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Phytochemical composition and antioxidant activities of king orange (*Citrus reticulata* × sinensis) cultivated in the Mekong Delta, Vietnam

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A B S T R A C T

Purpose: King orange (*Citrus reticulata* × sinensis) is a fruit spices native to tropical and subtropical regions that holds significant economic and nutritional value and is widely consumed in daily life. The primary chemical constituents of king orange include flavonoids (such as hesperidin and naringin), organic acids, vitamin C, and phenolic compounds. Due to its unique biological properties, nutritional benefits, and divers pharmacological effects, king orange is not only a widely consumed fruit but also a promising ingredient for developing natural functional foods, pharmaceuticals, and cosmetics. This study investigated the distribution of bioactive compounds and the antioxidant capacity in different tissues of king orange cultivated in four provinces of the Mekong Delta, Vietnam. **Research Method:** Physical characteristics of the fruit were analyzed, and phytochemical screening was performed identify secondary metabolites. Flavonoid and phenolic contents were quantified, and antioxidant activity was assessed using the DPPH assay. **Findings:** The fruits had thick, juicy flesh (42.4-51.2% w/w) and thin peel (27.2-35.2% w/w). Alkaloids, flavonoids, phenolics, and saponins were detected in both juice and peel extracts, while terpenoids were found only in the peel. The juice had the highest flavonoid and phenolic content, followed by flavedo and albedo extracts. Antioxidant activity was highest in the juice from "Can Tho" and in the peel extracts from "Vinh Long". **Research limitations:** No limitations were encountered. **Originality/Value:** Orange juice and peel are rich in bioactive compounds with antioxidant properties, highlighting their potential for health-promoting applications. *Citrus reticulata* is not only a widely consumed fruit but also a promising raw material for the development of natural functional food, pharmaceutical, and cosmetic products.

Keywords:
Antioxidant capacity, Bioactive compound, *Citrus reticulata* × sinensis, Flavonoids, Phenolics

INTRODUCTION

Citrus is one of the most important commercial fruit crops grown worldwide. Citrus fruit are globally valued for their nutritional and economic significance, with increasing attention toward their bioactive compounds that exhibit strong antioxidant and health promoting properties (Lu et al., 2023). Global production of citrus fruit is increasing, with king oranges accounting about 50% of total production, followed by tangerines/mandarins, lemons/limes, and grapefruit (USDA) (Liu et al., 2012). Citrus fruits are usually consumed either fresh or in the form of juice. Thus, a significant number of by-products of the juice industry have been created as the peel and non-edible parts account for almost 50% of the original fruit (Dawood et al., 2022). To solve the problem of waste from citrus crops, many previous studies have been conducted to take advantage of this abundant source of raw materials. Studies have found that citrus peels are rich in nutrients such as carbohydrates (El Fihry et al., 2022; Rahmani et al., 2020), vitamins (C and E), minerals (selenium, zinc, copper, iron, and manganese), and amino acids (Ani & Abel, 2018; Czech et al., 2020). Furthermore, citrus peels contain many phytochemicals including phenolic compounds (flavonoids, phenolic acids, and coumarins) (Lee et al., 2022; Liew et al., 2018) and terpenoids (limonoids and carotenoids) (Huang et al., 2022; Saini et al., 2022). This highlights the potential utilization of citrus waste in the production of pharmaceuticals and functional foods.

King Orange (*Citrus reticulata* × *sinensis*) is a citrus fruit variety cultivated in Vietnam, especially in the Mekong Delta region (because this is fertile alluvial land and has a hot and humid tropical climate). Provinces with large king orange growing areas in the Mekong Delta include Vinh Long, Hau Giang, Dong Thap, and Can Tho. King oranges are prize for their distinctive flavor, high nutritional value, and human health benefits. Therefore, in addition to being used in fresh form, king oranges have also been researched to create many other product lines such as king orange wine, cider king oranges, and soft-dried king oranges (Nguyen & Nguyen, 2022; Tuyen et al., 2022). In addition, Huynh et al. (2022) evaluated the physicochemical characteristics, antibacterial, antifungal, and antioxidant properties of king orange peel essential oil (*Citrus nobilis*). However, in Vietnam, there are currently no specific data available regarding the chemicha composition different part of king oranges, particularly concerning their polyphenol content and oxidative stability. Therefore, this study was conducted to determine the distribution ratio, phenolic compound content, and antioxidant activity of various fruits parts collected from four major king orange-growing provinces in the Mekong Delta. The results contribute to providing scientific data on the characteristics and composition of the king orange in the Mekong Delta, especially the components related to biological properties, including phenolic compounds and flavonoids, as well as evaluating the antioxidant potential of different components of the king orange. Furthermore, the research results will be the basis for using the components of the king orange as raw materials for different purposes, such as juice from the pulp, tea from the white peel and essential oil from the green peel, etc. The results obtained will inform consumers and orient future use.

MATERIALS AND METHODS

Raw materials

King Orange fruits were sampled in four provinces including Vinh Long (VL), Hau Giang (HG), Dong Thap (DT), and Can Tho (CT). All fruits harvested at the commercial maturity stage. Fruits were harvested at commercial maturity, identified by uniform by uniform peel color, full size, and total soluble (TSS) value of 8-11 °Brix, ensuring consistent ripeness across samples. About 10 kg of king oranges were randomly purchased in each local place. Then, the fruits were washed to remove external impurities, avoid strong collisions, and air-dried under laboratory conditions. Washed fruits were weighed and measured to determine the weight, diameter, and height. Subsequently, each fruit was manually separated into two parts consisting of peel (flavedo and albedo) and flesh (fruit juice and carcass).

Chemicals

The chemicals used included gallic acid, quercetin, Folin-Ciocalteu reagent (Sigma-Aldrich, Germany), 2, 2-diphenyl-1-picrylhydrazyl (Tokyo Chemical Industry, Japan), absolute ethanol (Cemaco, Vietnam), Na_2CO_3, CH_3COOK, Na_2HPO_4, $K_3Fe(CN)_6$, CCl_3COOH, $FeCl_3$, $AlCl_3$, I_2, and KI (Xilong Scientific, China).

Evaluation of the parts ratio of king orange

King orange samples from each province were used to evaluate the fruit weight, diameter, and height. The king orange was then peeled and separated into parts, including the peels (flavedo-green peel and albedo-white peel) and flesh (fruit juice, fruit carcasses).

Recovery of extracts and phytochemical screening in each part of king orange

The fruit peels (flavedo and albedo) were chopped (average thickness 1-2 mm) and dried in a convection drying cabinet at a temperature of 40^{o}C until the moisture content of the sample dropped below 10%. The sample was ground with a blender (MX-V310KRA, Panasonic, Japan) and stored in a dehumidifier. Fifty grams of peel powder is immersed in 200 mL of absolute methanol, and the soaking time is at least 24 h. The extraction process was repeated 4 times. The extracts from the immersions were collected, and vacuum rotation at 40^{o}C to remove the solvent and obtain extracts (Trang et al., 2018). In particular, the fruit juice was pressed, and pure fruit juice was used to qualitatively evaluate some natural compounds. The juice was stored at -20^{o}C until analysis.

The qualitative method based on certain criteria, such as color, precipitation reactions, and emulsion development, is presented in Table 1. The extracts were prepared at concentrations of 100 mg/mL.

Determination of total phenolic and flavonoid contents in king orange methods

The total phenolic content was determined based on the method of Tran et al. (2025) with the following adjustments: 1 mL of the sample was added to a test tube, supplemented with 2.5 mL of 10% Folin-Ciocalteu reagent, and vortexed evenly (Tran et al., 2025). After 5 min, 2 mL of 2% (w/v) Na_2CO_3 was added to the mixture. The reaction was kept in the dark for 45 min at room temperature. The spectral absorption of the reaction mixture was measured at a wavelength of 765 nm. The standard used was gallic acid (20-120 µg/mL). The total phenolic content in the extract was determined based on the calibration equation of gallic acid and was expressed as mg/g of gallic acid equivalents (mg GAE/g).

The total flavonoid content was determined as described by Tran et al. (2025). First, 1.5 mL of 95% ethanol was added to 0.5 mL of samples that had been prepared in a test tube and allowed to stand for 5 min (Tran et al., 2025). Then, 0.1 mL of 10% $AlCl_3$ was added and the reaction was left for 6 min. Finally, 0.1 mL of 1 M CH_3COOK and 2.8 mL of distilled water were added, shaken well, and left to stabilize at room temperature for 45 min. The reaction mixture was measured for spectral absorption at a wavelength of 415 nm. The standard used was quercetin (10-100 µg/mL). The total flavonoid content in the extract was determined based on the calibration equation of quercetin and was expressed as mg/g of quercetin equivalents (mg QE/g).

Table 1. Qualitative methods for some natural compounds.

Compounds	Methods	Positive results
Alkaloids	0.5 mL sample + 3-4 drops of Wagner's reagent	Reddish brown color (Rindita et al., 2019)
Flavonoids	0.5 mL sample + 3-4 drops of 1% NaOH	Yellow to king orange-red color (Enerijiofi & Isola, 2019)
Phenolic	0.5 mL sample + 2-3 giọt $FeCl_3$ 5%	Green-blue black precipitate (Rindita et al., 2019)
Saponins	2 - 3 drops of olive oil	Milky emulsion (Pant et al., 2017)
Terpenoids	0.5 mL sample + 1 mL $CHCl_3$ + 2-3 drops of H_2SO_4	Purple red - blue green color (Enerijiofi & Isola, 2019)

Evaluation of the antioxidant capacity of king orange

The part-by-part oxidation resistance of king oranges was assessed using the DPPH method performed by Ye et al. (2013) and adjusted as follows: 200 µL sample at different concentrations was prepared in test tubes, 1 mL of 0.1 mM DPPH was added to the prepared test tubes, and the mixture was shaken well (Ye et al., 2013). The mixture was left stable in the dark at room temperature for 15 min, and the spectral absorption of the reaction mixture was measured at a wavelength of 517 nm. Results are recorded based on IC_{50} (µg/mL) values.

Statistical analysis

Data were processed using the Microsoft Excel 2010 software (Microsoft Corporation, USA) and statistical analysis using the statistical software Statgraphics Centurion XV (Statgraphics Technologies, Inc., USA).

RESULTS AND DISCUSSION

Distribution ratio of king orange parts in some provinces in the Mekong Delta

The results of the distribution of the components in the king oranges are recorded in Table 2. It can be seen that the distribution ratio between proportions in king orange has a significantly difference. In general, in king orange, the flesh constitutes the largest portion of the fruit, ranging from 64.78 to 72.84% w/w, of which the fruit juice accounts for 42.39-51.20% w/w. particularly, the peel represents from 27.17 to 35.22% w/w, with the proportion of green peel consistently higher than that of the white peel. According to the recorded reality, the difference in the source of king oranges produced in different localities will be different.

Table 2. Distribution ratio and the main components of the king orange fruits.

Province	Diameter (cm)	Height (cm)	Weight (g)	Flesh		Peel	
				Juice (%)	Carcass (%)	Albedo (%)	Flavedo (%)
Vinh Long	7.82±0.54	6.35±0.46	206.56±15.41	51.20	21.64	12.66	14.51
Hau Giang	6.93±0.51	5.58±0.43	156.34±13.78	42.39	22.39	16.33	18.89
Dong Thap	6.73±0.35	5.65±0.28	124.67±10.56	48.44	17.35	13.03	21.18
Can Tho	8.65±0.74	7.12±0.62	252.45±17.34	44.30	24.82	9.17	21.72

Fig. 1. Height of king oranges in DT, HG, VL, and CT provinces.

Fig. 2. Diameter of king oranges in DT, HG, VL, and CT provinces.

Figure 1 and Figure 2 show that the land conditions, soil and cultivation practices are different, the king orange trees in each region have differences in fruit size, peel thickness, color. King oranges in the three provinces have different ripening and harvesting times such as Dong Thap around October - February, Hau Giang from November - March and Vinh Long has many harvests and is most abundant in December - February.

The results of this study are consistent with the publication of Mahato et al. (2018), who evaluated the distribution of components of citrus fruit as a basis for their optimal utilization. In addition, when comparing the volume, size and distribution ratio between the components of king orange samples collected in some popular growing provinces in the Mekong Delta region, differences were also shown. In particular, the king orange sample in Can Tho has a large size compared to the rest of the provinces. King Orange samples in Dong Thap province showed the smallest size among the 4 surveyed provinces. Specifically, the king orange fruit sampled in Can Tho has an average diameter of 8.65 cm and a height of 7.12 cm. The average weight of the fruit is 252.45 g of which the juice, carcass, white and green peel account for 44.30%, 24.82%, 9.17%, 21.72%, respectively. On the other hand, king oranges in Dong Thap have a smaller average diameter with 6.73 cm and a height of 5.65 cm. The average weight of the fruit accounts for about 60% (124.67 g) of the mass of king oranges grown in Can Tho, of which the juice, carcass, albedo and flavedo account for 48.44%, 17.35%, 13.03%, 21.18%, respectively. The reason for this difference may be that climatic conditions (temperature, day length, light and water level), cultivation conditions (crop density, soil properties, soil type and soil fertility) and cultivation methods (irrigation dosage, fertilization) have influenced the distribution between components (Luro et al., 2020; Stewart & Ahmed, 2020).

Qualitative results of phytochemical present in each part of king orange

The results from Table 2 indicate the difference in the distribution ratio of king orange parts in some provinces in the Mekong Delta region. On that basis, in this experiment, phytochemicals were preliminarily identified in the peel and flesh of king oranges. The qualitative results are shown in Table 3.

Table 3. Qualitative results of the compounds in the fruit juice, green and white peel ethanol extraction

Compounds	VL			HG			DT			CT		
	Flavedo	Albedo	Juice	Flavedo	Albedo	Juice	Flavedo	Albedo	Juice	Flavedo	Albedo	Juice
Alkaloids	+	+	+	+	+	+	+	+	+	+	+	+
Flavonoids	+	+	+	+	+	+	+	+	+	+	+	+
Phenolic	+	+	+	+	+	+	+	+	+	+	+	+
Saponins	+	+	+	+	+	+	+	+	+	+	+	+
Terpenoids	+	+	-	+	+	-	+	+	-	+	+	-

Note: (+): presence and (-): absence. VL: Vinh Long, HG: Hau Giang, DT: Dong Thap, CT: Can Tho.

It can be seen that fruit juice and king orange peel ethanol extracts in 4 surveyed provinces all recorded the presence of alkaloids, flavonoids, phenolic, and saponins with color reactions specific to each type of compound. However, qualitative terpenoid results show that the color reaction occurs only when tested with extracted part of the peels. Overall, this result is consistent with many previously published results (Emojorho & Akubor, 2016; Gotmare & Gade, 2018; Simeon et al., 2018).

Despite this, results from other studies also show differences in qualitative outcomes. Roghini and Vijayalakshmi (2018) showed the presence of terpenoids in the flesh of *Citrus paradisi*. This may be due to studies using different types of solvents in the extraction process leading to the acquisition of different types of compounds (Abdelazem et al., 2021). In addition, the amount and type of compounds present in Citrus are varied and depend on the variety, species, harvest time and parts of the fruit as well as on climatic and cultivation conditions.

Plants produce chemicals called secondary metabolites that are not directly involved in growth but play an important role in the plants' natural defense system, including alkaloid compounds, flavonoids, terpenoids, and phenolic compounds. Flavonoids produced by plants help fight microbial attack and infection by disrupting microbial cell membranes (Dhiman et al., 2011). In humans, flavonoids in citrus have many beneficial properties such as anti-cancer, anti-inflammatory, and antiviral (Ullah et al., 2020). On the other hand, phenolic compounds produced by plants to help them resist stressful conditions. For humans, the consumption of fruits containing phenols has antioxidant effects and reduces the risk of cancer and cardiovascular disease (Stepanic et al., 2015). The majority of terpenoids are classified as secondary metabolites that function in plant defense against herbivores or in inhibiting the germination of neighboring plants. Terpenoids are the main components of citrus essential oils and are also important factors in creating the aroma of this plant family. These compounds are famous for their antibacterial properties, and the essential oil is used as a preservative for fruits, vegetables, meat, and processed food products (Gershenzon & Dudareva, 2007). Alkaloids are natural compounds containing heterocyclic nitrogen and synthesized from amino acid derivatives (Lv et al., 2015; Saini et al., 2022). Alkaloids are toxic components that protect plants from insects and parasitic plants. Therapeutically, alkaloids act as an anesthetic, cardioprotective, and anti-inflammatory agents (Heinrich et al., 2021). Saponins can create stable soap-like foam in aqueous solution, so they are used as natural detergents. Saponins can be considered part of the plants' defense system. They have been included in a large group of protective molecules which found in plants called “phytoanticipins” or “phytoprotectants”. Saponins have also been reported to have anti-inflammatory, hypoglycemic, and immune-stimulating effects (Kregiel et al., 2017).

Total phenolic and total flavonoid contents of each part of king orange

Many studies on the phytochemical composition of citrus berries have been carried out. The results indicate that citrus fruits, belonging to the Rutaceae family, contain significant amounts of natural flavonoids and phenolics (Rafiq et al., 2018). In this experiment, the flavonoid and phenolic content was determined, and the results are presented in Table 4. There are the differences in flavonoid content between fruit parts and trees grown in different provinces. The flavonoid content ranged from 19.57 to 79.67 mg QE/g in green peel extract, 4.30-9.78 mg QE/g in white peel extract, and 55.37-109.77 mg QE/g in fruit juice. In term of flavonoid content in each part, the green peel extract of VL king orange has the highest flavonoid content and DT king orange has the lowest flavonoid content. Meanwhile, the white peel extract of king oranges has the highest flavonoid content. CT king orange juice yielded the highest flavonoid content in the provinces surveyed. Similarly, when surveying phenolic content, it also showed differences between the different provinces and fruit parts tested. The phenolic content was recorded in the range of 11.81-30.95 mg GAE/g for green peel extract, 9.81-17.68 mg GAE/g for white peel extract, and 99.43-158.85 mg GAE/g for fruit juice. The results showed that VL king oranges had significantly higher total phenolic properties than other provinces, while CT king oranges had the highest total phenolic count. TPC content is determined by Folin-Ciocalteu reagent. This method reacts not only with polyphenols, but also with other reducing substances (vitamin C, reducing sugars, organic acids in king oranges, etc.). When the sample is rich in vitamin C, the measurement signal of polyphenols may be interfered with, leading to lower values than the actual value. Meanwhile, TFC content is usually determined by the $AlCl_3$ complexation method. Therefore, it is less interfered with by vitamin C or other reducing compounds. King oranges contain very high levels of flavanone glycosides (hesperidin, narirutin, didymin). This is the dominant flavonoid group in king orange juice. Meanwhile, other phenolic compounds besides flavonoids (such as phenolic acid, tannin) are quite low in king oranges. This makes flavonoids account for an overwhelming part of the total polyphenols, so the flavonoid measurement may be higher than TPC if the TPC method is affected by vitamin C.

In general, the results in Table 4 show that king orange outbreaks in the provinces had the highest flavonoid and phenolic contents, followed by green and white peels. This result is different from previously published results. Nearly all previous studies have reported that citrus fruit peels have higher amounts of flavonoids and phenolics than fruit flesh (Buyukkurt et al., 2019; Multari et al., 2020). This is explained as follows: the peel is the outer part of the fruit and is in direct contact with the environment, so it is easily damaged. Therefore, compounds produced by plants as a defense mechanism in response to environmental stresses and tend to concentrate in the crust (Bhattacharya et al., 2010). This difference may be due to different treatments of samples and extracted solvents in studies. Previous studies have treated samples by lyophilization (Costanzo et al., 2022; Xi et al., 2017). However, samples in this study were dried and extracted using ethanol solvents. This may be the cause of the loss of flavonoid and phenolic content in the peel due to the loss of some volatile compounds by heat.

Although the literature indicates that flavedo and albedo are richer in flavonoids and phenolics than fruit juice, the accumulation of phytochemicals is also influenced by factors such as genotype and environmental conditions. Zhang et al. (2018) also showed that the juice of some varieties of *Citrus reticulata* Blanco native to the US contains higher levels of flavonoids and phenolics than in its peel, in contrast, the same species in Italy gives the peel more flavonoids and phenolic juices (Zhang et al., 2018). Dong et al. (2019) suggested that relative air humidity impacts flavonoid accumulation by altering the activity of transcriptional activators and enzymes. As such, the results from this study will provide important information for the future study and use of king king oranges (Dong et al., 2019).

Table 4. Flavonoid and phenolic content in the fruit juice and extract of king orange peel.

Province	Total flavonoid content (mg QE/g)			Total phenolic content (mg GAE/g)		
	Flavedo	Albedo	Juice	Flavedo	Albedo	Juice
Vinh Long	79.67 ± 0.25[a]	4.98 ± 0.03[c]	89.94 ± 0.25[c]	30.95 ± 0.04[a]	17.68 ± 0.09[a]	149.68 ± 0.15[b]
Hau Giang	54.35 ± 0.34[b]	7.82 ± 0.07[b]	55.37 ± 0.16[d]	21.78 ± 0.02[b]	9.81 ± 0.02[c]	99.43 ± 0.05[d]
Dong Thap	19.57 ± 0.33d	9.78 ± 0.12[a]	102.35 ± 0.33[b]	11.81 ± 0.04[c]	14.05 ± 0.02[b]	105.61 ± 0.33[c]
Can Tho	31.50 ± 0.14[c]	4.30 ± 0.27[d]	109.77 ± 5.19[a]	21.31 ± 0.25[b]	14.07 ± 0.05[b]	158.85 ± 0.20[a]

Note: The total flavonoid and phenolic content values are the average values of the three repetitions. Letters followed by identical values were statistically non-statistically significant at 5% significance.

Table 5. The antioxidant capacity of fruit juice and peel extracts.

Province	IC_{50} (µg/mL)		
	Flavedo	Albedo	Juice
Vinh Long	3.835.0 ± 28.4^{d}	2.254.0 ± 27.4^{d}	130.78 ± 7.70^{b}
Hau Giang	5.894.3 ± 90.9^{a}	7.307.0 ± 353.2^{b}	90.64 ± 4.08^{c}
Dong Thap	5.285.3 ± 61.4^{c}	6.306.3 ± 41.8^{c}	159.88 ± 5.41^{a}
Can Tho	5.707.5 ± 182.3^{b}	7.876.0 ± 240.0^{a}	27.32 ± 3.35^{d}

Note: The IC_{50} value is the average of the three iterations. Letters followed by identical values were statistically non-statistically significant at 5% significance. VL: Vinh Long, HG: Hau Giang, DT: Dong Thap, CT: Can Tho.

Antioxidant activity of each part of king orange

Based on the qualitative and quantitative basis of the compounds contained in king oranges, the antioxidant capacity of king orange peel extract and juice were evaluated for DPPH radical scavenging activity. The antioxidant activities between parts of the king orange were different and were expressed through the IC_{50} (Table 5). In particular, fruit juice in most provinces has the lowest IC_{50} value and ranges from 27.32-159.88 µg/mL, followed by green peel extract (3,835.0-5,894.3 µg/mL) and white peel extract (2,254.0-7,876.0 µg/mL). This means that the antioxidant capacity of the juice is the highest and that the white peel has the lowest antioxidant capacity. The total polyphenol content (TPC) in the flavedo and albedo fractions of the samples from VL was higher than that from other locations. Therefore, this sample exhibited stronger antioxidant activity, indicating a positive correlation between TPC content and free radical scavenging ability. This result is also consistent with the results noted in Table 4, with the highest flavonoid and phenolic contents, followed by green and white peel. The difference in the antioxidant capacity between tissues may be due to the different flavonoid and phenolic contents in *Citrus* fruits (XU et al., 2009). Several previous studies have found a high correlation between DPPH radical scavenging activity and the total phenolic and flavonoid contents of the peels of other *Citrus* species (Papoutsis et al., 2016).

In addition, when comparing the of antioxidant properties of each tissue type in the provinces, the results in VL king orange samples showed that the white peel was higher than that of flavedo and the highest in 4 surveyed provinces. On the other hand, king orange juice grown in CT has antioxidant potential compared to other provinces with an IC_{50} of 27.32 µg/mL, while the rest of the provinces have an IC_{50} value in the range of 90.64-159.88 µg/mL. This result is consistent with those in the previous study by Sicari et al. (2016) when evaluating the phytochemical and antioxidant activity in the juice of *Citrus bergamia* collected in 7 regions of Southern Italy. All samples exhibited DPPH free radical scavenging activity with IC_{50} values ranging from 19.6 to 31.4 µg/mL (corresponding to the Melito and Palizzi samples (Sicari et al., 2016). From there, it shows that the difference in antioxidant capacity between the types of tissues in the fruit as well as between provinces and habitats may be the cause of this difference.

CONCLUSIONS

In king orange, the pulp accounted for the largest mass of all major components. Alkaloids, flavonoids, phenolics, saponins and terpenoids were detected in all king orange samples from the provinces and fruit parts tested, except for terpenoids, which were only found in the peel extract. The highest flavonoid and phenolic contents were in the juice, followed by flavedo and albedo extracts. In addition, the antioxidant capacity related to phenolic compound content and DPPH free radical scavenging ability of different parts of the fruit can be ranked in order as juice, flavedo extract and albedo extract. Future studies are needed to identify and evaluate the effects of individual bioactive compounds in vivo.

Conflict of interest
The Authors declare that there is no conflict of interest.

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