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Evaluation and comparison of the physicochemical properties of different varieties of citrus species

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Abstract
The objective of the present study was to investigate the physicochemical properties of seven sub families of citrus species from family Rutaceae. Citrus fruits (*Citrus* Species), from the family Rutaceae, consist of seven subfamilies with 148 genera. The seven sub families are *Citrus aurentifolia* (Dehi/Lime), *Citrus medica* (Sidaran), *Citrus sinensis* (Pani dodam), *Citrus reticulate* (Heen naran), *Citrus madurensis* (Nas naran), *Citrus limon* (Lemon dehi), *Citrus sinensis* (Oranges). Fruit samples from each variety were analyzed as per; weight per fruit and the hardness of the peel of each variety and the juice weight, volume per fruit, pH, and Total conductivity, Brix value, Vitamin C content and the titratable acidity of each variety were analyzed according to AOAC methods. Finally the data was statistically analyzed using Minitab 17 statistical package. According to the results it can be stated that at 0.05 significant level there are some differences in analyzed parameters among the species.

Keywords: brix value, family Rutaceae, Ph, Titratable acidity, vitamin C

1. Introduction
Citrus fruits are considered one of the world's largest fruit cultures. It has been found that there are 140 citrus producers. About 70 percent of the world's total citrus production is growing in the northern hemisphere, particularly in Brazil, the Mediterranean, and the United States. The largest producer in Europe is Spain, which is over 55% of European citrus production [1]. The fruit is commonly peeled and eaten fresh, or squeezed for its juice. It has a thick bitter rind that is usually discarded, but can be processed into animal feed by removing water using pressure and heat. It is also used in certain recipes as flavoring or a garnish. Citrus are also believed to have medicinal properties that are helpful in the fight against several diseases [2]. 6 Approximately one third of total citrus production is utilized for processing; this proportion is higher in the case of oranges as more than 40% of globally produced oranges are utilized. In addition, oranges account for more than 80% of total citrus utilization for processing [3]. Fruit juices are products for direct consumption and are obtained by the extraction of cellular juice fruit, this operation can be done by pressing, blending and diffusion depending on the type of fruits. Citrus fruits and citrus juices have several beneficial health and nutritive properties. Many studies have assessed the role of individual nutrients contained in citrus juices from various species [4]. In general, the literature indicates a protective effect of fruit against many chronic diseases and the specific role of citrus in some of these conditions partially associated with their antioxidant capacity of vitamin C and carotenoids and some phytochemicals as well as their nutrient content such as folic acid and potassium [5].

2. Materials and Methods
2.1 *Citrus* species collection and identification
Fruits were collected from main 3 areas those are Nugegoda, Gampaha and Galle then they were mixed together. Samples were collected randomly to generalize the geographical influence for the results. Botanical names of the samples were identified and certified from the botany division, Bandaranaike memorial ayurvedic research institute, Navinna, Maharagama.

2.2 Identification of properties and nutrient content of citrus juice of *Citrus* species
2.2.1 Sample preparation
In order to measure the properties and the nutrient content of the juice first fresh juice from selected species was prepared. Before preparing the juice the several other parameters related to fruit was measured. Those include,

Weight
Weight of each fruit taken to prepare juice was measured using an analytical balance.

Thickness of the Peel
Thickness of the peel is measured by the penetrometer.

2.2.2 Measuring the properties of samples
General properties of juice were measured as the properties of the juice prepared. Those properties include,

Juice weight
Juice weight was measured by using analytical balance.

pH Value
The digital pH meter (Hanna Instruments HI84435-01 Mini Titrator and pH Meter) was calibrated against standard buffer solutions. The citrus juice samples were mixed well to homogenize and the pH values were measured using the calibrated pH meter.

Total conductivity
Total conductivity was directly measured by conductivity meter

Brix value/ Total soluble solids
Brix value was measured by Brix meter.

Vitamin C content
Using the AOAC method 967.21 by using 2, 6-dichloroindophenol.

Titratable acidity
Using the AOAC method [6].

2.3 Statistical analysis
Collected data were first inserted in to Minitab 17 software and data were analyzed by statistical tools analysis of variance, mean comparison and Tukey comparison.

3. Results and Discussion
The resulting data were statistically analyzed using Minitab 17 statistical software and can be interpreted in the tables.

Table 1: Factorial information

Factor	Levels	Values
Variety	7	1 (Oranges), 2(Peni dodam), 3(Sidaran), 4(Heen Naran), 5(Naas naran),
		6(Lemon), 7(Lime)

The numerical values assigned for the citrus varieties in table 1 are applicable for all the experiments.

3.1 Weight of the samples Vs variety
Weight (g) versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance.
Accordingly, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, it can conclude that some of the weights of the fruit varieties have different means. The means of weights of varieties are shown in table 2.

Table 2: Means of weights of varieties

Variety	N	Mean	StDev	95% CI	
1 (Oranges)	3	157.69	10.15	(140.72,	174.67)
2(Peni dodam)	3	193.7	23.9	(176.7,	210.7)
3(Sidaran)	3	229.8	22.8	(212.8,	246.8)
4(Heen Naran)	3	65.45	4.04	(48.48,	82.42)
5(Naas naran)	3	23.64	4.09	(6.67,	40.61)
6(Lemon)	3	85.50	7.11	(68.53,	102.48)
7(Lime)	3	49.69	6.25	(32.72,	66.66)

According to above table, highest mean weight presented by Sidaran and the lowest mean weight presented by the Nas Naran and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Heen Naran is significantly low.

Table 3: Tukey Pairwise Comparisons of the mean weights of different varieties.

Variety	N	Mean	Grouping
3(Sidaran)	3	229.8	A
2(Peni dodam)	3	193.7	A B
1 (Oranges)	3	157.69	B
6(Lemon)	3	85.50	C
4(Heen Naran)	3	65.45	C
7(Lime)	3	49.69	C D
5(Naas naran)	3	23.64	D

Means that do not share a letter are significantly different.

As shown in above output, group A comprises Sidaran and Peni dodam, group B comprises Peni dodam and Orange, group C comprises Lemon, Heen naran and Lime and group D comprises Lime and Naas naran. As well as, Peni dodam represents both group A and B and Lime represent both group C and D. According to that there are significantly different combinations of mean weights and those mean weights are significantly different each other.

3.2 Hardness (kg) versus Variety
According to results of analysis of varience, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, the null hypothesis is rejected, and it can conclude that some of the hardness (kg) of the fruit varieties have different means. The means of hardness of varieties are shown in table 4.

Table 4: Means of hardness of varieties.

Variety	N	Mean	StDev	95% CI	
1(Oranges)	3	2.9000	0.1000	(1.4918,	4.3082)
2(Peni dodam)	3	11.033	0.950	(9.625, 12.442)	
3(Sidaran)	3	6.333	1.242	(4.925,	7.742)
4(Heen Naran)	3	3.733	1.079	(2.325,	5.142)
5(Naas naran)	3	2.067	1.343	(0.658,	3.475)
6(Lemon)	3	11.20	1.83	(9.79, 12.61)	
7(Lime)	3	8.500	0.520	(7.092,	9.908)

According to above table, highest mean hardiness (kg) presented by Peni dodam and the lowest mean hardiness (kg) presented by the Naas Naran and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Orange is significantly low.

Table 5: Tukey Pairwise Comparisons of hardness of varieties

Variety	N	Mean	Grouping
6(Lemon)	3	11.20	A
2(Peni dodam)	3	11.033	A
7(Lime)	3	8.500	A B
3(Sidaran)	3	6.333	B C
4(Heen Naran)	3	3.733	C D
1 (Oranges)	3	2.9000	D
5(Naas naran)	3	2.067	D

Means that do not share a letter are significantly different

As shown in above output, group A comprises Lemon, Peni dodam and Lime, group B comprises Lime and Sidaran, group C comprises Sidaran and Heen naran and group D comprises

Heen naran, Orange and Naas naran. As well as, Lime represents both group A and B, Sidaran represent both group B and C and Heen naran represent both group C and D. According to that there are significantly different combinations of mean hardness (kg) and those mean hardness (kg) are significantly different each other.

3.3 Juice weight (g) versus Variety

Juice weight (g) per fruit versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the mean juice weight of the seven varieties are equal. According to that, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, the null hypothesis is rejected, and it can conclude that some of the juice weight of the fruit varieties has different means. The means of juice weights of varieties are shown in table 6.

Table 6: Means of juice weight of varieties.

Variety	N	Mean	StDev	95% CI
1 (Oranges)	3	46.15	7.68	(39.16, 53.13)
2(Peni dodam)	3	37.20	10.26	(30.21, 44.18)
3(Sidaran)	3	54.85	2.96	(47.86, 61.83)
4(Heen Naran)	3	31.75	2.00	(24.77, 38.74)
5(Naas Naran)	3	7.83	2.57	(0.84, 14.81)
6(Lemon)	3	37.14	3.66	(30.16, 44.13)
7(Lime)	3	23.32	5.07	(16.33, 30.30)

According to above table, highest mean juice weight presented by Sidaran and the lowest mean juice weight presented by the Naas Naran and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Heen Naran is significantly low.

Table 7: Tukey Pairwise Comparisons of juice weight of varieties.

Variety	N	Mean	Grouping	
3(Sidaran)	3	54.85	A	
1 (Oranges)	3	46.15	A B	
2(Peni dodam)	3	37.20	B	C
6(Lemon)	3	37.14	B	C
4(Heen Naran)	3	31.75	B	C
7(Lime)	3	23.32		C D
5(Naas naran)	3	7.83		D

Means that do not share a letter are significantly different.

As shown in above output, group A comprises Sidaran and Orange, group B comprisesOrange, Peni dodam, Lemon and Heen naran, group C comprises Peni dodam, Lemon, Heen naran and Lime and group D comprises Lime and Naas naran. As well as, Orange represents both group A and B, Peni dodam, Lemon and Heen naran represents both group B and C and Lime represent both group C and D. According to that there are significantly different combinations of mean juice weight and those mean juice weight are significantly different each other.

3.4 Juice volume (ml) versus Variety

Juice volume (ml) versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the mean juice volume of the seven varieties are equal. According to that, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, the null hypothesis is rejected, and it can conclude that some of the juice volumes of the fruit varieties have different means.

Table 8: Means of juice volumes of varities

Variety	N	Mean	StDev	95% CI	
1 (Oranges)	3	41.00	3.00	(35.58,	46.42)
2(Peni dodam)	3	32.67	5.51	(27.25,	38.09)
3(Sidaran)	3	43.00	5.57	(37.58,	48.42)
4(Heen Naran)	3	23.333	1.528	(17.913,	28.754)
5(Naas naran)	3	7.90	2.03	(2.48, 13.32)	
6(Lemon)	3	30.67	2.31	(25.25,	36.09)
7(Lime)	3	21.00	7.21	(15.58,	26.42)
Pooled St Dev = 4.37721					

According to above table, highest mean juice volume presented by Sidaran and the lowest mean juice volume presented by the Naas Naran and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Heen Naran is significantly low.

Table 9: Tukey Pairwise Comparisons of juice volume of varieties.

Variety	N	Mean		Grouping	
3(Sidaran)	3	43.00	A		
1 (Oranges)	3	41.00	A	B	
2(Peni dodam)	3	32.67	A	B	C
6(Lemon)	3	30.67		B	C
4(Heen Naran)	3	23.333			C
7(Lime)	3	21.00			C
5(Naas naran)	3	7.90			D

Means that do not share a letter are significantly different.

As shown in above output, group A comprises Sidaran, Orange and Peni dodam, group B comprises Orange, Peni dodam and Lemon, group C comprises Peni dodam, Lemon, Heen naran and Lime and group D comprises Naas naran. As well as, Orange represents both group A and B, Peni dodamrepresents group A, B and C and Lemon represent both group B and C. According to that there are significantly different combinations of mean juice volume and those mean juice volumes are significantly different each other.

3.5 pH versus Variety

pH versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the means pH of the seven varieties are equal. According to that, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, the null hypothesis is rejected, and it can conclude that some of the pH of the fruit varieties have different means. The means of pH values of varieties are shown in table 10.

Table 10: Means of pH values of varities

Variety	N	Mean	StDev	95% CI	
1 (Oranges)	3	3.700	0.201	(3.488,	3.912)
2(Peni dodam)	3	4.8700	0.0866	(4.6576,	5.0824)
3(Sidaran)	3	3.0433	0.1501	(2.8310,	3.2557)
4(Heen Naran)	3	3.587	0.367	(3.374,	3.799)
5(Naas naran)	3	2.9300	0.0265	(2.7176,	3.1424)
6(Lemon)	3	2.71333	0.00577	(2.50096,	2.92571)
7(Lime)	3	2.7200	0.0200	(2.5076,	2.9324)

According to above table, highest mean pH presented by Peni dodam and the lowest mean pH presented by the Lemon and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Lemon is significantly low.

Table 11: Tukey Pairwise Comparisons of pH values of varieties.

Variety	N	Mean	Groupin g
2(Peni dodam)	3	4.8700	A
1 (Oranges)	3	3.700	B
4(Heen Naran)	3	3.587	B
3(Sidaran)	3	3.0433	C
5(Naas naran)	3	2.9300	C
7(Lime)	3	2.7200	C
6(Lemon)	3	2.71333	C

Means that do not share a letter are significantly different.

As shown in above output, group A comprises only Peni dodam, group B comprises Orange and Heen naran and group C comprises Sidaran,Naas naran, Lime and Lemon. There are no any shared combinations of fruits. According to that there are significantly difference mean pH values for different groups.

3.6 Total Conductivity (ms/cm) versus Variety

Conductivity (mS/cm) versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the mean conductivity of the seven varieties are equal. According to that, the p-value is 0.327, and it is higher than the level of significance 0.05. Thus, the null hypothesis is not rejected, and it can conclude that all conductivity values of the fruit varieties have equal means. The means of Total Conductive of varieties are shown in table 12.

Table 12: Means of Total Conductive of varieties

Variety	N	Mean	StDev	95% CI
1 (Oranges)	3	3.417	0.628	(2.712, 4.122)
2(Peni dodam)	3	4.313	0.221	(3.608, 5.018)
3(Sidaran)	3	4.177	0.190	(3.472, 4.882)
4(Heen Naran)	3	3.357	0.623	(2.652, 4.062)
5(Naas naran)	3	3.680	0.590	(2.975, 4.385)
6(Lemon)	3	3.993	0.598	(3.288, 4.698)
7(Lime)	3	4.017	0.834	(3.312, 4.722)

According to above table, highest mean conductivity presented by Peni dodam and the lowest mean conductivity presented by the Orange and the difference between lowest and highest values are significantly low. Comparing to fruits varieties, the standard deviation of the Sidaran is significantly low.

Table 13: Tukey Pairwise Comparisons of mean conductivity of varieties.

Variety	N	Mean	Grouping
2(Peni dodam)	3	4.313	A
3(Sidaran)	3	4.177	A
7(Lime)	3	4.017	A
6(Lemon)	3	3.993	A
5(Naas naran)	3	3.680	A
1 (Oranges)	3	3.417	A
4(Heen Naran)	3	3.357	A

Means that do not share a letter are significantly different.

All the mean conductivity of fruits comprises in a one group. Therefore, a significant different of mean conductivity cannot be determine exactly. Which means all the means are approximately equal. It can be concluded that all the samples approximately contains equal amount of total ions that are responsible to the slightly equal total conductivity.

3.7 Brix value versus Variety

Brix value versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the mean brix values of the seven varieties are equal. According to that, the p-value is 0.000, and it is less than the level of significance 0.05, and it can conclude that some of the brix values of the fruit varieties have different means.

Table 14: Means of brix values of varieties

Variety	N	Mean	St Dev	95% CI
1 (Oranges)	3	9.000	0.781	(7.988, 10.012)
2(Peni dodam)	3	10.333	0.586	(9.321, 11.345)
3(Sidaran)	3	10.133	1.097	(9.121, 11.145)
4(Heen Naran)	3	10.367	0.961	(9.355, 11.379)
5(Naas naran)	3	7.000	0.866	(5.988, 8.012)
6(Lemon)	3	8.467	0.839	(7.455, 9.479)
7(Lime)	3	6.833	0.379	(5.821, 7.845)

According to above table, highest mean brix value presented by Heen Naran and the lowest mean brix value presented by the Lime and the difference between lowest and 48 highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Lime is significantly low.

Table 15: Tukey Pairwise Comparisons of brix values of varieties

Variety	N	Mean	Grouping	
4(Heen Naran)	3	10.367	A	
2(Peni dodam)	3	10.333	A	
3(Sidaran)	3	10.133	A	
1 (Oranges)	3	9.000	A	B
6(Lemon)	3	8.467	A	B
5(Naas naran)	3	7.000		B
7(Lime)	3	6.833		B

Means that do not share a letter are significantly different.

As shown in above output, group A comprises Heen naran,

Peni dodam, Sidaran, Orange and Lemon and group B comprises Orange, Lemon, Naas naran and Lime. As well as, Orange and Lemon are shared in both group A and B. Therefore, it can be concluded that every fruit have significantly difference mean brix values except Orange and Lemon.

3.8 TA % (w/w) versus Variety

TA% (w/w) versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the mean TA% (w/w) of the seven varieties are equal. According to that, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, the null hypothesis is rejected, and it can conclude that some of the TA% (w/w) of the fruit varieties have different means.

Table 16: Means

Variety	N	Mean	StDev	95% CI
1 (Oranges)	3	0.2169	0.0240	(0.0530, 0.3808)
2(Penidodam)	3	0.1566	0.0276	(-0.0073, 0.3205)
3(Sidaran)	3	0.5892	0.0221	(0.4253, 0.7531)
4(Heen Naran)	3	0.2802	0.0535	(0.1163, 0.4441)
5(Naas naran)	3	0.8917	0.0309	(0.7278, 1.0556)
6(Lemon)	3	1.468	0.325	(1.304, 1.632)
7(Lime)	3	1.5176	0.1064	(1.3537, 1.6815)

Pooled StDev = 0.132370

According to above table, highest mean TA% (w/w) presented by Lime and the lowest mean TA% (w/w) presented by the Penidodam and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Sidaran is significantly low.

Table 17: Turkey Pairwise Comparisons of titratable acidity of varieties.

	Variety	N	Mean	Grouping
7	(Lime)	3	1.5176	A
6	(Lemon)	3	1.468	A
5	(Naas naran)	3	0.8917	B
3	(Sidaran)	3	0.5892	B C
4	(HeenNaran)	3	0.2802	C D
1	(Oranges)	3	0.2169	D
2	(Panidodam)	3	0.1566	D

Means that do not share a letter are significantly different.

As shown in above output, group A comprises Lime and Lemon, group B comprises Naas naran and Sidaran, group C comprises Sidaran and Heennaran and group D comprises Heennaran, Oranges and Penidodam. As well as, Sidaran represents both group B and C and Heennaran represent both group C and D. According to that there are significantly different combinations of mean TA% (w/w) and those mean TA%(w/w) are significantly different each other.

3.9 Vitamin C Content (mg/100g) versus Variety

Vitamin C Content (mg/100g) versus variety analysis examines whether there is a significant difference between the means of the above seven varieties of fruits under 0.05 level of significance. Results mentioned that the acceptance of the null hypothesis; the mean Vitamin C Content (mg/100g) of the seven varieties are equal. According to that, the p-value is 0.000, and it is less than the level of significance 0.05. Thus, the null hypothesis is rejected, and it can conclude that some of the Vitamin C Content (mg/100g) of the fruit varieties have different means.

Table 18: Means of Vitamin C of varieties.

Variety	N	Mean	St Dev	95% CI
1 (Oranges)	3	48.839	1.241	(47.505, 50.174)
2(Penidodam)	3	54.192	0.869	(52.857, 55.526)
3(Sidaran)	3	45.212	1.074	(43.878, 46.547)
4 (Heen Naran)	3	59.012	0.634	(57.678, 60.346)
5(Naas naran)	3	28.663	1.248	(27.328, 29.997)
6(Lemon)	3	41.758	1.209	(40.423, 43.092)
7(Lime)	3	23.840	1.121	(22.506, 25.174)

Pooled StDev = 1.07743

According to above table, highest mean Vitamin C Content (mg/100g) presented by Heennaran and the lowest mean Vitamin C Content (mg/100g) presented by the Lime and the difference between lowest and highest values are significantly high. Comparing to fruits varieties, the standard deviation of the Heennaran is significantly low.

Table 19: Tukey Pairwise Comparisons of Vitamin C of varieties.

Variety	N	Mean	Grouping
4(HeenNaran)	3	59.012	A
2(Penidodam)	3	54.192	B
1(Oranges)	3	48.839	C
3(Sidaran)	3	45.212	D
6 (Lemon)	3	41.758	E
5(Naas naran)	3	28.663	F
7(Lime)	3	23.840	G

Means that do not share a letter are significantly different.

As shown in above output, all the means represents different groups to each other. This means all the means are significantly different each other.

4. Conclusion

Sri Lankan *Citrus* varieties have always being used by the local and also by some foreigners as a source of fruit, fresh juice, and also as a medicine from the ancient past. Through the study of citrus fruits it was able to come to conclusion that there are wide variety of nutritional benefits as well as potential qualities are present in most of the *Citrus* varieties which make them suitable to be used as a functional food.

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