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Research Article

FATTY ACIDS COMPOSITION IN MACADAMIA SEDES OIL (*MACADAMIA INTEGRIFOLIA*) FROM ECUADOR

CARRILLO W[1]*, CARPIO C[1], MORALES D[1], VILCACUNDO E[2], ÁLVAREZ M[1]

[1]Laboratory of Functional Foods, Faculty of Foods Science and Engineering, Technical University of Ambato, Av. Los Chasquis y Rio Payamino, Campus Huachi, CP 1801334, Ambato, Ecuador. [2]Faculty of Health and Human Sciences, Bolivar State University, Academic Campus "Alpachaca" Av. Ernesto Che Guevara s/n y Av. Gabriel Secaira, EC. 020150, Guaranda, Ecuador. Email: wi.carrillo@uta.edu.ec

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ABSTRACT

Objective: The aim of this study was to determine the fatty acids composition in a *Macadamia* seeds oil sample cultivated in Ecuador.

Methods: *Macadamia* oil was obtained of *Macadamia* seeds using the cold pressing method. Fatty acids analysis was performed using the gas chromatography method with a mass selective detector and using the database library NIST14.L to identify the compounds.

Results: *Macadamia* seeds have a high content of unsaturated fatty acids with 41.36% of oleic acid. *Macadamia* seeds oil has 37.77% of polyunsaturated fatty acids of which 3.79% ω-6 α-linoleic and 33.98% of ω3 α-linolenic. *Macadamia* seeds only have 9.33% of palmitic acid.

Conclusions: *Macadamia* seeds are a good source of monounsaturated fatty acids with a good content of ω-6 α-linoleic. This profile enables their use as a good and healthy oil to be used in the food industry in Ecuador.

Keywords: *Macadamia*, *Macadamia integrifolia*, Fatty acids, Gas chromatography-mass selective detector, Methyl ester, Omega acids.

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INTRODUCTION

Macadamia is a genus of flowering plants belonging to the Proteaceae family, being cultivated for its edible kernels. There are four species of *Macadamia*; all species are typical in subtropical rainforests along the East coast of Australia. Two of the species, *Macadamia integrifolia,* and *Macadamia tetraphylla*, generate edible nuts and are of commercial importance in the world [1,2]. *M. integrifolia*, commonly known as the smooth-shell *Macadamia*, provides kernels with higher quality, whereas *M. tetraphylla*, known as the rough-shell *Macadamia*, is more adaptable and can grow more easily at low temperatures or over a wider range of temperatures [3-5]. The other two species, *Macadamia ternifolia* and *Macadamia jansenii*, are inedible, as they contain cyanogenic glycosides which are toxic and they are not apt to human consume [6].

Macadamia is the only Australian plant that has been domesticated on a commercial scale as a food crop in other countries. *Macadamia* is cultivated mainly in Australia, the USA (Hawai and California) and South Africa. There are also expanding industries in Brazil, Guatemala, and Kenya, and smaller industries in New Zealand, Malawi, Paraguay, Ecuador, and other countries [7-9]. The worldwide production of *Macadamia* sp. is approximately 44,000 metric tons (kernel), 86% of which come from Australia, South Africa, Kenya, the United States, and Malawi. Australia is the World's largest producer, with approximately 14,100 metric tons [10]. *M. integrifolia* contain approximately 70% of oil and its oil is the most highly monounsaturated fatty acids, which possibly help lower blood cholesterol, and its regular consume can help to reduce the risk of heart disease. *M. integrifolia* has a high oleic acid content and low level of saturated and polyunsaturated fatty acids. The low content of polyunsaturated fatty acids (PUFAs) produces good stability and less susceptibility to *Macadamia* seed oil oxidation, as PUFAs are more susceptible to oxidative degradation. *Macadamia* seed oil has a high content of monounsaturated fatty acids. Studies have been conducted to evaluate the effect of nut consumption in the human health [11,12]. The *Macadamia* kernel is a rich source of lipids, proteins, and important micronutrients. However, its chemical composition can vary considerably depending on the variety, seed maturity, geographic location and growth conditions, such as quality of soil [7].

The aim of this work was to characterize the composition of fatty acids methyl esters (FAMEs) present in *Macadamia* oil samples cultivated in Ecuador using the gas chromatography-mass selective detector (GC-MSD).

METHODS

Oil extraction

Macadamia was obtained in the supermarket of Ecuador. *Macadamia* oil sample was obtained from *Macadamia* seeds using the cold pressed method. Oil was then stored at 4.0 ± 2°C. Oil extraction was conducted using a Soxhlet apparatus for approximately 5 hrs with hexane as solvent, with a solid to solvent ratio of 1/7 m/v. After the extraction process, the flask contents were filtered, and the liquid fraction containing the lipid extract and solvent was poured into a 250 mL flask of a rotary film evaporator to remove the solvent. The obtained oil was collected, evaporated under nitrogen, weighed, and stored in sealed amber glass vials at −20°C until analysis [13].

Fatty acids analysis by GC-MSD

The fatty acid composition of oil extracted from *Macadamia* seeds was analyzed by injecting FAMEs [14] into an Agilent Technologies 7980 A system gas chromatography (Agilent, Santa Clara, CA) equipped with a MSD 5977A GC/MSD, an auto-sampler 7693, column (60 m × 250 μm ×0.25 μm, Agilent 122-7062). The oven temperature was programmed as follows: From 80°C; ramp 1: To 100°C at 20°C/minute during 1 minute; ramp 2: At 200°C at 25°C/minute during 10 minutes; ramp 3: At 250°C at 2°C/minute. The injector and detector temperatures were set at 250°C. Helium was used as carrier gas at a linear flow velocity of 1.4 mL/minute.

RESULTS

Fig. 1 shows the commercial *Macadamia* seeds without skin before extraction oil by cold pressed.

Macadamia oil sample was obtained using the cold pressing method; fatty acids were subsequently methyl esterified (FAMEs). FAMEs from *Macadamia* oil were identified using the GC/MSD analytical method. The spectrum of precursor ions produced in the ionization of the mass apparatus was compared with similar spectrums available in the three different databases of the Library NIST14. L. Eight majority peaks were identified with their associated retention time: C16:0 with a retention time of 19.379 minutes; C16:1 with a retention time of 20.314 minutes; C18:0 with a retention time of 26.056 minutes; C18:1 with retention of 26.928 minutes; C18:2 with retention time of 27.167 minutes; C18:3 with retention time of 28.677 minutes; C20:0 with retention time of 33.468 minutes and finally C20:1 with a retention time of 34.350 minutes (Fig. 2).

The concentration of FAMEs was calculated with a peak area percentage. FAMEs were characterized: C16:0 palmitic acid with 9.11% of fatty content, C16:1 palmitoleic with 12.48% of fatty content, C18:0 stearic acid with 3.93% of fatty content, C18:1 oleic acid with 63.36% of fatty content, C18:2 linoleic acid (LA) with 3.79% of fatty content, C18:2 LA with 3.22% of fatty content, C18: 3 linolenic acid with 1.69% of fatty content; C20:0 arachidic acid with 3.31% of fatty content, and finally, C20:1 gadoleic acid with 2.90% of fatty content (Table 1).

Fig. 1: *Macadamia* seeds without skin

FAMEs

When the *Macadamia* fatty acid composition is compared to some common vegetable oils, it can be seen that olive oil has a high content of mono-unsaturated fatty acids, C18:1 named oleic acid with 77.6% of oleic acid. It can be seen that *Macadamia* oil from Ecuador has a high content of mono-unsaturated fatty acids with a content of 63.36% of oleic acid. *Macadamia* oil has also a low content of PUFAs with 5.01%. Olive oil contains few ω-6 and ω-3 fatty acids with 9.0% and 1.0%, respectively, and *Macadamia* oil contain 3.22% of ω-6 and 1.79% of ω-3 (Table 2).

Many of the chronic conditions, cardiovascular diseases, diabetes, cancer, obesity, autoimmune diseases, rheumatoid arthritis, asthma, and depression, are associated with an increased production of thromboxane A2, leukotriene B4, IL-1α, IL-6, tumor necrosis factor, and C-reactive protein. The previous molecule levels increase with increases in ω-6 fatty acid intakes and decrease with increases in ω-3 fatty acid intakes [15,16].

DISCUSSION

Lipids are a major component of the human diet. Essential fatty acids (EFA) are crucial dietary constituents for normal growth, development, and maintain of internal homeostasis. High quantities of EFA may be found in plant seeds distributed in many regions of the world such as South America in plants such as sachainchi (*Pluketenia volubilis*), ungurahui (*Oenocarpus bataua*) and *Macadamia* (*Macadamia integrofolia*). These plants can provide oils with a high concentration of monounsaturated fatty acids, that can help preventing cardiovascular diseases through different mechanisms [17]. The consumption of saturated fat in Ecuador is high, and the balance of ω3 and ω6 is not correct in many processed foods. Dietary EFA includes LA, an n−6 FA, and alpha-linolenic acid (ALA), an n−3 FA. LA and ALA cannot be synthesized by the human organism being necessary to supply them through foods in diet intake [18-20]. More importantly, EFA are metabolized with very long chains (VLC) PUFAs. For instance, LA is converted to VLCPUFA arachidonic acid (AA), and ALA is converted to both VLCPUFAs eicosapentaenoic acid and docosahexaenoic acid. Both EFA and their associated VLCPUFA metabolites are important for different organism functions, including growth, immunity function, and cognitive development [21,22]. It is known that nuts are energy dense and provide 23.4 to 26.8 kJ/g of calories with a high-fat content (45-75% of weight), but mostly unsaturated fatty acids [23]. Results of different epidemiologic studies have suggested that there may be a connection between frequent nut consumption and decreased incidences of several chronic diseases [24]. Recent emerging scientific studies have demonstrated that the bioactive constituents of nuts have cardioprotective, antiobesity, anticancer, and antioxidant effects mediated by different mechanisms in the human body [25,26].

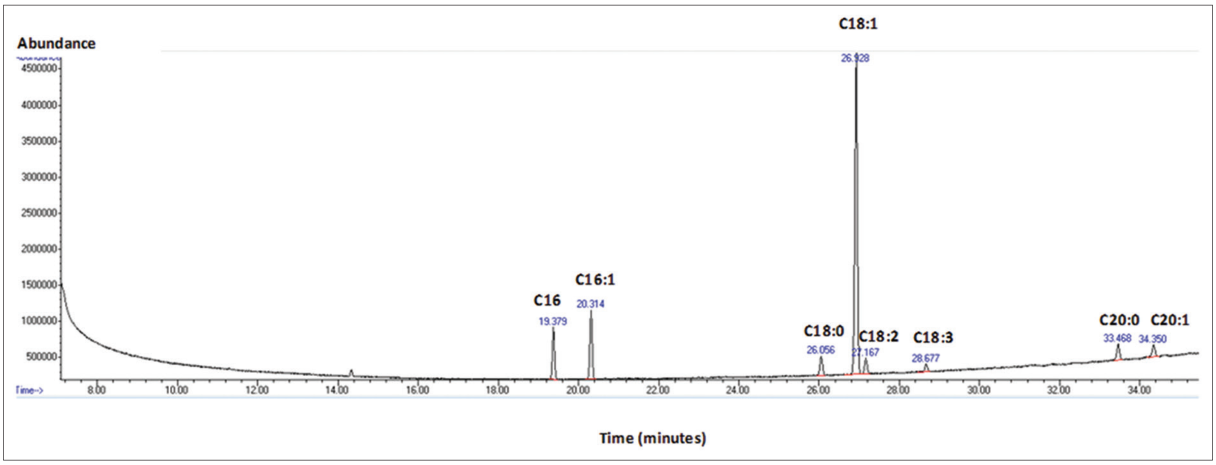

Fig. 2: Gas chromatography mass selective detector analysis of fatty acids present in *Macadamia* oil sample

Table 1: Fatty acids composition of Samboseeds oil sample from Ecuador by GC/MSD analysis and their percentage

Retention time (minutes)	Peak area ratio %	Carbon number: Double bound	FAMEs name
19.379	9.11	C16:0	Palmitic acid
20.314	12.48	C16:1	Palmitoleic acid
26.056	3.22	C18:0	Stearic acid
26.928	63.36	Δ9C18:1	Oleic acid
27.177	3.22	Δ9,12C18:2	Linoleic acid
28.677	1.79	Δ9,12,15C18:3	Linolenic acid
33.468	3.31	C20:0	Arachidic acid
34.350	2.90	C20:1	Gadoleic acid

FAMEs: Fatty acids methyl esters

Table 2: Fatty acid composition (%) of eight vegetable oils

Reference	Vegetable oil	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
9	Olive oil	13.8	1.4	2.8	71.6	9.00	1.0	NR	NR
9	Sunflower oil	5.2	0.1	3.7	33.7	56.5	0.0	NR	NR
9	Palm oil	44.8	0.0	4.6	38.9	9.5	0.4	NR	NR
9	Soybean Oil	10.1	0.0	4.3	22.3	53.7	8.1	NR	NR
9	Corn oil	11.6	0.0	2.5	38.7	44.7	1.4	NR	NR
10	Sacha inchi oil	3.98	0.0	3.12	8.58	34.98	47.04	0.0	0.0
11	Sambo oil	9.33	0.0	6.84	41.36	33.98	0.0	0.0	0.0
	Macadamia oil	9.11	12.48	3.93	63.36	3.22	1.69	3.31	2.90

The American Heart Association, the Canadian Cardiovascular Society [27], the US Food and Drug Administration (US Food and Drug Administration, 2003) [28], and the US Department of Agriculture (US Department of Health and Human Services and US Department of Agriculture, 2015) have recommend the regular consumption of nuts to the general population, in the context of a healthy diet for their good properties [29].

The results obtained in this study are in accordance to fatty acids levels from *Macadamia* seeds reported in different studies in the science literature. It has been reported that in *Macadamia* has a high content of monounsaturated fatty acids such as oleic acid, Venkachalam, and Shate, 2006 reported 58.51% of oleic acid, 1.81% of ϖ-6, and 2.58% of ϖ-3 from *M. integrofolia* [30].

Phatanayinde *et al*., 2012 reported 59.4% of oleic acid, 2.4% of ϖ 6% and 0.13% of ϖ-3 from *M. integrofolia* [31]. On the other hand, Kaijser *et al*., 2000 reported 40.55% of oleic acid, 2.63% of ϖ 6%, and 0.17% of ϖ-3 from *Macadamia tetraphyla* [32]. Firestone, 2006 reported 56% of oleic acid and 2.0% of ϖ-6 from *M. tetraphyla* and 59% of oleic acid and 3.0% of ϖ-6 from *M. ternifolia* [33]. All *Macadamia* oil studied by the previous authors presented a high content of oleic acid between 40.55-59.0% of oleic acid out of total fatty acids. In this study, the *Macadamia* seed oil presented a similar high content of oleic acid and a low content of linoleic and linolenic acids. Oleic acid is recommended by Food and Drugs Administration (FDA) as an intake of monounsaturated fatty acids to reduce the risk of cardiovascular diseases. In 2004, the FDA authorized a health claim on olive oil on coronary heart disease: "Limited and not conclusive scientific evidence suggests that eating about two tablespoons (23 g) of olive oil daily may reduce the risk of coronary heart disease due to the monounsaturated fat in olive oil. To achieve this possible benefit, olive oil is to replace a similar amount of saturated fat and not increase the total number of calories you eat in a day" (CFSAN/Office of Nutritional Products, 2004)[34]. A recent study from the European Food Safety Authority (EFSA) supports the effects of virgin olive oil phenols on low-density lipoprotein (LDL) oxidation (EFSA, 2011) [35]. The extra virgin olive oil contains monounsaturated fatty acid (oleic acid) and phenols compounds with antioxidant capacity. It is known that oxidation of LDL cholesterol is a key factor important in the development of atherosclerosis, promoting the formation of foam cells in the subendothelial space of the vascular wall. Oleic acid and phenols help to prevent this oxidation when incorporated in the human diet daily [36]. *Macadamia* seed oil has a good proportion of oleic acid. *Macadamia* seed oil can be a good alternative in Ecuador to be used in the food industry due to its high nutritional quality and its high content of oleic acid.

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