

Review Article

Argan oil: Occurrence, composition and impact on human health

Zoubida Charrouf¹ and Dominique Guillaume²¹ Laboratoire de Chimie des Plantes et de Synthèse Organique et Bioorganique, Rabat, Morocco² FRE 2715, Reims, France

Edible argan oil is traditionally prepared by Berber women who manually crunch the roasted kernels of *Argania spinosa* fruits. Unroasted kernels furnish a cosmetic-grade oil. Argan groves are currently shrinking due to unfavorable conditions. To stop this trend, a program aimed at increasing the argan tree economical value is in progress in Morocco. Its concept is that the natives will preserve argan trees only if the major part of the wealth resulting from the argan grove production directly benefits them. Because of its high dietary value, argan oil has appeared as the best derivative to rapidly satisfy such assumption. Consequently, year after year, cooperatives have been implanted to produce argan oil of high quality on a large scale. The delicate hazelnut taste of argan oil, combined with its high level in unsaturated fatty acids, has allowed its swift commercial success and, nowadays, argan oil of standardized quality is marketed worldwide. Moroccan farmers are now beginning to plant argan trees, confirming the full success of this ambitious program. This review summarizes the methods used to prepare argan oil, its composition, the strategies available to certify argan oil quality, and finally the impact of argan oil on human health.

Keywords: *Argania spinosa* / Cardiovascular protection / Dietary oil / Fatty acid / Morocco

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1 Introduction

Argan oil is prepared from the fruits of argan trees (*Argania spinosa* (L.) Skeels) following a multistep process [1]. When the kernels contained in the argan fruits are slightly roasted prior to grinding, edible argan oil is obtained. Unroasted kernels are saved to prepare an oil used in cosmetology. Until the 1980's, argan oil was, at best, considered as a tourist attraction sold in recycled plastic bottles along the dusty Moroccan roads. It is now frequently referred to as "the world's most expensive vegetable oil". Such metamorphosis is the result of an intensive program aimed at preserving the argan tree through the production of high-grade argan oil in rural women cooperatives [1]. This program has necessitated the improvement of argan oil production techniques, and the ascertainment of argan oil chemical and microbiological quality. The cardiovascular-protective properties of argan oil have ascertained its popularity among consumers. After a

brief description of the importance of the argan tree in the Moroccan economic system, this review will successively describe these three aspects.

2 The argan tree

The argan tree of the family Sapotaceae is only endemic in Morocco, where argan groves naturally cover about 8000 km². The argan tree is a slow-growing spiny tree and is either shrubby or up to 10 m high when isolated and growing in a favorable environment [2]. The argan tree life span frequently exceeds 200 years. The argan tree actively protects the superficial earth crust against heavy rain or wind-induced erosion. Because its root network reaches deeply into the soil, the argan tree presents the ability to resist severe drought, and it is often the ultimate warrior when the desert is encroaching on the land. The argan tree's large canopy also shades domestic cultures and maintains the soil fertility. Because in Morocco traditional rural rules consider the argan grove as a public property where dwellers can freely circulate, argan tree leaves are frequently used by native farmers as "hanging forage" for goats or camels. Such practice, associated with (1) the overuse of argan wood as fuel, (2) the necessity to obtain more land to

Correspondence: Zoubida Charrouf, Laboratoire de Chimie des Plantes et de Synthèse Organique et Bioorganique, Faculté des Sciences, Université Mohamed V-Agdal, Avenue Ibn Batouta, BP1014, Rabat, Morocco.

E-mail: zcharrouf@menara.ma**Fax:** +212-37-713279

always produce more fresh vegetables for the tourism industry, and (3) several consecutive unprecedented arid years, has fragmented the argan groves, rendering the argan tree a possibly endangered species. To rescue the argan groves, the phytochemical analysis of the argan tree began 15 years ago in order to putatively discover new economically interesting molecules and hence increase the argan tree market value. Indeed, several new secondary metabolites have been isolated from different parts of the tree [3–6] and molecules useful in the cosmetology domain have been identified from its leaves [7].

However, argan oil remains the main viable economic resource produced by the argan tree so far. Its worldwide marketing is currently being successfully achieved and is giving to the argan groves the necessary momentum to positively envision their rescue. Nevertheless, only the discovery of new outputs for argan products will ascertain the safety of the argan groves in the long term.

3 Argan oil preparation

3.1 Traditional method

Traditionally, argan oil is exclusively prepared by women [1]. Once the ripe fruits have been collected, their peel and pulp are discarded, affording ovoid argan nuts of the size of a big olive. Argan nuts are then manually broken, the women firmly holding them between their thumb and index finger along the longest seed diagonal and violently hitting them with a stone. The kernels are then collected and roasted for a few minutes in clay plates if dietary argan oil is to be prepared. The roasted kernels are then crushed with a manual millstone, affording a brownish dough that is subsequently hand-mixed with warm water for several minutes. The wet dough is then hand-pressed, becomes solid and releases a brown emulsion that is decanted after several minutes to furnish the argan oil. The extraction residue (press cake) is very bitter, still rich in oil and used to feed cattle. Preparation of argan oil by the traditional method is very slow, and for a single person, starting from the collected fruits, 20 h of work are necessary to prepare 1 L of oil. The preservation of traditionally prepared argan oil is often limited to a few weeks, and natives believe that the addition of salt increases the preservation period.

Traditionally prepared argan oil suffers from many drawbacks, definitively precluding its large-scale marketing. For example, the added water is often of poor microbiological quality; to avoid the time-consuming fruit peeling step, argan fruits are frequently given to goats that naturally reject “peeled” argan nuts in their stools and, finally, even prepared by the same woman, different batches of traditionally prepared argan oil taste differently, the taste being sometimes not satisfactory for the consumers. The use of unsatisfactory sanitary conditions also reduces the preservation time of argan

oil (sometimes to just a few weeks). However, when prepared according to sanitarily controlled rules, traditionally prepared argan oil can be preserved for up to 1 year.

3.2 Extraction method developed in the women cooperatives

In the women cooperatives, strict rules for the preparation of argan oil have been implemented [1]. Furthermore, argan oil is extracted using mechanical presses, making the mixing of the dough and water unnecessary. Simultaneously, the use of presses has dramatically increased the yield in oil, with the press cake now containing less than 10% of oil. In the women cooperatives, fruit peeling is achieved using scratching machines that pull out the fruit peel and pulp. For the roasting step, gas roasters are used. Because the delicate hazelnut taste of dietary argan oil is a consequence of the roasting procedure, standardization of this step has allowed the production of an oil of reproducible flavor on a large scale. In the cooperatives, the overall time necessary to prepare 1 L of oil has been reduced by one fifth compared to the traditional method, the most painful tasks being the most shortened.

3.3 Industrial method

For industrial or laboratory purposes, argan oil can be extracted from pulverized kernels by lipophilic solvents. After solvent evaporation, argan oil is directly obtained. Only the cosmetics industry uses argan oil prepared according to this method. The term “enriched argan oil” describes an argan oil obtained by flash distillation of argan oil prepared by one of the above-mentioned methods [8]. The level of unsaponifiable matter (see Section 4) in this type of oil is three times lower than that observed in the press-extracted oil.

4 Chemical features and composition of argan oil

The edible argan oil density at 20 °C, relative to the density of water at the same temperature, ranges from 0.906 to 0.919. At the same temperature, its refractive index is 1.463–1.472, and its acid value between 0.8 and 2.5 [9]. The acid value easily discriminates extra-virgin argan oil, fine-virgin argan oil, virgin argan oil, and lampante argan oil (Table 1); the acid value of extra-virgin argan oil must be lower than 0.8 [9]. The variability of the extra-virgin argan oil acid value as a function of various parameters has been studied. Together with the seed origin, the technology associated with argan oil extraction is also a parameter possibly modifying the argan oil acid value [10]. Comparing argan oil samples prepared from roasted *versus* non-roasted kernels, mechanically peeled *versus* goat-digested fruits, and fruits originating from different geographical regions, acid values ranging between 0.15 and 0.9 have been observed [10].

Table 1. Acid and peroxide values of virgin argan oil.

	extra-virgin	fine-virgin	virgin	lampante
Acid value	≤0.8	≤1.5	≤2.5	>2.5
Peroxide value	≤15	≤20	≤20	no limit

Acylglycerols, including 95% of triacylglycerols, constitute 99% of the argan oil. The remaining 4% are composed of monoacylglycerols (0.27–0.65%), diacylglycerols (0.68–1.53), and free fatty acids (1.1–2%) [11]. The two main fatty acids found in argan oil acylglycerols are oleic acid (O) (46–48%) and linoleic acid (L) (31–35%) (Table 2), a mono- and a diunsaturated fatty acid, respectively. The third and fourth main fatty acids found in argan oil are palmitic acid (P) (11–14%) and stearic acid (S) (4–7%) [8, 10]. These two latter acids are saturated fatty acids.

Table 2. Percentages of fatty acids found in argan oil.

Acid	%	Acid	%	Acid	%
Oleic	43–49	Linoleic	29–36	Palmitic	11–15
Stearic	4–7	Palmitoleic	0.3–3	Arachidic	<0.5
Linolenic	<0.2	Behenic	<0.2	Myristic	<0.1

The major triacylglycerols found in argan oil include two or more oleic acid residues. Other frequently encountered triacylglycerols include two linoleic acid residues and one oleic acid moiety or two oleic acid residues and one palmitic acid moiety (Table 3) [12].

Table 3. Percentages of the major triacylglycerols found in virgin argan oil.

TG	%	TG	%	TG	%
OOL	19.5	OOO	12.8	PLL	6.3
POL	13.6	POO	11.5	SOO	3.4
OLL	13.6	LLL	7.4	PPO	3.2

TG, triacylglycerols; O, oleic acid; L, linoleic acid; P, palmitic acid, S, stearic acid.

Unsaponifiable matter constitutes 1% of argan oil. It is made of carotenes (37%), tocopherols (8%), triterpene alcohols (20%), sterols (29%), and xanthophylls (5%). In extra-virgin argan oil, the levels of tocopherols are between 600 and 900 mg/kg. The main tocopherol found in argan oil is γ -tocopherol (between 81 and 92%) [12]; it is a strong antioxidative agent. α -, β -, and δ -tocopherols represent 2.4–6.5%, 0.1–0.3%, and 6.2–12.8%, respectively, of the total tocopherol

fraction. Other phenols have also been identified as traces using mass spectroscopy; they might also act as antioxidants. These phenol derivatives include caffeic acid, oleuropein, vanillic acid, tyrosol, ferulic acid, syringic acid, catechol, resorcinol, (–)-epicatechin, and (+)-catechin [13, 14]. Five ubiquitous triterpene alcohols have also been identified: tirucallol (27.9%), β -amyrine (27.3%), butyrospermol (18.1%), lupeol (7.1%), and 24-methylene cycloartanol (4.5%).

5 Ascertaining argan oil quality

The success of argan oil on the international market has created a need for a new legislation to protect the consumer purchasing argan oil. Three questions are generally asked by the consumers: (1) Is my argan oil – and will it continue to be – coming from seeds collected exclusively in Morocco? (2) Is the oil 100% pure argan oil or is it adulterated with cheap oils? And (3) am I purchasing high-quality argan oil?

5.1 Is my argan oil really coming from seeds collected exclusively in Morocco?

Although the argan tree is only naturally endemic in Morocco, because of the recent economical success of argan oil, the idea of growing argan trees in other subtropical countries has recently emerged. This could lead to the production of argan oil of uncertified quality, affecting the argan oil business in Morocco, and could annihilate the efforts made to save the argan forests. So, the Moroccan government is currently applying to obtain a Geographical Indication (GI) for argan oil. Initially specifically intended for European products such as Parmesan cheese, Roquefort cheese or Champagne, such protection can now be extended to non-European countries and, for example, an application is being contemplated for bhut jolokias, the world's hottest chili grown in Northeastern India. As soon as the GI will be granted to argan oil, only argan oil prepared from seeds collected in Morocco and following strictly established rules will be sold as such.

5.2 Has my argan oil been adulterated with cheap oils?

The high price of argan oil is likely to stimulate fraudulent attempts to sell adulterated argan oil. Consequently, adulteration detection methods are necessary. To solve this question, advantage has been taken of the peculiar sterol composition of argan oil. Sterols are terpenoid derivatives commonly found in plants and as minor components in most vegetable oils. Argan oil contains between 142 and 220 mg of phytosterols per 100 g of oil [9]. The two major sterols found in argan oil are schottenol and spinasterol [8]. Interestingly, argan oil contains only traces of campesterol [12] (Table 4), a phytosterol commonly found in most of the other vegetable oils. This observation is of utmost importance since it means that addition of

Table 4. Percentages of sterols found in virgin argan oil.

Sterol	%
Schottenol	44.0–49
Spinasterol	34.0–44
Δ^7 -Avenasterol	4–7
Cycloeucalenol	<5
Stigmasta-8,22-diene- 3β -ol	3.2–5.7
Citrostadienol	3.5–4
Campesterol	≤ 0.4

traces of an oil containing campesterol to argan oil will dramatically modify its sterol composition while the hypothesis of an artificial removal of campesterol from cheap oil for fraudulent purposes is not likely. Conditions allowing the measurement of argan oil campesterol levels by gas chromatography have recently been designed; thus, this method can be proposed, possibly in addition to fatty acid composition determination and other classical methods, to detect argan oil adulteration [15]. The combination of such methods will ascertain argan oil purity up to 95%.

5.3 Is my argan oil of high quality?

Goats are particularly fond of argan fruits [16]. In addition to microbiologic concerns, goat-depulpd fruits furnish an oil having modified organoleptic properties. Particularly, differences have been observed in the volatile component composition of the oil [17], with major differences occurring in the alcohol and ester series (Table 5). Consequently, discarding such an oil is not only a question of microbiological concern (that could be solved by a sterilization step), but is also a question of quality. However, analysis of the volatile components of argan oil is unlikely to become a method certifying the quality of argan oil because of the difficulties associated with its setup. Because out-of-range peroxide values have been observed on argan oil samples prepared from goat-

Table 5. Occurrence of selected odorants in edible extra-virgin argan oil prepared from mechanically peeled or animal peeled kernels.

Odorant	MP argan oil	AP argan oil
(<i>E</i>)-Oct-2-en-1-ol		+
(<i>E</i>)-Hept-2-enal		+
Phenylacetaldehyde		+
(<i>Z</i>)-Non-3-enal	+	
(<i>R</i>)- δ -Decalactone	+	
1-Carvone	+	
Citronellol		+
Eugenol		+

MP, mechanically peeled; AP, animal peeled.

peeled fruits [10], the use of this parameter is currently studied to detect this type of fraud. However, a statistical analysis over the years is still necessary to confirm the possible use of this factor as a discriminating test.

6 Pharmacological properties of argan oil

6.1 Traditionally claimed properties

Dietary argan oil is considered by the Berber population to be choleric, hepatoprotective, and useful to treat hypercholesterolemia and atherosclerosis [18, 19]. Argan oil would also prevent miscarriage. Cosmetic-grade oil cures skin pimples, juvenile acne, and chicken pox pustules. It also reduces the rate of appearance of wrinkles and is used to fight dry skin and dry hair.

6.2 Scientifically investigated pharmacological properties of argan oil

A *cis*-unsaturated fatty acid-rich diet is recommended for the prevention of cardiovascular diseases [20]. Because of its high level in oleic and linoleic acids and other minor constituents, the impact of argan oil on the cardiovascular function has been actively investigated using animal models, isolated cells/organs, or human epidemiologic studies [21–25]. These studies have fully confirmed the traditionally known cholesterol- and triacylglycerol-lowering effects of argan oil in humans, together with its hypotensive effect. Consequently, argan oil consumption clearly reduces cardiovascular risks, and argan oil can be used as an anti-atherogenic oil [26]. In addition, argan oil has been shown to possess antioxidant properties [27, 28]. Minor components of argan oil are also likely to be responsible for some of its pharmacological properties [29]. Among those, the phenolic fraction of argan oil has been shown to inhibit low-density lipoprotein oxidation [30] and to have an anti-proliferative effect on human prostate cancer cell lines [31]. However, so far, the most advanced clinical researches have only established that an argan oil-enriched diet can be recommended to patients having cardiovascular diseases [32].

7 Conclusion

During the last 5 years, argan oil has found its place on the highly competitive international edible oil market. This is the result of its unique organoleptic properties associated with its cardioprotective properties. This success is a very positive sign for the preservation of the argan tree, the argan forests and hence, in general, the biodiversity.

Conflict of interest statement

The authors have declared no conflict of interest.

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