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Oil Content and Fatty Acid Composition of the Seeds of 16 Avocado (*Persea americana*) Accessions Collected From Southern China and Their Application in a Soap Bar

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Abstract

The avocado (*Persea americana*), an edible fruit, is one of the main agricultural products in many tropical regions. Avocado fruit is rich in fat, and commercialized for fresh consumption and industrially processed leaving seed as a major residue. Avocado seed from the industry is worthy of attention for certain industrial applications and feasibility. Transforming avocado seed lipids into ecologically friendly or sustainable materials suitable for the cosmetic industry is promising from the perspective of green and environmental protection. The oil contents and fatty acid compositions of the seeds of 16 avocado accessions collected from southern China were investigated, revealing significant differences among most of the accessions. Seventeen fatty acids were identified and quantified by gas chromatography-mass spectrometry in the seeds of all 16 avocado accessions. Linoleic (40.14%), palmitic (23.54%), and oleic acids (16.23%) were the major fatty acids in the seeds, and the total contents of unsaturated fatty acids in the seeds were all higher than those of saturated fatty acids. The biochemical properties of the avocado seed oils relevant to their application in industrial practice were examined [*e.g.*, the acid (3.74 mg KOH/g oil), iodine (124.09 g I_2/100 g oil), peroxide (49.83 meq H_2O_2), and saponification (167.98 mg KOH/g oil) values]. Furthermore, the bar soap containing avocado seed oil was made, and its physicochemical properties (pH and foamability) were evaluated.

Keywords: avocado, fatty acids, seed bio-oil, cosmetics

1. Introduction

Avocado (*Persea americana* Mill.), a member of the family Lauraceae of the order Laurales, is a plant native to Central America, South America, and Mexico (Schaffer et al., 2012). The avocado is among the most economically important subtropical/tropical fruit crops in the world, and production and consumption levels having increased dramatically during the last 150 years (Schaffer et al., 2012). In the world, the total area of avocado cultivation has reached 563,916 hectares, with almost ten tons per hectare in the annual production of avocado in 2016 (FAOSTAT, 2018). The consumption of avocado in the whole world has rapidly increased from 3,426,294 tons in 2008 to 5,567,044 tons in 2016 (FAOSTAT, 2018). One factor contributing to this marked increase was the constant expansion of avocado products into new markets in parts of the world where avocado was previously unknown or scarcely available (Schaffer et al., 2012). In China, the total area of avocado cultivation has reached over 20,000 hectares, with over six tons per hectare in the annual production of avocado

in 2016 (FAOSTAT, 2018). The consumption of avocado in China has slowly increased from over 95,000 tons in 2008 to 122,942 tons in 2016 (FAOSTAT, 2018). Nowadays, there are many avocado-planting regions in provinces across southern China cultivating foreign cultivars with superior quality (*e.g.*, Fuerte, Hass, and Shepard) along with native Chinese cultivars and accessions (Ge et al., 2017a).

In recent years, there has been growing interest in identifying phytochemical alternatives to the synthetic substances commonly used in the food, pharmaceutical, and cosmetic industries. This effort was supported by consumer concerns over the safety of products containing synthetic chemicals, which were believed to cause or enhance negative health effects and pollute the environment (Vinha et al., 2013; Galvão et al., 2014). Although vegetable oils have traditionally been used primarily in the food industry, they are gaining applications in, for example, the cosmetic industry (Lourith et al., 2014, 2016). In terms of oil content in the fruit, avocado fruit was exceeded only by the fruits of the palm and olive trees (Knothe, 2013). Remarkably, the lipid content in avocado could reach 5% to 30% of the fruit fresh weight, depending on the cultivar, seasonality, and planting conditions (Rodríguez-Carpena et al., 2011; Vinha et al., 2013; Galvão et al., 2014). Avocado fruit lipids contained 50% to 60% monounsaturated fatty acids and 10% to 15% polyunsaturated linoleic and linolenic acids, which were beneficial to human cardiovascular health (Dreher & Davenport, 2013). Furthermore, avocado fruit lipids could be used in non-food industries, for example, as an alternative biodiesel source instead of the conventional petroleum-based diesel fuel (Giraldoa & Moreno-Piraján, 2012; Knothe, 2013). In addition, the high non-saturated content of avocado fruit lipids provided superior skin permeability and sunscreen performance, and could be used in sunscreen cream as the emulsifier (Santo et al., 2014).

Given the increasing demand for vegetable oils in the cosmetic industry (Lourith et al., 2014, 2016; Wu et al., 2015), transforming avocado seed lipids into ecologically friendly or sustainable materials suitable for the cosmetic industry, in particular for personal health products, is promising. In this context, we firstly evaluated and compared the yields and fatty acid compositions of oils from avocado seed. To explore the potential values of the major residue (seed) of avocado fruit, we then determined the physicochemical properties of avocado seed oil to evaluate the oil's applicability in cosmetic applications. In addition, a soap containing avocado seed oil was made and the physicochemical properties of the soap were assessed with respect to possible cosmetic applications.

2. Materials and Methods

2.1 Plant Material, Reagents, and Sample Preparation

The 16 avocado accessions used in the present study were obtained from Ge et al. (2018). Six ten-year old trees were collected from each accession. Two homogeneous trees were used as a unit with three biological repetitions for each accession. The samples of 18 mature fruits of each biological repetition in each accession were randomly collected when the mesocarp dry matter was ≥ 22% based on the criterion according to Medina-Carrillo et al. (2017), and immediately transported to the laboratory in standard foam boxes used for export packaging. The fruit samples were maintained at 5 °C to 6 °C. The seeds were separated from the fruits, homogenized using a domestic blender, and then stored at 4 °C for a maximum of one week before analysis.

2.2. Determination of Total Lipid Contents

Oil content was evaluated using the method of Ge et al. (2017b). Eighteen seeds of each biological repetition in each accession were mixed. The total lipid content was expressed as g/100 g on a fresh weight (FW) basis. The experiments were performed in three biological replicates for each accession.

2.3 Gas Chromatography-Mass Spectrometry (GC-MS) Analysis and Fatty Acid Identification

The fatty acid profiles were determined as described by Ge et al. (2017b). Eighteen seeds of each biological repetition in each accession were mixed. The analyses were performed using an Agilent7890B-7000B GC-MS (Santa Clara, CA, USA) equipped with a DB-5MS column (60 m × 0.25 mm i.d., 0.25-μm film thickness) using helium (1.2 mL/min) as the carrier gas. The fatty acid methyl esters (FAMEs) were identified by comparing the retention times of the peaks with those of commercial standards and comparing the respective ion chromatograms with those reported in the NIST 2011 library. The FAMEs were quantified against methyl nonadecanoate, which was added as an internal standard and then quantified using the calibration curves of the respective FAMEs ($R^2 \geq 0.995$). The contents of the FAMEs were expressed as mg/100 g FW. The experiments were performed in three biological replicates for each accession.

2.4 Biochemical Properties of Avocado Seed Oil

The acid, iodine, peroxide, and saponification values were determined from the mixed avocado seed oil (a mixture of the seed oils of 16 avocado accessions), and the standard AOAC methods (Association of Official

Analytical Chemists, 2000, Method number Cd 3a-63, Cd 1-25, Cd 8-53 and Cd 3-25, respectively) were used. All determinations were carried out in triplicate.

2.5 Formulation of the Bar Soap

The self-made bar soap containing the mixed avocado seed oil was made via saponification with NaOH. To prepare the soap, 14.11 g NaOH was dissolved in 47 mL purified water and kept at 40 °C. The oil mixture (86.21 g) was heated to 80 °C and added dropwise to the NaOH solution. Subsequently, the mixture was added to a rotary evaporator to allow oil saponification at 50 °C for 1 h, after which a pasty liquid appeared. The liquid was poured gradually into a mold and kept at 25 °C for two weeks.

2.6 Physicochemical Properties of the Bar Soap

The pH values of the self-made bar soap solutions (10%) in deionized water were measured (S20K, Mettler Toledo Ltd., Shanghai, China) in triplicate after the bar soaps were stored for 15 days under normal conditions and under ultraviolet (UV) irradiation (10 W, 60 lux, 365 nm). A commercial soap (Nice, Shanghai, China) stored under normal conditions was tested in the same way. The avocado seed oil bar soap (1.0 g) was added to a 100-mL glass measuring cylinder containing 50 mL deionized water and shaken vigorously for 2 min to generate foam. The height of the foam generated was determined immediately following shaking and after 10, 20, 30, 40, 50, and 60 min. The foamability tests were repeated in triplicate under normal conditions and under UV irradiation (10 W, 60 lux, 365 nm). A commercial soap (Nice, Shanghai, China) was tested in the same way under normal conditions.

2.7 Statistical Analysis

All determinations were carried out in three measurements and the results are given as means±standard deviation. The data were analyzed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). Significant differences among the fruit characteristics, oil contents, and fatty acid compositions of the 16 avocado accessions were verified by one-way analysis of variance, and Duncan's multiple comparison test was used to determine the statistical significance of differences between means at a 95% confidence level.

3. Results and Discussion

3.1 Total Lipid Contents and Fatty Acid Compositions of Avocado Seed Identification

The total lipid contents of the seeds of the 16 avocado accessions are presented in Table 1, indicating significant differences between most of the accessions ($p < 0.05$). Hass had the highest total seed lipid content (4.75 g/100 g FW), followed by DL-2 (2.05 g/100 g FW). The seed lipid contents of the remaining 14 avocado accessions were lower, ranging from 0.99 to 1.78 g/100 g FW. The seed lipid contents determined in the present study were in accordance with the results of Galvão et al. (2014) and Rodríguez-Carpena et al. (2011), but the Hass seed lipid content measured herein was much lower than that determined by Vinha et al. (2013) (14.7 g/100 g FW). The variation of the total lipid levels of the seeds of the avocado cultivars from around the world could be due to the different cultivation conditions, varieties, or mature degrees of fruits.

Table 1. Total lipid contents (mean value±standard deviation, g/100 g FW, n = 3) of the seeds of 16 avocado accessions grown in southern China

Accession	Total lipid content
RN-1	1.60±0.04a
RN-5	0.99±0.01b
RN-11	1.76±0.00d
RN-12	1.78±0.01d
RN-15	1.28±0.00e
RN-16	1.37±0.01f
Hass	4.75±0.05g
DL-1	1.51±0.02h
DL-2	2.05±0.02i
DL-3	1.69±0.03j
DL-4	1.04±0.02c
RLW-1	1.04±0.01c
RLW-2	1.18±0.06k
RLW-3	1.29±0.06e
RLW-4	1.02±0.00bc
GY-8	1.07±0.01c

Note. Different letters within the column are significantly different ($p < 0.05$).

The fatty acid compositions of the seeds of the 16 avocado accessions are provided in Table 2, 3. The same 17 fatty acids were detected in the seeds of all 16 avocado accessions, although significant differences in composition were observed among most of the accessions ($p < 0.05$). The major fatty acids (≥ 15%, the percentage of the individual fatty acid out of the total fatty acid content) quantified in avocado seed oil in the present study were linoleic acid (40.14%), palmitic acid (23.54%), and oleic acid (16.23%). Intermediate amounts (1% to 15%, the percentage of the individual fatty acid out of the total fatty acid content) of palmitoleic acid (5.78%), linolenic acid (4.63%), stearic acid (3.01%), and myristic acid (1.76%) were detected, and small amounts (≤ 1%, the percentage of the individual fatty acid out of the total fatty acid content) of the remaining 10 fatty acids were found. These results were in accordance with the previous study showing that linoleic, palmitic, and oleic acids were the predominant fatty acids in avocado seed oil (Galvão et al., 2014). The content of linoleic acid was slightly higher than those of palmitic acid and oleic acid in this study, which was basically in agreement with the results of Galvão et al. (2014). In the present study, 69% of TFA were unsaturated, while the remaining 31% were saturated (Table 4). TFA varied from 949.86±26.40 mg/100 g FW in RLW-4 to 4677.33±108.45 mg/100 g FW in Hass. ΣUFA ranged from 615.27±11.22 mg/100 g FW in RN-5 to 3263.69±26.48 mg/100 g FW in Hass, while ΣSFA varied between 270.59±10.27 mg/100 g FW in RLW-4 to 1413.64±81.97 mg/100 g FW in Hass. The palmitic acid was most abundant fatty acid, with noticeable differences in palmitic acid content between samples ($p < 0.05$). The greatest palmitic acid content was observed in Hass (1253.96 mg/100 g FW), while the lowest content was found in RLW-4 (192.67 mg/100 g FW). Among UFAs, linoleic acid was the most abundant, with contents ranging from 354.80 (RN-5) to 1497.57 (Hass) mg/100 g FW. The ΣUFA/ΣSFA ratios varied from 1.81 to 2.62, which were in accordance with the results of Galvão et al. (2014) (Table 4).

Table 2. The major and intermediate fatty acids compositions (mean value±standard deviation, mg/100 g FW, n = 3) in the seeds of 16 avocado accessions grown in southern China

Fatty Acid	Accession															
	RN-1	RN-5	RN-11	RN-12	RN-15	RN-16	Hass	DL-1	DL-2	DL-3	DL-4	RLW-1	RLW-2	RLW-3	RLW-4	GY-8
Saturated Fatty Acids (SFAs)																
Myristic acid (C14:0)	27.95± 0.32a	22.00± 0.44be	26.03± 0.93f	37.39± 0.95g	28.03± 1.01a	25.93± 1.16f	37.10± 1.61g	28.52± 1.14a	32.37± 0.39h	45.76± 2.40i	25.83± 1.14f	20.77± 0.67bc	21.79± 0.54bce	20.06± 0.36cd	18.80± 0.52d	22.85± 0.48e
Palmitic acid (C16:0)	337.69 ±1.38a	250.99 ±6.13c	492.56 ±20.51e	393.72 ±18.81b	288.07 ±9.28f	359.00 ±3.12ab	1253.96 ±78.12g	328.46 ±13.48a	449.95 ±4.23h	353.04 ±6.42a	244.23 ±16.07c	219.77 ±5.20cd	220.61 ±7.45cd	290.48 ±3.72f	192.67 ±8.17d	221.02 ±7.51cd
Stearic acid (C18:0)	46.32± 0.71ab	42.40± 0.45c	46.32± 0.53ab	66.30± 1.44f	44.92± 0.28 a	46.31± 0.65ab	79.42± 1.31g	47.15± 0.83b	51.28± 0.88h	54.04± 1.25i	39.90± 0.84de	39.10± 1.76e	40.76± 0.24cde	41.13± 0.92cd	35.65± 1.10j	33.47± 0.74k
Unsaturated Fatty Acids (UFAs)																
Palmitoleic acid (16:1)	63.27± 1.76a	60.44± 3.07ab	89.40± 1.96d	70.37± 3.06e	54.00± 1.64bc	48.32± 0.34c	580.62± 15.20f	54.09± 1.62bc	76.72± 0.97e	56.53± 0.88ab	38.39± 0.90g	52.86± 1.02bc	55.93± 2.24abc	73.84± 1.50e	40.58± 0.35g	33.40± 0.87g
Oleic acid (C18:1)	179.85 ±3.38a	160.58 ±1.27b	342.58 ±5.66c	253.38 ±7.53d	266.08 ±1.34e	174.51 ±0.17a	1070.98 ±7.87f	202.49 ±5.56g	276.01 ±5.11h	177.53 ±1.70a	139.93 ±1.61i	126.29 ±1.15j	209.35 ±6.59g	220.10 ±6.33k	156.33 ±6.50b	109.57 ±3.17l
Linoleic acid (C18:2)	594.92 ±8.76a	354.80 ±5.73b	579.50 ±4.80c	687.49 ±4.73d	420.24 ±6.79e	626.84 ±7.44f	1497.57 ±2.14g	711.32 ±3.97h	966.26 ±6.23i	845.22 ±7.30j	465.78 ±8.32k	466.84 ±4.46k	454.37 ±9.16l	536.61 ±5.17m	413.25 ±8.16e	433.65 ±7.69n
Linolenic acid (C18:3)	109.01 ±0.58a	38.83± 1.14b	61.20± 1.33cd	71.52± 2.97ef	74.37± 1.85e	61.30± 2.68cd	113.15 ±1.24g	64.29± 2.06d	101.35 ±4.43h	109.62 ±0.14a	47.53± 1.90i	51.96± 1.81j	60.15± 0.83c	64.19± 1.76d	68.70± 1.08f	63.58± 1.24cd

Note. Different letters within the same row are significantly different ($p < 0.05$); ΣSFA = total saturated fatty acids; ΣUFA = total unsaturated fatty acids; TFA = total fatty acids.

Table 3. The small amounts of fatty acids compositions (mean value±standard deviation, mg/100 g FW, n = 3) in the seeds of 16 avocado accessions grown in southern China

Fatty Acid	Accession															
	RN-1	RN-5	RN-11	RN-12	RN-15	RN-16	Hass	DL-1	DL-2	DL-3	DL-4	RLW-1	RLW-2	RLW-3	RLW-4	GY-8
Saturated Fatty Acids (SFAs)																
Capric acid (C10:0)	0.84± 0.03a	0.21± 0.01bc	0.34± 0.02e	1.11± 0.06f	0.46± 0.00g	0.98± 0.04h	0.78± 0.04i	0.75± 0.02i	0.59± 0.02j	0.93± 0.05k	0.73± 0.03i	0.18± 0.01b	0.18± 0.01b	0.27± 0.01d	0.25± 0.01cd	0.61± 0.02j
Hendecanoic acid (C11:0)	0.61± 0.02a	0.11± 0.00b	0.24± 0.01d	0.52± 0.02f	0.31± 0.01g	0.21± 0.01e	0.94± 0.02h	0.65± 0.01i	0.29± 0.01j	0.90± 0.02k	0.54± 0.01f	0.14± 0.01bc	0.14± 0.01c	0.14± 0.01bc	0.22± 0.00de	0.77± 0.02l
Lauric acid (C12:0)	1.41± 0.03a	0.56± 0.01b	1.09± 0.04c	4.61± 0.11e	6.76± 0.06f	1.96± 0.04g	3.48± 0.08h	2.93± 0.09i	2.32± 0.05j	4.04± 0.07k	3.36± 0.08l	1.02± 0.06cd	0.96± 0.06d	1.44± 0.02a	1.77± 0.07m	1.93± 0.06g
Tridecylic acid (C13:0)	2.66± 0.06a	1.16± 0.01b	2.24± 0.09c	5.33± 0.07d	3.04± 0.07e	1.78± 0.06f	7.15± 0.06g	3.31± 0.08hi	2.36± 0.08c	5.21± 0.03d	4.15± 0.04j	3.44± 0.21h	3.23± 0.01i	3.70± 0.10k	6.57± 0.08l	2.94± 0.02e
Pentadecanoic acid (C15:0)	2.20± 0.06a	0.45± 0.01b	1.18± 0.02c	3.35± 0.04j	1.17± 0.05c	1.32± 0.04de	2.54± 0.10k	1.71± 0.09i	1.38± 0.02ef	1.57± 0.08gh	1.47± 0.04fg	0.94± 0.04l	0.88± 0.04l	1.22± 0.05cd	1.66± 0.09hi	1.25± 0.08cd
Heptadecanoic acid (C17:0)	48.06± 1.51a	18.64± 0.54b	1.81± 0.08cd	64.87± 1.00g	30.17± 0.09h	2.00± 0.04cd	1.97± 0.03cd	2.62± 0.00 c	2.67± 0.07c	2.42± 0.06cd	1.55± 0.04de	0.72± 0.07ef	0.63± 0.04ef	0.98± 0.01ef	0.81± 0.03ef	1.99± 0.09cd
Arachic acid (C20:0)	1.35± 0.06a	0.59± 0.03e	1.09± 0.06d	2.35± 0.10f	1.48± 0.04h	1.27± 0.05ab	6.01± 0.05i	2.42± 0.04fg	2.48± 0.08g	2.03± 0.09j	1.22± 0.04bc	1.16± 0.02cd	0.84± 0.05k	1.06± 0.03d	1.24± 0.04bc	1.65± 0.09l
Behenic acid (C22:0)	4.99± 0.04a	1.48± 0.00b	2.04± 0.05c	7.85± 0.09d	3.42± 0.12e	6.38± 0.23h	9.54± 0.31i	11.80± 0.27j	8.42± 0.37k	8.17± 0.04k	3.11± 0.08fg	2.85± 0.09g	2.44± 0.05l	3.34± 0.08ef	3.85± 0.08m	7.62± 0.17d
Tricosane acid (C23:0)	14.70± 0.15a	3.88± 0.15b	6.41± 0.29c	10.60± 0.52d	7.44± 0.08g	10.71± 0.29de	10.75± 0.24de	13.83± 0.10h	11.39± 0.17f	11.04± 0.47ef	6.37± 0.13c	5.21± 0.15i	5.24± 0.21i	7.35± 0.14g	7.10± 0.08g	8.87± 0.07j
Unsaturated Fatty Acids (UFAs)																
Myristoleic acid (C14:1)	1.88± 0.07a	0.62± 0.01b	2.56± 0.01c	2.46± 0.06c	2.55± 0.02c	1.15± 0.04d	1.37± 0.03e	3.37± 0.21f	4.38± 0.14g	6.41± 0.10h	2.58± 0.07c	0.64± 0.06b	0.61± 0.05b	0.47± 0.03i	0.41± 0.04i	2.06± 0.03j

Note. Different letters within the same row are significantly different ($p < 0.05$); ΣSFA = total saturated fatty acids; ΣUFA = total unsaturated fatty acids; TFA = total fatty acids.

Table 4. Saturated fatty acids (SFA), unsaturated fatty acids (UFA), and total fatty acids (TFA) profile (mean value±standard deviation, mg/100 g FW, $n = 3$) in the seeds of 16 avocado accessions grown in southern China

Fatty Acid	Accession															
	RN-1	RN-5	RN-11	RN-12	RN-15	RN-16	Hass	DL-1	DL-2	DL-3	DL-4	RLW-1	RLW-2	RLW-3	RLW-4	GY-8
ΣSFA	488.77	342.47	581.35	598.00	415.27	457.85	1413.64	444.15	565.50	489.15	332.46	295.30	297.70	371.17	270.59	310.90
	±4.37	±7.78	±22.63	±23.21	±11.09	±5.73	±81.97	±16.20	±6.37	±10.98	±18.54	±8.29	±8.71	±5.45	±10.27	±9.41
ΣUFA	948.93	615.27	1075.24	1085.22	817.24	912.12	3263.69	1035.56	1424.72	1195.31	694.21	698.59	780.41	895.21	679.27	642.26
	±14.55	±11.22	±13.76	±18.35	±11.64	±10.67	±26.48	±13.42	±16.88	±10.12	±12.80	±8.50	±18.87	±14.79	±16.13	±13.00
TFA	1437.70	957.74	1656.58	1683.22	1232.51	1369.97	4677.33	1479.71	1990.22	1684.46	1026.67	993.89	1078.11	1266.38	949.86	953.16
	±18.00	±19.00	±36.39	±41.56	±22.73	±16.40	±108.45	±29.62	±23.25	±21.10	±31.34	±16.79	±27.58	±20.24	±26.40	±2.41
ΣUFA/ΣSFA	1.94	1.80	1.85	1.81	1.97	1.99	2.31	2.33	2.52	2.44	2.09	2.37	2.62	2.41	2.51	2.07

Note. Different letters within the same row are significantly different ($p < 0.05$); ΣSFA = total saturated fatty acids; ΣUFA = total unsaturated fatty acids; TFA = total fatty acids.

3.2 Confirmation of Biochemical Properties of Avocado Seed Oil

The biochemical properties of avocado seed oil were evaluated and compared with those of unconventional seed bio-oils (Table 5). These properties were vital for the application of crude extracted oil in cosmetics (Lourith et al., 2014). A lower acid value corresponds to a better quality of bio-oil (Wu et al., 2015). The acid value of avocado seed oil was higher than that of avocado and mango seed oil determined by Galvão et al. (2014) and Wu et al. (2015), but lower than those of other two seed bio-oils (Lourith et al., 2016; Warra, 2016). The iodine value of avocado seed oil detected in the present study exceeds those of other seed bio-oils except for that of pumpkin seed oil (Table 5). This high iodine value implies an enhanced degree of oxidation or hydrogenation resulting from the degree of UFAs (Wu et al., 2015), when the oil was stored in the sealed state. That displayed that the seeds of avocado contained higher unsaturated fatty acid compositions than other seed bio-oils. Similarly, the peroxide value also has the positive correlation with unsaturated fatty acid content (Lourith et al., 2014; Warra, 2016). The avocado seed oil in the present study had the same peroxide value as Para rubber and *Neocarya macrophylla* seed oils (Lourith et al., 2014; Warra, 2016). The saponification value of the avocado seed oil was lower than most of the other seed bio-oils (Table 5). The saponification value in the present study indicated that the proportion of long-chain or great-molecular-weight fatty acids in the avocado seed oil had more than twice than those of the majority of seed bio-oils (Table 5). This saponification value was in accordance with the fatty acid profiles shown in Table 2, 3, which presented that the major fatty acids quantified in avocado seed oil were long-chain fatty acids (linoleic acid, palmitic acid, and oleic acid).

Table 5. Physicochemical properties of avocado seed oil and other crops seed oils (mean value±standard deviation, $n = 3$)

Species	AV (mg KOH/g oil)	IV (g I_2/100 g oil)	PV (meq H_2O_2)	SV (mg KOH/g oil)	Reference
Avocado seed oil	3.74±0.06	124.09±1.14	49.83±0.76	167.98±10.75	Present study
Avocado seed oil	(1.19±0.01)–(2.23±0.10)	(62.09±0.35)–(68.53±1.92)	-	(206.7±1.61)–(261.5±3.17)	Galvão et al. (2014)
Dalbergia odorifera seed oil	-	106.53±0.53	-	196.78±0.61	Zheng et al. (2012)
Date plum seed oil	-	76.66±0.28	-	191.28±0.50	Nehdi et al. (2010)
Mango seed oil	3.4	45.9	-	185.6	Wu et al. (2015)
Moringa oleifera seed oil	-	69.45±1.20	-	186.67±2.01	Anwar et al. (2003)
Neocarya macrophylla seed oil	12.97±0.01	32.07±0.01	45.48±0.02	153.30±0.10	Warra (2016)
Para rubber seed oil	-	42.34±0.43	47.33±0.22	149.25±1.56	Lourith et al. (2014)
Pumpkin seed oil	-	153.66±0.65	-	175.00±1.30	Rezig et al. (2012)
Rambutan seed oil	3.95±0.06	47.00±0.20	-	186.00±1.00	Soís-Fuentes et al. (2010)
Rambutan seed oil	-	50.30±1.24	-	182.10±0.16	Manaf et al. (2013)
Rambutan seed oil	4.35±0.00	44.17±0.30	-	246.73±0.10	Lourith et al. (2016)

Note. AV: acid value, IV: iodine value, PV: peroxide value, SV: saponification value.

3.3 Determination of Physicochemical Properties of the Bar Soap

Fats and oil are primary raw materials of cosmetic detergent products owing to alkaline saponification of the fatty acid constituents (Wu et al., 2015; Lourith et al., 2016). The level of alkalinity for cosmetic detergent products is directly related to skin sensitivity (Lourith et al., 2016). The alkalinity of the self-made bar soap stored for 15 days under normal conditions was higher than that of the commercial soap. During UV irradiation, the alkalinity of the self-made bar soap solution decreased and ultimately became lower than that of the commercial soap after 15 days (Figure 1). However, the alkalinities of the self-made bar soap solutions were within the range of soap Chinese national standard values for the commercial bar soap after storage for 15 days under normal conditions or under UV irradiation (QB/T 2485-2000, 2001). Lourith et al. (2016) suggested that the alkalinity of the freshly prepared bar soaps containing rambutan seed oil was within the range from 10.39 to 10.54, and the alkalinity slightly decreased after the bar soaps were stored under ambient condition for 15 days (Lourith et al., 2016). In this experiment, the alkalinity (9.48) of the self-made bar soap solution was slightly lower than that (10.33 and 10.48) of rambutan seed oil bar soap solution (Lourith et al., 2016), when the avocado seed oil and rambutan seed oil bar soaps were all stored for 15 days under normal conditions.

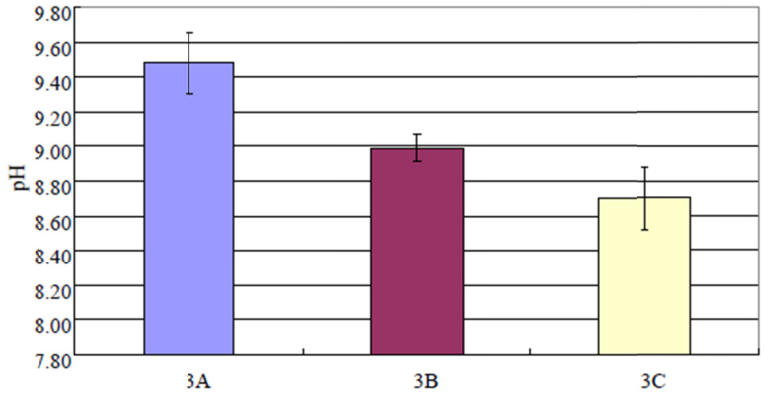

Figure 1. The pH (mean value±standard deviation, n = 3) of the self-made bar soap solution. The self-made bar soap stored for 15 days under normal conditions (1A); the commercial soap solution under normal conditions (1B); the self-made bar soap solution stored for 15 days under UV irradiation (10 W) (1C). Vertical bars represent standard deviations

Foamability is one of the most important properties for cosmetic detergent products (Wu et al., 2015; Lourith et al., 2016). The foaming property of the self-made bar soap solution was tested and compared with that of the commercial soap solution. The foam height of the self-made bar soap solution progressively decreased from the beginning of storage to 60 min (Figure 2). This phenomenon was also observed by Wu et al. (2015) and Lourith et al. (2016). In addition, the foam height of the self-made bar soap solution was lower than that of the commercial soap solution at all times. Wu et al. (2015) reported that the foam height of mango seed oil bar soap solution was higher than that of a commercial soap solution for the first three hours of storage but then became lower than that of the commercial soap solution (Wu et al., 2015). In this experiment, we could not aware of the specific components in the selected commercial soap, which concerned trade secrets. We speculated that some chemical additives such as liquid paraffin, squalane and squalene were included in the commercial soap, which might enhance the foaming properties (Shrestha et al., 2006; Qin et al., 2013). The foamability of the self-made bar soap solution was not different under normal conditions and under UV irradiation, indicating that UV irradiation did not greatly affect the foamability.

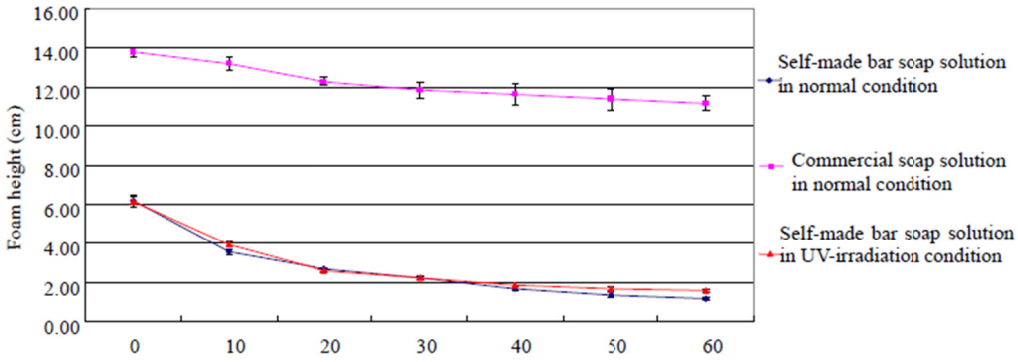

Figure 2. The foamability testing of the self-made bar soap solution (mean value±standard deviation, $n = 3$). Vertical bars represent standard deviations

4. Conclusions

Oil contents and fatty acid compositions of the seeds of 16 avocado accessions collected from southern China and their application in cosmetics have been studied. The seeds of 16 avocado accessions differed in oil content and fatty acid composition. Linoleic (40.14%), palmitic (23.54%), and oleic acids (16.23%) were the dominating fatty acids in the avocado seed. Avocado seed oil showed superior biochemical properties than some other seed bio-oils and displayed great promise as a raw material in the cosmetic industry. The bar soap containing avocado seed oil was made. Therefore, transforming of the seed oil that is by-product into cosmetics is encouraged.

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