ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 48(4): 409-419, December 2023

NUTRITIONAL PROFILING OF AVOCADO (*Persea americana)* CULTIVARS CULTIVATED IN BANGLADESH

M. S. HOSSAIN[1], M. Z. RAHMAN[2], N. A. JEANY[3]
M. B. RAHMAN[4] AND M. M. MASUD[5]

Abstract

The rising demand for avocado fruit from its recognized nutritional value which has significant positive impacts on human health. The current investigation was undertaken to analyze the nutritional values, chemical composition, fatty acids profile and minerals content of avocado fruit cultivars cultivated in Bangladesh. The findings revealed varying levels of key components across different cultivars where cultivar PA-Joy002 had a higher content of dry matter 30.92%, total soluble solids 7.31° Brix, oil 18.57%, crude protein 4.44%, carbohydrate 4.14%, and fibre 4.50% than the BARI released var. BARI Avocado-1. The major fatty acids profile of pulp-oil of avocado cultivar PA-Joy002 revealed that the oil contained high amount of oleic acid 35.99%, linoleic acid 25.02%, palmitic acid 28.25%, palmitoleic acid 9.85%, and lenolenic acid 2.30%, respectively. Moreover, cultivar PA-Joy002 contained significantly higher amount of unsaturated (UFAs, 71.35 %) fatty acids than saturated (SFAs, 32.58 %) fatty acids, and the ratio of UFAs to SFAs was also higher 2.19. The results also indicated that 100 g of dry pulp of avocado sample contains calcium 861.19 mg, potassium 1374.63 mg, magnesium 503.02 mg, phosphorus 341.14 mg, sodium 7.10 mg, iron 9.30 mg, and zinc 3.72 mg of the same cultivar. Findings of this study indicated that cultivar PA-Joy002 was nutritionally rich and promising to use as a functional food due to their high content of nutritional elements, essential fatty acids and minerals, and versatile applications of its pulp.

Keywords: Chemical compositions, Fatty acid profile, Minerals, *Persea americana*, Proximate composition, Pulp.

Introduction

Avocado (*Persea americana* Mill.*)* a member of the Lauraceae family, is gaining popularity worldwide due to its exceptional nutritional composition and health benefits. In Bangladesh, although relatively new, its' demand is steadily increasing owing to its recognized nutraceutical properties and positive impacts on human health or multiple application (Ge *et al.*, 2017b). The sweet and pleasant taste of mature avocado pulp makes it a popular food choice. Scientific studies have consistently highlighted the health benefits of avocado oil, often drawing parallels

[1]Senior Scientific Officer, Central Laboratory, Research Wing, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, [2]Senior Scientific Officer, Horticulture Research Centre, BARI, Gazipur, Bangladesh, [3]Scientific Officer, Central Laboratory, Research Wing, BARI, Gazipur, Bangladesh, [4]Senior Scientific Officer, Research Wing, BARI, Gazipur, Bangladesh, [5]Senior Scientific Officer, Soil Science Division, BARI, Gazipur, Bangladesh.

between its nutritional properties and those of olive oil. Consumption of avocado oil has been linked to favorable changes in blood lipid profiles, including decreased levels of low-density lipoproteins and increased levels of high-density lipoproteins. These changes contribute to lower blood triglycerides levels, thus reducing the risk of vascular disease (Gokkaya *et al.,* 2021). Moreover, avocados are esteemed for their high mineral content, with notable levels of potassium (K), magnesium (Mg), phosphorus (P) and calcium (Ca) found in the pulp (Arackal and Parameshwari, 2021). This minerals composition offers several health benefits; K and Mg aid reducing hypertension and preventing cardiovascular diseases, and alleviate symptoms of asthma and migraine attacks (Dembitsky *et al.*, 2011). Phosphorus is involved in various biological processes; and Ca is essential for proper functioning of the human body (Ciosek *et al.*, 2021). Avocado fruit is reach in lipids, comprising up to 10% to 25% of its fresh weight (Ge *et al.,* 2017a), with a significant portion being unsaturated fatty acids (60 to 65%) like linoleic, palmitoleic, linolenic acids, known for their health benefits (Ramos-Aguilar *et al.*, 2019). The consumption of monounsaturated fatty acids such as oleic acids contributes to reducing blood pressure, preventing body weight increase, and controlling the development of hyperglycemia (Yang *et al.*, 2011). Various factors affect the chemical composition of avocados, including cultivation location, cultivar type, maturity condition, and fruit part measured (Nasri *et al.*, 2021; Ramos-Aguilar *et al.*, 2021). The economic value of avocados as a promising crop in Bangladesh, it is required to undertake a comparative analysis of the chemical differences between avocado cultivars based on its nutritional value. Hence, this study aims to determine and compare the major constituents of the avocado variety and promising cultivar available in Bangladesh.

Materials and Methods

Experiments were carried out with two avocado cultivars, BARI Avocado-1 and PA-Joy002, which were domestically grown in Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur. Upon reaching proper maturity, fruit samples were collected and analyzed at Central Laboratory, Research Wing, BARI, Gazipur. All the fruits were washed with fresh water, and sanitized with 1% chlorine solution, and selected according to the absence of injuries. Subsequently, the fruits were cut into half and separated into the pulp, peel and core. The fruit samples were preserved in refrigerator maintaining at 5°C to 6°C temperature. The pulps were separated from the fruits, homogenized and mashed using a blender. The samples were oven dried at 70°C until getting constant weight, and then stored at 4°C for a maximum of one week before analysis.

Determination of moisture and dry matter of avocado fruit pulp

The moisture content of the samples was determined, following the method outlined by the Association of Official Analytical Chemists (AOAC, 1990). Ten gram of fresh pulp was weighed and dried in an oven at 70ºC for 16 h. The data were calculated by determining the difference in weight and reported as percentages. The dry matter was calculated by determining differences in the percentages of humidity.

Measurement of total soluble solid

A Pocket Pal-1 portable digital refractometer (Atago, USA), with a scale from 0 to 35°Brix, was used to determine the total soluble solids of the samples. The readings were taken directly from the equipment and the results were expressed in °Brix (method ADAC 925.09) (Latimer, 2016).

Extraction of oil from pulps and determination of percentage yield

Oil content was estimated using the method described by Ge *et al.,* (2017b). Nine mature fruits were randomly collected from each cultivar, and the pulps were separated and mixed respectively. The homogenized pulps were dried in an oven at 70^{o}C for 12 h and ground into powder. The dried powder (5 g) was put into the round bottom flask and 100 ml of solvent petroleum ether was added. The mixture was transferred into the Soxhlet extractor and the oil was extracted. Finally, the extracted solutions were evaporated using a rotary evaporator, and the residue was weighed. The percentage oil yield was determined as:

$$\% \text{ oil yield} = W_{oil} / W_{pulp} \times 100$$

Determination of proximate composition of pulp

Proximal analysis was carried out using the methods described by AOAC, 1990. Fiber content was determined by weighing 2 g of each sample in porous glass crucibles and placing them in a automated fiber analyzer (Fibertec 8000, FOSS, Hillerod, Denmark); the samples were subjected to acid digestion (sulfuric acid 1.25% v/v) and alkaline digestion (NaOH 1.25% v/v) for 1 h. After this time, the samples underwent a washing process with distilled water; the crucibles with the digested samples were removed and placed in an oven at 105^{0}C for 1 h. Finally, they were placed in a desiccator, cooled and weighed, and were expressed the results as percentage. In terms of protein content, 1 g of each sample was weighed in a tube, and 2 tablets of catalyst mixture (Na_2SO4 + $CuSO_4$) and 15 ml of concentrated sulfuric acid were added. The tubes were placed in a digestion block and heated at 400^{0}C for 1 h and were cooled. They were placed in a protein analyzer (Kjeltec model 8400, FOSS, Denmark) where distillation and titration were carried out, and the results were expressed as percentage. Carbohydrate content was determined anthrone colorimetric method by AOAC, 935.08. The absorbance of the samples and standard were read from a spectrophotometer at 630 nm against the blank. To determine the ash content, 2 g of each sample was weighed using porcelain crucibles with a 25 ml capacity, and subjected to a calcination process at 500^{0}C in a muffle (48000, Thermolyne, Dubuque, IA, USA) for 12 h. The calcinated samples were cooled for 1 h and transferred to desiccators.

After that, each crucible was weighed. The ash content was calculated by determining the difference in weight.

Determination of fatty acid composition of oil from pulps

Fatty acid extraction procedure was previously described by the authors Hossain *et al.*, 2023. The fruit pulp powder (1 g) was treated with 5 ml of ethylated reagent and vortex a tubes, and were kept in overnight at normal temperature. After, then 5 ml of salt solution was added and mixed well. The upper oily layer was transferred to a capped and labeled glass vial for gas chromatography (GC) analysis. Chromatographic analysis of the fatty acid methyl esters (FAMEs) from the samples was conducted using a gas chromatograph (Thermo Scientific Company) apparatus equipped with an auto sampler, flame–ionization detector (FID) and supelco wax column (30 m x 0.25 µm film coating). The samples (2 µl) were injected with helium (1.2 ml/min) as a carrier gas, which was programmed for operating conditions such as column oven temperature 160°C @ with subsequent increase of 3°C/min until 180-220°C. Split ratio was 50% with injector 240°C and detector 250°C temperatures. The peak areas and total fatty acids composition were calculated for each sample by retention time using Thermo Scientific software. The standards of fatty acids methyl esters purchased from Sigma-Aldrich were also run under the same conditions for comparison with experimental samples. For calculation, the fatty acids were normalized to 100%, considering the composition (moles %) from fatty acid data (area %) and was expressed as percentage of total fatty acid methyl ester in the oil.

Mineral content of pulp

A mineralization process was applied to the samples according to the method proposed by Petersen, 2002. The dry pulp samples (1 g) were treated with conc. nitric (HNO_3) and perchloric acid ($HClO_4$) kept in normal temperature at overnight. The solution was digested at 160°C to 240°C, cooled, diluted to an appropriate concentration, and filtered. This filtrate was considered as the stock solution for further analysis. Ca and Mg were determined by KCl extractable method. K, Cu, Fe, Mn and Zn were determined by $NaHCO_3$ extraction followed by Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Japan). Boron (B) was determined by $CaCl_2$ extraction method. P was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. Individual minerals were quantified by comparing the corresponding standard mineral procured from the Sigma Aldrich Chemical Co., USA.

Statistical analysis

Data obtained for each analysis were expressed in triplicate. Mean values and standard deviation (SD) were used to express the results. Data was analyzed by One-way analysis of variance (ANOVA) using Turkey Multiple Comparisons Test by 5% level of significance.

Results and Discussions

Moisture and dry matter:

Moisture content is a key indicator of fruit maturity and perishability, with lower moisture content often indicating greater ripeness and longer shelf life (Kassim *et al.,* 2013). In present study, moisture content ranged from 69.08 to 71.44% in PA-Joy002 and BARI Avocado-1 cultivars (Table 1). Correspondingly, dry matter content was observed to be 28.56% in BARI Avocado-1 and 30.92 % in PA-Joy002 cultivar, respectively. Notably, dry matter content serves as a significant ($P<0.05$) for avocado fruits ripeness. As fruits mature, their oil content typically increases, leading to a rise in total dry matter. The dry matter concentration of avocado fruit pulp is wide contrast, varying from less than 20% for not good-tasting fruit that should be excluded for consumption to greater a 35% in fruit that is potentially appropriate for food processing treatments (Clark *et al.*, 2007). Consistent with existing literature, dry matter content in flesh avocado fruits in the study fell within a wide range from 13.25 to 31.4%, influenced by factors such as harvest date, region, and cultivar (Nair and Chandran, 2018).

The total soluble solids in fresh avocado pulp

The total soluble solids (TSS) content of both cultivars were similar. The TSS content was found 6.56ºBrix in BARI Avocado-1 and 7.31ºBrix in PA-Joy002 cultivar, respectively (Table 1). Among the various components of fruit, the total soluble solids (i.e., the percentage of solids that are dissolved in the matrix of the food) in ºBrix, have a primary role in their quality due to the influence on thermophysical, chemical, and biological properties. It is also a parameter which tends to increase with the progress of ripening due to the biosynthesis of the plant and degradation of polysaccharides. As expected, given that this physico-chemical parameter represents one of the best ways to evaluate the degree of sweetness of the fruit, and the fruit pulp is the only edible part of the avocado. The TSS are higher in the pulp. The suggestion to use TSS as indication for fruit ripeness, quality, and sweetness sprang from a desire for an accessible and rapid analytical method to assess sugar concentration. The findings align closely with those of El-Moniem *et al.,* (2022), who reported a TSS value of 9.50ºBrix in avocado fruit.

The proximate analysis of avocado pulp

Avocado fruits are renowned for their high oil content compared to other fruits and vegetables. Table 1 illustrates the oil content of the flesh in the avocado cultivars revealing significant differences ($P <0.05$) between them. PA-Joy002 exhibited higher oil content (18.57% on the wet basis) compared to BARI Avocado-1 (16.26% on the wet basis). Variability in oil content among avocado cultivars is well-documented in the literature, with reported ranges from 8 to 25% depending on factors such as cultivar, environment and agricultural practices (Magwaza and Tesfay, 2015). Furthermore, when considering dry weight, the oil content of avocado flesh can be 70%, with variations attributed to factors like regions of growth, cultivar, maturing and ripening season, harvest times, agricultural and climatic factors, time of picking and portion of fruit (Ferreyra *et al.*, 2016). The ash contents were also similar (P>0.05) with values of 1.64% (in BARI Avocado-1) and 1.58% (in PA-Joy002). The crude fiber contents of the two cultivars were similar and BARI Avocado-1 and PA-Joy002 were values of 4.02% and 4.50%, respectively (Table 1). These results are high as compared to the presented by Krumreich *et al.*, (2018).The protein content of both cultivars showed no significantly difference (P>0.05) with values of 4.44% and 4.25% of BARI Avocado-1 and PA-Joy002, respectively. Carbohydrate content varied between the cultivars, with values of 3.37% BARI Avocado-1 and 4.14% for PA-Joy002 (Table 1).

Table 1. Chemical composition (DW) of the pulp of avocado cultivars

Nutritional components	BARI Avocado-1	PA-Joy002
Moisture (%)	71.44 ± 1.15a	69.08 ± 0.94a
Dry matter (%)	28.56 ± 0.92b	30.92 ± 0.89a
TSS (^{o}Brix)	6.56 ± 0.44a	7.31 ± 0.29a
Crude Fat/lipid (%)	16.26 ± 1.14b	18.57 ± 1.63a
Crude Protein (%)	4.44 ± 0.53a	4.25 ± 0.76a
Crude Fiber (%)	4.02 ± 0.72a	4.50 ± 0.47a
Ash (%)	1.64 ± 0.27a	1.58 ± 0.22a
Carbohydrate (%)	3.37 ± 0.48a	4.14 ± 0.27a

- Values (Mean ± standard deviation, three replicates). Different letters in the same row means significantly differences among cultivars at P<0.05.

Fatty acid composition of avocado fruits

Regarding fatty acids composition of the avocado cultivars were presented in Table 2. The major fatty acids in the avocado pulp oil quantified in the present study palmitic acid (32.86% and 28.25%), linoleic acid (22.82% and 25.02%), oleic acid (30.27% and 35.99%), and intermediate amounts of palmitoleic acid (9.85% and 8.04%), linolenic acid (1.89% and 2.30%), and stearic acid (1.90% and 1.45%) were found in BARI Avocado-1 and PA-Joy002 cultivars (Table 2, Fig 1, and Fig 2). Small amounts of arachidic acid (0.19% and 0.37%) and myristic acid (0.26% and 0.51%) were also found in the same cultivars. Palmitic and stearic acids are the predominant saturated fatty acids among the interesterified fats, and they have been related to cholesterol levels in the body (Van Rooijen *et al.*, 2020). Oleic acid has beneficial effects for human health, such as reducing blood pressure, bad cholesterol levels (Lopez-Huertas, 2010) and thus, food consumption, which also means avoiding obesity (Tutunchi *et al.*, 2020). The present results, palmitic, palmitoleic, oleic and linoleic acids were observed dominant fatty acids in avocado pulp oil of present results (Fig 1 and Fig 2) and were found similar results reported by Rohman *et al.*, 2016. However, more than 65 to 71% of the total fatty acids

(TFA) in the avocado pulp oil were unsaturated, with the remaining 30 to 35% being saturated (Table 2). The total content of unsaturated fatty acids (ΣUFA) 64.83% in BARI Avocado-1 and 71.35% in PA-Joy002 cultivars. The total content of saturated fatty acids (ΣSFA) varied between 35.21% in BARI Avocado-1 and 32.58% in PA-Joy002. The polyunsaturated fatty acids content was less than 30%. This value can be considered good for the stability of the oil because the double bonds in fatty acids are susceptible to oxidation. Among these studied, PA-Joy002 highest value of polyunsaturated fatty acids (27.32%), and BARI Avocado-1 lowest value (24.71%). According to Salgado *et al.*, (2008b), the fatty acid composition of avocado oil confirms the possibility of using it as a substitute for olive oil or as a raw material by the food industry, due to its physicochemical similarity and taste. On the other hand, the ΣUFA/ΣSFA ratios in the avocado cultivars ranged from 1.85 to 2.19, which were in accordance with those of the Collinson and Barker cultivars but below that of the Fortuna cultivar (3.49) (Galvao *et al.*, 2014).

Table 2 Fatty acid profile of oil from avocado cultivars.

Fatty acids	Content (%)	
	BARI Avocado-1	PA-Joy002
Monounsaturated fatty acids (MUFA)		
Oleic/ω-9 ($C_{18:1}$)	30.27 ± 1.71b	35.99 ± 1.69a
Palmitolic ($C_{16:1}$)	9.85 ± 0.37a	8.04 ± 0.59b
Polyunsaturated fatty acids (PUFA)		
Lenoleic/ω-6 ($C_{18:2}$)	22.82 ± 1.84a	25.02 ± 1.48a
Lenolenic/ω-3 ($C_{18:2}$)	1.89 ± 0.04a	2.30 ± 0.22b
Saturated fatty acids (SFA)		
Palmitic ($C_{16:0}$)	32.86 ± 1.28a	28.25 ± 1.35b
Stearic ($C_{18:0}$)	1.90 ± 0.06a	1.45 ± 0.09b
Myristic ($C_{14:0}$)	0.26 ± 0.03b	0.51 ± 0.08a
Arachidic ($C_{20:0}$)	0.19 ± 0.03b	0.37 ± 0.04a
ΣSFA	35.21	32.58
ΣMUFA	40.12	44.03
ΣPUFA	24.71	27.32
ΣUFA	64.83	71.35
ΣUFA/ ΣSFA	1.85	2.19

***** ΣSFA = total saturated fatty acids; ΣUFA = total unsaturated fatty acids; ΣMUFA = total monounsaturated fatty acids; ΣPUFA = total polyunsaturated fatty acids. Values (Mean ± standard deviation, three replicates). Different letters in the same row means significantly differences among cultivars at P<0.05. % (w/w) dry matter basis.

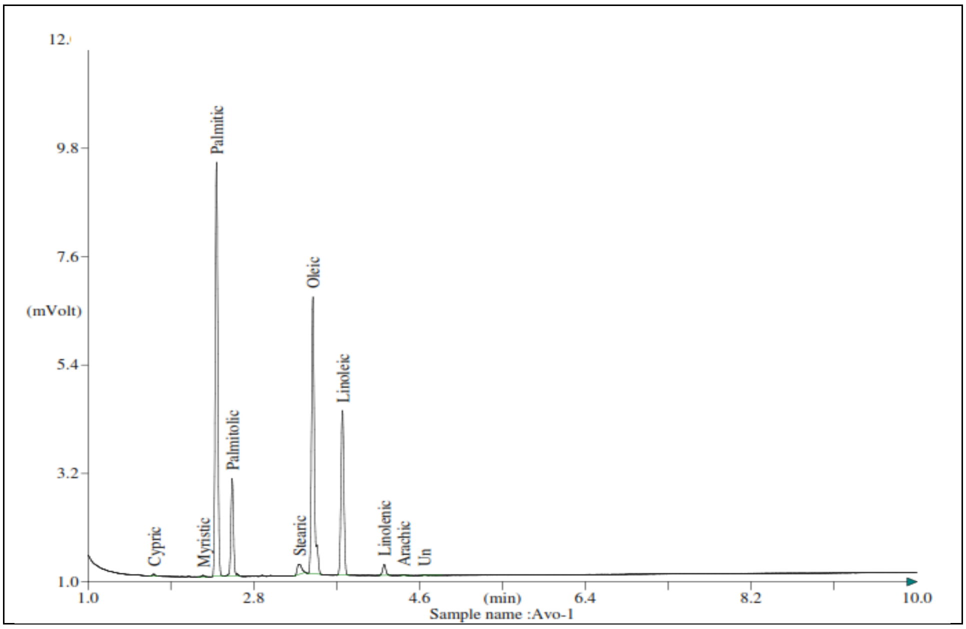

Fig 1. Chromatogram of fatty acid composition of the pulp oil of BARI Avocado-1,

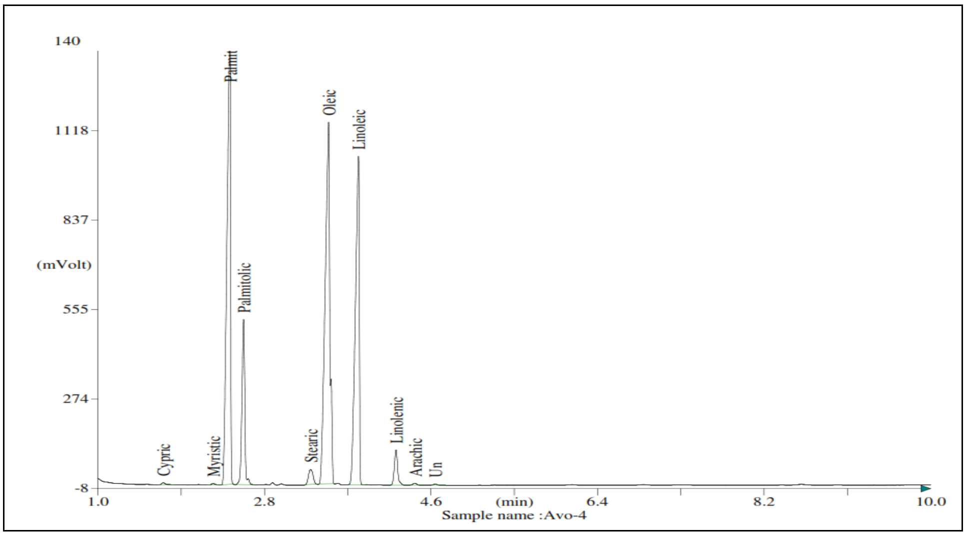

Fig 2. Chromatogram of fatty acid composition of the pulp oil of PA-Joy002 cultivar.

Mineral content of avocado fruit pulp

Minerals are essential inorganic substances needed at a certain amount for the proper functioning of human cells. Mineral composition of the two different samples of avocado pulp is shown in Table 3, for comparison of the results obtained with avocado selected lines and variety values are also included. The average results indicated that 100 g of dry pulp of avocado sample contains calcium (838.03 and 861.19 mg), potassium (1416.82 and 1374.63 mg), magnesium (512.11 and 503.02 mg), phosphorus (361.01 and 341.14 mg), sodium (8.00 and 7.10 mg), iron (8.35 and 9.30 mg), zinc (4.55 and 3.72 mg), manganese (0.18 and 0.25 mg) and copper (0.54 and 0.65 mg) of BARI Avocado-1 and PA-Joy002 cultivars, respectively. Comparing the BARI Avocado-1 and PA-Joy002 avocado cultivar, the PA-Joy002 cultivar has greater calcium, iron, manganese, and copper content but less magnesium, phosphorus, potassium, and zinc. These minerals play vital roles in human health, and their consumption through fruits is recommended. Mg, Fe, P, K, Na has a strong presence in plant foods, and also plays an essential role in human body maintenance; it is associated with energy metabolism, enzyme cofactors and the prevention of chronic disease. Zinc found in varying concentrations in plant foods, is essential for enzyme structure and activity. Its consumption is known to boost the immune system and may hold promise in enhancing immunity against diseases like COVID-19 (Nedjimi, 2021).

Table 3. Mineral content of avocado pulps

Minerals	Amount in mg / 100g	
	BARI Avocado-1	PA-Joy002
Macro-elements		
Calcium (Ca)	838.03 ±2.84b	861.19 ± 3.17a
Magnesium (Mg)	512.11 ± 2.93a	503.02 ± 3.15b
Phosphorus (P)	361.01 ± 1.13a	341.14 ± 2.03b
Sodium (Na)	8.00 ± 0.39a	7.10 ± 0.26b
Potassium (K)	1416.82 ± 3.02a	1374.63 ± 4.34b
Micro-elements		
Iron (Fe)	8.35 ± 0.37b	9.30 ± 0.51a
Zinc (Zn)	4.55 ± 0.51a	3.72 ± 0.04b
Copper (Cu)	0.54 ± 0.03b	0.65 ± 0.04a
Manganese (Mn)	0.18 ± 0.04a	0.25 ± 0.04a

- Values (Mean ± standard deviation, three replicates). Different letters in the same row means significantly differences among cultivars at P<0.05 % (w/w) dry matter basis.

Conclusion

Avocados are highly nutritious and functional fruits, rich in a wide number of chemical constituents, phytochemicals, and essential micro and macronutrients that play important roles in helping to promote human health. The edible fruit (mesocarp) of avocado has high essential oil (fatty acids) which contain high amounts of anti-cholesterol agents and nutrients. In this study, results showed significant differences between the different avocado cultivars ($p < 0.05$) and were detected, with palmitic, oleic, and linoleic acids being predominant in all avocado cultivars, accounting for 90–95% of the fatty acid compositions. The study revealed significant differences among avocado cultivars, with palmitic, oleic, and linoleic acids being predominant in fatty acid compositions. Avocado pulp oil was found to be abundant in unsaturated fatty acids, making up over 65 to 71% of the total fatty acids, suggesting potential benefits for cardiovascular health. The ratios of ΣUFA/ΣSFA were larger than reference values, which indicated that avocado could serve as a food supplement in the diet to decrease the level of cholesterol and fats, preventing the risk of cardiovascular disease. Additionally, all cultivars proved to be excellent sources of key minerals such as Ca, K, P, Mg, Na, Fe and Zn. Besides, the new cultivars, PA-Joy002 exhibited particularly high level of unsaturated fatty acids (UFA, 71%), and low content of saturated fatty acids (SFA, 29%) and favorable ratio of UFAs to SFAs 2.19 indicating its potential as a nutritionally rich option. Thus, the new cultivar, PA-Joy002 was identified as the promising and nutritionally rich cultivar; hence, the cultivar can be utilized in breeding programs to develop as a variety.

References

AOAC. 1990. Official Methods of Analysis. Association of Official Analytical Chemists International. In: Horwitz, W. (Ed), AOAC Press, Washington, DC.

Arackal, J. J. and S. Parameshwari. 2021. A detailed evaluation of fatty acid profile and micronutrient analysis of chapattis incorporated with avocado fruit pulp. *Mater. Today Proc.* **45:** 3268–3273.

Ciosek, Z. K. Kot, D. Kosik-Bogacka, N. Lanocha-Arendarczyk and I. Rotter. 2021. The effects of calcium, magnesium, phosphorus, fluoride, and lead on bone tissue. *Biomolecules.* **11:** 506.

Clark, C. J., A. White, R. B. Jordan and A. B. Woolf. 2007. Challenges associated with segregation of avocados of differing maturity using density sorting at harvest. *Postharvest Biol. Technol.* **46:** 119-127.

Dembitsky, V. M., S. Poovarodom, H. Leontowicz, M. Leontowicz, S. Vearasilp, S. Trakhtenberg and S. Gorinstein. 2011. The multiple nutrition properties of some exotic fruits: Biological activity and active metabolites. *Food Res. Int.* **44:** 1671–1701.

El-Moniem, E. A. A. A., A. Y. I. Thabet *et al*. 2022. Reducing chemical fertilizers partially by using natural alternative sources of organic fertilizers and its impact on "Hass" avocado trees. *Egypt J. Chem.* **65:** 1255–1264.

Ferreyra, R., G. Selles, J. Saavedra, J. Ortiz, C. Zuniga, *et al.* 2016. Identification of pre-harvest factors that affect fatty acid profiles of avocado fruit (*Persea americana* Mill) cv. "Hass" at harvest. *S. Afr. J. Bot.* **104:** 15-20.

Galvao, M. D. S., N. Narain and N. Nigam. 2014. Influence of different cultivars on oil quality and chemical characteristics of avocado fruit. Food Sci. Techno. Campinas. **34:** 539-546.

Ge, Y., X. Y. Si, X. E. Lin, J. S. Wang, X. P. Zang and W. H. Ma. 2017a. Advances in avocado (*Persea americana* Mill.). *China South Fruit.* **46:** 63-70.

Ge, Y., X. Y.Si, J. Q. Cao, Z. X. Zhou, W. L. Wang and W. H. Ma. 2017b. Morphological characteristics, nutritional quality, and bioactive constituents in fruits of two avocado (*Persea americana*) varieties from hainan province, China. *J. Agril. Sci.* **9:** 8-17.

Gokkaya, E. O., S. Yesilot, M. Ozgocmen, R. Aslankoc and C. A. Acar. 2021. Protective effects of resveratrol and avocado oil against paracetamol-induced hepatotoxicity in rats. *Drug Chem. Toxicol.* **8:** 1-9.

Hossain, M. S., K. C. Saha, M. M. Islam, M. Z. Noor and D. A. Choudhury. 2023. Assessment of nutritional composition, bioactive compounds and antioxidant activity of chia seeds grown in Bangladesh. *Bangladesh J. Agric. Res*. **48(2):** 259-270.

Kassim, A., T. S. Workneh and C. N. Bezuidenhout. 2013. A review on postharvest handling of avocado fruit. *Afr. J. Agric. Res.* **8:** 2385-2402.

Latimer, G.W. 2016. Official methods of analysis of Association of Official Analytical Chemists (20th ed.). Rockville: AOAC International.

Magwaza, L. S. and S. Z. Tesfay. 2015. A review of destructive and non-destructive methods for determining avocado fruit maturity. *Food Bioproc. Technol.* **8:** 1995-2011.

Nair, S. S. and A. Chandran. 2018. Nutrient composition of avocado fruits of selected cultivars grown in Kerala. *Int. J. Food Sci. Nutr*. **3:** 65-67.

Nasri, C., Y. Halabi, H. Harhar, F. Mohammed, A. Bellaouchou, A. Guenbour and M. Tabyaoui. 2021. Chemical characterization of oil from four avocado varieties cultivated in Morocco. *OCL*. **28:** 19.

Nedjimi, B. 2021. Can trace element supplementations (Cu, Se, and Zn) enhance human immunity against COVID-19 and its new variants? *J. Basic Appl. Sci.* **10:** 33.

Petersen, L. 2002. Analytical methods Soil, Water, Plant material, Fertilizer. p. 61-70. Bangladesh: Soil Resource Management and Analytical Services, Soil Resources Development Institute, Danida, Dhaka.

Ramos-Aguilar, A. L., J. Ornelas-Paz, *et al.* 2021. Effect of cultivar on the content of selected phytochemicals in avocado peels. *Food Res. Int.* **140:** 110024.

Richard, D., K. Kefi, U. Barbe, P. Bausero and F. Visioli. 2008. Polyunsaturated fatty acids as antioxidants. *Pharm. Res.* **57:** 451-455.

Rohman, A., A. Windarsih, S. Riyanto *et al.* 2016. Fourier transforms infrared spectroscopy combined with multivariate calibrations for the authentication of avocado oil. *Int. J. Food Properties.* **19:** 680-687.

Salgado, J. M., F. Danieli, M. A. B. Regitano-D'arce, A. Frias and D. N. Mansi. 2008b. Ooleo de abacate (*Persea Americana* Mill.) comomateria-prima para a industria alimenticia. *Food Sci. Technol.* **28:** 20-26.

Tutunchi, H., A. Ostadrahimi and M. Saghafi-Asl. 2020. The effects of diets enriched in monounsaturated oleic acid on the management and prevention of obesity: A systematic review of human intervention studies. *Adv. Nutr*. **11:** 864–877.

Van Rooijen, M. A and R. P. Mensink. 2020. Palmitic acid versus stearic acid: Effects of interesterification and intakes on cardiometabolic risk markers-A systematic review. *Nutrients* **12:** 615.

Yang, Z. H., H. Miyahara and A. Hatanaka. 2011. Chronic administration of palmitoleic acid reduces insulin resistance and hepatic lipid accumulation in KK-A y Mice with genetic type 2 diabetes. *Lipids Health Dis.* **10:** 120.