Food & Nutrition Journal
Kane R, et al. Food Nutr J. 8: 301.
https://www.doi.org/ 10.29011/2575-7091.100201
www.gavinpublishers.com



Research Article

# *Balanites Aegyptiaca* (L.) Delile (Desert Date Palm), a Plant of Mauritanian Flora: Fruits Biological Activities and Jam Valuation

**Rouguiata Kane[1*], Zeinabou Sidoumou[1], Yacouba Diagana[1], Nicolas C. Mensah Ayéssou[2], Manef Abderrabba[3], Dorsaf Ben Hassine[3,4*]**

[1]EBIOMESN (Marine Eco Biology, Environment, Health and Nutrition) research unit, Department of Biology, University of Nouakchott Al-Aasriya, Nouakchott, Mauritania

[2]Analysis and Testing Laboratory, polytechnic high school, Cheikh Anta Diop University of Dakar, Senegal

[3]Laboratory Materials Molecules and Applications, IPEST, La Marsa, Carthage University, Tunisia

[4]National Agronomic Institute of Tunisia, Food Industry Department, Carthage University, IRESA, Tunisia

[*]**Corresponding authors:** Rouguiata Kane, rakikane16@gmail.com. EBIOMESN (Marine Eco Biology, Environment, Health and Nutrition) research unit, Department of Biology, University of Nouakchott Al-Aasriya, Nouakchott, Mauritania

Dorsaf Ben Hassine, dorsaf.benhassine@inat.ucar.tn, Laboratory Materials Molecules and Applications, IPEST, La Marsa, Carthage University, Tunisia & National Agronomic Institute of Tunisia, Food Industry Department, Carthage University& IRESA, Tunisia.

**Citation:** Kane R, Sidoumou Z, Diagana Y, Ayéssou NCM, Abderrabba M, Ben Hassine D. (2024) *Balanites Aegyptiaca* (L.) Delile (Desert Date Palm), a Plant of Mauritanian Flora: Fruits Biological Activities and Jam Valuation. Food Nutr J 9: 301. DOI: 10.29011/2575-7091.100201

**Received Date:** 21 May 2024; **Accepted Date:** 1 July 2024; **Published Date:** 5 July 2024

**Abstract**

*Balanites aegyptiaca* (L.) Delile (*B. aegyptiaca*) is a plant belonging to the Mauritanian flora that is known for its therapeutic properties and traditional use. However, there is limited documentation on the physicochemical composition and potential uses of this plant. The overall objective of this study is to analyse the physicochemical composition of the plant's fruits and explore ways to enhance their value. In fact, this study was articulated on three steps: firstly, we focused on the chemical investigation of the Aqueous (AQ) and Ethanolic (EtOH) extracts of *Balanites aegyptiaca* (L.) Delile fruits. Then, we examined its antioxidant and antibacterial activities. Finally, the possibility of transformation of fruit pulp into jam was established followed by the analysis of total phenolic compounds of the latter product. Results highlighted that the jam had the highest total polyphenol (expressed in mg EAG/g DM) and flavonoid (expressed in mg QE/ g DM) content (297.87 ± 1.7 mg EAG / g DM; 12.74 ± 0.6 mg QE/g)), followed by the AQ extract (71.87 ± 1.2 mg EAG / g DM; 4.9 ± 0.1 mg QE/g DM) and the EtOH extract (63.64 ± 0.8 mg EAG / g DM; 0.44 ± 0.007 mg QE/g DM). The antioxidant activity of the extracts was measured by their $IC_{50}$ values, which ranged from 10.96 ± 1.7 to 14.27 ± 0.6 µg/mL for the jam, AQ, and EtOH extracts, respectively. Regarding antibacterial activity, the EtOH extract exhibited significant bactericidal activity against *Escherichia coli* ATCC 35150 and *Staphylococcus aureus* ATCC 6538, with Inhibition Zone Diameters (IZD) ranging from 20.25 to 31 mm, respectively. The jam produced was free from total coliforms, yeasts, and molds, indicating its high hygienic quality and suitability for consumption. Panelist that contributes to the sensory analysis found the jam to be enjoyable.

**Keywords:** *Balanites Aegyptiaca* (L.) Delile; Chemical Composition; Antioxidant Activity; Antibacterial Activity; Jam Sensory Analysis

## Introduction

*Balanites aegyptiaca* (L.) Delile is an indigenous tree that is highly exploited for its fruits and leaves, its edible fruit is used in the manufacturing of soap and cosmetic products, while the pulp is processed into various consumable and commercial products [1]. The seeds produce a fixed oil rich in important nutrients that can be used for culinary purposes and biodiesel. *B. aegyptiaca* is commercially important due to its various uses. Its leaves and fruits are used as livestock fodder, while its wood is utilized in furniture manufacturing and charcoal production for both fuel and industrial purposes. Additionally, the seed oil is used as biodiesel [2]. Cherif et al. [3] conducted extensive literature reviews on *B. aegyptiaca*, which revealed critical research gaps in its distribution ecology, socio-economic importance, reproductive biology, ecophysiological performance, genetic diversity, and propagation initiatives. In Mauritania, the «toogga» project team is the first to have studied the desert date oil from trees in Mauritania in detail, in fact this team is working on the production of edible oil and cosmetic oil from *B.aegyptiaca* fruit kernels [4].Moreover, data on the practice of traditional medicine in Mauritania are scarce due to the lack of official legislative texts on this practice [5].

*Balanites aegyptiaca* (L.) Delile is a plant that belongs to the Balanitaceae or Zygophyllaceae family. It is commonly known as the 'desert date palm' [6]. In Mauritania, it is called 'Tooga' in Hassaniya (an Arabic dialect spoken by the Moors, an ethnic group), Sexene, Mourtodé, and Soumpe in Soninke, Pular, and Wolof, respectively, which are languages spoken by other ethnic groups [7]. The plant is widespread in arid and semi-arid areas and grows wild in Africa, Asia, and the Arabian Peninsula.

*Balanites aegyptiaca* (L.) Delile is a tropical plant species. Its aegyptiaca variety is adapted to Sahelian climates with temperatures ranging from 20 to 45 ˚C and alluvial areas with limited access to water. It prefers savannah for natural regeneration and is intolerant to shade. The fruit pulp (mesocarp) contains 64-72% carbohydrates, crude protein, saponins, vitamin C, and other essential minerals for human consumption [8]. *B. aegyptiaca* (L.) Delile fruit is composed of epicarp (5-9%), mesocarp (28-33%), endocarp (49-54%), and stone (8-12%) [7]. This plant has been used for medicinal purposes in Egypt since ancient times and possesses antioxidant, anti-inflammatory, antidiabetic, and anticancer properties [9]. Usman et al. [10] conducted a chemical investigation and discovered that the fruit pulp, leaves, and rind of *B. aegyptiaca* (L.) Delile contain active compounds such as polyphenols and flavonoids. These compounds exhibit insecticidal, antidiabetic, and antibacterial properties [11].

The aim of this study is to analyse the physicochemical components of *B. aegyptiaca* fruit and jam, specifically the flavonoid and polyphenol content. Additionally, the antibacterial capacity of AQ and EtOH extracts from the fruit and the jam was studied. Besides, the antioxidant capacity was evaluated. A sensory analysis of the jam was conducted to explore potential alternative uses for the plant's fruit.

## Material and methods

### Harvesting and preparation of fruit extracts

*Balanites aegyptiaca* (L.) Delile fruits were harvested when mature, then dried between January and February in the province of Assaba, located between 16˚and 17˚11'N and 17˚ and 12˚51'W [12]. The mesocarps were separated from the seeds using a knife (figure 1). To prepare the extracts, 10 g of fruits were macerated in a mixture of 100 mL of distilled water and, 10 g of fruits were mixed with 100 mL of ethanol, then filtered using Whatman No.2 paper. The filtrates were placed in a rotavapor (model RS 100-pro) to remove the solvents and recover the crudes extracts. The extracts were stored in amber vials at 4°C for further analysis. The extraction method used for the fruits of *Balanites aegyptiaca* was chosen based on the investigation of Usman et al. [10]. It was demonstrated that water, ethanol and methanol are the best solvent to extract phytochemical compounds. Besides, the distilled water and ethanol are more accessible and less expensive and considered as green solvents. The extraction yield was calculated using the following formula:

$\text{Yield } (\%) = (m_1/m_2) \times 100$ , ($m_1$: mass recovered in g, $m_2$: mass of plant material introduced in g)

Fruit Peeling | Evaporation of solvent extract rotavapor | Fruit AQ extract

**Figure 1:** Fruit extraction process.

### Phytochemical content of the extracts

The Total Polyphenols (TPC) and Flavonoids (TFC) content of the fruit extracts using spectrophotometric methods, specifically the Folin-Ciocalteu and Dowd methods, as previously defined by Ben Hassine et al. [13]. Gallic acid and quercetin were used as references, and the results were expressed as grams of standard equivalents per kilogram of extract dry mass (GAE and QE, respectively; g/Kg dm). For the TPC, 10 mL of Folin-Ciocalteu reagent was mixed with 100 mL of distilled water. Then 500 µL of Folin-Ciocalteu reagent was added to 100 µL of the AQ extract.

After that, the solution was incubated at room temperature for 5 minutes, then 400 µL of freshly prepared sodium carbonate solution ($Na_2CO$, 75g/L) were added. The overall mixture was incubated for 20 minutes at room temperature until the solution turns blue. A spectrophotometer (model CECIL CE 7400) was used to take readings against a blank at 765 nm. The concentration of total polyphenols was calculated using the regression line equation y=ax+b. For the TFC, the colorimetric method with 2% anhydrous Aluminum Trichloride ($AlCl_3$) was used to carry out the analysis. To perform the procedure, 500 µL of AQ extract was mixed with 500 µL of $AlCl_3$ solution and incubated for 15 minutes at room temperature. The absorbance of different samples were taken using a spectrophotometer (model CECIL CE 7400) against a blank (methanol and extract) at 415 nm. The concentration of total flavonoids in the AQ extract was determined either graphically or by calculating the equation of the regression line y=ax+b.

**Antioxidant activity**

The radical scavenging capacity of the extracts against DPPH (1,1-diphenyl-2picrylhydrazyl) was evaluated using the method outlined by Ben Hassine et al. [13] Ascorbic acid was used as a reference, and the absorbance was measured at 517 nm. The antioxidant activity was expressed as the percentage of scavenging activity and the $IC_{50}$. The extracts were diluted and mixed with a 0.02 mM methanolic solution of DPPH. The concentrations of the extract solutions were increased. After incubating for 30 minutes at 25 ˚C, the spectrophotometer (model CECIL CE 7400) was used to measure the absorbance of the (DPPH) solution and samples. A blank test was performed using the same procedure with a solution without the extract.

**Antimicrobial potency evaluation**

The AQ and EtOH fruits extracts were tested against gram-positive bacteria (*Staphylococcus aureus* ATCC 6538) and gram-negative bacteria (*Escherichia coli* ATCC 35150). These strains were provided by the food industries department of National Agronomic Institute of Tunisia. Antibiotic discs used for disc diffusion assays were Penicillin (P), Gentamicin (G), and Erythromycin 500 (E). The test was performed according to the method described by Ben Hassine et al [13]:

The antimicrobial power was studied using the disk diffusion method in agar medium. This involved depositing sterile Whatman paper disks (6 mm) impregnated with extract solutions at 1.5 and 10 µg/mL, obtained from stock solutions (3 mg/mL), on Müller Hilton agar that was previously seeded with bacterial strains. After incubation at 37 ˚C for 48 hours, the strain's resistance to the extracts was determined by measuring the diameter (ϕ) of the inhibition zone. The tests were performed three times, and the following notification was applied to classify the sensitivity of the strains to AQ and EtOH fruit extracts:

(-): 6 mm <Φ<10 mm: the strain is insensitive to the action of fruit extracts (F.E)

(+): 10 mm ≤ Φ<15 mm: the strain is sensitive to the action of F.E.

(+ +): 15 mm ≤ Φ<20 mm: the strain is very sensitive to the action of F.E.

(+ + +): Φ> 20 mm: the strain is extremely sensitive to the action of F.E.

Φ: the diameter of the inhibition zone in mm, (6 mm= diameter of the disc).

***Balanites aegyptiaca* (L.) Delile fruit valuation**

**Preparation of jam**

The jam was prepared according to the guidelines provided by CODEX STAN [14].

The fruits were first sorted, rinsed, and then the outer layer was removed. Next, 100 g of fruit was mixed with 200 g of sugar. To this mixture, 500 mL of distilled water was added. The mixture was then boiled for 30 minutes at 104 ˚C until a thick and viscous mixture was obtained.

**Microbiological analysis**

The enumeration of total coliforms, yeasts, and molds, as well as psychrophilic, mesophilic, and thermophilic bacteria, was established following the directives of standard [15]. Total coliforms were enumerated on Desoxycholate medium after incubation for 24 hours at 37 ˚C. Yeasts and molds were detected using Sabouraud agar with chloramphenicol and incubated for 3-5 days at 25 ˚C.

Psychrophiles, mesophiles, and thermophiles were cultured on Plate Count Agar at 4 ˚C for 3-5 days, 37 ˚C for 24 hours, and 44 ˚C for 24 hours, respectively.

The enumeration of FAMT (flore aerobic mesophile total) was performed following the guidelines of the standard [16], and the bacterial count should be less than $3\times10^5$ CFU (colony-forming units)/mL.

The enumeration of fecal coliforms was carried out according to the standard [17], and the bacterial count should be less than $10^3$ CFU/mL.

Yeast and mold enumeration was conducted in accordance with standard [18]. The detected microorganisms must be less than $3\times10^3$ CFU/mL.

**Physico-chemical analysis**

**Determination of pH**

The pH of the jam was measured using the AOAC method [19].

The pH meter (type pH 50+) was used to directly read the pH value by immersing its glass electrode in a beaker containing 50 mL of jam.

**Refractive index**

The refractive index was determined using the AOAC method [19]. A small amount of the sample was placed in the center of the prism of the refractometer (Abbe model Kern ORT-1), and the Brix degree was read on the graduated ruler at the bottom of the device, which was illuminated with an electric lamp.

**Titrable acidity**

The titrable acidity of the product was evaluated using the AOAC method [19]. Acid-base determination was performed with a 0.1 N NaOH solution in the presence of phenolphthalein as a colored indicator. The acidity was calculated using the following formula and expressed in meq or mg of citric acid per 100 g of product:

$TA = 100 \times (\frac{V_1}{V_0})$, where TA is the titratable acidity, v1 is the volume in mL of the test sample, and V0 is the volume in mL of 0.1 N NaOH.

**Sensory analysis**

Hedonic test was conducted to measure the level of appreciation for *B. aegyptiaca* fruit jam based on specific criteria. At least 60 tasters were required for this test [20]. Acceptance tests were used to determine whether the formulated jam would be consumed based on its organoleptic properties [21], including texture, color, smell, taste, and overall appreciation. The panel consisted of 60 individuals between the ages of 18 and 56, comprising 32 men and 28 women, who were all willing participants in the study. They were instructed to evaluate the texture, color intensity, aroma, taste (sweetness, bitterness, astringency), and overall enjoyment using a 5-point scale ranging from 0 to 4.

**Statistical analysis**

Statistical analysis was conducted using Microsoft Excel 2007. The data was presented as a percentage or mean (±) Standard Deviation (SD) of three assays for antioxidant activity and phytochemical assays. Quantitative data was compared using one-way ANOVA followed by Dunnett's post-ANOVA test. The results were considered significant when the p-value < 0.05.

**Results and Discussions**

**The extraction yields**

The obtained results showed that the AQ extract of the fruits gave a higher yield than the EtOH extract with values of 55.5% and 13.9%, respectively. Ibrahim et al. [22], found that the methanolic fruit powder extract of Balanites aegyptiaca exhibited an extraction yield of 31.1%. these results are lower than the results obtained for the AQ extract. Elamine and Satti [18] found a value of 25.8% for the methanol extract of *B. aegyptiaca* leaves, which is lower than the AQ extract yield of the current study.

Elamine and Satti [23] found an extraction yield value of 25.8% for the methanol extract of *B. aegyptiaca* leaves which is lower than the yield of the AQ extract of our study. the current data shows that the solvent, the extraction method as well as the plant part used would have a great influence on the extraction yield. This investigation suggest that water would be the best solvent to obtain a better extraction yield for the fruit of *B.aegyptiaca*.

**Total polyphenols content (TPC) in fruit extracts and jam**

Table 1 shows that AQ extracts contain more polyphenols than EtOH extracts, with respective amounts of 71.87 ± 1.2 and 63.64 ± 0.8 mg GAE/g DM. Abdelaziz et al. [7] demonstrated that 80% methanol aqueous solution from *B. aegyptiaca* fruit was tested in 5 different cities in Mauritania, resulting in values ranging from 222 ± 2.5 to 396 ± 4.8 mg GAE/100 g DM. Abdallah et al. [24] found that the methanolic extract of the fruits contained a total of 212 ± 1.3 mg/g GAE of polyphenols per 100 mg/mL of DM. Usman et al. [10] determined the total polyphenol content of AQ and ETOH *B. aegyptiaca* root extracts to be 179.48 ± 1.99 mg EAG/g MS and 260.07 ± 2.31 mg GAE/g DM, respectively. These values are higher than those reported in this study. In their study, Nitiema et al. [25] found that the total polyphenol content of fresh stem bark of *B. aegyptiaca* was 80.72 ± 2.11 mg GAE/g. Other studies on the ethanolic and aqueous extracts of trunk bark reported values of 0.52 ± 0.416 mg GAE/g, 55.51 ± 0.0446 mg/g GAE DM, and 44.12 ± 0.39 mg/g GAE, respectively, as cited by [26-28]. These results are significantly higher than those of the current study. The results obtained from this study show that the fruits of *B. aegytiaca* are rich in phenolic compounds which justifies their use in traditional medicine and could be beneficial in the field of pharmacopoeia. According to Tula et al. [29], the difference in results could be attributed to various factors such as the type of solvent used, the extraction method, the plant organ used, the geographical location, and the age of the cultivated plant.

Regarding the jam, the TPC value was 297.87 ± 1.7 mg GAE/g DM, which is higher than the fruit TPC of 71.87 ± 1.2 mg GAE/g DM. Mehinagic et al. [30] reported that the increase in phenolic compounds can be explained by the release of phenolic compounds initially associated with cell walls. This release is induced by heating and is linked to the degradation of these walls.

Data on the impact of heat treatments on the content of polyphenols in fruits are rare and sometimes contradictory, according to the literature. Kebe [31] reported that treating tomatoes at temperatures up to 88 ˚C for 2 to 30 minutes does not affect their initial polyphenol content. However, the polyphenol content increases by about 40% after 45 minutes at 180 ˚C, 200 ˚C, or 220 ˚C, or when

making apple sauce. Our finding may suggest that *B. aegyptiaca* fruit jam is a very high source of phenolic compound and it can be used for therapeutic purposes.

Roy et al. [32] reported that cooking vegetables at a moderate temperature of 50 °C for 10 to 30 minutes preserves 80 to 100% of their phenolic compounds. Similarly, Mazzeo et al. [33] confirmed the positive effect of blanching on the phenolic compounds of several vegetables. They explained that this may be due to the inactivation of the enzymes responsible for the oxidation of polyphenols, specifically polyphenoloxidase.

Renard et al. [34] demonstrated that phenolic compounds in the plant matrix remain stable during heat treatments commonly used in the food industry. They also found that physical separation steps (such as refining and peeling) are the most damaging to phyto-micronutrient concentrations in the epidermis.

**Table 1:** Total Polyphenol and flavonoids content of the samples analyzed.

| Sample | Total polyphenols TPC (mg GAE/g DM) | Total flavonoids TFC (mg QE/g DM) |
|---|---|---|
| AQ fruit extract | 71.87 ± 1.2 | 4.99 ± 0.1 |
| EtOH fruit extract | 63.64 ± 0.8[a] | 0.44 ± 0.007 |
| Jam | 297.87 ± 1.7[a,b] | 12.74 ± 0.6[a,b] |

The data were compared by one-way ANOVA followed by Dunnett's post-ANOVA test: a) significant difference compared to the AQ fruit extract; b) significant difference compared to the EtOH fruit extract. ($P<0.005$)

**Total flavonoids content (TFC) in the fruit extracts and the jam**

According table 1, the TFC values of the AQ fruit extract were higher than those of the EtOH extract, with respective amounts of approximately 4.99 ± 0.1 and 0.44 ± 0.07 mg QE/g DM. Compared to Hassan et al. [35], the total flavonoid content of the aqueous extract of the trunk bark was found to be 28.71 mg QE/g. Mhya et al. [27] conducted a study on the ethanolic extract of the trunk bark of B. aegyptiaca and found 3.59 ± 0.032 mg QE/g. This result is lower than the AQ extract of the fruits studied here.

Nitiema et al. [25] also studied the ethanolic extract, but of the fresh stem bark of *B. aegyptiaca*, and found 88.70 ± 1.65 mg QE/g. This result suggests that this part of the plant is richer in flavonoids than the fruits. The observations made by Mhya et al. [27] regarding the low solubility of flavonoids in water are supported by the results obtained in this study. Usman et al. [10] also found high values of 69.17 ± 0.32 and 95.52 ± 0.41 mg QE/g for the AQ and EtOH *B. aegyptiaca* root extracts, respectively, which confirm these statements about low solubility of flavonoids in water.

Based on the results of this study and the literature, it appears that *B. aegyptiaca* (L.) Delile fruits are rich in flavonoids, which give them therapeutic properties for humans. Further studies in the agrifood and pharmacopoeia fields could isolate possible biological compounds.

The total flavonoid content in the jam was determined to be 12.74 ± 0.6 mg QE/g, which is higher than the value obtained for the fruits (4.9 ± 0.1 mg QE/g DM), indicating an increase in flavonoid content. This phenomenon has been previously explained by Bourgou et al. [36], Hocini and Merabet [37], and Derrardja [38].

Bourgou et al. [36] investigated the extraction of flavonoids from pure and mixed extracts of *Euphorbia helioscopia* using different methods. They concluded that the decoction method was more effective than maceration, suggesting that temperature positively affects extraction. Hocini and Merabet [37] reported that the flavonoid content is greatly influenced by the solvent, extraction time, and temperature. A study was conducted on various solvents and extraction times. The extracts that underwent a temperature of 70 °C for 6 hours had the highest flavonoid content. Conversely, flavonoid concentrations decreased in extracts obtained at a temperature of 30 °C for 2 to 4 hours of extraction. Extracts obtained after 6 hours of extraction showed an increase in flavonoid content. These findings support the results of the authors. Derrardja [38] reported that the increase in flavonoid content could be attributed to the efficiency of the extraction process resulting from the application of heat. The results indicated that prepared jam is a highly nutritious food for humans and can help prevent nutritionally related diseases.

**Antioxidant activity of extracts and jam**

The $IC_{50}$, or 50% inhibitory concentration, of the DPPH free radical is the concentration of antioxidant required to inhibit 50% of the free radicals. It is a measure of the antioxidant's effectiveness. The $IC_{50}$ value represents the concentration of a compound needed to reduce the initial concentration of the DPPH° radical by 50% and is inversely related to its antioxidant capacity. A lower $IC_{50}$ value indicates a greater antioxidant activity of the compound [39]. Table 2 shows that the jam had the highest antioxidant activity with an $IC_{50}$ of 10.96 ± 1.7 µg/mL, followed by the AQ extract of fruit with an $IC_{50}$ of 12.61 ± 0.3 µg/mL, and the EtOH extract of fruit with an $IC_{50}$ of 14.27 ± 0.6 µg/mL. Results were compared to ascorbic acid which exhibited an $IC_{50}$ equal to 4.2 ± 0.2 µg/mL. Amadou et al. [40] conducted a study comparing the antioxidant activity of fresh and boiled aqueous extracts of *B. aegyptiaca* (L.) Delile fruits. The results showed that the antioxidant activity of boiled extracts was higher (97%) than that of fresh extracts (88.2%). The antioxidant activity of the fruit in this study was lower (27.32%) than that of the boiled extracts, which could be attributed to the differences

in sample processing procedures. In a study conducted by Koko et al. [9] on the antioxidant power of ethanolic fruit extract, the percentage inhibition was 14.4%. The current study found a value of 13.19%, which is slightly lower. This difference could be attributed to the dilutions performed. Additionally, Usman et al. [10] reported maximum inhibition values of 81.04 ± 0.9% and 35.11 ± 0.2% for the ethanolic and aqueous extracts of *B. aegyptiaca* roots, respectively. In a review by Murthy et. [41], several research studies demonstrate that extracts and phytochemicals isolated from desert date display antioxidant, anticancer, antidiabetic, anti-inflammatory, antimicrobial, hepatoprotective and molluscicidal activities. Mesocarp of fruits, seeds, leaves, stem and root bark are rich sources of saponins. These tissues are also rich in phenolic acids, flavonoids, coumarins, alkaloids and polysterols. Some constituents show antioxidant, anticancer and antidiabetic properties. Our results show that the fruit of Balanites could be beneficial for the treatment and prevention of many diseases.

**Table 2:** Inhibitory concentration ($IC_{50}$) of extracts and jam using radical DPPH.

| Samples | $IC_{50}$ (µg/mL) |
|---|---|
| AQ fruit extract | 12.61 ± 0.3 |
| EtOH fruit extract | 14.27 ± 0.6[a] |
| Jam | 10.96 ± 1.0[7a,b,c] |
| Ascorbic acid | 4.2 ± 0.2[d] |

The data were compared by one-way ANOVA followed by Dunnett's post-ANOVA test: a) significant difference from the AQ fruit Extract; b) significant difference compared to the EtOH fruit extract; c) significant difference compared to the AQ Fruit Extract; d) significant difference from jam.

**Antimicrobial activity**

Based on table 3, the AQ fruit extract was found to be ineffective against *E. coli* and *S. aureus*, while the EtOH extract showed high sensitivity. At the lowest concentration (1 µL/mL), the fruit EtOH extract demonstrated significant sensitivity against *E. coli* and *S. aureus*, with an Inhibition Zone Diameter (IZD) greater than 20 mm. Based on our findings, the EtOH fruit extract demonstrated greater potency than the antibiotics Penicillin (8 mm for *E. coli* and 13 mm for *S. aureus*) and Erythromycin (15 mm for *E. coli* and 16 mm for *S. aureus*). Ampicillin was ineffective against *S. aureus*, whereas the EtOH fruit extract inhibited the growth of this microbial strain. Concerning Doxycycline, EtOH fruit extract was more effective against *E. coli* (IZD = 18 mm). Our results indicate that the extracts were more sensitive towards *E. coli*, but equally sensitive against *S. aureus* (IZD = 35 mm). It is worth noting that Abdulhamid and Sani [6] found that *S. aureus* was resistant to the aqueous extract of *B. aegyptiaca* leaves, while *E. coli* was sensitive to the same extract (IZD=12.5 ± 0.25 mm). It was established by Usman et al. [42], that the aqueous extract of the stem bark of *Balanites aegyptiaca* does not inhibit the growth of *Salmonella typhi*, *S.aureus* and *E.coli*, while the ethanol extract has shown a remarkable activity. These findings are in line with those detailed in the current investigation. This result demonstrated the influence of the solvent used on the biological activity. The ability of *B. aegyptiaca* showing sensitivity to two different strains of bacteria (gram positive and gram-negative bacteria) supports its application as a broad spectrum antimicrobial agent with the largest efficacy.

Our findings showed that the fruits have a stronger antibacterial capacity than the leaves. Based on the obtained results, it was observed that the EtOH extract was more sensitive than the AQ extract. This confirm that EtOH is the optimal solvent for extracting phytochemical compounds from fruits that may have cause an antibacterial activity. In fact, it was highlighted that the alcoholic extracts were rich in very potent bio-actives compounds like nucleosides, polysaccharides, proteins, polyphenols, etc. [43].

**Table 3:** Diameter of inhibition zone of the fruit ethanolic and aqueous extract against *E.coli* and *S.aureus.*

| | Zone of inhibition (mm) AQ fruits extract (µl/ mL) | | | Zone of inhibition (mm) of EtOH fruits extracts (µl/ mL) | | | antibiotics | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Test organism** | 1 | 5 | 10 | 1 | 5 | 10 | **Ampicillin** | **Penicillin** | **Erythromycin** | **Doxycycline** |
| ***E. coli*** | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 24.25±1.06 | 26.75±2.75 | 28.75±0.25 | 27±0.00 | 8±0.00 | 15±0.00 | 18±0.00 |
| ***S. aureus*** | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 31±2 | 27.5±0.7 | 20.25±1.7 | 0.00±0.00 | 13±0.00 | 16±0.00 | 35±0.00 |

### Microbiological analysis of the jam

To evaluate the suitability of the prepared jam for human consumption, the total aerobic mesophilic flora (FAMT), total and fecal coliforms, yeasts, and molds were enumerated. The absence of fecal coliforms indicates that good hygienic practices were followed during the jam processing, and consumption of the product will not have a negative impact on the consumer's health. pH is an important indicator of food quality and safety.

### Physicochemical analysis of Jam

Table 4 summarizes the physicochemical analysis results of the jam.

**Table 4:** Physico-chemical characteristics of the jam.

| characteristics | Values |
|---|---|
| pH | 5.22 |
| ° Brix (%) | 72.50 |
| Titrable acidity (mg / 100 g of product) | 8.00 |

### The pH

The pH of the jam was measured using a pH meter (pH 50+ model) by immersing the electrode in the sample. The pH is one of the most important factors that must be monitored and controlled in jam production for optimum gel condition, the obtained pH reading was 5.22, indicating that the jam is slightly acidic. Bazizen and Kadi [44] reported that a pH of 6.10 is sufficient to inhibit the growth of most bacteria. The pH of the current study indicates a value of 5.22, which means that the jam presents an adequate medium to prevent bacterial proliferation and is therefore good for human health.

### The degree of Brix

The dry soluble solids content of our product was measured at eye level using a handheld refractometer, which is an indicator of quality. Our obtained value was 72.5%, Akubor [45] found a value of 72.5% for African locust bean jam, which is consistent with our results. According to Akubor [45], the soluble solids content is an important quality property in food processing, as approximately 55% of soluble solids are sugars. The amount and proportion of glucose and fructose can affect the sensory qualities of fruits. Chawafambira et al. [46] have shown that lower Brix values (< 65%) can affect shelf life. Additionally, lower Brix values can result in a consistency that is ideal for the growth of bacteria and molds. In our study, the obtained value indicates that the jam is of good quality.

### The titratable acidity

It was determined by the colorimetric method using phenolphthalein as a color indicator. The results are presented in the table 4, we found a value of 8 mg of citric acid/100 g of jam. According to Chawafambira et al. [46] pH and acidity are inversely proportional; indeed, the acidity of the pulp is an important aspect in jam making as low pH is required for gel formation. Fruits naturally contain acids, mainly citric acid, but other acids such as malic acid and tartaric acid can also be found in a few fruits. The source of the triable acidity noted in the jam could be attributed to the presence of natural acids in the fruit [47].

### Sensory analysis

Sensory evaluation of *B.aegyptiaca* fruit jam was conducted to assess panelist perception and acceptability. The responses of the panelists (60 tasters) concerning the organoleptic evaluation of texture, color, smell, and taste were resumed in Table 5. Regarding the texture, 80% of the panelist agreed that the jam had a honey texture, 13. 33% said it had a creamy texture and only 6.66% classified it as a pasty texture. According to these results, the jam responds to the textural characteristics of honey.

Color is one of the most important quality parameters of jams related to the perception and reception of the product [11]. 65% of the tasters rated the color as light brown, 33.33% as dark brown

and 1.66% as black, this light brown color could be due to the natural red brownish pigment present in the fruit pulp [4]. The high color values could be attributed to the carotenoid pigment in the *B.aegyptiaca* fruit.

73.33% found the smell acceptable. The pleasant smell was considered by 18.33% and only 8.33% considered it unpleasant. Alqahtani [4] reported that the aroma of jam enriched with fruit pulp could be improved due to the interaction between sucrose and organic acids.

Regarding the taste, 31.66% described it as slightly bitter, 55% as moderately sweet and 28.33% defined it as moderately astringent. The tasters were called to give a general appreciation of the jam and 36.66% considered it appreciable.

**Table 5:** Results of the hedonic organoleptic assessment.

| Criteria | Description | | Responses (%) |
|---|---|---|---|
| **Texture** | Honey | | 80.00 |
| | Creamy | | 13.33 |
| | Pasty | | 6.66 |
| **Color** | Light brown | | 65.00 |
| | Dark brown | | 33.33 |
| | Black | | 1.66 |
| **Smell** | Pleasant | | 18.33 |
| | Acceptable | | 73.33 |
| | unpleasant | | 8.33 |
| **Taste** | **Bitterness** | Very little | 15 |
| | | Little | 31.66 |
| | | moderately | 20 |
| | | highly | 21.66 |
| | | Very strongly | 11.66 |
| | **Sweet** | Very little | 1.66 |
| | | little | 13.33 |
| | | moderately | 55.00 |
| | | highly | 25.00 |
| | | Very strongly | 5.00 |
| | **Astringent** | Very little | 26.66 |
| | | Little | 31.66 |
| | | moderately | 28.33 |
| | | Highly | 10.00 |
| | | Very strongly | 3.33 |
| **General taste** | Very bad | | 00.00 |
| | Bad | | 13.33 |
| | Appreciable | | 36.66 |
| | Good | | 36.66 |
| | Very good | | 13.33 |

## Conclusion

The aim of this work is the valuation of an endemic Mauritanian plant *B. aegyptiaca* (L.) through the determination of the phytochemical composition, the antioxidant and the antimicrobial activity of aqueous and ethanolic fruit extracts. A contribution to the transformation of the fruit into jam and its physicochemical and sensory evaluation were also conducted. According to the obtained results, it can be concluded that *B. aegyptiaca* fruit possesses good antioxidant and antibacterial potential. The fruit also contains biochemical compounds such as polyphenols and flavonoids, which justifies its traditional use for therapeutic purposes. The prepared jam showed a high content of polyphenols and flavonoids as well as a good antioxidant capacity. Promising results were obtained according to the sensory analysis and the microbiological quality of the jam. Since the agri-food sector for *B. aegyptiaca* plant remains relatively unexplored in Mauritania, and looking to the findings highlighted in this study, additional deep analysis and valuation have to be investigated in the future. It could offer a new sustainable socioeconomic strategy for the development a new edible product beneficial for health.

## Acknowledgments

The authors thank the government of Mauritania and the French embassy in Nouakchott for providing a scholarship to R.K. they also thank Souleymane Diop and Abderahmane Diop for their help in some research and the translation.

## Author contributions

Experiments and the manuscript writing were done by Rouguiata Kane, under the direction of Dorsaf Ben Hassine who supervised and validated the experiments and proofread and refined the

manuscript to be ready for publication. Manef Abdderrabba provided solvents and material to perform the experiments. Diagana Yacouba provided the samples. Zeinabou Mint Sidoumou refined the English of the manuscript. Nicolas Mensah Aessou contributed to the writing and corrections of the manuscript. All authors have read and agreed to the published versoin of the manuscript.

## Conflict of interest

The authors declare that they have no conflict of interest.

## References

1. Ouédraogo S, Bondé L, Ouédraogo O, Ouédraogo A, Thiombiano A, et al. (2019) What Extent Do Tree Size, Climate and Land Use Influence the Fruit Production of *Balanites aegyptiaca* (L) Delile in Tropical Areas (Burkina Faso)? . International journal of fruit science 20: 282-299.
2. Farag MA, Baky MH, Morgan I, Khalifa MR, Rennert R, et al. (2023) Comparison of *Balanites aegyptiaca* parts: metabolome providing insights into plant health benefits and valorization purposes as analyzed using multiplex GC-MS, LC-MS, NMR-based metabolomics, and molecular networking†. RSC Adv.13: 21471-21493 | 21471.
3. Chérif AA, Houndonougbo J, Idohou R, Mensah S, Azihou AF, et al. (2023) Towards sustainable conservation and domestication of *Balanites aegyptiaca* L. (Zygophyllaceae) in Africa: progress and challenges. Journal of Arid Environments 218: 105053.
4. Alqahtani NK, Alnemr TM, Ahmed AR, Ali S (2022) Effect of Inclusion of Date Press Cake on Texture, Color, Sensory, Microstructure, and Functional Properties of Date Jam. Processes 10: 2442.
5. Yebouk C, Redouan FZ, Benitez G, Bouhbal M, Kadiria M, et al. (2019) Ethnobotanical study of medicinal plants in the Adrar Province, Mauritania. Journal of Ethnopharmacology 246: 1-14.
6. Abdulhamid A, Sani I (2016) Preliminary Phytochemical Screening and Antimicrobial Activity of Aqueous and Methanolic leave extracts of *Balanites aegyptiaca* (L.). International Research Journal of Pharmaceutical and Biosciences 3: 1-7.
7. Abdelaziz SM, Mohamed Lemine FM, Tfeil HO, Filali-Maltouf A, Boukhary OMSA (2020) Phytochemicals, Antioxidant Activity and Ethnobotanical Uses of *Balanites aegyptiaca* (L.) Del. Fruits from the Arid Zone of Mauritania, Northwest Africa. Plants 9: 1-15.
8. Ogala H, Elinge CM, Wawata IG, Adegoke AI, Muhammad AB, et al. (2018) Extraction and physicochemical analysis of desert date (*Balanitesaegyptiaca*) seed oil. Inter International Journal of Advanced - The conclusion has been improved, limitation and perspective have been added. Academic Research 4: 1-12.
9. Koko SE, Talib M, Elfatih F, ZainAlabdeen EM, Kabbashi AS (2017) Antioxidant. activity and phytochemical screening of *Balanites aegyptiaca* fruits. World journal of pharmaceutical and medical research 3: 47-50.
10. Usman A, Mohammed Y, Muhammed HO, Usman NL, Zakari AH (2020) Phytochemical Screening and Antioxidant Activity of *Balanites Aegyptiaca* Root Bark Extracts: Influence of solvent. Communication in physical - The conclusion has been improved, limitation and perspective have been added. sciences 5: 156-164.
11. Eke-Ejiofor J, Allen JE, Ekeolisa IC (2019) Physicochemical, Sensory Properties and Bacteria Load of Jam Produced from Squash (Cucurbita) Fruit. Food Science and Nutrition Technology 4: 7.
12. Vall AOM, Boumediana AOI, Soule AO, Gueye M, Labat JN (2011) Contribution to the study of flora in Mauritania: Evaluation of the biodiversity of Assaba (Açaba). Bulletin of the scientific - The conclusion has been improved, limitation and perspective have been added. institute, Rabat, life sciences section, n°33: 53-64.
13. Ben Hassine D, El Euch SK, Rahmani R, Ghazouani N, Kane R, et al. (2021) Clove Buds Essential Oil: The Impact of Grinding on the Chemical Composition and Its Biological Activities Involved in Consumer's Health Security. BioMed Research International 21: 11.
14. CODEX STAN 296- (2009). Codex Standard for Jams, Jellies and Marmalades.
15. NF V 08- 010. (1996) Food microbiology general rules for preparing dilutions for biological examination.
16. NF V 08-051. Food microbiology. Enumeration of microorganisms by counting the colonies obtained at 30 ˚C. routine method.
17. NF O8-060. Enumeration of thermolaterant coliforms by counting the colonies obtained at 44 ˚C.
18. NF EN ISO 7954: 1988. Microbiology-general guidance for enumeration of yeasts and moulds colony technique at 25 ˚C.
19. AOAC, (1995) Official method of analysis of the association of the official analytical chemists international, (16th edn). AOAC international arlington, VA, 250p.
20. NF ISO 5492, V00-150 (1992)- Sensory analysis.
21. NF ISO 8587 (2006)- sensory analysis –ranking methodology.
22. Ibrahim OHM, Al-Qurashi AD, Asiry KA, Magdi AA, Alhakamy MNA, et al. (2022) Investigation of Potential In Vitro Anticancer and Antimicrobial Activities of *Balanites aegyptiaca* (L.) Delile Fruit Extract and Its Phytochemical Components.11: 2621.
23. Elamin MM, Satti AA (2013) Insecticidal potentialities of Balanites aegyptiaca extracts against the khapra beetle (Trogoderma granarium). Global Advanced Research Journal of Environmental Science and Toxicology 2: 005-010.
24. Abdallah EM, Ben Hsouna A, Al-Khalifa KS (2012) Antimicrobial, antioxidant, and phytochemical investigation of *Balanites aegyptiaca* (L.) Del. edible fruit from Sudan. Journal of Biotechnology. 11: 11535-11542.
25. Nitiema LW, Sombié PAED, Koala M, Del Fiore A (2020) phytochemical composition and antioxidant activity of *Balanites aegyptiaca*, Securidaca longepedunculata and Acacia gourmaensis used against seed-borne fungi in Burkina Faso. Current journal of Applied science and technology. 39: 79-87.
26. Mhya DH, Anigo KM, Umar IA, Alegbejo JO (2016) Effects of Aqueous Fraction of Ethanolic Extract of *Balanites aegyptiaca* Stembark on Glucose Metabolic Enzymes in Streptozotocin-induced Diabetic Rats. International - The conclusion has been improved, limitation and perspective have been added. Journal of Biochemistry Research. 13: 1-12.
27. Mhya DH, Anigo KM, Umar IA, Alegbejo JO (2018) Corrigendum: Effects of Aqueous Fraction of Ethanolic Extract of *Balanites aegyptiaca* Stem-bark on Glucose Metabolic Enzymes in Streptozotocin-induced Diabetic Rats. International Journal of Biochemistry Research. 13: 1-12.
28. Ojo OO, Ladeji OO, Olayaki LA, Jide-Ojo CC (2015) Hepatoprotective and antioxidant efficacy of aqueous stem bark extracts of *Balanites aegyptiaca* (Linn.) Del. against acetaminophen induced liver injury in rats. - The conclusion has been improved, limitation and perspective have been added. Journal of Medicinal Herbs and Ethnomedicine 1: 89-96.

29. Tula MY, Danchal TB, Iruolaje FO, Onyeje GA (2014) Studies on Phytochemical Constituents and Antibacterial Potentials of Extracts of *Balanites aegyptiaca* (Del.) Parts on Antibiotic Resistant Bacterial Isolates. European. European Journal of Medicinal Plants 4: 854-864.

30. Mehinagic E, Bourles E, Jourjon F (2011) Compounds of fruits of nutritional interest: impact of transformation processes on polyphenols. Swiss journal Viticulture, Arboriculture Horticulture 43: 364-368.

31. Kebe M (2014) Incidence of heat treatments on the parenchyma of Apple (Malus Domestica) and diffusion of phenolic compounds. Doctoral thesis in biochemistry Avignon 239.

32. Roy MK, Takenaka M, Isobe S, Tsushida T (2007) Antioxidant potential, anti-proliferative activities, and phenolic content in water-soluble fractions of some commonly consumed vegetables: Effects of thermal treatment. Food Chemistry 103: 106–114.

33. Mazzeo T, Denis N'Dri D, Chiavaro E, AttilioVisconti A, Fogliano V, et al. (2011) Effect of two cooking procedures on phytochemical compounds, total antioxidant capacity and color of selected frozen vegetables. Food Chemistry 128: 627-633.

34. Renard CMGC, Caris-Veyrat C, Dufour C, Le Bourvellec C (2014) The fate of polyphenols and carotenoids in heat-treated fruits and vegetables. Agronomic innovations 42: 125-137.

35. Hassan LEA, Dahham SS, Mohammed Saghir SA, Mohammed AMA, Eltayeb NM, et al. (2016) Chemotherapeutic potentials of the stem bark of *Balanites aegyptiaca* (L.) Delile: an antiangiogenic, antitumor and antioxidant Agent. BMC Complementary and Alternative Medicine 16: 1-13.

36. Bourgou S, SerairiBeji R, Medini F, Ksouri R (2016) Effect of solvent and extraction method on the content of phenolic compounds and the antioxidant potential of Euphorbia helioscopia. Journal of New Sciences, Agriculture and Biotechnology 28: 1649-1655.

37. Hocini S, Merabet A (2016) Effect of solvent, extraction time and temperature on the antioxidant activity of leaves of Hyoscyamusalbus and Pulicaria odora. Master's thesis in food technology bioprocesses, Algeria. 44.

38. Derrardja AD (2014) Impact of two technological processes (juice and jam) and drying on apricot polyphenols and carotenoids. Master's thesis in food technology. Constantine 130.

39. Haddoudi M, Mellouk H, Bejany B, Dani A, Digua K (2014) Valorization of spent coffee grounds: oil extraction and evaluation of antioxidant activity. Les technologies LES TECHNOLOGIES DE LABORATOIRE 8: 36.

40. Amadou I, Le GW, Shi YH (2012) Effect of Boiling on the Cytotoxic and Antioxidant Properties of Aqueous Fruit Extract of Desert Date, *Balanites aegyptiaca* (L.) Delile. Tropical Journal of Pharmaceutical Research 11: 437-444.

41. Murthy HN, Yadav GG, Dewir YH, Ibrahim A (2021) Phytochemicals and Biological Activity of Desert Date (*Balanites aegyptiaca* (L.) Delile). Plants 10: 32.

42. Usman A, Mohamed Y, Opaluwa OD (2020) phytochemicals, Antibacterial, Antioxidant and Cytotoxic Analyses of Balanites Aegyptiaca Stem Bark Extracts. Nigerian Research Journal of Chemical Sciences 4: 301.

43. Shashidhar MG, Giridhar P, Udaya Sankar K, Manohar B (2013) Bioactive principles from Cordyceps sinensis: A potent food supplement - A review. J Funct Foods 5: 1013-1030.

44. Bazizen F, Kadi L (2015) Effet de la transformation des dattes et de la conservation du produit dérivé sur les caractéristiques physico-chimiques et microbiologiques : Cas de la variété Ghars. Mémoire de master : Bejaia 35.

45. Akubor PI (2023) Quality evaluation of pulp powder. Croatian Journal of Food Science and Technology 15: 1-10.

46. Chawafambira A, Sedibe MM, Mpofu A, Achilonu MC (2020) The potential of Uapaca kirkiana fruit jam for delivery of Lactobacillus rhamnosus yoba as probiotic. African journal of Food Agriculture Nutrition and Development 20: 16161-16177.

47. Habbache I, Sebkhi S (2013) Antioxidant content and antioxidant activities of some varieties of industrial jams. Master's thesis in applied biochemistry, Algeria 74.