Vol. 20(4), pp.150-158, April, 2021
DOI: 10.5897/AJB2021.17327
Article Number: B56E3FA66624
ISSN: 1684-5315

http://www.academicjournals.org/AJB

ACADEMIC JOURNALS
expand your knowledge

African Journal of Biotechnology

Full Length Research Paper

Composition and balance of the analytical fractionation of desert date (*Balanites aegyptiaca* L.) seeds harvested in Senegal

Djibril Diedhiou[1,2,3*], Mamadou Faye[1,2], Laure Candy[1], Virginie Vandenbossche[1], Gérard Vilarem[1], Oumar Sock[2] and Luc Rigal[1]

[1]Laboratoire de Chimie Agro-Industrielle (LCA), ENSIACET, INP de Toulouse, 4 Allée Emile Monso - BP 44362-31030 Toulouse Cedex 4, France.
[2]Laboratoire Eau, Energie, Environnement et Procédés Industriels (LE3PI), ESP, UCAD, Senegal.
[3]UFR Sciences et Technologies Alimentaires, Université du Sine Saloum El Hadji Ibrahima Niass (USSEIN) BP 55 Kaolack, Senegal.

Received 9 February, 2021; Accepted 24 March, 2021

The desert date (*Balanites aegyptiaca* L.) can be one of the most common trees in Senegal. Thus, the objective is to carry out an analytical fractionation of these seeds to consider prospects for valuing the different constituents and a diagram of fractionation processes. The physical characterization of the seeds made it possible to know the fruit-seed and kernel-hull proportions. The chemical composition of the seeds shows that three main fractions represent 90% of its dry matter: The fibrous (68%), the lipid (14%) and the proteins (nearly 9%). The kernel is made up of 34.50% (80% of the lipid) and 28.75% of proteins (or 93% of the protein) while the hull is essentially fibrous, 90% contains 85% of the fibers. The high proportion of unsaturated fatty acids oleic and linoleic (73%) associated with those of saturated fatty acids (palmitic and stearic) in high proportions (27%) and the high contents of sterols (2.11 g/kg), and in tocopherols (512.40 mg/kg), make desert date oil an excellent food oil. On the other hand, it has qualities that make it suitable for use in various non-food applications. Proteins are made up of three main amino acids: glutamic acid (20.35%), arginine (14.42%) and aspartic acid (11.29%). The amino acid composition is close to that of oil seeds whose cakes are widely used in animal or even human food. Given their essentially lignocellulosic composition, the hulls obtained from shelling can be used as fuel or be extruded and used for the manufacture of composite agro-materials.

Key words: Desert date, *Balanites aegyptiaca*, seeds, analytical fractionation, proteins, lipids.

INTRODUCTION

Pollution concerns the high cost of fossil fuels and the depletion of non-renewable resources provide the impetus for scientists to explore other sources of energy and materials. Biofuels, as a source of renewable energy, are

*Corresponding author. E-mail: djidied@hotmail.com, djibril.diedhiou@ussein.sn.

a good alternative to non-renewable fuels. Besides, the use of materials of biological origin, easily biodegradable and eco-compatible, offers an alternative to synthetic materials. Thus, exploring the potential of desert date seeds can be envisaged. The desert date (*Balanites aegyptiaca* L.) belongs to the Zygophyllaceae family which thrives in arid and semi arid regions of Africa, the Arabian Peninsula, and in the driest areas of Pakistan and India (Hall and Walker, 1991; Chapagain et al., 2006). Desert date is a species that generally lives on the plains up to 1000 m above sea level in areas where the annual average temperature varies between 20 and 30°C, and those where annual rainfall ranges from 250 to 400 mm (Schmidt and Joker, 2001). This species can be one of the most common in Senegal (Ndoye et al., 2004). The tree produces fruits at 5 to 7 years reaching a maximum in 15-25 years (Mohamed et al., 2002). The annual production of a tree is estimated to be about 100 to 150 kg (Elamin and Satti, 2013). It can live for 100 years including 75 years of fruiting. The fruit is a drupe 2.5 to 7 cm long and 1.5 to 4 cm diameter comprising a epicarp (5-9%), mesocarp (28-33%), endocarp (49-54%) and of the kernel (8-12%; Mohamed et al., 2002). The kernel may contain 30-60% oil and 20-30% protein (Aviara et al., 2005). Fruits are green or yellow and become smooth at maturity (Chothani and Vaghasiya, 2011). Desert date has many uses including food, medicinal or cosmetic with fruits, kernels and oil used for human consumption. Various extracts are used in traditional medicine, in wound healing and as a laxative but also to treat many diseases such as jaundice, yellow fever, syphilis, diarrhea, epilepsy, and hemorrhoid (Chaudhry and Khoo, 2004). *B. aegyptiaca* also has anti-inflammatory, anthelmintic, insecticide, antifungal, antibacterial, molluscicide properties and is used as an antidote against snake bites (Mohamed et al., 2002; Chothani and Vaghasiya, 2011).

The objective of the present study is to carry out an analytical fractionation of the desert seeds, to establish theoretical material balances and to propose diagrams of fractionation and possibilities of valorization of the extracts, by-products and raffinates obtained during the extraction.

MATERIALS AND METHODS

Plant

The plant material used in this work consisted of desert date seeds obtained from mature dry fruits harvested in the central and northern regions of Senegal. The seeds were dried with sun exposure at the open air and then in an oven at 40°C and the kernels and the hulls were separated by shelling.

Solvents and reagents

All chemical reagents, standards and solvents are of analytical (HPLC) grade (Sigma-Aldrich, France).

Dry matter

The dry matter content was determined according to French standard NF V 03-903. It is calculated after drying a sample of about 1 g in an oven at 103°C until constant mass.

Minerals content

The ash content was determined by measuring the mass loss of a sample through its incineration in a muffle oven, electrically heated at 550°C for 3 h (NF V 03-922). After incineration, white, light gray or reddish ashes are obtained, visibly devoid of charcoal. The sample was then cooled in a desiccator and weighed at room temperature.

Lipid extraction

The lipid content was determined by using the standardized soxhlet method (NF ISO 734-1) which consists of extracting the lipids contained in the matter with cyclohexane for minimum of 6 h. An amount of about 30 g of seeds was used. The soxhlet extractor is equipped at its base with a 250 mL flask into which 200 mL of solvent has been introduced. The oil used for the tocopherols analysis was extracted by cold centrifugation using cyclohexane.

B. aegyptiaca physicochemical properties

The physicochemical propreties were determined according to standardized methods: density (AFNOR T60-214), viscosity (ASTM D 445), flash point (ASTM D 93), freezing point, pour point (ASTM D 97), cloud point (ASTM D 2500), acid value (AFNOR T60-204), saponification value (AFNOR T60-206), iodine value (AFNOR T60-203), peroxide value (AFNOR T60-220), ash content (ASTM D 482), carbon residue content (ASTM D 189), sulphur content (ASTM D 4294), sediment content (ASTM D 4052) and water content (ASTM D 4052) (ASTM, 2011). However, the refractive index was measured at 25°C by direct reading with a refractometer ABBE RMT model (EXACTA + OPTECH France 77646 CHELLES France) while the calorific value was estimated using the following empirical relationship (Haidara, 1996):

Calorific value = 11380 - Iodine value - 9.15 × saponification value.

Fatty acids analysis

The fatty acid profile was determined by analysis of fatty acids methyl esters (FAME) in gas chromatography (GC) according to the French Standard NF ISO 5508 standard. The esterification was carried out in two steps, solubilization of the oil by tert-butyl methyl ether (TBME) and uploading trimethyl sulphonium hydroxide 0.5 M in methanol (TMSH). The analysis was performed in type GC 3800 equipped with a Varian CP-select column for FAME fused silica WCOT (length 50 m, internal diameter 0.25 mm, film thickness 0.25 µm) coupled with a flame-ionization detector (FID) heating the components at 250°C. The carrier gas was helium (flow rate of 1 mL/min). The injection was Split (1: 100 µL 1 250°C for 55 min). The temperature programming was 185°C for 40 min and then rose from 185 to 250°C at 15°C/min and finally 250°C for 10.68 min (analysis time 55.01 min). The standard used was the MGFA (SI) and the data was processed with Varian Star software.

Glycerides and triglycerides analyses

Analysis of glycerides and triglycerides were carried out after the

Table 1. Dimensions, masses, average proportions of fruit, seed, kernel and hull in the desert date (*B. aegyptiaca*).

Operation	Component	Length (cm)	Width (cm)	Mass (g)	Proportion (% DM)
Fruit-seed separation	Fruit	-	-	2.24	52.17
	Seed	2.27	1.27	2.04	47.83
Seed shelling	Kernel	1.58	0.80	0.56	27.67
	Hull	2.27	1.27	1.44	72.33

glycerides silylation by 50 µL of methyl imidazole with 1 mL N-Methyl-N-trimethyl silyl-Hepta Fluoro butyramide (MSHFBA). The analyses were performed by gas chromatography (Perkin Elmer) equipped with a CP Sil column 8CB Low Bleed MS Varian, length 15 m, internal diameter 0.32 mm, film thickness 0.25 µm. The injection was on column type 1 µL. The temperature program was 55°C for 0.5 min, then 200°C min^{-1} to 340°C and 340°C for 40 min. Helium was the carrier gas (column head pressure 15 psi). The injection into the oven was performed under the following conditions: 55°C for 0.5 min, 45°C min^{-1} to 80°C, 10°C min^{-1} up to 360°C and 360°C for 16 min. FID carried out detection at 365°C. The compounds were identified through comparison of the retention time with standards reference and the quantification was carried out by external calibration.

Sterols analysis

Sterols were analyzed on the unsaponifiable fraction after silylation by Methyl trimethylsilyl heptafluorobutyramide (MSHFBA + 50 µL 1 methyl imidazole). The analysis was performed by GPC (Perkin Elmer lane 2) coupled to an FID (365°C) and equipped with a column CPSil 8 CB (Varian) of length 30 m, diameter 0.25 mm and film thickness 0.25 µm. The injection was on column type (1 µL), the carrier gas was helium and the column head pressure was 100 kPa.

The injector temperature programming was 55°C for 0.5 min, then increase from 55 to 340°C at 200°C min^{-1} and stabilization at 340°C for 30 min. The temperature of the oven was 160°C for 0.5 min, then rose from 160 to 260°C at 20°C min^{-1} and stabilization at 260°C for 5.5 min then rise from 260 to 300°C at 2°C/min then maintaining the temperature for 10 min at 300°C finally a rise from 300 to 350°C at 45°C min^{-1} and stabilization at 350°C for 3 min.

Tocopherols analysis

The analysis of the tocopherols of desert date oil, using the standards of α, γ and δ-tocopherols by external calibration was performed according to EN ISO 9936. Exactly 10 mg of oil were diluted with 1 mL of cyclohexane. The sample was analyzed by HPLC Dionex type equipped with a Kromasil 100 column SIL 5 µ (250 × 4 mm) and a fluorescence detector (λex = 290 nm and λem = 317 nm). The eluent was composed of mixture isooctane/ isopropanol (99.5%/0.5%) at a flow rate of 1.1 mL/min.

Proteins analysis

The proteins concentrations were determined by the Kjeldahl method according to French standard NF V 18-100. It consists of determining the total nitrogen content in the sample to obtain an ammonium salt. The proteins concentrations was performed using an automatic device consisting of a Kjeltec 8400 Analyzer and Kjeltec 8420 Treader and consists of transformation by mineralization of organic nitrogen in the treated sample (400 mg) and also consists of an acid-base determination of inorganic nitrogen (ammonia).

Amino acids analysis

The amino acids dosage of the proteins of the desert date seeds was performed according to the European Standard. The analysis was performed by ion-exchange liquid chromatography using Biochrom 30+ equipped with a packed column, of the PEKK type, filled with cation exchange resin, under the following conditions: 20 to 99°C, use of pressure 24 to 150 bars, injection volume 1 to 5000 µL, and detection by photometer 440 to 570 nm.

Parietal constituents analysis

The method of Van Soest and Wine (1968) also known as ADF-NDF assay makes it possible to determine lignins, celluloses and hemicelluloses. It is based on the difference in solubility of the components. The Neutral Detergent Fiber (NDF) attacks and solubilizes all the compounds except the cellulose, hemicellulose and lignin. The first Acid Detergent Fiber (ADF) permanganate attack solubilized the compounds except cellulose and lignin. The second ADF attacks left cellulose only. These attacks are carried out in a device called a Tecator Fibertec M1017.

RESULTS AND DISCUSSION

Physical characteristics of the seeds

The physical characteristics obtained (Table 1) from 50 samples are in accordance with the data found in the literature. 100 kg of fruit can provide almost 48 kg of seeds. Manual shelling of the seed shows a very clear difference in the hull/kernel distribution. This result shows that shelling 100 kg of seeds will provide approximately 27.5 kg of desert date kernel.

Chemical composition of the seeds

Apart from many minority compounds, in particular from metabolic origin and which are valuable in traditional medicine, three main fractions represent 90% of the dry matter of the seeds. These fractions are the fibrous fraction (cellulose, hemicelluloses and lignin; 68%), the

Table 2. Fibers composition of whole seeds of desert date.

Parietal Fibers	Cellulose (% DM)	41.66
	Hemicelluloses (% DM)	20.31
	Lignin (% DM)	5.76
	Total (% DM)	67.73

Table 3. Distribution of fibers between the kernel and the hull of the desert date.

Parameter	Cellulose (% DM)	Hemicelluloses (% DM)	Lignin (% DM)	Fibers (% DM fibers)
Seed	62	29	9	100
Kernel	75	22	3	15
Hull	60	31	9	85

Table 4. Lipid content and distribution in the kernel and the hull of desert date seeds.

Parameter	Seed	Kernel	Hull
Lipid content (% DM)	14.08	34.46	3.38
Potential lipid mass (% DM seed)	-	9.5	2.4

lipid fraction (14%) and the protein fraction (consisting of all proteins and polypeptides; 8%) characterized by the protein nitrogen content and the amino acid composition.

The fibrous fraction

The parietal fibers represent nearly 68% of the dry matter (Table 2). The hulls are essentially fibrous in nature (almost 90%) and contain most of the fiber (85%) of the entire seed (Table 3). The hull and kernel fibers are of different compositions. Hull fibers are more lignified (9%) than kernel fibers (3%). Mainly cellulosic, the cellulose-hemicelluloses proportion is different; hull fibers contain 60% cellulose, while kernel fibers contain 22% hemicelluloses and 75% cellulose.

The lipid fraction

The extractable lipid potential per gram of dry matter is 14.08% for the seed, 34.46% for the kernel and 3.38% for the hull (Table 4). The assays carried out show that 80% of the lipids in the seed come from the kernel.

Unlike the oil extracted from kernels, which is light yellow, oil extracted from the hulls is transparent and more viscous, reflecting the presence of waxes as in the case of sunflower hulls (Briffaud and Melcion, 1986; Brisson, 1996; Dekker and Wallis, 1983; Evon, 2008; Thibault et al., 1989).

Composition and physico-chemical characteristics of the oil

Composition of fatty acids

Desert date oil has four (4) major fatty acids: linoleic acid C18: 2 (37.58%), oleic acid C18: 1 (34.35%), palmitic acid C16: 0 (13.74%) and C18 stearic acid: 0 (13.34%) (Table 5). These results are comparable to those obtained in other previous studies (Chapagain et al., 2009; Deshmukh and Bhuyar, 2009; Gutti et al., 2012; Mohamed et al., 2002).

The simultaneous presence of unsaturated oleic and linoleic fatty acids in high proportion (72.55%) associated with that of saturated palmitic and stearic acids in high and equivalent proportions (27.45%) makes desert date oil an original oil for food. This fatty acid composition is not found in the main oils produced industrially (coconut, cotton, peanuts, palm, rapeseed, soy, sunflower), nor in minor oils (Gustone and Pandley, 1997). Only sesame oil (C16: 0 = 9%; C18: 0 = 6%; C18: 1 = 38%; C18: 2 = 45%) and Brazil nut oil (*Bertholletia myrtaceae:* C16: 0 = 14%; C18: 0 = 9%; C18: 1 = 29%; C18: 2 = 47%), for example, have similar profiles.

Composition of glycerides and triglycerides

Triglycerides represent 98.01% of the desert date oil (Table 6). This triglyceride content is consistent with that

Table 5. Composition of fatty acids of desert date oil (%).

Fatty acids	%
C14: 0 Myristic acid	0.19
C16: 0 Palmitic acid	13.74
C16: 1 Palmitolic acid	0.18
C17: 0 Heptadecanoic acid	0.12
C18: 0 Stearic acid	13.34
C18: 1n9c Oleic acid	34.35
C18: 2n6c Linoleic acid	37.58
C20: 0 Arachidic acid	0.4
C18: 3n3a Linolenic acid	0.04
Saturated fatty acids	27.45
Unsaturated fatty acids	72.55

Table 6. Proportion of glycerides from desert date oil (%).

Glycerides	%
Triglycerides	98.01
Diglycerides (C16 and C18)	1.28
Monoglycerides C18	0.00
FAA (C16 et C18)	0.70

Table 7. Proportion of triglycerides (%) of desert date oil.

Triglycerides	%
PPlL (Palmitic, Palmitolic, Linoleic)	4.83
POL (Palmitic, Oleic, Linoleic)	33.87
SOL (Stearic, Oleic, Linoleic)	61.31

P: Palmitic acid C16: 0; Pl: Palmitolic acid C16: 1; L: Linoleic acid C18: 1; O: Oleic acid C18: 1; S: Stearic acid C18: 0.

of most seed oils and fats of animal origin, generally more than 98% (Gustone and Pandley, 1997). The diglycerides C16 and C18 are in a low proportion (1.28%). Free fatty acids (FAA), responsible for acidity represent 0.70% of the desert date oil.

The analysis of the triglycerides shows that the desert date oil consists mainly of two major triglycerides (Stearic acid, Oleic acid, Linoleic acid [SOL]: 61.31%) and (Palmitic acid, Oleic acid, Linoleic acid [POL]: 33.87%) (Table 7). These two triglycerides (SOL + POL) represent 95.18% of the total triglycerides of the desert date oil. This triglyceride profile is consistent with the fatty acids composition of the oils. All these results confirm that this oil is made up of reserve lipids. It also contains a minority fraction of metabolic lipids.

Phytosterols composition

Desert date oil has a fairly high sterols content (2.11 g/kg of oil or 0.21%). This content is lower than the average of peanut oil (1.6%), of neem oil (3.34%) (Diedhiou al., 2015), of sunflower oil (3.4%), rapeseed oil (7.3%) or corn germ oil (13.8%) known for their richness in phytosterols (Gustone and Pandley, 1997). The major phytosterols are β-sitosterol (0.75 g/kg or 35.54%), stigmasterol (0.6 g/kg or 28.43%) and cycloarterol (0.24 g/kg or 11.37%) (Table 8).

Table 8. Phytosterols composition of desert date oil.

Composition	g/kg	%
Cholesterol	0.09	4.26
Campesterol	0.03	1.42
Stigmasterol	0.6	28.43
β-Sitosterol	0.75	35.54
Δ^5-Avenasterol	0.2	9.47
Cycloarterol	0.24	11.37
Citrostadienol	0.02	0.95
Not identified	0.18	8.53
Total	2.11	100

As in desert date oil, high levels of β-sitosterol are found in most phytosterols from vegetable oils such as olive oil (84.3%), peanut oil (62.3%), sunflower oil (61.9%), rapeseed oil (45-61%), soybean oil (47-59%) and sesame oil (59-62%) (Besbes et al., 2004; Feinberg et al., 1987; Merrien et al., 1992). β-sitosterol is the most studied sterol because of its importance and its physiological effects on health (Yang et al., 2001).

Numerous clinical studies have shown that the consumption of approximately 2 g per day of β-sitosterol lowers LDL-cholesterol by approximately 10% (Lütjohann et al., 1995) and several scientific publications have focused on the anti-tumor effects of phytosterols and especially β-sitosterol (Awad et al., 2000). Thus, it has been proven that phytosterols can reduce the risk of certain types of cancer (Shahzad et al., 2017; Blanco-Vaca et al., 2019 ; Hannana et al., 2020; Le Goff et al., 2019), in particular that of the lung (Mendilaharsu et al., 1998), the breast (Ronco et al., 1999), the esophagus (Stefani et al., 2000), stomach (McCann et al., 2000), colon (McCann et al., 2003) and ovary (Stefani et al., 2000). They could also stimulate immune responses in people infected with HIV (Breytenbach et al., 2001). Phystosterols are known for their many therapeutic virtues such as reducing cholesterol levels, obesity, diabetes or inflammatory diseases (Feng et al., 2020; Hannana et al., 2020; Le Goff et al., 2019; Shahzada et al., 2017) and their properties such as antioxidant, antibacterial or antifungal (Burčová, 2018; Hannana et al., 2020).

Composition of tocopherols

The tocopherols content of desert date oil is 512.40

Table 9. Tocopherol content of desert date oil.

Tocopherol	mg/kg	%
α-tocopherol	343.4	67.18
β-tocopherol	51	9.95
γ-tocopherol	73	14.25
δ-tocopherol	45	8.78
Total	512.4	100

mg/kg. The α-tocopherol is the major compound with a content equal to 343.4 mg/kg (67.18% of the total tocopherols) (Table 9). This tocopherols content is close to that found in sunflower oil (546 mg/kg). This value remains much lower than that of rapeseed oil (1153 mg/kg) or wheat germ oil (2571 mg/kg) (Gustone and Pandley, 1997).

Due to their antioxidant activity (Yang et al., 2020), tocopherols play an important role in the stabilization of oil during its conservation (Demir and Cetin, 1999). They are also known for their positive health effects. Indeed, they prevent the oxidation of polyunsaturated fatty acids in the blood and protect Low Density Lipoproteins (LDL) from oxidation induced by free radicals causing the development of arteriosclerotic lesions (Morris et al., 2005; Schneider, 2005). They can also participate in the reduction of cardiovascular diseases and have anti-cancer properties (Beardsell et al., 2002; Bramley et al., 2000; Yang et al., 2020).

Physico-chemical characteristics of the oil

The results of the physico-chemical characterization reveal a low acidity (0.5 mg/g) and a saponification index of 182.2 mg/g. Its high Iodine Number Saponification value (INS) 116 confirms its quality for soap production. Its iodine value (66.7 g/100 g) is related to the unsaturated nature of the oil (72.5%).

The relatively high calorific value (40.3 MJ/kg) is close to that of diesel which is 43.8 MJ/kg (Vaitillingom, 2006). This result confirms that this oil is an interesting raw material for the production of biodiesel, considering that the use of vegetable oils or animal fats as biofuel is linked to 80% to their lower calorific value (LCV) (Kulkarni et al., 2007; Stavarache et al., 2007). The high flash point value (132°C) confirms that there is no risk of ignition or explosion during handling or storage under normal conditions (ASTM, 2011).

The protein fraction

Based on an average nitrogen content of 16%, the protein content of desert date seed can be estimated at 8.74%, at 27.76% in its kernel and 2.17% in its hull (considering the nitrogen to protein conversion factor of 6.25). This protein content of desert date grains is of the same order of that of rapeseed grains (17 to 23%) (Kowalska et al., 2019). A comparison of the protein content in the seed, the kernel and the hull shows that, as with the lipid fraction, the majority of the proteins is in the kernel.The fractionation obtained by shelling seeds and extracting the kernel oil will lead to a protein-rich kernel (42%). As this value is comparable to that of most industrial cakes available on the market, its recovery for animal and even human feed would be interesting.

The analysis of the amino acid composition of the protein fraction shows its proximity to that of oleoproteaginous. The essential amino acids composition remains very close to that of sunflower, rapeseed, soybean (Godon, 1985), peanut and sesame (Babiker, 2012) obtained after extraction of lipids (Table 10).

Theoretical results of the fractionation by dehulling of desert date seed

The composition and distribution of the fibers of desert date seeds thus make it possible to estimate the theoretical balance in lipids, proteins, fibers (cellulose, hemicelluloses and lignin) and other constituents in the kernel and the hull obtained from100 kg of seeds. The results of the composition reveal that shelling 100 kg of desert date seeds makes it possible to produce nearly 27.5 kg of kernel capable of providing 9.5 kg of oil, 7.6 kg of proteins, 4.2 kg of fibers (cellulose, hemicelluloses and lignin) and 6.2 kg of other constituents, and 72.5 kg of hulls containing 65 kg of fibers (Table 11). Compared to the theoretical yield of oil extraction, without shelling, the loss linked to shelling can be estimated between 15 and 20% compared to the potential of extractable oil from the seed, knowing that 80% of the lipids of the seed come from the kernel. The oil obtained from kernel can have several fields of applications such as food, cosmetics and soap, formulation of emulsion, energy, etc.

After the solvent extraction, the seeds leave a solid raffinate consisting mainly of fibers (86%). The preliminary shelling of the seeds makes it possible to reduce the fiber content of the meal even if it results in a loss of oil obtained from the separated kernels. The oil cakes obtained after extracting the oil from the kernels are rich in proteins (42.36%) and their amino acids composition (Table 10) shows that they can be used in animal feed.

The separated hulls, mainly lignocellulosic, could be converted into fibrous granulate usable as fuel for domestic uses or to produce the energy necessary for operation in a biomass boiler. Based on the calorific value of the main constituents (cellulose, hemicelluloses and lignin), a significant energy production can be estimated. In fact, a ton of desert date hull (1.38 tons of seeds) will provide an amount of heat equal to 18,285.3 MJ. Other applications of the fibrous fractions of the hulls

Table 10. Amino acids composition of desert date seeds and comparison with other oilseeds.

Amino acids	Desert date (%)	Godon (1985)		
		Sunflower (%)	Soybean (%)	Rapeseed (%)
Aspartic Acid (Asp)	11.01	8.2	10.6	7.1
Threonine (Thr)	3.27	3.7	4	4.8
Serine (Ser)	4.46	4.5	5.6	6.,5
Glutamic acid (Glu)	19.87	15.9	18.9	14.9
Glycine (Gly)	7.16	5.9	4.3	4.6
Alanine (Ala)	4.08	4.7	4.5	4.3
Cysteine (Cys)	3.14	1.8	0.2	2.5
Valine (Val)	4.76	4.6	5	5.2
Methionine (Met)	0.56	2.3	1.5	2.2
Isoleucine (Ile)	3.64	4.1	4.7	4
Leucine (Leu)	6.60	5.9	9.8	6.4
Tyrosine (Tyr)	2.24	2.8	3.9	2.9
Phenylanine (Phe)	6.25	4.3	4	3.8
Histidine (His)	2.19	2.5	3.1	2.7
Triptophan (Trp)	-	1.2	-	1.3
Lysine (Lys)	3.64	3.9	6.3	6.2
Arginine (Agr)	13.96	7.9	7.8	6
Proline (Pro)	4.71	4.3	3.5	6.3

Table 11. Theoretical balance of mechanical fractionation by shelling of the desert date seeds.

Parameter		Kernel	Hull
Dry matter (kg)		27.5	72.5
Lipids (kg)		9.5	2.4
Proteins (kg)		7.6	1.6
Fibers	Cellulose (kg)	3.3	39
	Hemicelluloses (kg)	0.8	20
	Lignin (kg)	0.1	5.8
	Total Fibers (kg)	4.2	65
Other constituents (kg)		6.2	3.7

could be envisaged and studied in the field of materials, in particular particle and fiber panels.

Conclusion

The results of the analytical fractionation of desert date seeds confirm several possibilities of valorization and allow to consider the processes of their transformation. This fractionation shows that the shelling of the seeds and the pressing of the kernels allows the production of an oil (yields between 30 and 60% depending on the lipid potential). Its high proportion of unsaturated fatty acids especially oleic and linoleic representing 72% of total fatty acids makes desert date oil a quality edible oil. Its composition and physicochemical properties open up various possibilities for non-food applications such as soap making, biofuels, agrochemicals, especially in the formulation of biopesticides. The cake from oil extraction with a high protein content (42.3%) can be used as animal feed. The aqueous fractionation of kernels makes it possible to coextract the oil and the secondary metabolites, in particular the saponins (whose presence is confirmed in the literature) as an emulsion which can be used in agrochemistry, pharmacy, cosmetics or food.

The essentially fibrous hulls can be transformed into aggregates (calorific value of 18.3 MJ/kg) and used as fuel for domestic uses or biomass boilers. These hulls

could also be extruded and mixed with other vegetable materials for the manufacture of composite agromaterials.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors thank Department for Cooperation and Cultural Action (SCAC) of the Embassy of France at Dakar (Senegal) for their financial support.

REFERENCES

ASTM (American Society for Testing and Materials) (2011). Spécifications sénégalaises applicables aux carburants, Norme sur le Diesel.

Aviara NA, Mamman E, Umar B (2005). Some Physical Properties of *Balanites Aegyptiaca* Nuts. Biosystems Engineering 92(3):325-334.

Awad AB, Chan KC, Downie AC, Fink CS (2000). Peanuts as a source of β-sitosterol, a sterol with anticancer properties. Nutrition and Cancer 36(2):238-241.

Babiker MS (2012). Chemical Composition of Some Non-Conventional and Local Feed Resources for Poultry in Sudan. International Journal of Poultry Science11:283-287.

Beardsell D, Francis J, Ridley D, Robards K (2002). Heath promiting constituents inplement derived edible oils. Journal of Food Lipids 9:1-34.

Besbes S, Blecker C, Deroanne C, Bahloul N, Lognay G, Drira NE, Attia H (2004). Date Seed Oil: Phenolic, Tocopherol and Sterol Profiles. Journal of Food Lipids 11(4):251-265.

Blanco-Vaca F, Cedó L, Julve J (2019). Phytosterols in Cancer: from molecular mechanisms to preventive and therapeutic potentials. Current Medicinal Chemistry 26(37):6735-6749.

Bramley PM, Elmafda I, Kafatos A, Kelly FJ, Manios Y, Roxborough HE, Schuch W, Sheehy PJA, Wagner KH (2000). Vitamin E. Journal of Science of Food and Agriculture 80:913-938.

Breytenbach U, Clark A, Lamprecht J, Bouic P (2001). Flow cytometric analysis of the Th1-Th2 balance in healthy individuals and patients infected with the human immunodeficiency virus (HIV) receiving a plant sterol/sterolin mixture. Cell Biology International 25:43-49.

Briffaud J, Melcion JP (1986). Aptitude variétale du tournesol au décorticage. Revue Française des Corps Gras 33:11-17.

Brisson S (1996). Procédé pilote de fractionnement des coques de tournesol : étude rhéologique de la fraction hémicellulosique et de ses applications en formulation, Thèse de Doctorat, INP, Toulouse. https://oatao.univ-toulouse.fr/24677/1/MAGIMEL_Alice.pdf

Chapagain BP (2006). Characterization of desert date (*Balanites aegyptiaca*) saponins and their biological activities, PhD Thesis, Ben-Gurion University of the Negev https://www.doc-developpement-durable.org/file/Culture/Arbres-Fruitiers/FICHES_ARBRES/Dattier-dudesert_Balanites%20%C3%A6gyptiaca/CHARACTERIZATION%20OF%20DESERT%20DATE.pdf

Chapagain BP, Yehoshua Y, Wiesman Z (2009). Desert date (*Balanites aegyptiaca*) as an arid lands sustainable bioresource for biodiesel. Bioresource and Technology 100(3):1221-1226.

Chaudhry TM, Khoo CS (2004). Balanites herbs potential remedy for HIV/AIDS and other ailments. Hamdard Medicus 47(1):42-44.

Chothani DL, Vaghasiya HU (2011). A review on *Balanites aegyptiaca* Del. (desert date): phytochemical constituents, traditional uses and pharmacological activity. Pharmacognosy Review 5(9):55-62.

Dekker RFH, Wallis AFA (1983).Autohydrolysis-explosion as pre-treatment for the enzymic saccharification of sunflower seed hulls. Biotechnology Letters 5(5):311-316.

Demir C, Cetin M (1999). Determination of tocopherols, fatty acids and oxidative stability of pecan, walnut and sunflower oils. Deutsche Lebensmittel-Rundschau 95:278-282.

Deshmukh SJ, Bhuyar LB (2009).Transesterified Hingan (Balanites) oil as a fuel for compression ignition engines. Biomass and Bioenergy 33(1):108-112.

Diedhiou D, Faye M, Vilarem G, Mar Diop CG, Sock O, Rigal L (2015). Physical characteristics, chemical composition and distribution of constituents of the neem seeds (*Azadirachta indica* A. Juss) collected in Senegal. Research Journal of Chemical Sciences 5(7):52-58.

Elamin MM, Satti AA (2013). Insecticidal potentialities of *Balanites aegyptiaca* extracts against the khapra beetle (*Trogoderma granarium*), Global Advanced Research J. Environmental Science and Toxicology 2(1):005-010.

Evon P (2008). Nouveau procédé de bioraffinage du tournesol plante entière par fractionnement thermo-mécano-chimique en extrudeur bi-vis : étude de l'extraction aqueuse des lipides et de la mise en forme du raffinat en agromatériaux par thermomoulage, Thèse de Doctorat., INP, Toulouse.

Feinberg M, Favier JC, Ireland-Ripert J (1987). Répertoire général des aliments. In Tables de Composition des Corps Gras. Paris: Lavoisier-Tec & Doc.

Feng S, Belwal T, Li L, Limwachiranon J, Liu X, Luo Z (2020). Phytosterols and their derivatives: Potential health-promoting uses against lipid metabolism and associated diseases, mechanism and safety issues. Comprehensive Reviews in Food Science and Food Safety 19(4):1243-1267.

Godon B (1985). Les protéines végétales. Coordination. Lavoisier. https://www.lavoisier.fr/livre/agro-alimentaire/proteines-vegetales-2e-ed/godon/descriptif-97827430011

Gustone FD, Pandley FB (1997). Lipid technologies Applications. New York: Marcel Dekker INC. https://www.researchgate.net/profile/Casimir-Akoh/publication/48215148_Food_Lipids_Chemistry_Nutrition_Biotechnology/links/599d40c345851574f4b0c415/Food-Lipids-Chemistry-Nutrition-Biotechnology.pdf.

Gutti B, Bamidele SS, Bugaje IM (2012). Characterization and composition of *Balanites aegyptiaca* seed oil and its potential as biodiesel feedstock in Nigeria. Journal of Applied Phytotechnology in Environmental Sanitation 1(1):29-35.

Haidara AO (1996). Valorisation d'une huile végétale tropicale : l'huile de pourghère. Mémoire Maitrise, Canada, Université de Sherbrooke.

Hall JB, Walker DH (1991). *Balanites aegyptiaca* Del. - A monograph. School of Agricultural and Forest Science, University of Wales, Banger.

Hannana MA, Sohagb AAM, Dasha R, Haquec MN, Mohibbullahd M, Oktaviani DF, Hossainb TM, Choi H, Moona IS (2020). Phytosterols of marine algae: In sights into the potential health benefts and molecular pharmacology. Phytomedicine 69(153201):1-19.

Kowalska G, Kowalski R, Hawlena J, Rowiński R (2019). Seeds of oilseed rape as an alternative source of protein and minerals. Journal of Elementology 25(2):513-522.

Kulkarni MG, Dalai AK, Bakhshi NN (2007). Transesterification of canola oil in mixed methanol/ethanol system and use of esters as lubricity additive. Bioresource Technology 98:2027-2033.

Le Goff M, Le Ferrec E, Mayer C, Mimouni V, Lagadic-Gossmann D, Schoefs B, Ulmann L (2019). Microalgal carotenoids and phytosterols regulate biochemical mechanisms involved inhuman health and disease prevention. Biochimie 167:106-118.

Lütjohann D, Björkhem I, Beil UF, Von Bergmann K (1995). Sterol absorption and sterol balance in phytosterolemia evaluated by deuterium-labeled sterols: effect of sitostanol treatment. Journal of Lipid Research 36:1763-1773.

McCann SE, Freudenheim JL, Marshall JR, Graham S (2003). Risk of human ovarian cancer is related to dietary intake of selected nutrients, phytochemicals and food groups. The Journal of Nutrition 133:1937-1942.

McCann SE, Freudenheim JL, Marshall JR., Brasure JR, Swanson MK, Graham S (2000). Diet in the epidemiology of endometrial cancer in Western New York (United States). Cancer Causes and Control 11:965-974.

Mendilaharsu M, De Stefani E, Deneo-Pellegrini H, Carzoglio J, Ronco

A (1998). Phytosterols and risk of lung cancer: a case-control study in Uruguay. Lung Cancer 21:37-45.
Merrien A, Morice J, Pouzet A, Morin O, Sultanac C (1992). Graines oléagineuses des climats tempérés et leurs huiles. In Karlskind A, Ed. Manuel des corps gras. Paris pp. 116-164.
Mohamed AM, Wolf W, Spieß WEL (2002). Physical, morphological and chemical characteristics, oil recovery and fatty acid composition of *Balanites aegyptiaca* Del. Kernels. Plant Foods for Human Nutrition 57(2):179-189.
Morris MC, Evans DA, Tangney CC, Bienias JL, Wilson RS, Aggarwal NT, Scherr PA (2005). Relation of the tocopherol forms to incident Alzheimer disease and to cognitive change. The American Journal of Clinical Nutrition 81(2):508-514.
Ndoye M, Diallo I, Gassama/Dia YK (2004). Reproductive biology in *Balanites aegyptiaca* (L.) Del., a semi-arid forest tree. African Journal of Biotechnology 3(1):40-46.
Ronco A, Stefani ED, Boffetta P, Deneo-Pellegrini H, Mendilaharsu M, Leborgne F (1999). Vegetables, Fruits, and Related Nutrients and Risk of Breast Cancer: A Case-Control Study in Uruguay. Nutrition and Cancer 35(2):111-119.
Schmidt L, Jøker D (2001). Danida forest seed centre, seed leaflet 21 p.
Schneider C (2005). Chemistry and biology of vitamin E. Molecular Nutrition & Food Research 49(1):7-30.
Shahzada N, Khanb W, Shadab MD, Asgar A, Singh SS, Sharmad S, Al-Allaf FA, Abduljalee Z, Ibrahima IAA, Abdel-Wahaba AF, Afifya MA, Al-Ghamdi SS (2017). Phytosterols as a natural anticancer agent: Current status and future perspective. Biomedicine & Pharmacotherapy 88:786-794.
Stavarache C, Vinatoru M, Maeda Y (2007). Aspects of ultrasonically assisted transesterification of various vegetable oils with methanol. Ultrasonics Sonochemistry 14(3):380-386.
Stefani ED, Brennan P, Boffetta P, Ronco AL, Mendilaharsu M, Deneo-Pellegrini H (2000). Vegetables, Fruits, Related Dietary Antioxidants, and Risk of Squamous Cell Carcinoma of the Esophagus: A Case-Control Study in Uruguay. Nutrition and Cancer 38(1):23-29.
Thibault JF, Crépeau MJC, Quemener B (1989). Composition glucidique des graines de colza et de tournesol. Sciences des Aliments 9(2):405-412.
Vaitillingom G (2006). Utilisations énergétiques de l'huile de coton. Cahiers Agricultures 15(1):144-149.
Van Soest PJ, Wine RH (1968). Determination of lignin and cellulose in acid detergent fiber with permanganate. Journal of American Oil Chemists Society 51(4):780-784.
Yang B, Karlsson RM, Oksman PH, Kallio HP (2001). Phytosterols in Sea Buckthorn (*Hippophaë rhamnoides* L.) Berries: Identification and Effects of Different Origins and Harvesting Times. Journal of Agricultural and Food Chemistry 49(11):5620-5629.
Yang CS, Luo P, Zeng Z, Wang H, Malafa M, Suh N (2020). Vitamin E and cancer prevention: Studies with different forms of tocopherols and tocotrienols. Molecular Carcinogenesis 59(4):365-389.