CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

BIOACTIVE COMPOUNDS, ANTIOXIDANT ACTIVITY AND LIPID CONTENT OF VARIOUS AVOCADO FRUITS

Van Lam Nguyen[1]✉, Thi Dinh Tran[2], Thi Huyen Bui[1], Souksavanh Paxayavong[1] and Thi Lan Huong Tran[3]

[1] Department of Biochemistry and Food Biotechnology, Faculty of Food Science and Technology, Vietnam National University of Agriculture, Hanoi, Vietnam
[2] Department of Food Processing Technology, Faculty of Food Science and Technology, Vietnam National University of Agriculture, Hanoi, Vietnam
[3] Department of Food and Nutrition, Faculty of Food Science and Technology, Vietnam National University of Agriculture, Hanoi, Vietnam
✉ *lamvan.nguyen@yahoo.com*

https://doi.org/10.34302/crpjfst/2022.14.2.4

Article history:
Received:
18 April 2021
Accepted:
8 March 2022

Keywords:
Avocado;
Carotenoids;
Flavonoids;
Lipid;
Persea americana;
Polyphenol.

ABSTRACT

Avocado fruits (*Persea americana*), native to Central America and Mexico, are highly nutritious and grown widely in tropical and subtropical regions. They are rich in fatty acids and other bioactive compounds such as vitamin E, carotenoids and phenolic compounds. Recently, avocado cultivars grown in Vietnam have gained more interest due to their value. This study aimed to investigate variations in lipid contents and bioactive compounds among avocado cultivars grown in Vietnam. Avocado fruits were harvested at mature green and transferred to the laboratory and stored at room temperature for ripening. Lipid content was measured by extraction with hexane. Phenolic content, antioxidant activity and carotenoid content were determined using the Folin-Ciocalteu, DPPH and spectral methods, respectively. The results showed that the lipid content varied from 35.41% for Sap bong cultivar to 61.40% for 034 cultivar. Booth 3 cultivar showed the highest total phenolic content (6.46 mg GAE/g DW), while this value is the lowest for HAC cultivar (2.67 mg GAE/g DW). Flavonoid content also significantly varied between cultivars from 0.70 to 2.01 mg catechin/g DW. Carotenoid content ranged from 38.55 µg/g for HAC to 226.77 µg/g for Nam long. Variations in chlorophyll a and chlorophyll b contents were also observed. Chlorophyll a and chlorophyll b contents varied from 127.60 to 316.30 µg/g and 46.83 to 223.81 µg/g, respectively. Significant variations in the lipid content and the bioactive compounds between the avocado cultivars provide information to select high quality avocado fruits for commercial purposes.

1. Introduction

Avocado (*Persea Americana* Mill.) belonging to the family of *Lauraceae* and is an important fruit native to Mexico and Central America (Tremocoldi *et al.*, 2018). This fruit is worldwide grown in tropical and subtropical regions (Qin and Zhong, 2016). Mexico is the top avocado producer in the world, accounting for 30% of the world production (Tremocoldi *et al.*, 2018). Avocado varieties are very diverse, but only two cultivars, Hass and Fuerte are commonly grown for commercialisation (Rodríguez-Carpena *et al.*, 2011). Avocado fruit is a nutritious and tasty fruit containing high amount of lipids, vitamins and minerals (Tan *et al.*, 2017).

Avocado fruit is considered a healthy fruit. This fruit is an excellent source of fatty acids in which monounsaturated fatty acids account for 71%, then 13% polyunsaturated fatty acids and 16% saturated fatty acids (Dreher and Davenport, 2013). Lipid content of avocado fruits varies depending on varieties. For instance, Peraza-Magallanes *et al.* (2017) showed the lipid content varied from 7.39 to 36.98% among seven avocado genotypes. Variations in lipid content were also observed in other avocado genotypes: 2.59 to 11.87% fresh weight between seven Taiwan domestic avocado genotypes (Teng *et al.*, 2016) and from 18.28 to 26.77% fresh weight among eight avocado genotypes (Espinosa-Alonso *et al.*, 2017). Lipid content can also be affected by geographic locations (Donetti and Terry, 2014, Ferreyra *et al.*, 2016), harvest time (Wang *et al.*, 2012, Donetti and Terry, 2014) and storage conditions (Vekiari *et al.*, 2004).

Avocado fruit is also rich in bioactive compounds which are potential to use in cosmetics, medical and food industries (Dreher and Davenport, 2013, Rodriguez-Lopez *et al.*, 2017). This fruit contains natural antioxidants such as carotenoids and polyphenols (Lu *et al.*, 2009, Vinha *et al.*, 2013). Avocado fruit is one of few foods containing high levels of antioxidant vitamins (vitamin C and vitamin E) (Dreher and Davenport, 2013). Other pigment bioactive compounds such as chlorophylls and anthocyanins also present in avocado fruits (Ashton *et al.*, 2006). The contents of these bioactive substances vary depending on varieties (Espinosa-Alonso *et al.*, 2017, MARDIGAN *et al.*, 2019), growing locations (Lu *et al.*, 2009), harvest time (Wang *et al.*, 2012) and storage conditions (Donetti and Terry, 2014, Campos *et al.*, 2019).

Vietnam is one of Asian countries where avocados have been grown and this fruit has recently gained more interest for domestic uses as well as for export purposes. In Vietnam, avocados are mainly cultivated in central highlands and South East regions where ecological conditions are suitable for them to produce great yield and fruit quality (Hoang *et al.*, 2013, Hoang *et al.*, 2017). These studies, however, primarily focused on yields, agro-bio parameters and nutritional values. Our study aimed to investigate bioactive compounds and lipid content of 15 selected avocado varieties with the purpose to select avocados with high quality for growth.

2. Materials and methods

2.1. Chemicals and reagents

1,1-diphenyl-2-picryl-hydrazyl (DPPH) and Trolox were analytical-graded and purchased from Sigma (USA). Gallic acid and Folin–Ciocalteu reagent were purchased from Merk (Germany).

2.2. Sample collection

Avocado fruits were collected from avocado trees grown in Phuoc An town, Krong Pak district, Dak Lak province, Vietnam. Five to seven fruits of each avocado variety were picked using specialized tools. Avocado fruits had the same maturity (commercial stage).

Fruits after being harvested were encoded, individually packed with tissue paper, wrapped in foam, individually packed with perforated PE bags, within 24 h transported by air to the laboratory.

Hass avocado grown in Australia were bought at Adelaide Central market and was transported to the Laboratory by air. This avocado was used as a reference.

At the laboratory, the fruit was kept at 20-22 ^{o}C until ripe (about 3-5 days). Three fruits of each cultivar were then cut in half, the flesh, the skin and the seed were separated. The flesh was homogenized by a blender. All samples were stored at -18 ^{o}C and then freeze dried. The freeze-dried flesh was kept in the zip bags and was stored at -18 ^{o}C for further analysis.

2.3. Lipid content determination

Lipid was extracted by n-hexane and the lipid content was calculated based on sample weight reduction after lipid extraction. In brief, the extraction was performed in triplicate. 0.25 g of sample was weighed into a prepared filter bag and lipid was then extracted in three replicates from each avocado cultivar with 45 mL of n-hexane in 10-mL flask for 7 hours for two times. The sample was re-washed with n-hexane and was then dried at 105 ^oC for 3 hours before weighing for lipid content calculation.

2.4. Determination of total phenolic content

Fruit extracts for the determination of total phenolic, flavonoid contents and antioxidant activity were prepared using the method adapted from Alothman *et al.* (2009) with some modifications. 0.4 grams of freeze-dried sample were extracted with 8 mL ethanol 70% for 3h at room temperature. The sample was regularly shaken every 10 minutes. The extract was then centrifuged at 6000 rpm for 10 minutes and the supernatant was collected and stored at -20^{o}C. The extraction of each variety was carried out in triplicate.

Total phenolic content was measured using the Folin-Ciocalteu method described by Fu *et al.* (2011). In brief, 0.5 mL of the diluted sample was transferred into a test tube and 2.5 mL of 1:10 diluted Folin-Ciocalteu reagent was then added and mixed well. After 4 minutes, 2 mL of 7.5% Na_2CO_3 were added. The reaction was incubated at room temperature in the dark for 2h and the absorbance of the mixture was then measured at 760 nm using a UV–visible spectrophotometer (UV-Vis 1800, Shimadzu, Japan). The results were expressed in mg gallic acid equivalents/g dry weight (mg GAE/g DW) using a gallic acid standard curve. A stock solution of 1 mg/mL gallic acid was prepared and the calibration curve was then established based on working-standard solutions of 0.02, 0.04, 0.06, 0.08 and 0.1 mg/mL.

2.5. Determination of flavonoid content

Flavonoid content was determined by a method described by Baba and Malik (2015). In brief, 1000 µL of crude extract was mixed with 4 mL of distilled water and then 0.3 mL of 5% $NaNO_2$ solution. After 5 mins of incubation, 0.3 mL of 10% $AlCl_3$ solution was added, and the mixture was allowed to stand for 6 min. Then, 2 mL of 1 mol/L NaOH solution were added. The mixture was allowed to stand for 15 min, and absorbance was measured at 510 nm. The flavonoid content was calculated from a calibration curve of catechin with working standard solutions of 0, 0.01, 0.02, 0.04, 0.06, 0.08 mg/mL and the result was expressed as mg catechin equivalent per g dry weight.

2.6. Antioxidant capacity measurement

Antioxidant capacity was determined using the 1,1-diphenyl-2-picryl-hydrazyl (DPPH) assay described by Thaipong *et al.* (2006) with some modifications. The stock solution of DPPH was made by dissolving 24 mg of DPPH with 100 mL of methanol and then kept at -23^{o}C until needed. The working solution of DPPH was prepared by diluting 10 mL of the stock solution with 45 mL of methanol. The reaction was carried out by mixing 300 µL of diluted fruit extract with 2850 µL of the DPPH solution for 30 minutes. A control was also prepared by using 150 µL of methanol instead of fruit extract. The absorbance was then measured at 515 nm using a spectrophotometer (Lambda 25, Perkin Elmer, USA). The results were expressed in Trolox equivalents (µM TE/g DW) using a Trolox standard curve. The standard curve was established based on Trolox standard solutions.

2.7. Determination of chlorophyll and carotenoid contents

The chlorophyll and carotenoid contents were determined by the method of Kotíková *et al.* (2011). 0.3 g of sample was extracted with 6 mL of 100% acetone at 4 ^oC for 5 hours. The sample then was centrifuged at 6000 rpm for 10 mins and the supernatant was collected for absorbance measurement at three wavelengths: 662 nm, 645 nm, 470 nm.

Calculation of chlorophyll and carotenoid contents:

$$C_a = 17{,}75 * A_{662} - 2{,}35 * A_{645} \quad (1)$$

$$C_b = 18{,}61 * A_{645} - 3{,}96 * A_{662} \quad (2)$$

$$C_{x+c} = (1000 * A_{470} - 2{,}27 * C_a - 81{,}4 * C_b)/227 \quad (3)$$

The conversion into µg/g DW

$$\text{Content} = \frac{A*V}{m} \quad (4)$$

In which

C_a: Chlorophyll a concentraion (µg/mL)

C_b: Cholorophyll b concentration (µg/mL)

C_{x+c}: Carotenoid concentration (µg/mL)

A: C_a, C_b or C_{x+c}

m: sample weight (g)

2.8. Statistical analysis

Data and comparisons were analyzed using R version 3.6.2. LSD test was used for the comparison of the means.

3. Results and discussions

3.1. Fruit weight and the proportion of pulp, skin and seed of 15 avocado fruits

The fruit weight varied significantly from 233.6 ± 7.3 to 757.2 g/fruit for Hass cv. and Hong ngoc cv., respectively (Table 1). Similar to Hass cv., Bo mo and bo nuoc cv. had small fruit weight, while Bi xanh cv. showed high fruit weight as Hong ngoc cv. The proportion of pulp, skin and seed also varied widely between the cultivars. Booth 3 cv. had the least pulp proportion of only 56.2% and showed the highest skin and seed proportions of 15.5% and 28.3%, respectively. In contrast, the pulp proportion of Bi xanh cv. was 90.0% since its skin and seed account for only 5.5% and 4.0%, respectively. Cu ba and Sap dai co chai cv. also showed high pulp proportion of 83.5% and 80.0%, respectively.

3.2.Variations in total phenolic, flavonoid contents and antioxidant activity

Phenolics naturally present in fruits and its content varied depending on the type of fruits as well as fruit genotypes. This study showed total phenolics in avocado pulp varied from 2.67 ± 0.10 mg GAE/g DW for HAC cv. to 6.46 ± 0.55 mg GAE/g DW for Booth 3 cv. (Table 2) among avocado fruits grown in Vietnam. Both cultivars belong to the imported group. Sap bong cv. showed the highest total phenolics of 4.84 ± 0.79 mg GAE/g DW, while Sap dai co chai cv. had the lowest total phenolics of 2.77 ± 0.06 mg GAE/g DW among domestic cultivars. Sap thuong, Bi xanh and Trinh 10 cultivars are domestic cultivars with relatively high total phenolics (Table 2). Hass cv. showed the lowest total phenolics in all 15 cultivars with 1.89 ± 0.09 mg GAE/g DW. Genetic differences could result in variation in total phenolics between the avocado cultivars. A previous study also showed two avocado varieties, Hass and Fuerte had different total phenolics of 1.0 and 1.75 mg GAE/g DW, respectively (Rodríguez-Carpena *et al.*, 2011). Husen *et al.* (2014) reported avocado pulp contains 2.36 mg GAE/g DW. A study by Fu *et al.* (2011) indicated phenolic content varied from 11.88 to 585.52 mg GAE/100 g fresh weight (FW) among 62 fruits in which the total phenolics of avocado was 21.86 mg GAE/100 g FW. Booth 3 cv. in our study is a recently imported cultivar of Vietnam and gains interest due to high phenolic content in this avocado fruit can be beneficial for health.

Table 1. Variation in fruit weight, the proportion of pulp, skin and seed among 15 avocado cultivars. Results are means ± SD (n=2-5). Different letters show significant differences (P<0.05).

Cultivar	Fruit weight (g/fruit)	Pulp (%)	Skin (%)	Seed (%)
Domestic cultivars[(1)]				
Bi xanh	738.1 ± 108.1[a]	90.5 ± 0.2[a]	5.5 ± 0.3[e]	4.0 ± 0.1[h]
Bo mo	241.4 ± 33.7[hi]	71.8 ± 1.1[f]	10.8 ± 0.3[c]	17.4 ± 1.0[cdef]
Bo nuoc	233.9 ± 34.8[hi]	68.3 ± 2.6[g]	11.6 ± 2.0[bc]	20.2 ± 0.8[bc]
Nam long	527.2 ± 71.7[bc]	74.3 ± 2.4[def]	7.0 ± 0.4[e]	18.8 ± 2.1[bcde]
Sap bong	311.9 ± 13.2[fgh]	77.3 ± 3.7[cde]	6.9 ± 3.1[e]	15.9 ± 2.7[defg]
Sap dai co chai	468.1 ± 52.3[cd]	80.0 ± 1.6[bc]	6.2 ± 0.1[e]	14.1 ± 1.6[fg]
Sap deo tron	419.9 ± 41.5[de]	68.0 ± 2.2[g]	10.6 ± 0.2[c]	21.5 ± 2.0[b]
Sap thuong	292.7 ± 9.7[ghi]	77.8 ± 2.3[cd]	6.5 ± 0.2[e]	15.7 ± 2.2[efg]
Trinh 10	302.9[fghi]	74.1[dfe]	11.4[bc]	14.6[fg]
034	468.3 ± 78.7[cd]	77.5 ± 3.2[cd]	9.5 ± 1.4[cd]	13.0 ± 2.0[g]
Imported cultivars[(2)]				
Booth 3	378.8 ± 29.1[ef]	56.2 ± 0.5[h]	15.5 ± 0.4[a]	28.3 ± 0.2[a]
Cu Ba	597.5[b]	83.5[b]	7.5[de]	9.1[i]
HAC	369.6[efg]	73.2[ef]	10.5[c]	16.3[cdefg]
Hong ngoc	757.2[a]	70.5[fg]	7.3[de]	22.2[b]
Foreign cultivar[(3)]				
Hass	233.6 ± 7.3[i]	67.3 ± 2.5[g]	13.6 ± 1.2[ab]	19.1 ± 1.6[bcd]

[(1)] Avocado cultivars have been domesticated in Vietnam.
[(2)] Avocado cultivars have recently been grown in Vietnam.
[(3)] Avocado fruits were grown in Australia.

Table 2. Variation in polyphenol, flavonoid contents and antioxidant activity among 15 avocado cultivars. Results are means ± SD (n=3). Different letters show significant differences (P<0.05).

Cultivar	Total phenolics (mg GAE/g DW)	Flavonoid (mg catechin/g DW)	Antioxidant activity (µM TE/g DW)
Domestic cultivars[(1)]			
Bi xanh	4.17 ±0.37[bcd]	1.42 ± 0.06[de]	5.63 ± 0.27[defg]
Bo mo	3.18 ± 0.57[efg]	1.48 ± 0.06[de]	5.74 ± 0.98[def]

Bo nuoc	3.55 ± 0.82^{cde}	1.35 ± 0.25^{ef}	7.49 ± 0.57^{ab}
Nam long	2.92 ± 0.42^{fg}	1.65 ± 0.08^{bcd}	5.10 ± 0.66^{efg}
Sap bong	4.84 ± 0.79^{b}	2.01 ± 0.18^{a}	4.90 ± 0.56^{gh}
Sap dai co chai	2.77 ± 0.06^{fg}	1.91 ± 0.05^{ab}	5.41 ± 0.36^{efg}
Sap deo tron	3.52 ± 0.26^{def}	1.42 ± 0.18^{de}	6.86 ± 0.69^{bc}
Sap thuong	4.66 ± 0.63^{bc}	1.79 ± 0.36^{abc}	5.92 ± 0.05^{de}
Trinh 10	4.05 ± 0.49^{bcd}	1.31 ± 0.18^{ef}	8.02 ± 0.08^{a}
034	3.46 ± 0.52^{def}	0.95 ± 0.34^{gh}	5.71 ± 0.91^{defg}
Imported cultivars(2)			
Booth 3	6.46 ± 0.55^{a}	1.51 ± 0.08^{cde}	4.11 ± 0.16^{hi}
Cu Ba	4.11 ± 0.42^{bcd}	1.26 ± 0.08^{ef}	5.04 ± 0.21^{ef}
HAC	2.67 ± 0.10^{gh}	1.11 ± 0.04^{fg}	2.69 ± 0.06^{j}
Hong ngoc	2.75 ± 0.23^{fg}	0.70 ± 0.06^{h}	6.25 ± 0.06^{cd}
Foreign cultivar(3)			
Hass	1.89 ± 0.09^{h}	1.45 ± 0.11^{de}	4.01 ± 7.66^{i}

(1) Avocado cultivars have been domesticated in Vietnam.
(2) Avocado cultivars have recently been grown in Vietnam.
(3) Avocado fruits were grown in Australia.

Flavonoids, a group of phenolics, were also identified in pulp of 15 avocado cultivars. This variable was significantly varied between the cultivars. Within the domestic cultivars, flavonoid content ranged from 0.95 ± 0.34 mg catechin/g DW for 034 cv. to 2.01 ± 0.18 mg catechin/g DW for Sap bong cv. (Table 2). This content of the imported cultivars varied from 0.70 ± 0.06 to 1.51 ± 0.08 mg catechin/g DW for Hong ngoc and Booth 3 cv. respectively. Total flavonoid content of Hass cv. (a foreign cultivar) was 1.45 ± 0.11 mg GAE/g DW. Total flavonoid content significantly varied from 0.08 mg catechin/g DW for avocado to 20.69 mg catechin/g DW for Lolly fruit among 30 selected fruits grown in the Philippines (Recuenco *et al.*, 2016). The difference in extraction methods could result in lower total flavonoid of avocado in the study compared to our study. In fact, the extraction in our study was carried at 30 °C for 3 hours, while in the study by Recuenco *et al.* (2016) the sample was extracted by homogenizing for 5 minutes before filtering. Another study found significant variation in total flavonoid content of fruit pulp from 14.4 to 714.2 mg catechin/100 g FW among 18 selected tropical fruits grown in Brazil (Barreto *et al.*, 2009). Flavonoids are natural antioxidants which prevent various diseases such as cancer, Alzheimer's disease, atherosclerosis and they are the potential component in nutraceutical, pharmaceutical, medical and cosmetical products (Panche *et al.*, 2016). The natural presence of flavonoids in the edible avocado part is the natural antioxidants for health benefits.

Antioxidants are compounds which are able to gain free radicals and reduce oxidation processes in living organisms. Antioxidants are very diverse and they can be phenolic compounds, carotenoids or unsaturated fatty acids (Rao and Rao, 2007, Richard *et al.*, 2008, Williamson, 2017). Natural antioxidants exist widely in fruits including avocado and their effect is measured by their activity (Fu *et al.*, 2011, Nguyen *et al.*, 2019). This study found the antioxidant activity in avocado pulp of the 15 selected cultivars significantly varied from 2.69 ± 0.06 µM TE/g DW for HAC cv. to 8.02 ± 0.08 µM TE/g DW for Trinh 10 cv. (Table 2). HAC cv. belongs to the imported group, while Trinh 10 is a domestic cultivar. Other domestic cultivars also showed high antioxidant activities ranging from 4.90 ± 0.56 to 7.49 ± 0.57 µM TE/g DW. To our knowledge, information on total phenolic, total flavonoid and antioxidant activity of avocado grown in Vietnam is limited. Therefore, this study contributes to understanding on bioactive compounds of these avocado cultivars.

3.3.Variations in chlorophyll and carotenoid contents

Avocado pulp shows colour ranging from dark green adjacent to the skin, then pale green and yellow adjacent to the seed and this is the presence of pigments such as chlorophylls and carotenoids (Ashton *et al.*, 2006). The results from Table 3 showed chlorophyll content varied from 137.8 ± 18.0 µg/g DW for Trinh 10 cv. to 259.6 ± 2.46 µg/g DW for Bo nuoc cv. within the domestic cultivars and from 127.6 ± 33.7 µg/g DW for HAC cv. to 316.3 ± 11.3 µg/g DW for Cu ba cv. among the imported cultivars. The chlorophyll b content was lower than the chlorophyll a content and this value varied from 46.8 ± 0.16 µg/g DW for Trinh 10 cv. to 118.6 ± 48.8 µg/g DW for 034 cv. within the domestic cultivars and from 79.2 ± 27.9 µg/g DW for HAC to 223.8 ± 9.6 µg/g DW for Cu ba cv. within the imported cultivars. Hass cv. contained 195.6 ± 11.9 and 128.2 ± 1.8 µg/g DW chlorophyll a and chlorophyll b, respectively. Ashton *et al.* (2006) also found that the chlorophyll a content was higher than the chlorophyll b content in the avocado flesh. Their study showed the chlorophyll content was the highest in dark green flesh and the lowest in yellow flesh.The carotenoid content in avocado pulp significantly varied between avocado cultivars. This content ranged from 63.7 ± 8.1 µg/g DW for Sap thuong cv. to 226.8 ± 10.3 µg/g DW for Nam long cv. among the domestic cultivars, while it varied from 38.6 ± 7.5 µg/g DW for HAC cv. to 192.5 ± 35.5 µg/g DW for Hong ngoc cv. among the imported cultivars. Hass cv. contained the lowest carotenoid content of 32.8 ± 1.2 µg/g DW. Ashton *et al.* (2006) reported the carotenoid content in avocado flesh varied depending on the part of flesh and the ripening state. The total carotenoid content at 2 days after harvest was about 5.1 µg/g FW in dark green flesh, 2.2 µg/g FW in pale green flesh and 3.5 µg/g FW in yellow flesh. Carotenoids also occur in variety of fruits and vegetables such as tomato which has high carotenoid content (8.1 µg/g FW at ripe stage) (Nguyen and Dao, 2018).

Table 3. Variation in chlorophyll a, chlorophyll b and carotenoid contents among 15 avocado cultivars. Results are means ± SD (n=3). Different letters show significant differences ($P<0.05$).

Cultivar	**Chlorophyll a (µg/g DW)**	**Chlorophyll b (µg/g DW)**	**Carotenoid (µg/g DW)**
Domestic cultivars$^{(1)}$			
Bi xanh	193.1 ± 18.8^{cde}	76.7 ± 20.1^{fgh}	142.8 ± 2.7^{c}
Bo mo	227.8 ± 50.3^{bcd}	115.3 ± 28^{bcde}	88.7 ± 15.3^{def}

Bo nuoc	259.6 ± 2.46^{abc}	112.1 ± 7.5^{bcdef}	131.2 ± 12.2^{c}
Nam long	232.4 ± 72.8^{bcd}	86.7 ± 18.6^{defgh}	226.8 ± 10.3^{a}
Sap bong	233.0 ± 31.1^{bcd}	98.1 ± 32.2^{cdefg}	93.9 ± 21.7^{de}
Sap dai co chai	224.7 ± 91.2^{bcd}	98.4 ± 22.5^{cdefg}	74.9 ± 28.0^{ef}
Sap deo tron	136.1 ± 25.1^{e}	56.3 ± 14.9^{h}	82.3 ± 16.6^{ef}
Sap thuong	170.0 ± 11.3^{de}	72.4 ± 8.8^{gh}	63.7 ± 8.1^{fg}
Trinh 10	137.8 ± 18.0^{e}	46.8 ± 0.16^{h}	77.0 ± 8.1^{ef}
034	294.2 ± 84.8^{ab}	118.6 ± 48.8^{bcd}	116.0 ± 33.2^{cd}
Imported cultivars$^{(2)}$			
Booth 3	146.7 ± 41.8^{e}	100.7 ± 20.4^{cdefg}	70.3 ± 13.8^{ef}
Cu Ba	316.3 ± 11.3^{a}	223.8 ± 9.6^{a}	141.2 ± 12.1^{c}
HAC	127.6 ± 33.7^{e}	79.2 ± 27.9^{efgh}	38.6 ± 7.5^{gh}
Hong ngoc	258.7 ± 35.1^{abc}	119.6 ± 65.7^{b}	192.5 ± 35.5^{b}
Foreign cultivar$^{(3)}$			
Hass	195.6 ± 11.9^{cde}	128.2 ± 1.8^{bc}	32.8 ± 1.2^{h}

$^{(1)}$ Avocado cultivars have been domesticated in Vietnam.
$^{(2)}$ Avocado cultivars have recently been grown in Vietnam.
$^{(3)}$ Avocado fruits were grown in Australia.

3.2. Variations in total lipid content

The avocado fruits are the good source of lipids which is rich in unsaturated fatty acids (Teng *et al.*, 2016). The total lipid content of avocado pulp varied widely among these avocado cultivars. Within the domestic cultivars, Sap dai co chai cv. had the lowest total lipid content of 35.4 ± 1.2%, while 034 cv. showed the highest content of 61.4 ± 4.1%. Within the imported cultivars, this value ranged from 44.3 ± 2.6 to 59.2 ± 5.6% for HAC cv. and Cu ba cv., respectively. Hass cv. showed the highest lipid content of 72.4 ± 5.4% (Figure 1). Significant difference in total lipid content between the Australian Hass cv. and cultivars planted in Vietnam could be due to genetic variation or geographical effect. Another study in 7 avocado genotypes also found the total lipid content significantly varied from 7.39 to 36.98% and Hass cv. showed the highest total lipid content. Takenaga *et al.* (2008) also reported variation in the total lipid content in pulp of three avocado cultivars grown in Japan. Fuerte and Bacon are domestic cultivars and contained 18.7 and 21.8% total lipid, while the imported Hass cultivar had 18.2% total lipid. The total lipid content in our study showed higher than that in these previous studies since our results were calculated per dry weight, while this were measured per fresh weight in the previous research.

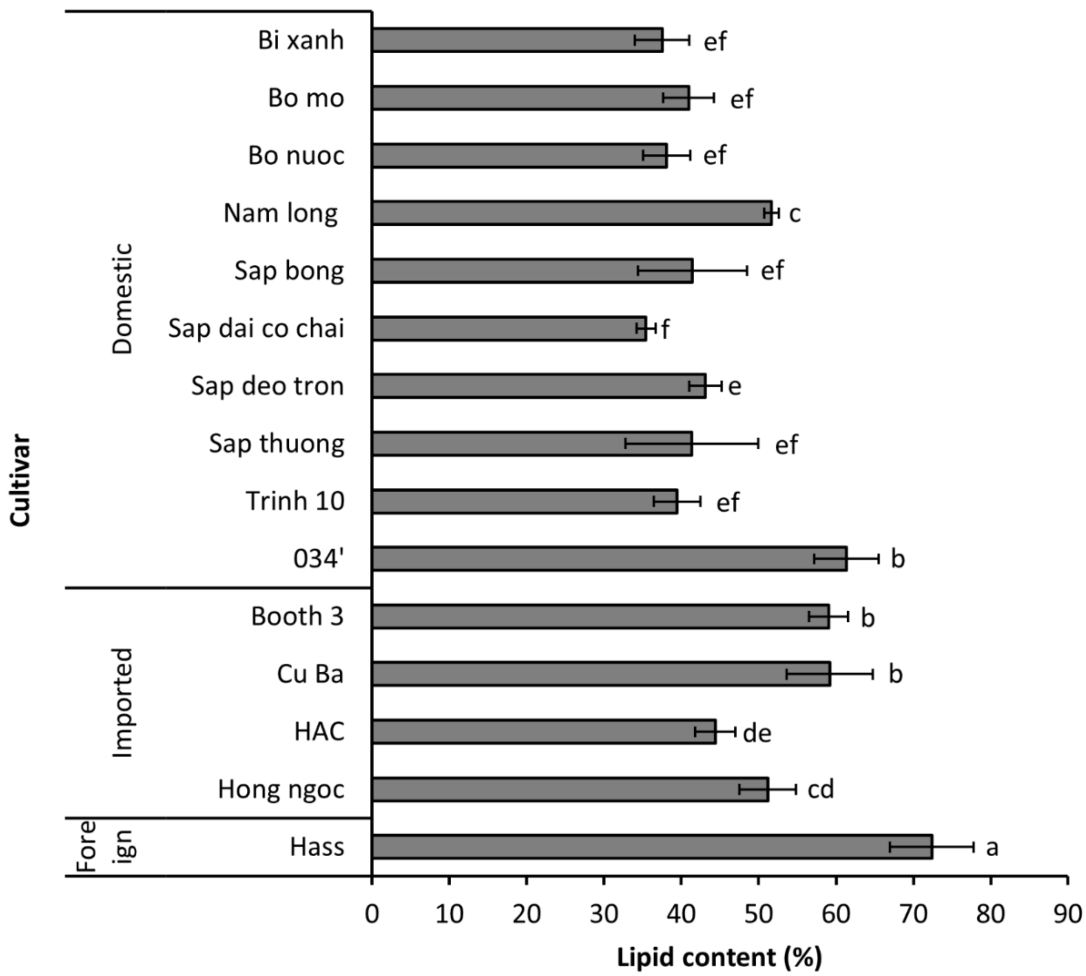

Figure 1. Total lipid content of 15 avocado cultivars. Results are means ± SD (n=3). Different letters show significant differences (P<0.05).

4. Conclusions

Our study showed that the avocado cultivars grown in Vietnam are good sources of bioactive compounds such as phenolics, flavonoids, chlorophyll and carotenoids. Booth 3 cv. showed the highest total phenolics, while Sap bong cv. had the highest flavonoid content. Bo nuoc and Cu ba cv. contain high contents of chlorophyll a and chlorophyll b, respectively and Nam long cv. indicated the highest amount of carotenoid. The total lipid varied widely between avocado cultivars and 034 cv. showed the highest total lipid content among avocado cultivars planted in Vietnam. Variations in bioactive compounds as well as total lipid content among the avocado cultivars indicates genetical diverse between these cultivars and this suggests they can be valuable sources for food as well as other applications.

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ACKNOWLEDGEMENTS

This research is funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number: 02/2018/TN.