma, taste, and overall acceptability.

The sensory ratings for all attributes of FPGJ varied greatly while the sensory ratings for CPGJ were consistent and rated above that of FPGJ samples. Thus, CPGJ is more preferred by the panelists. Most of the sensory attributes were rated below 'like moderately', therefore taste, aroma, and color should be optimized in the future product development. The properties of the above mentioned preferred samples may be used as a basis for the preparation of a better quality grape juice.

This study demonstrates that CPGJ is preferred in terms of sensory evaluation. In addition, we show that FPGJ is not significantly different from CPGJ in terms of total phenolic and radical scavenging activity, but they are significantly different in terms of total flavonoid and total anthocyanin, with FPGJ having slightly higher functional property mean values than CPGJ.

Acknowledgments

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