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Uses and variability in the quality of Balanites aegyptiaca oil from the Guéra, Ouaddaï and Wadi Fira regions (Chad)

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Abstract

Balanites aegyptiaca, a major fruit-bearing species of the Sudano-Sahelian savannas, plays an important nutritional and socio-economic role. This study compares the chemical composition of the kernels and the physicochemical characteristics of the oils obtained from three regions of Chad (Guéra, Ouaddaï, and Wadi Fira). Kernels from Ouaddaï and Wadi Fira show the highest lipid contents (50.54% and 43.53%, respectively) and protein levels (≈28%), whereas those from Guéra are characterized by a higher carbohydrate content (39.77%). Traditionally pressed oils exhibit higher acidity and acid values, particularly for Guéra region (8.89% et 17.77 mg KOH/g), reflecting variable quality, while oils extracted by the Soxhlet method generally display lower acidity (1.51,0.84 et 0.78% of oleic acid), fewer impurities, and better stability. Higher iodine values observed in oils from Wadi Fira and Ouaddaï indicate a greater degree of unsaturation. These results highlight the influence of geographical origin and extraction method on the quality of B. aegyptiaca kernel oils and confirm their strong potential for valorization.

Keywords: *Balanites aegyptiaca; chemical composition; provenance; oils; extraction method.*

Résumé

Balanites aegyptiaca, espèce fruitière majeure des savanes soudano-sahéliennes, joue un rôle important sur les plans nutritionnel et socio-économique. Cette étude compare la composition chimique des amandes et les caractéristiques physico-chimiques des huiles issues de trois provenances du Tchad (Guéra, Ouaddaï et Wadi Fira). Les amandes de Ouaddaï et Wadi Fira présentent les teneurs les plus élevées en lipides (50,54 % et 43,53 %) et en protéines (≈28 %), tandis que celles de Guéra se distinguent par une plus forte teneur en glucides (39,77 %).

Les huiles pressées traditionnellement montrent des acidités et indices d’acide plus élevés, surtout pour la région de Guéra (8.89% et 17.77 mg KOH/g), traduisant une qualité variable, alors que les huiles extraites par Soxhlet affichent globalement de faibles acidités (1.51,0.84 et 0.78% d’acide oléique), moins d’impuretés et une meilleure stabilité. Les indices d’iode plus élevés à Wadi Fira et Ouaddaï indiquent une plus grande insaturation des huiles. Ces résultats mettent en évidence l’influence de la provenance et de la méthode d’extraction sur la qualité des huiles d’amandes de B. aegyptiaca et confirment leur fort potentiel de valorisation.

Mots clés : Balanites aegyptiaca, composition chimique, provenance, huiles, méthode d'extraction.

1.INTRODUCTION

A large proportion of the global production of oilseeds and oil-bearing fruits comes from developed countries, which constitutes a definite risk for the future of Africa and raises major political and economic challenges. Oilseeds play a crucial economic role because they are widely exported and therefore represent important sources of foreign currency.

In sub-Saharan Africa, forest resources play a major role in meeting the daily needs of communities (**Bognounou et al., 2001**). According to FAO (2004), about 80% of the African population depends heavily on natural resources for their survival.

Moreover, products derived from the processing of oilseeds contribute to a balanced diet for populations, particularly in Africa, due to their high lipid content and, for some species, their protein richness. A few plants dominate the global market: soybean, oil palm, rapeseed, sunflower, and groundnut. However, other oilseed species with significant regional importance should not be overlooked. This is the case for olive in

Mediterranean countries, shea tree in West Africa, sesame, neem, and other lesser-known species such as the desert date palm or the sago palm, to mention only the African continent (**Ribier and Rouzière, 2011**).

Balanites aegyptiaca, or desert date, is a shrub widely distributed in the Sudano-Sahelian zone and can reach a height of about ten meters. Its bark is fissured; the leaves are alternate, bifoliolate, and measure approximately 5 cm in length and 4 cm in width. The flowers are greenish, and the fruits are ovoid drupes, 3 to 4 cm long, very angular, greenish during maturation and light yellow at full ripeness. The seeds can be exploited for almond oil extraction (**Maydell, 1984**), the pulp for pharmacological and food uses (confectionery), and the nut as fuel. Its oil is suitable for use as table oil. In addition, it is appropriate for hair care due to its richness in linoleic acid and as a moisturizing body lotion because of its high oleic acid content. It can also be used in soap formulation owing to its high saponification value (**Tiétiambou et al., 2015**). From a medicinal perspective, its oil exhibits antiviral and antimicrobial properties. Such valorization could offer significant economic opportunities (**Soloviev et al., 2003**).

Chad is a Sahelian country where forest and fruit resources play a crucial role in food security and the livelihoods of rural populations. Among these resources, Balanites aegyptiaca, commonly known as the desert date, occupies an important place due to its many food, medicinal, and economic uses.

The extraction and proper processing of fats derived from underexploited species could significantly increase the supply of edible or industrial oils and contribute to poverty reduction among local populations.

The desert date has been the subject of studies mainly focused on the oil extracted from its seeds, which exhibits remarkable antioxidant, anti-inflammatory, and antiviral properties (**Singh et al., 2020; Nitiema et al., 2020; Khamis et al., 2020; Iroha and Hamilton-Amachree, 2019**). Balanites aegyptiaca has been selected as one of the four tree species to be used in the Great Green Wall for Africa project, initially conceived as a plantation belt 15 km wide and approximately 7,800 km long, stretching from Senegal to Djibouti across 11 countries. This project is now viewed as an opportunity to strengthen ecosystem resilience (**Goffner et al., 2019**). The development of this species represents an important challenge for several countries in the region facing advancing desertification (**Dougabka et al., 2021**).

Within this context, the present study aims to investigate the variability in the quality of Balanites oil from three (03) regions of Chad—Guéra, Ouaddaï, and Wadi Fira—and to evaluate different oil extraction methods from Balanites aegyptiaca fruits in order to improve the physicochemical, organoleptic, and sensory quality of the oil according to the three provenances, while maximizing the yield of this oilseed, which is of great sociocultural, economic, medicinal, and industrial importance. Rural women are the main actors involved in the exploitation of B. aegyptiaca. The primary valorization of the desert date concerns the extraction of kernel oil, which contains between 44% and 51% oil (**Ribier, 1993**). This oil is considered edible, although this status is not officially recognized in all countries. The many difficulties encountered in the traditional oil extraction process constitute a major barrier to its adoption by local populations. Processing equipment for B. aegyptiaca fruits is almost nonexistent. Do the kernels from Guéra, Ouaddaï, and Wadi Fira have the same physicochemical properties? Do the oils extracted from kernels originating from these three localities have the same potential uses?

The physical and chemical characterization of these oils would help to address these questions.

The objective of this study is to compare the quality of oils from three (03) localities in the Sudano-Sahelian zone of Chad (Guéra, Ouaddaï, and Wadi Fira) in order to promote their use and large-scale processing.

Balanites aegyptiaca oil exhibits interesting physicochemical and nutritional properties that justify its industrial valorization.

This study is highly important as it will provide valuable information to scientists, engineers, and industrial stakeholders about fruits with interesting nutritional composition in relation to their areas of origin, in order to effectively guide their industrial exploitation. This work will also provide essential parameters needed to design suitable equipment for cleaning, grading, cracking, grinding, drying, aeration, and storage adapted to the properties of local fruits.

2. MATERIALS AND METHODS

Study areas

In Chad, Balanites aegyptiaca is a characteristic and emblematic species of the Chadian semi-arid zone. This plant is of great socio-economic importance throughout its natural range of distribution due to its multiple uses

(**Dougabka, 2022**). Balanites is well adapted to the arid conditions of the Sahelian zone, which extends between the 200- and 800-mm isohyets over an area of 490,570 km². The soils are sandy tropical ferruginous soils, poor in organic matter.

The vegetation is characterized by: shrub savanna in the southern part of the country, where Acacia species and Balanites dominate, with a ground layer composed mainly of Andropogon species; and steppe (or pseudo-steppe) in the northern part, characterized by very open woody formations with a grass layer dominated by Aristida species. The fauna is abundant and diverse (**PANA-Chad, Nov. 2009**).

The study was conducted in the three Sudano-Sahelian zones of Chad, namely Guéra (located in the 12th parallel North and 18th parallel Est), Ouaddaï (located in the 12th and the 16th parallels North), and Wadi Fira (located in the 14th parallel North and 20th parallel Est), which represent the main areas of distribution of Balanites aegyptiaca (**Abdoulaye et al., 2017**).

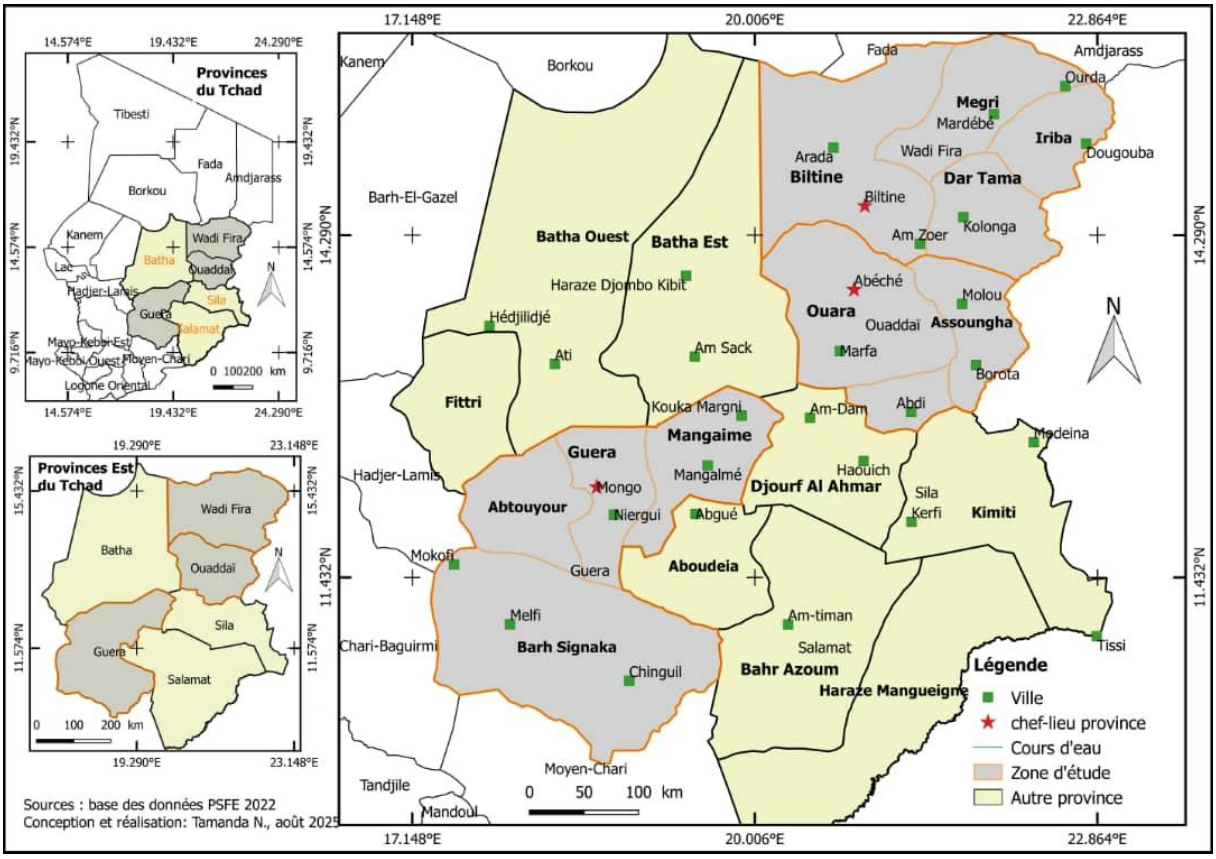

Figure 1:Localizationof the study areas

Source : Design and productionTamanda. N (2025)

2.1. Plant material

Sampling

The plant material used in this study consisted of three (3) samples selected following the ethnobotanical survey (Figure 2). These were fruits of B. aegyptiaca. They were collected in three (03) departments of Chad, namely Mongo (Guéra), Abéché (Ouaddaï), and Biltine (Wadi Fira), more specifically in their respective localities: Sawa, Darsalam, and Batounao.

The fruits were harvested in the wild in the three localities mentioned above. For physicochemical and nutritional analyses, five (5) kilograms of fruits from each locality were collected at different periods, then properly packaged in plastic bags and stored away from moisture. The fruits were not collected on the same day. Fruits from the locality of Sawa (Guéra) were collected during June 2025 (A), while fruits from Darsalam (Ouaddaï) and Batounao (Wadi Fira) were collected during July 2025 (B and C, respectively).

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A B C

Figure III.1: The fruits of Guéra (**A**);The fruits of Ouaddaï (**B**);The fruits of Wadi Fira (**C**)

The plant materials used in the oil extraction process are the kernels of B.*aegyptiaca*

2.2. Technical material

The technical equipment used in the extraction processes of B. aegyptiaca (Table 1) was based on the various artisanal methods developed by rural women in the three (03) Sahelian-Sudanian regions of Chad, namely Guéra, Ouaddaï, and Wadi Fira.

Tableau 1: The equipment used in the artisanal extraction of oil from the kernels of Balanites aegyptiaca

Equipements	**Extraction process**
Hammer and stone	Crushing
Mortar and pestle/stone grinding wheel	Grinding
Bowl and sieve	Sieving
Plastic bottle or calabash	Packaging

2.2. Methodology

2.2.1. Artisanal extraction

General workflow

Several successive operations were carried out during this work, namely:

→ Cleaning of fresh fruits by manual sorting; immature and damaged fruits as well as impurities were removed, and the fruits were characterized (mass, dimensions);

→ Pulping of the fruits to obtain the pulp, leaving the stones, which were then characterized (mass, dimensions);

→ Crushing to remove the shells, after which the kernels were characterized (mass, dimensions);

→ Grinding of the kernels to obtain kernel flour, on which moisture and oil content were determined;

→ Characterization of the oil extracted from the kernel flour.

Figure 2 shows the oil extraction process diagram

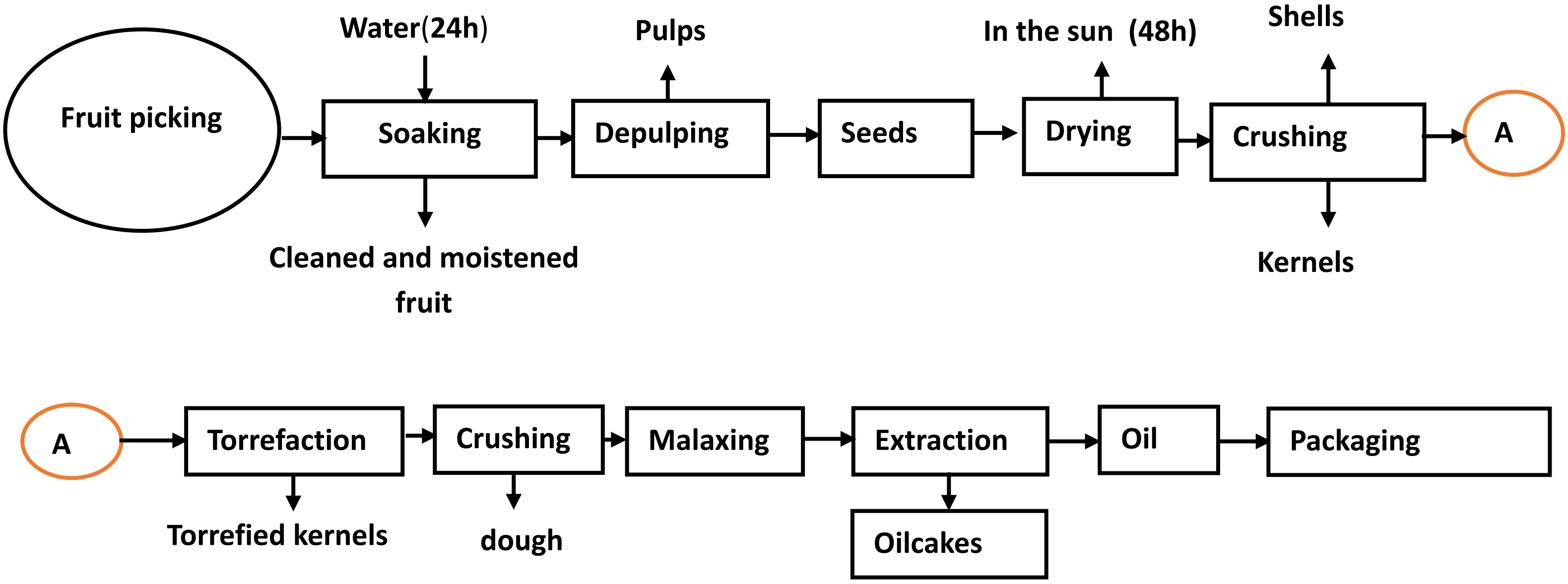


Figure 2:Diagram of the Balanites oil extraction process

2.2.2. Soxhlet extraction

Operating procedure

The extraction of B. aegyptiaca oils was carried out using a Soxhlet apparatus (Figure 3), with hexane as the extraction solvent. Several trials were conducted using 40 g of each sample of B. aegyptiaca kernel paste, prepared in cartridges made of filter paper and introduced into the Soxhlet apparatus. Subsequently, 250 mL of hexane were poured into a 500 mL flask prepared for this purpose.

The system was heated to a temperature of 70 °C for 10 hours (maximum lipid extraction conditions for the experiment). The resulting extract contained a hexane–oil mixture, which was separated using a rotary evaporator at a temperature of 70 °C and a rotation speed of 400 rpm, allowing the recovery of B. aegyptiaca oils.

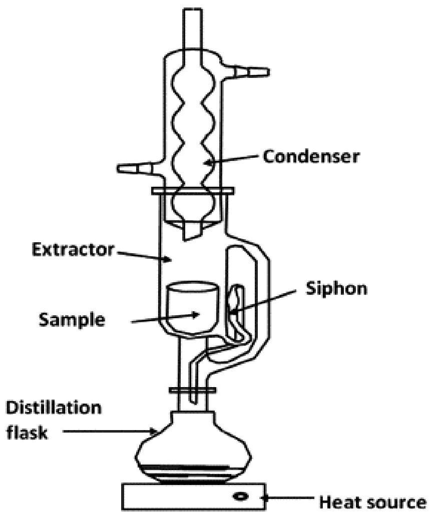


Figure 4 : Extraction device, Soxhlet apparatus

2.3. Physicochemical characterization of kernels and oils of B. aegyptiaca.

All physicochemical analyses were carried out at the Food Quality Control Center (CECOCDA) in N'Djamena, Chad.

The chemical composition of Balanites aegyptiaca kernels, including moisture, ash, lipid, and protein contents, was determined according to the following methods: ISO 721-1:2024, ISO 2171:02/2023, ISO 11085, ISO 20483:2014, and ISO 26642:2010, respectively.

The physicochemical characteristics of B. aegyptiaca oils (locally pressed oils and those extracted by Soxhlet), such as moisture and volatile matter content, insoluble impurities, acid value, acidity (% oleic acid), peroxide value, iodine value, and saponification value, were determined according to the following standards: NF EN ISO 2171 June 2010, NF EN ISO 663 04/17, NF EN ISO 660/2020, NF EN ISO 3960 04/17, NF EN ISO 3961/1996, and NF EN ISO 3657/2002.

2.4. Data collection

A semi-structured interview was administered to a sample of 190 users in three (03) villages, taking into account the different ethnic groups of the populations from the three (03) study zones: Ouaddaï and Wadi Fira (Maba, Mimi, Arab, Tama, and Abcharib), and the Guéra region (Kenga, Dadjo, and Sokoro).

Tableau 2:Distribution of respondents by ethnicity and gender in the selected sites

	Ethnic groups								
	Ouaddaï and Wadi Fira					**Guéra**			**Number of people surveyed**
	Maba	**Mimi**	**Arabe**	**Tama**	**Abcharib**	**Kenga**	**Dadjo**	**Sokoro**	
Households	12	10	11	9	8	11	6	8	75
Men	14	6	5	5	10	12	6	6	64
Women	21	19	13	12	14	26	12	9	126
Total	35	25	18	17	24	38	18	15	190

2.5. Analysis of survey data

All survey analyses were conducted using Sphinx Plus² software – Lexica Edition V5, with a significance level set at 5%.

The ethnobotanical studies carried out in the three (03) Sahelian regions of Chad required the use of an ethnobotanical survey form. The main points of the questionnaire focused on the local names, the different uses of the tree (food, traditional medicine, trade, and other uses), indigenous knowledge, and other information related to products derived from the different parts or organs of the Balanites aegyptiaca tree (leaves, stems, bark, fruits, wood, growth, uses, shell, roots, vernacular names, harvesting techniques, average quantity of fruits harvested per season, flowering periods, harvesting periods, storage techniques, etc.).

This information was collected through individual interviews with indigenous populations as well as people from neighboring villages. To facilitate understanding by respondents, local village chiefs who master the native languages assisted in the survey process.

3. RESULTS AND DISCUSSION

3.1. Local Names of Balanites aegyptiaca

The local designation of Balanites aegyptiaca was specific to each socio-cultural or sociolinguistic group. Table 3 below presents the various names attributed to B. aegyptiaca by the different ethnic groups in the study areas.

Tableau 3: Name of Balanites aegyptiaca by the different ethnic groups in study areas.

Regions	Ouaddaï et Wadi Fira					Guéra		
Ethnic groups	Maba	Abcharib	Mimi	Tama	Arabe	Kenga	Dadjo	Sokoro
Naming	Mallak	Ougounti	Kamara	Hounoud	Hadjlidj	Kamdagna	Tawkitché	Milli

3.2. Physicochemical characteristics of kernels and oils of B. aegyptiaca from the three (03) regions

3.2.1. Chemical composition of B. aegyptiaca kernels from three (03) provenances

The mean moisture content of B. aegyptiaca kernels was 4.97 ± 0.95% for kernels from Guéra, 5.05 ± 1.29% for Ouaddaï, and 5.60 ± 1.54% for Wadi Fira. The highest moisture content was observed in kernels from the Wadi Fira region.

The mean lipid content of B. aegyptiaca kernels was 37.28 ± 1.03% for Guéra, 50.54 ± 0.52% for Ouaddaï, and 43.44 ± 0.45% for Wadi Fira. Kernels from Ouaddaï exhibited the highest lipid content, which may be attributed to the climatic and pedological conditions prevailing in this locality.

Ash content varied among the studied regions, with values of 4.58% for Guéra, 3.67% for Ouaddaï, and 2.68% for Wadi Fira. Kernels from Guéra showed the highest ash content, indicating substantial mineral richness and clear compliance with the CODEX STAN 210-1999 standard (≥ 3.14%). Ouaddaï kernels also exhibited compliant values, reflecting satisfactory quality. Conversely, kernels from Wadi Fira presented ash contents below the recommended threshold, suggesting lower mineral content or potential mineral losses during post-harvest processing. This regional variability may be related to pedoclimatic differences and processing practices. Overall, only the Guéra and Ouaddaï regions meet CODEX requirements, whereas Wadi Fira warrants further investigation to improve product conformity.

Protein contents of *Balanites* kernels varied across regions, with values of 22.95% for Guéra, 27.86% for Ouaddaï, and 27.92% for Wadi Fira. A gradual increase in protein content was observed from Guéra to Wadi Fira. The value recorded for Guéra slightly exceeded the maximum limit set by CODEX STAN 210-1999 (≤ 22%), indicating near conformity. In contrast, kernels from Ouaddaï and Wadi Fira showed markedly higher protein levels, reflecting regulatory non-compliance. These differences may be associated with pedoclimatic conditions, fruit maturity, and agricultural practices. Despite this non-compliance, the results highlight the high protein richness of the kernels, suggesting significant nutritional potential. However, adaptation of standards or specific valorization strategies may be required for improved commercial exploitation.Carbohydrate contents also varied by region, with values of 39.77% for Guéra, 21.60% for Ouaddaï, and 28.55% for Wadi Fira. Guéra exhibited the highest carbohydrate level, largely exceeding the maximum limit defined by CODEX STAN 210-1999 (≤ 26.7%), indicating marked non-compliance. Conversely, Ouaddaï kernels showed compliant values, reflecting better carbohydrate balance. Wadi Fira kernels displayed slightly higher values than the standard threshold, revealing moderate non-compliance. These regional variations may be attributed to pedoclimatic conditions, fruit maturity stage, and cultivation practices. Overall, only the Ouaddaï region complies with the CODEX standard for carbohydrates, emphasizing the influence of geographical origin on the biochemical composition of Balanites kernels.

Tableau 4: Chemical composition of Balanites aegyptiaca kernels from the three regions

Parameters	**Regions**			**References /Methods**
	Guéra	**Ouaddaï**	**Wadi Fira**	
Moisture(%)	4.97	5.05	5.60	ISO 721-1 :2024
Ash (%)	4.58	3.67	2.68	ISO 2171 :02/2023
Lipids (%)	37.28	50.54	43.53	ISO 11085
Proteins (%)	22.95	27.86	27.92	ISO 20483 : 2014
Carbohydrates (%)	39.77	21.6	28.55	ISO 26642 : 2010

3.2.2. Chemical characterization of traditionally pressed B. aegyptiaca oil from the three (03) localities

The acid values of B. aegyptiaca oil were 13.68 ± 0.09 mg KOH/g for Ouaddaï, 12.40 ± 0.07 mg KOH/g for Wadi Fira, and 17.77 ± 0.16 mg KOH/g for Guéra. These values are far above the recommended limit of 4 mg

KOH/g established by CODEX STAN 210-1999. They do not corroborate the values reported by **Tayeau et al.** (**1955**), which ranged from 0.9 to 1.27 mg KOH/g, and are higher than those reported by **Mohamed, A. and Mohammed,A**(**2018**), who obtained values of 1.51mg KOH/g. High acid values indicate elevated impurity levels and low stability of traditionally pressed B. aegyptiaca oils in all three Sudan–Sahelian regions of Chad. Such values may also reflect oil aging and rancidity. The acid value is a technological indicator of extraction conditions; prolonged delays between kernel grinding and oil extraction favor enzymatic hydrolysis of triglycerides by endogenous lipases.Furthermore, acid value provides insight into oil shelf-life, as freefatty acids act as pro-oxidant agents. According to CODEX STAN 210-1999 standards, acidity (expressed as % oleic acid) was also excessively high across all regions, confirming oil degradation and aging. The peroxide value, which reflects the degree of oil oxidation, was 5.19, 4.79, and 6.39 meq O_2 /kg for Guéra, Ouaddaï, and Wadi Fira, respectively. No statistically significant difference ($p > 0.05$) was observed among the regions. These values are below 10 meq O_2 /kg, which is characteristic of most conventional oils and indicates acceptable oxidation levels (**Rossell, 1993**). The low peroxide values suggest that the oils did not undergo significant hydrolysis or oxidation, likely due to immediate analysis following extraction. Regarding oil color, Guéra oil exhibited a golden-yellow hue consistent with CODEX STAN 210-199 standards, whereas oils from Ouaddaï and Wadi Fira were dark yellow, indicating oxidation or degradation associated with suboptimal extraction conditions. Dark coloration may also result from exposure to light or heat. Measures to improve Balanites oil quality are therefore necessary, including awareness of food quality and safety standards.

Moisture and volatile matter contents were highest in Guéra (0.38%), followed by Ouaddaï (0.32%) and Wadi Fira (0.21%). Only Wadi Fira approached the CODEX STAN 210-1999 limit (≤ 0.2%), indicating better potential oil stability. Insoluble impurities were extremely high across all regions, peaking in Guéra (11.28%) and lowest in Wadi Fira (8.06%), far exceeding the CODEX limit (≤ 0.05%), reflecting insufficiently controlled traditional processing methods. The iodine value increased from Guéra (86.62 g/100 g) to Ouaddaï (94.20 g/100 g) and Wadi Fira (99.58 g/100 g). However, all oils showed unsaturation levels well below the CODEX STAN 210-1999 range (132–162 g/100 g). Saponification values were high and comparable among regions, with a maximum in Ouaddaï (198.81 mg KOH/g). Oils from Guéra (196.02 mg KOH/g) and Wadi Fira (195.70 mg KOH/g) were similar. Overall, these values fall within or at the upper limit of the CODEX standard (189–198 mg KOH/g). Thus, Wadi Fira oil demonstrates relatively better quality, despite general non-compliance related to traditional extraction methods.

Tableau 5:Physico-Chemical characteristics of traditionally pressed Balanites aegyptiaca oils

Parameters	**Guéra**	**Ouaddaï**	**Wadi Fira**	**Reference/Method**
Color	Darkyellow	Darkyellow	Golden yellow	Internalmethod
Humidity level and volatile matter (%)	0.38	0.32	0.21	NF IN ISO 2171JUNE2010
Insolublesimpurities (%)	11.28	11.05	8.06	NF IN ISO 663 04/17
Acid value (mg KOH/g)	17.77	13.68	12.40	
Acidity (% of oleicacid)	8.89	6.84	6.20	NF IN ISO 660/2020
Peroxydevalue (mEq O_2/kg)	5.19	4.79	6.39	NF IN ISO 3960 04/17
Iodinevalue (g/100g)	86.62	94.20	99.58	NF IN ISO 3961/1996
Saponification value (mg KOH/g)	196.02	198.81	195.70	NF IN ISO 3657/2002

3.2.3. Chemical Characterization of Solvent-Extracted (n-Hexane)

B. aegyptiaca oil from three (03) provenances

Soxhlet-extracted B. aegyptiaca oils exhibited high moisture and volatile matter contents

(≈ 10.3–10.5%), indicating insufficient dehydration of raw materials. Insoluble impurities remained substantial (7.31–8.86%), reflecting limited purification post-extraction. Acid and acidity indices were relatively low, particularly for Ouaddaï andWadi Fira, suggestingmoderate lipid hydrolysis. Low to moderate peroxide values (3.60–5.59 meq O_2 /kg) indicated limited primary oxidation. Low iodine values (33–41.24) characterized weakly unsaturated oils, with a slight increase in unsaturation from Guéra to Wadi Fira. Finally, moderate saponification values (148.86–164.97 mg KOH/g) reflected regional differences in average fatty acid chain length while remaining consistent with a similar lipid nature.

Tableau 6: Physicochemical characteristics B.aegyptiaca oils extracted by Soxhlet with hexane

Parameters	Guéra	Ouaddaï	Wadi Fira	Référence/Méthode
Color	Golden yellow	Golden yellow	Golden yellow	Internalmethod
Humidity level and volatile matter (%)	10.32	10.52	10.29	NF IN ISO 2171JUNE2010
Insolubles impurities (%)	8.86	7.69	7.31	NF IN ISO 663 04/17
Acid value (mg KOH/g)	3.02	1.68	1.56	NF IN ISO 660/2020
Acidity (% of oleicacid)	1.51	0.84	0.78	
Peroxydevalue (mEq O_2/kg)	3.60	5.59	4.68	NF IN ISO 3960 04/17
Iodinevalue (g/100g)	33	38.07	41.24	NF IN ISO 3961/1996
Saponification value (mg KOH/g)	164.97	148.86	153.75	NF IN ISO 3657/2002

3.3. Field Survey Data

3.3.1. Distribution of Respondents by Ethnicity and Gender

Several socio-cultural and sociolinguistic groups were identified, with Kenga (20%) predominating in Guéra and Maba (18.42%) in Ouaddaï and Wadi Fira. Women represented 66.31% of respondents across all regions, compared to 33.69% men, corroborating the strong involvement of women in Balanites oil extraction activities.

3.3.2. Uses of B. aegyptiaca Oil and Plant Organs

Local populations utilized multiple parts of Balanites, including pulp, whole fruit, kernel, seed, leaves, oil, roots, bark, stems, branches, and the entire tree (Table 7). Seven use categories were identified, dominated by food (55.5%), medicinal (30.4%), commercial (36.1%), artisanal (31.9%), cosmetic (7%), and fodder uses (17.8%). The most frequently used organs were bark (23.6%), roots (19.9%), and leaves (17.8%). Oil use was primarily food-related (32.1%), followed by commercial (35.8%), medicinal (17.9%), and cosmetic (14.2%) applications. Overall, 86.4% of respondents recognized the desert date tree, and 69.1% were familiar with its fruits, confirming its presence in the Sudan–Sahelian zones of Chad. Balanites oil was appreciated by 85.9% of respondents. Food and medicinal uses were the most prominent, consistent with previous studies (**Assogba et al., 2011; Donhouede et al**., **2022**). Despite diverse applications, usage intensity varied among populations, influenced by socio-cultural factors. Harvesting methods also differed by region, with collection by picking (83.3%), gathering (51.8%), and beating (40.3%), the high gathering rate reflecting natural tree growth.

Tableau 7: Specific known and practiced uses of *Balanites*

Variables	Terms	Number of surveyed people (N)	Pourcentage (%)
Knowledge of the desert date	Oui	165	86,4
	Non	25	13,1
Knowledge of the *Balanites* fruits	Oui	167	87,4
	Non	23	12
Usaesof the Balanites fruits	Alimentary	105	55,5
	Medicinal	58	30,4
	Commercial	69	36,1
	Artisanal	61	31,9
	Feed	34	17,8
Uses of the Balanites tree	Stem	76	39,8
	Root	38	19,9
	Fruit	24	12,6
	Pulp	33	17,3
	Bark	45	23,6
	Branch	48	25,1
	Leaf	34	17,8
	Wood	20	10,5
	Shell	8	4,2

Harvest method	Harvestingwith stick	159	83,3
	Picking	99	51,8
	Stone-throwing	77	40,3
Knowledge of the oil	Yes	144	75,8
	No	45	23,5
Uses of the *Balanites* oil	Alimentary	61	32,1
	Medicinal	34	17,9
	Cosmetic	27	14,2
	Commercial	68	35,8
Appreciation of the *Balanites* oil by the surveyed people	Yes	164	85,9
	No	25	13,6

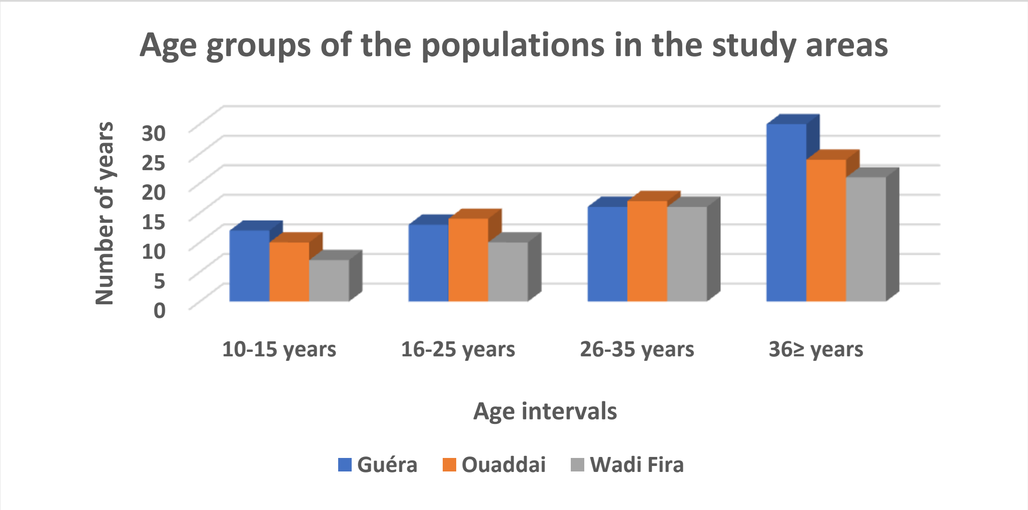
Tableau 8: The different artisanal methods of extracting oil from the desert date palm used in the three study regions.

Process	**Guéra**	**Ouaddaï**	**Wadi Fira**
Harvesting	On the ground/Stone-throwing	On the ground	On the ground
Cleaning /Soaking	Yes	Yes	Yes
Depulping	Yes	Yes	Yes
Crushing	With stone or hammer	With stone	With stone
Drying	Yes	Yes	Yes
Torrefaction	Yes	No	No
Grinding	Grinding in mortar orby animal traction	Grinding in mortar or in grindstone	Grinding in mortar or in grindstone
Water adding	Yes	Yes	Yes
Pressing /mixing	With stone ou by animal traction	in grindstone	in grindstone
Oil collection	Withcloth or cup	With a cup	With a cup
Conservation	Gallon	Calabash or Gallon	Calabash or Gallon

3.3.3. Socioeconomic and Professional Profiles of Respondents

3.3.3.1. Demographic Characteristics

Age: In all three regions, respondents were predominantly over 36 years old, indicating that knowledge and oil extraction practices are mainly held by older individuals.



Education level: Across regions, 68.94% were unschooled, 19.47% had primary education, 8.94% secondary education, and only 2.63% tertiary education, highlighting limited technical expertise in oil extraction practices.

Occupation: Farmers represented the largest group (50.5%), followed by housewives (27.4%), pastoralists (14.7%), traders (6.3%), and others (1.5%). This confirms that oil extraction activities are primarily carried out by rural farmers and housewives.

Religion: Rural women involved in Balanites oil extraction predominantly practice Islam (86.8%), although local traditional practices may also influence their activities. This economic activity reflects resilience and strong attachment to ancestral knowledge systems within a community-based and religious framework.

Tableau 9: Demographic characteristics of the study sites.

Variables	Terms	Number of surveyed people (N)	Pourcentage (%)
Gender	M	64	33,69
	F	126	66,31
Age ranges	10-15 years	24	12,63
	16-25 years	23	12,1
	26-35 years	43	22,63
	36 ≥ years	100	52,63
Level of education	Unschooled	131	68,94
	Primary	37	19,47
	Secondary	17	8,94
	higher	5	2,63
Profession	Farmers	96	50,5
	Breeders	28	14,7
	Traders	12	6,3
	Housewives	52	27,4
	Others	3	1,5
Religions	Muslims	165	86,8
	Christians	17	8,9
	Others	5	2,6

CONCLUSION

In summary, this study highlights significant regional variability in the quality of oils extracted from Balanites aegyptiaca kernels in Chad, particularly in Guéra, Ouaddaï, and Wadi Fira. Differences were observed in kernel chemical composition and oil quality, underscoring the influence of provenance and extraction methods on physicochemical properties. Kernels from Ouaddaï and Wadi Fira exhibited higher lipid and protein contents, whereas Guéra kernels were richer in carbohydrates.

Traditional pressing methods yielded oils with high acidity, especially in Guéra, adversely affecting stability and purity. In contrast, Soxhlet extraction produced oils of superior quality, characterized by lower acidity, fewer impurities, and improved stability, with higher iodine values indicating greater unsaturation, particularly in Wadi Fira and Ouaddaï oils.

These findings confirm the high nutritional and economic potential of B. aegyptiaca oil while emphasizing the need to promote modern extraction techniques to enhance product quality. This study therefore opens promising perspectives for the sustainable exploitation of this species in the Sudano–Sahelian regions of Chad.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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