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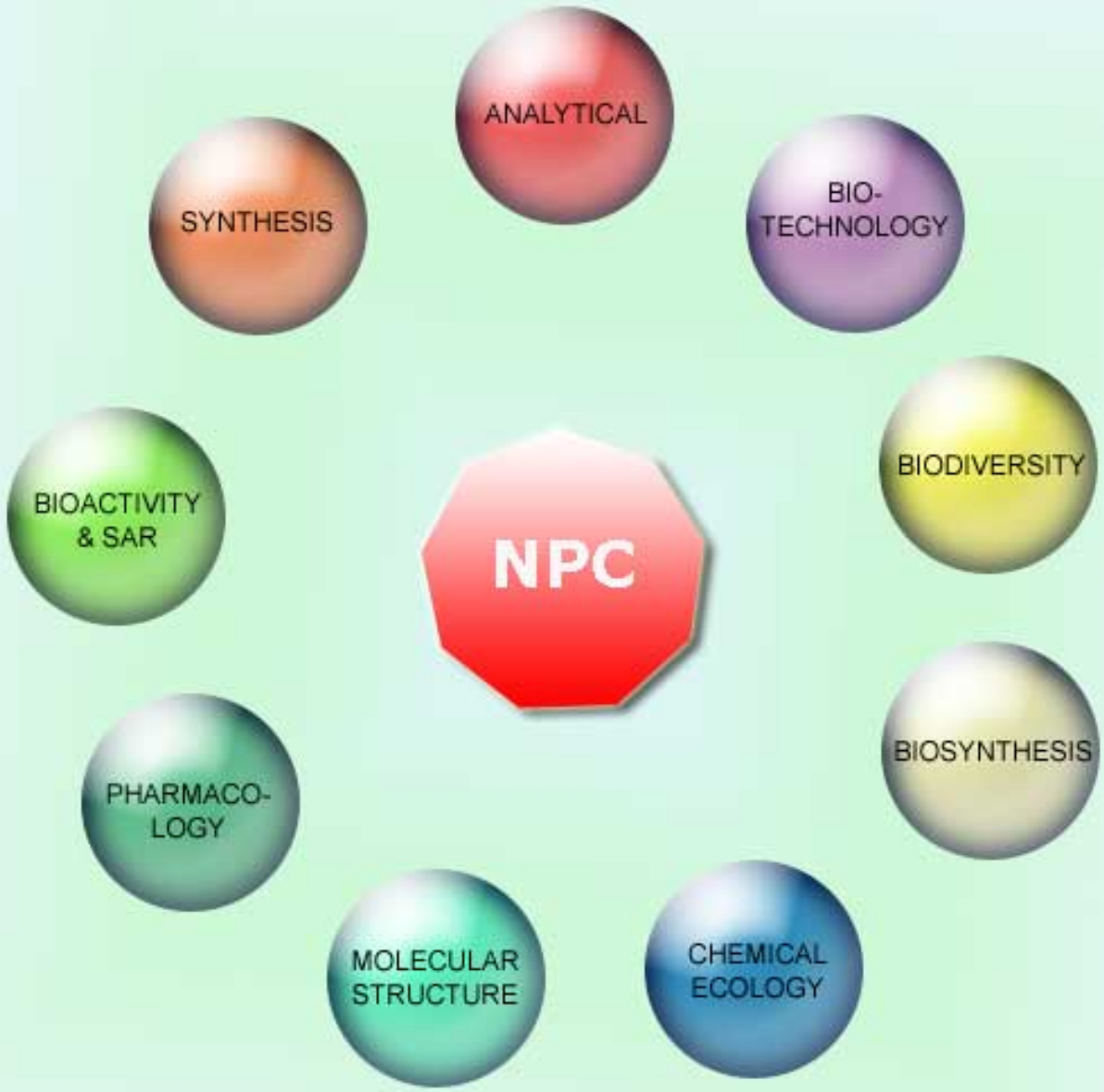

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Argan oil, Functional Food, and the Sustainable Development of the Argan Forest

Zoubida Charrouf[a] and Dominique Guillaume[b,*]

[a]*Laboratoire de Chimie des Plantes et de Synthèse Organique et Bioorganique*, *Faculté des Sciences*, *Université Mohamed V-Agdal*, *Avenue Ibn Batouta*, *BP1014*, *Rabat*, *Morocco*

[b]*FRE 2715*, *51 rue Cognacq Jay*, *51100 Reims*, *France*

dominique.guillaume@univ-reims.fr

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For years, in southwestern Morocco, the decline of the argan forest has been accompanied by the concomitant desert encroachment. Preservation of this forest by increasing the economic value of argan tree was proposed twenty years ago, but successful large scale production of certified, high quality argan oil, an edible oil introduced as a functional food, has only been recently achieved. Argan oil is now marketed in most developed countries, despite its elevated price, and protection of the argan forest is now seriously being considered. The aim of this work is to present the recent progress made in argan oil production, the ways explored to commercialize the oil extraction by-products, and recent attempts to use other argan tree parts as part of a long term aim to preserve the argan forest.

Keywords: *Argania spinosa*, argan oil, argan grove, nutraceutic.

The argan tree (*Argania spinosa* L.; Sapotaceae) is only endemic to Southwestern Morocco, where the argan forest, recognized by UNESCO as a biosphere reserve in 1998, nowadays covers slightly more than 8000 km^2, an area that was twice as large at the end of the nineteenth century [1]. Furthermore, at that time, the argan forest density was 10,000 trees per km^2 as opposed to 30 at the present time. Such dramatic shrinking is the combined result of several consecutive extremely arid years, of the overuse of argan wood as fuel, and of the destruction of young and old plants by goats freely grazing in the forest. Therefore, to protect the argan trees, this trend had to be reversed and safeguarding the argan forest became vital. Because the Berbers are traditional argan forest dwellers, their active participation was necessary to rescue the argan forest. In 1986, an ambitious and nation-wide program aimed at vigorously increasing the economic value and marketing of the argan tree was launched by the Moroccan Government. This program anticipated that part of the resulting profits should return to the native population and another part would be used for the preservation of the argan forest. The key idea of this program was first, the modernization of argan oil production methods that would allow its implementation as a functional food on the global market, and secondly, the isolation of new metabolites from the tree to develop new and valuable markets.

Argan oil

Edible argan oil is produced by pressing the slightly roasted kernels of the argan tree fruits. Unroasted kernels furnish an oil that is used as a cosmetic. Though the price of cosmetic grade argan oil is higher than that of the edible oil, until now, the market share of the latter is much larger, and as a consequence, this drives down the economic value of the oil.

Roasting the kernels modifies the volatile composition of the oil [2] and provides the dietary argan oil with its typical hazelnut taste and copper color. Both cosmetic and edible oils have strong antioxidant and human health properties [3]. Edible argan oil is choleretic, hepatoprotective and regulates cholesterolemia, lipaemia and prevents atherosclerosis [4]. Prevention of miscarriage and

inflammation are additional traditionally claimed properties for both types of oil [5]. Cosmetic grade argan oil is used as an ointment to reduce skin pimples, juvenile acne scars and chicken pox pustules. The oil also slows skin wrinkling, reduces dry skin and produces shiny hair and strong nails [4b]. Cosmetic argan oil is an ingredient commonly used by the major cosmetic laboratories. The pharmacological properties of argan oil were initially attributed to its high content of the two unsaturated fatty acids, oleic and linoleic acids [4a]. Indeed olive oil, which is also rich in unsaturated fatty acids, presents quite similar pharmacological properties. However, the main interest in argan oil is its high content (29-36%) of linoleic acid [6], an essential fatty acid belonging to the ω-6 series. The linoleic acid content of argan oil is two to ten times higher than that of olive oil. Minor components, such as tocopherols and phenolic compounds [6b, 7], are also involved in the physiological properties of the oil, and not necessarily only because of their antioxidant and preservative effects [8].

Because of the nutritive and pharmacological properties of argan oil, developed countries have rapidly opened their markets to it, and the oil is now sold in gourmet stores and as a nutraceutical. This early success has strongly encouraged argan oil producers to create customer loyalty by producing an oil of constant composition and quality. However, the task is difficult, because the chemical composition of the oil is influenced by various factors (for example, genetic, climatic, soil, and fruit origin). Whereas genotypic and phenotypic variations have to be accommodated, technological factors should be carefully controlled to guarantee the oil quality for customer satisfaction.

Argan oil preparation

The traditional method: For years, argan oil has been prepared by Berber women following an ancestral, multistep process (Figure 1) [9]. Once the fallen, ripe fruits have been collected, they are sun-dried for a few days and their wrinkled peel is then manually removed, affording argan nuts. These latter are then delicately broken between two stones, releasing between one and three white kernels. When edible argan oil is prepared, the kernels are gently roasted on clay plates for a few minutes, using argan shells to produce a mild fire. The roasted kernels are then crushed using a home made millstone composed of a bedstone and a cone-shaped rotating piece, largely pierced in its center and into which the kernels are introduced. The brownish viscous liquid obtained is mixed with water and the dough is kneaded by hand for several minutes, slowly becoming solid and releasing an emulsion from which argan oil is finally decanted. From 100 kg of dried-fruits, 2 to 2.5L of oil can be obtained after 58 hours of work. The solid residue remaining after the maximum quantity of oil has been collected is very bitter, but highly nutritious. It still contains some oil, together with proteins and carbohydrates. This material is traditionally used to feed goats and cows. Because the fruit peeling step is laborious and time consuming, argan fruits are sometimes given to goats, and the argan nuts can then be collected from the goat stools. However, such a method raises microbiological and quality concerns, as the taste of the oil and its chemical composition are altered. The addition of water to the ground kernels is also a frequent source of chemical and bacteriological contamination. Such steps are inconsistent with the production of high quality argan oil and have now been discontinued.

The mechanical method: Improvements made to the general flow sheet (Figure 2) were designed to eliminate ambiguities concerning the oil quality. Consequently, only pulped fruits were entered into the process, and the use of water was eliminated.

The suppression of the use of both goat-depulped fruits and water has solved quality matters. However, hand-depulping and hand-pressing are tedious and time consuming steps, and any improvement in these steps will result in a much more efficient and productive process.

The first improvements have resulted from the use of depulping machines that have been introduced to replace the hand-depulping step. Basically, these machines consist of thorny plates, which scratch the fruits until the complete removal of the peel and pulp has been achieved. The naked fruits are then collected and broken following the ancestral method. Optimizing the roasting step is also a necessity for the production of an oil of repeatable taste. This has been achieved by use of gas-burners. These latter allow the precise control and standardization of the roasting time (10 min) and of the distance separating the flame and the kernels. These standard conditions have definitively eliminated the risk of burnt tasting oils. Finally, to replace the hand-press step, electric endless mechanical presses are used. Kernels are pressed at room temperature and no

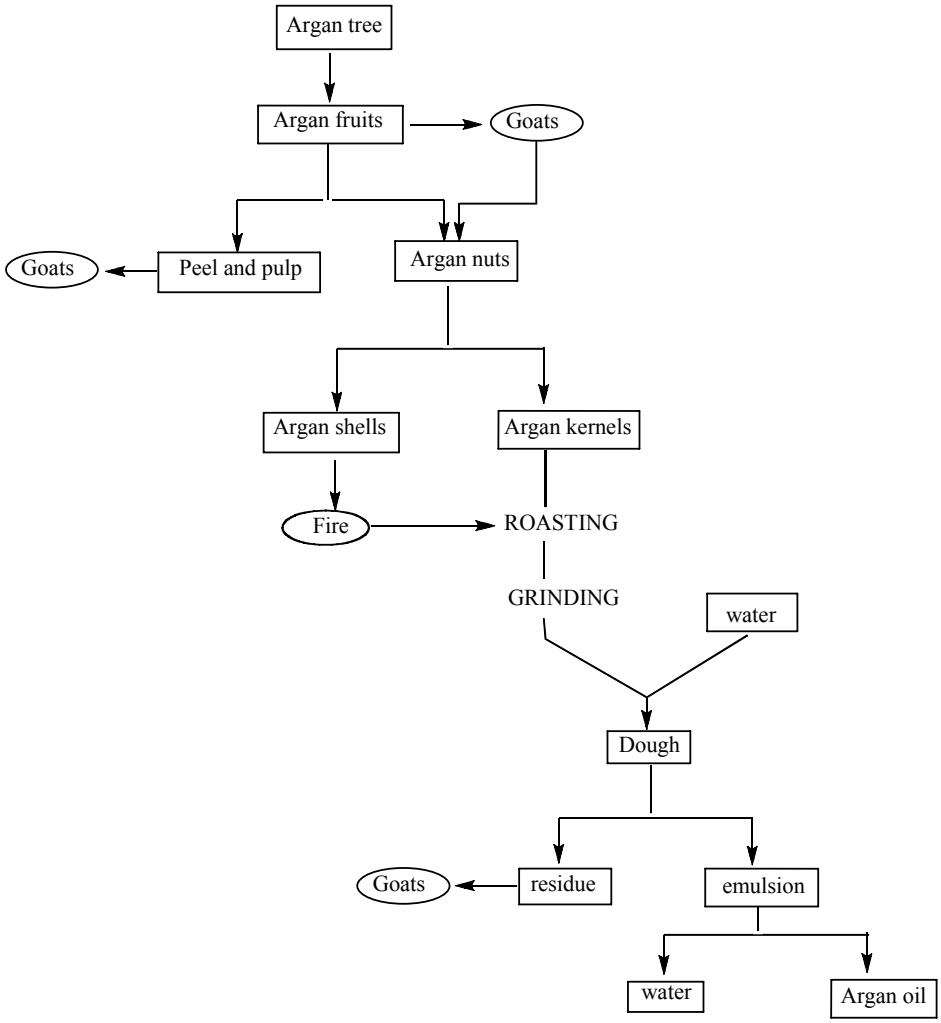

Figure 1: Flow sheet of the traditional method used for edible argan oil preparation.

water is necessary. Furthermore, not only is the yield of oil increased considerably, but the time necessary to press 1 kg of kernels is reduced by a factor of three to four.

Argan oil quality

Market penetration and building of customer loyalty are two essential steps in the cycle of success depicting functional food promotion [10]. For this, product quality is a prerequisite. However, quality problems faced in the nutraceutical field are often more complex than in the pharmaceutical domain [11]. Consequently, methods allowing the detection of adulteration have been carefully designed. In the case of argan oil, fraud can result from the marketing of an oil prepared using either poor sanitary conditions or from adulteration with various cheap vegetable oils.

Adulteration with cheap vegetable oils can be easily detected thanks to the natural low level of campesterol in argan oil; this sterol is largely encountered in most cheap vegetable oils. Measurement of the campesterol level by gas-chromatography appears to be the simplest method to detect adulteration [12]. Differentiation between mechanically pressed, traditionally prepared oils processed in good sanitary conditions, and traditionally prepared oils processed under poor sanitary conditions is much more complex. The volatile composition of argan oil prepared in these conditions is different [2], but analysis of the volatile components is not likely to become a fraud detection method because of its inherent implementation difficulty. A large increase in the oil peroxide value could become a clue indicating the use of goat-depulped fruits, but such a possibility needs to be confirmed [6a].

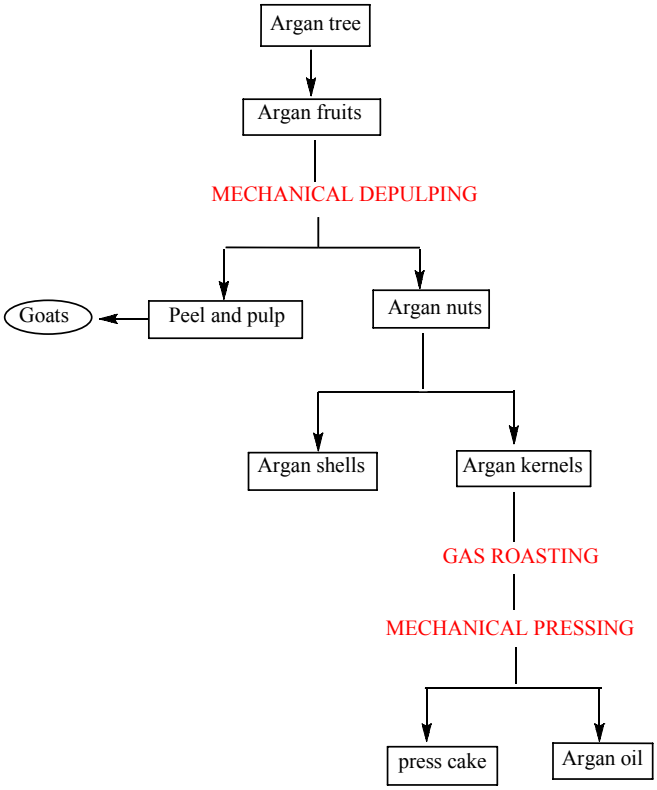

Figure 2: Flow sheet of the mechanical method used for edible argan oil preparation.

Future trends in the utilization of other resources from the argan tree

Although the marketing of argan oil is a real success, it is hazardous to assume that the long term preservation of the argan forest can rely on a single product. Consequently, it is necessary to diversify production from the argan forest, and a search for new bio-active compounds from the argan tree and its byproducts is currently being undertaken. The search for cosmetic products is part of the "LS Argan program" [13].

Argan wood: Argan wood is claimed to possess gastroprotective properties [4b]. The argan tree shows strong resistance to pathogenic agents, which has led to the supposition that it contains protective molecules in its wood. Consequently, phytochemical analysis of argan tree bark has been carried out in order to identify putative antibacterial molecules. Indeed, several triterpenoid saponins belonging to the D12-oleanane series have been identified from argan tree bark [14]. This type of molecule is commonly found in plants of the Sapotaceae family and has been found in various part of *A. spinosa* [15]. Whereas saponins are known to possess antimicrobial properties [16], none of the molecules isolated from argan tree bark so far has shown promising antimicrobial properties. This suggests either that the initial assumption is erroneous or that minor and as yet unidentified molecules are responsible for the antimicrobial effect. The resistance of *A. spinosa* to infection could also be the result of a synergistic action of the different molecules. These hypotheses are still currently being evaluated.

Press cake: The traditional use of press cake is as a cattle food, but its use as a shampoo and its antiscabies properties have also been reported [4b]. Although mechanical presses furnish a "low-fat" press cake, it is still used mainly for cattle feed. In the cooperatives, the press cake obtained has not been in contact with water and thus its preservation is much improved. Nowadays, the cooperatives sell the press cake in large bags. However, this market remains local and cannot sustain argan grove preservation. Furthermore, the mechanical preparation of argan oil has dramatically increased the quantity of press cake produced daily and new uses for this are actively being investigated.

The press cake contains proteins, a high level of saponins [4a], and phenolic derivatives [7]. The saponins are responsible for the foaming properties of the press cake and for its strongly bitter taste, precluding its use so far as human food. Nevertheless, press cake molecules have shown encouraging results on the cosmetic and drug markets. Indeed, high molecular weight proteins isolated from the press cake have recently been shown to possess a tightening effect on human skin, together with an anti-wrinkle activity [17]. These proteins have been included in cosmetic preparations that are now on the market. Moreover, saponin containing press cake fractions have been shown to possess antidiabetic and antiproliferative properties [18]. The success of at least one of these two openings could be sufficient to maintain the survival of the argan forest.

Argan tree leaves: Argan tree leaves are traditionally used for their antipyretic and antiinflammatory properties [4b]. The leaves contain high levels of flavonoids, some of which have been shown to possess anti-collagenase activity. Consequently, these flavonoids have been included in cosmetic preparations [19]. Interestingly, argan tree leaf picking is a non-damaging practice, for pruning is an annual necessity to select the best stalks and hence favor fruit production. This operation, that was

often neglected, is now strongly encouraged and the purchase of the leaves from dwellers constitutes an additional income for the argan forest population.

The successful marketing of edible argan oil has safeguarded the argan forest for the short term. However, the cosmetic and drug uses of argan products could constitute the additional markets necessary for long term preservation. However, it is likely that there will be many pitfalls paving the way to the sustainable development of the argan forest [20]. From an agricultural standpoint, new risks appear regularly, for example, in order to reduce the kernel collection time, the idea of selection of argan trees giving easy-to-break nuts has been recently proposed [21]. Such genotypic selection would lead to a dramatic loss in terms of biodiversity, which is the exact opposite of the initial project.

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