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CHARACTERIZATION OF THE NUTRITIONAL COMPOSITION, PH, AND COLOUR ATTRIBUTES OF KING ORANGE (*Citrus sinensis*) JUICE FROM DIFFERENT CULTIVATION REGIONS IN VIETNAM

Nguyen Van Loi[1,*], Vu Thi Cuong[2] and Bui Phuong Thao[3]
[1]*University of Science, Vietnam National University, Hanoi, Vietnam*
[2]*Hanoi University of Industry, Hanoi, Vietnam*
[3]*People's Police Academy, Hanoi, Vietnam*
[*]Corresponding author: Nguyen Van Loi, email: nguyenvanloi@hus.edu.vn

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Abstract. In Vietnam, king oranges are cultivated throughout the country, especially in the Tuyen Quang, Bac Ninh, Phu Tho, Lang Son, Vinh Long, and Dong Thap provinces, occupying large cultivation areas and contributing substantially to national production. Therefore, the objective of this study is to determine the nutritional composition, pH, and colour indexes of king orange juice in different cultivating regions, in order to provide a scientific basis for developing a process for industrial scale bottling and long-term preservation of king orange juice, which is essential and has high scientific and practical significance. The process involved several steps, extracting and collecting the juice from king oranges, then using physicochemical, biochemical, and sensory analysis methods to determine several nutritional indicators, pH levels, and the colour of the king orange juice. The research results showed that the Tuyen Quang king orange juice had higher soluble solids, total sugar content, vitamin C content, vitamin A content, and pH value than other orange juices. Specifically, king orange juice from Tuyen Quang exhibited a soluble solid of content of 10.93 ± 0.9 (°Bx), a total sugar content is 10.39 ± 0.8 (g/100mL), a vitamin C content is 14.36 ± 0.4 (µg/100mL), a vitamin A content is 53.16 ± 1.2 (mg/100mL), a protein content is 1.32 ± 0.3 (g/100mL) and a pH value is 4.3 ± 0.2. Among the six king orange juices evaluated, the Tuyen Quang king orange juice had a brighter, more characteristic, and more attractive yellow colour than the other samples. These results suggest that soil conditions, weather, climate, and growing conditions also affect the nutritional components and colour of king orange juice.

Keywords: colour, different cultivating regions, king orange juice, nutritional components.

1. Introduction

In Vietnam, king oranges (*Citrus sinensis)* are grown in all regions, particularly in the Tuyen Quang, Bac Ninh, Phu Tho, Lang Son, Vinh Long, and Dong Thap provinces, where they occupy large cultivation areas and contribute substantially to total citrus production. King oranges are characterized by a thick, rough hand bumpy peel that turns yellow upon ripening, along with flesh. The average weight of a king orange is about 170 - 190g. In addition, the peel is rich in essential oils, while the flesh contains sugars, proteins, minerals, and vitamins.

Orange juice is the most widely consumed fruit juice worldwide, particularly in Europe [1]. It is an important dietary source of vitamin C, folate, polyphenols, hesperidin, and flavonoids such as hesperidin, which contribute significantly to their daily intakes [1]. Previous studies have shown that orange juice can provide approximately 15% of the recommended daily intake of vitamin C for children and adolescents and 8% for adults.

Some steps of the process used for the industrial production of orange juice are known to impact its nutritional composition, especially for vitamin C. Consistently, commercial orange juice may have a different nutritional composition from homemade orange juice; however, no good quality analytical study has been performed to compare the nutritional composition between the two types of orange juice [2], [3]. Carotenoid, flavonoid, and vitamin C concentrations were determined in fresh orange segments and a puree-like homogenate derived thereof, as well as freshly squeezed, flash pasteurized, and pasteurized juices [3]. King orange trees are widely grown in many provinces, specifically in Tuyen Quang province with 9.300 hectares, Bac Ninh province with 2.643.2 hectares, Lang Son province with 326.7 hectares, Phu Tho province with 365.4 hectares, Vinh Long province with 1,800 hectares, and Dong Thap province with 473.6 hectares. Lutein and β-cryptoxanthin were slightly degraded during dejuicing, whereas β-carotene levels were retained. Vitamin C levels remained unaffected, whereas flavonoid levels decreased eightfold upon juice extraction, most likely due to the removal of flavonoid-rich albedo and juice vesicles [2]. Therefore, the objective of this study is to determine some nutritional and colour indicators of king orange juice in different cultivating regions, in order to provide a scientific basis for developing a process for industrial scale processing, bottling, and long-term preservation of king orange juice, which is essential and has high scientific and practical significance.

2. Materials and methods

2.1. Material

Six king orange (*Citrus sinensis*) samples were collected at commercial maturity (220 days after flowering) from the provinces of Tuyen Quang, Bac Ninh, Lang Son, Phu Tho, Vinh Long, and Dong Thap, Vietnam. From 220 days onwards, the king oranges begin to ripen [4]. These experiments were repeated three times, and the average of the results was taken. These king oranges are grown according to Viet Gap standards. King oranges used in the experiment must meet quality standards, be pest-

free and undamaged, and ensure food safety and hygiene. King orange fruits were packed in perforated foam containers and transported to the laboratory for subsequent analyses.

2.2. Methods

- Methods for processing king orange juice

Based on preliminary investigations, the method for processing king orange juice was proposed as follows. The fresh king oranges were washed with tap water, peeled, cut crosswise, and placed in a juicer. The juice was extracted, then centrifuged and filtered. The centrifugation process was performed at 1500 rpm for 10 minutes to separate the liquid and solid fractions. The king orange juice was filtered twice: first through a 0.05mm stainless steel filter to remove large impurities and then through filter paper to remove smaller impurities. The recovered king orange juice was stored in specialized 1.5 L polyethylene (PE) plastic bottles equipped with tight-fitting caps. Prior to use, all bottles were thoroughly cleaned and sterilized. After bottling and sealing, the king orange juice samples were stored in a refrigerator or cold storage at 2-4°C awaiting analysis or processing into food products [5].

- Method for determining soluble dry matter content

The soluble solids content of king orange juice was determined using an ATAGO N-1α refractometer (ATAGO Co., Ltd., Japan) and expressed as ^{o}Bx at 20^{o}C. When light passes through a solution with different dissolved solids, the light is refracted with different refraction angles, allowing the soluble solids content of the sample to be determined [5].

- Method for determining total sugar content

The total sugar content of the king orange juice was determined according to the Vietnamese National Standard TCVN 4594. This method is carried out according to the principle of extracting total sugar from the sample with hot water, using hydrochloric acid to hydrolyze it into glucose. The amount of glucose was determined through reactions with phenol solution, $Fe_2(SO_4)_3$, and $KMnO_4$ [6].

- Method for determining total protein content

The protein content of king orange juice was determined according to the Vietnamese National Standard TCVN 9936. In this method, organic matter was decomposed with concentrated sulfuric acid, alkalinize reaction products, ammonium in boric acid solution, then it was titrated with standard sulfuric acid solution [7].

- Method for determining vitamin A content

The vitamin A content of king orange juice was determined according to the Vietnamese National Standard TCVN 8972-1. The method was carried out according to the principle that retinol was saponified with a solution of potassium hydroxide in ethanol or methanol and extracted with a suitable solvent. It was then determined by high-performance liquid chromatography with a fluorescence detector or an ultraviolet detector. Substances were identified based on retention time and determined by the external standard method, using peak area or peak height [8].

- Method for determining vitamin C content

The vitamin C content of king orange juice was determined according to the Vietnamese standard TCVN 8977. This method was performed on the principle that vitamin C was extracted from the analytical sample using metaphosphoric acid solution. A reducing

solution was used to convert dehydrogenated *L*(+) ascorbic acid. The total *L*(+) ascorbic acid content was determined by HPLC with a UV detector at a wavelength of 265 nm [9].

- Method for determining colour

The colour of the king's orange juice was determined using a Colour Meter. Three measurements were taken, and the average value was calculated. The measurement results, displayed as L***(**lightness), a***(**redness/greenness), and b***(**yellowness/blueness) indices, were compared to a colour ball. L* ranges from 0 to 100, corresponding to colours from black to white; a* ranges from -60 to +60, corresponding to colours from green to red; and b* ranges from -60 to +60, corresponding to colours from blue to yellow. The process of measuring the colour of king orange juice was as follows: Step 1: Place the first king orange juice sample on a PE plastic plate and position the plate in the center of the glass surface. Step 2: Measure the colour and record the L*, a*, and b* values. Step 3: Perform the same experiment with the second king orange juice sample and record the data L*, a*, b* [10].

- Method for determining the pH value

The pH value of King's orange juice was measured with a HACH HQ11D portable pH meter. The pH meter was calibrated using pH 4 and pH 7 buffers. Measurement of pH value was measured at room temperature using 10 mL of King's orange juice [11].

- Method for determining sensory value

The sensory properties of king orange juice were evaluated using a descriptive sensory analysis method. This approach was employed to characterize the sensory attributes of the juice, including colour, aroma, taste, and appearance. The panel consists of nine members who were trained to become familiar with the sensory properties of colour, aroma, taste, and the state of king orange juice, and then determined the intensity scale as a nine-point scale. Members received scoring sheets and samples of King Orange Juice to be evaluated, then tested the samples and determined the intensity of each required characteristic on the nine-point scale used. The descriptive method was carried out through the following steps: Selecting the characteristics to be evaluated, conducting preliminary tests so that members agree on how to use the established intensity scale, and evaluating the intensity of the selected characteristics on the scale [12].

- Statistical analysis

Analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were used to determine the significance of differences between means ($p \leq 0.05$). Results were indicated by the mean of standard error values of three replication determinations [13].

3. Results and discussion

3.1. Some nutritional components of king orange juice samples in different cultivating regions

The content of vitamin C, vitamin A, total sugar, and total protein plays an important role in king orange juice. These are indices used to assess the quality of king orange juice. The levels of these nutrients in king orange juice also depend on soil conditions, weather, climate, the ripeness of the king oranges, and growing conditions.

The results of determining some nutritional components of king orange juice in different cultivating regions are shown in Table 1.

Table1. Some nutritional components of the king orange juice samples in different cultivating regions

No.	King orange juice	Analytical indicators				
		Soluble dry matter content (°Bx)	*Total sugar content (g/100mL)*	*Total protein content (g/100mL)*	*Vitamin A content (µg/100mL)*	*Vitamin C content (mg/100mL)*
1	Tuyen Quang	10.93 ± 0.9	10.39 ± 0.8	1.32 ± 0.3	14.36 ± 0.4	53.16 ± 1.2
2	Bac Ninh	9.74 ± 0.6	9.17 ± 0.4	1.16 ± 0.2	13.67 ± 0.3	47.76 ± 1.5
3	Lang Son	9.87 ± 0.4	9.32 ± 0.3	1.25 ± 0.3	14.05 ± 0.5	49.54 ± 1.8
4	Phu Tho	9.93 ± 0.7	9.56 ± 0.7	1.24 ± 0.4	14.23 ± 0.4	51.03 ± 1.3
5	Vinh Long	10.82 ± 0.8	10.27 ± 0.8	1.28 ± 0.4	14.34 ± 0.3	53.07 ± 1.4
6	Dong Thap	10.71 ± 0.9	10.35 ± 0.7	1.34 ± 0.4	14.19 ± 0.2	52.85 ± 1.7

Note: Values are presented as the mean ± standard deviation.

The research results in Table 1 show that the soluble dry matter content of king orange juice is high. Specifically, the soluble dry matter content of Tuyen Quang king orange juice is 10.93 ± 0.9°Bx, Vinh Long king orange juice is 10.82 ± 0.8°Bx, Dong Thap king orange juice is 10.71 ± 0.9°Bx, Phu Tho king orange juice is 9.93 ± 0.7°Bx, Lang Son king orange juice is 9.87 ± 0.4°Bx and Bac Ninh king orange juice is 9.74 ± 0.6°Bx. The total sugar content of Tuyen Quang king orange juice is the highest at10.39 ± 0.8 g/100mL, followed by Dong Thap king orange juice, which is 10.35 ± 0.7 g/100mL, Vinh Long king orange juice is 10.27 ± 0.8 g/100mL Phu Tho king orange juice is 9.56 ± 0.7 g/100mL, Lang Son king orange juice is9.32 ± 0.3 g/100mL and Bac Ninh king orange juice is 9.17 ± 0.4 g/100mL. Total protein content in king orange juice ranges from 1.16 ± 0.2g/100mL to 1.34 ± 0.4 g/100mL, with the highest being Dong Thap king orange juice ranges, followed by Tuyen Quang king orange juice ranges, Vinh Long king orange juice ranges, Lang Son king orange juice ranges, Phu Tho king orange juice ranges, and Bac Ninh king orange juice ranges. Research results also show that the vitamin A content is high, usually ranging from 13.67 ± 0.3µg/100g to 14.36 ± 0.4µg/100g. The highest vitamin A content is in the Tuyen Quang, followed by the Vinh Long king orange juice, Phu Tho king orange juice, Dong Thap king orange juice, Lang Son king orange juice, and Bac Ninh king orange juice. The highest vitamin C content is in the Tuyen Quang, followed by the Vinh Long king orange juice, Phu Tho king orange juice, Dong Thap king orange juice, Lang Son king orange juice, and Bac Ninh king orange juice. The results for determining the soluble solids content, total protein content, and vitamin A content of the king orange juice samples in Table 1 are consistent with the research results of Aurelie C.R *et al.,* [1]. The research results of Aurelie C.R *et al*., [1] determined that the total sugar content is 8.35 ± 0.887 g/100mL and vitamin C is 47.8 ± 8.59 mg/100Ml of French king orange juice. Thus, the research results in Table 1 show a higher total sugar content and vitamin C than the research results of Aurelie C.R *et al*., [1]. This indicates that soil conditions, weather, climate, and growing conditions also affect the total sugar content and vitamin C of king orange juice.

3.2. The colour of king orange juice samples in different cultivating regions

The colour is an important indicator of the quality of the king's orange juice. Fresh king orange juice usually has a distinctive colour and does not separate into layers. During the preservation process, the colour of the king's orange juice, in particular, often changes. The results of determining the colour of the king's orange juice samples are shown in Table 2

Table 2. The colours of the king orange juice samples in different cultivating regions

No.	King orange juice	pH value	Sensory value	Analytical indicators	
1	Tuyen Quang	4.3 ± 0.2	Bright and distinctive yellow colour, and appealing. It has a mild sweetness, a distinctive aroma, and a homogeneous consistency.	L*	76.07 ± 0.85
				a*	0.14 ± 0.07
				b*	3.53 ± 0.09
2	Bac Ninh	3.8 ± 0.1	Bright yellow. It has a sweet taste mixed with a slightly sour taste and a distinctive aroma in a homogeneous state.	L*	73.15 ± 0.73
				a*	0.03 ± 0.05
				b*	3.27 ± 0.04
3	Lang Son	3.9 ± 0.2	Bright yellow. It has a sweet taste mixed with a slightly sour taste and a distinctive aroma in a homogeneous state.	L*	74.26 ± 0.54
				a*	0.06 ± 0.09
				b*	3.34 ± 0.08
4	Phu Tho	4.1 ± 0.1	Bright yellow. It has a sweet taste mixed with a slightly sour taste and a distinctive aroma in a homogeneous state.	L*	74.39 ± 0.91
				a*	0.07 ± 0.09
				b*	3.35 ± 0.07
5	Vinh Long	4.2 ± 0.1	Bright and distinctive yellow colour, and appealing. It has a mild sweetness, a distinctive aroma, and a homogeneous consistency.	L*	74.93 ± 0.76
				a*	0.12 ± 0.05
				b*	3.47 ± 0.07
6	Dong Thap	4.3 ± 0.2	Bright and distinctive yellow colour, and appealing. It has a mild sweetness, a distinctive aroma, and a homogeneous consistency.	L*	74.87 ± 0.82
				a*	0.09 ± 0.03
				b*	3.43 ± 0.06

Note: Values are presented as the mean ± standard deviation.

The research results in Table 2 show that Tuyen Quang and Dong Thap king orange juices have the highest pHis 4.3 ± 0.2, Vinh Long king orange juice has a pH is 4.2 ± 0.1, Phu Tho king orange juice has a pH is 4.1 ± 0.1, Lang Son king orange juice has a pH is 3.9 ± 0.2 and Bac Ninh king orange juice has the lowest pH is 3.8 ± 0.1. Tuyen Quang king orange juice, Vinh Long king orange juice, and Dong Thap king orange juice have a bright, distinctive, and attractive yellow colour. Meanwhile, Bac Ninh king orange juice, Lang Son king orange juice, and Phu Tho king orange juice have a lighter yellow hue. Tuyen Quang king orange juice has the highest L* value at 76.07 ± 0.85, followed by Vinh Long king orange juice with an L* value of 74.93 ± 0.76, Dong Thap king

orange juice with an L* value of 74.87 ± 0.82, Phu Tho king orange juice with an L* value of 74.39 ± 0.91, Lang Son king orange juice with an L* value of 74.26 ± 0.54 and the lowest is Bac Ninh king orange juice, with an L* value of 73.15 ± 0.73. The lower the L* value, the darker the colour of the king orange juice. The a* and b* values of Tuyen Quang king orange juice are the highest, followed by Vinh Long, Dong Thap, Phu Tho, and Lang Son king orange juices, with the lowest being Bac Ninh king orange juice. The lower the a* index, the less red the colour, and the lower the b* index, the less yellow the king orange juice. In the six king orange juice samples tested, the Tuyen Quang king orange juice had a brighter, more characteristic, and more attractive yellow colour than the other samples. Colour is also an important indicator of the freshness of king orange juice. During storage or heating (blanching, concentration), the L* index tends to decrease, meaning the king orange juice becomes darker and less clear due to Maillard reactions or oxidation. When the quality of the king orange juice decreases (due to spoilage or processing), the red colour (a*) usually decreases (towards 0 or more negative), showing a change from bright king orange yellow to yellowish brown. During storage, the index (b*) decreases, indicating that the king orange juice loses its natural bright yellow colour due to the breakdown of carotenoid pigments. This shows that soil, weather, and climate also greatly influence the colour and pH of king orange juice. The results of this study are also consistent with the results of Perez-Lopez A.J *et al*. [3].

4. Conclusions

This study has determined some nutritional, pH, and colour indices of king orange juice in different growing regions in Vietnam. The research results showed that the Tuyen Quang king orange juice had higher soluble dry matter content, total sugar content, vitamin C content, vitamin A content, and pH value than other orange juices. Specifically, the Tuyen Quang king orange juice had a soluble dry matter content is 10.93 ± 0.9 (^{o}Bx), the total sugar content is 10.39 ± 0.8 (g/100mL), the vitamin C content is 14.36 ± 0.4 (µg/100mL), the vitamin A content is 53.16 ± 1.2 (mg/100mL), the protein content is 1.32 ± 0.3 (g/100mL) and the pH is 4.3 ± 0.2. Among the six king orange juices tested, the Tuyen Quang king orange juice exhibited a brighter, more characteristic, and more attractive yellow colour than the other samples. This indicates that soil conditions, weather, climate, and growing conditions also affect the nutritional components and colour of king orange juice.

Note for contributor:

- Short bio: Nguyen Van Loi is an Associate Professor, Ph.D., and Senior Lecturer at VNU University of Science; Vu Thi Cuong is a Ph.D. and Lecturer at the HaUI Institute of Technology, Hanoi University of Industry; and Bui Phuong Thao is a Master's degree holder and Principal Lecturer at the Faculty of Economic Police, People's Police Academy.

- Author's contributions: Nguyen Van Loi: conceptualization, methodology, data analysis, supervision; Vu Thi Cuong: writing; Bui Phuong Thao: review & editing, visualization.

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