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# Biochemical and Agromorphological Characteristics of the Kernel of the Sahel Date Palm (*Balanites aegyptiaca* (L.) Del) from Ferlo, Senegal

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## Abstract

*Balanites aegyptiaca* (L.) Del is a multi-purpose tree species of significant socio-economic importance in the Sahelian region. Despite its high value for food, fodder, and medicine, little is known about the biochemical and agromorphometric variability of its kernels. This study aims to characterize the biochemical properties of *B. aegyptiaca* kernels collected from three communes in the Ferlo region of northern Senegal: Labgar, Dodji, and Doundodji. Nuts were classified into three size categories (small, medium, and large) based on weight and axis measurements. A total of 2250 nuts were analyzed for dry matter, moisture, fat, crude fibre, and organic matter content. The analysis of variance showed no significant effects of provenance or size for most parameters. However, a significant interaction between provenance and size was observed for crude fiber ($p = 0.0364$). Dry matter and fat content were relatively stable across provenances and sizes, while moisture content showed higher values in large nuts from Doundodji. Crude fibre varied significantly with provenance-size interaction, with small nuts from Doundodji exhibiting the highest values. Correlation analysis revealed a strong negative correlation between fat and crude fiber ($r = -0.84$, $p < 0.01$). Principal component analysis confirmed the consistency of the dataset, with over 94% of total variance explained by the first two components. These findings contribute to a better understanding of the biochemical diversity of *B. aegyptiaca* and may support its sustainable valorization and domestication in arid and semi-arid regions.

## Keywords

*Balanites aegyptiaca*, Biochemical and Agromorphological Characterization,

Dodji, Doundodji and Labgar, Senegal

## 1. Introduction

In sub-Saharan Africa, particularly in the Sahel, trees play a major role in the socio-economic and cultural life of populations, especially those in rural areas who depend heavily on woody plant resources to meet their daily needs. Also, woody fodder plays an important role in the forage balances of extensive livestock systems characterizing the Sahelian zone, as well as in difficult times [1].

The Sahel is a transition zone that is both floristic and climatic between the Sahara in the north and the Sudanese domain in the south [2]. It is in the form of a strip about 5500 km long and 400 to 500 km wide. It is present in a dozen African countries, from the mouth of the Senegal River to the Sudanese Jezirah [3] and is a region sensitive to climate variability [4].

However, in Senegal, this ecological zone is located in the north of the country, occupying an eco-geographical zone called Ferlo, located between the 100 and 500 mm isohyets [5]. The variation in climatic conditions in the Ferlo as well as the numerous droughts, population growth and the advance of the agricultural front, which began several decades ago, have led to changes in the floristic composition and vegetation structure [6] [7] and have strongly modified the living conditions of populations whose economy is based on extensive livestock farming. The vegetation provides natural pasture for livestock feed and allows rural populations to sustain themselves through the exploitation of various wood and non-wood products [8]. These populations find in the woody stratum fruits and supplementary foods, medicines, a source of energy, materials essential for the manufacture of objects of daily use and a substantial increase in the incomes of disadvantaged households [9] [10]. This situation leads to the overexploitation of multi-purpose trees with the consequent decline of many woody species. In addition, these resources are undergoing a significant degradation process as a result of multiple human interventions. This is why several initiatives have been carried out in this part of the country to conserve and rehabilitate natural resources.

Thus, agroforestry species such as *Balanites aegyptiaca* (L.) Del plays a leading role in the food and nutritional security of farmers through ecosystem services, including wood production and non-timber forest products. Up to 10 m tall, *Balanites aegyptiaca* has a wide geographical distribution. It is native to Africa and Asia [11]. In Senegal, the Ferlo is its preferred area [12]. This tree is a potential resource for rural populations. It is highly coveted by the population during the lean season. Indeed, all parts of the plant (roots, leaves, fruits, bark, thorns, and wood) are used for food, therapeutic, economic or socio-cultural purposes. In addition, as part of the fight against desertification in the Sahel, this species, which stands out for its robustness, drought resistance and longevity, was chosen among many others (*Acacia senegal* L., *Acacia seyal* L., *Ziziphus abyssinica* L., etc.), which is how it was massively replanted in Senegal as part of the ambitious Great Green Wall project. Thus, contributing to the sustainable development of the local economy [13]. The development of this species is an important issue for several countries in this region that are facing the problem of advancing desertification. In addition, *B. aegyptiaca*, although ecologically adapted to different soils and climatic conditions, presents risks of reducing its production potential. Indeed, overexploited, threatened by fires, overgrazing and drought, it is therefore subject to permanent anthropogenic pressure to which are added the environmental issues that endanger its survival [14].

Despite all these constraints that hinder the survival and production of *Balanites*, little information is available for the propagation and domestication of this species despite its socio-economic importance and daily use in the lives of populations. Studies on mineral characterization are almost limited in Senegal, which is why it is important or even urgent to act in favor of *Balanites aegyptiaca* in order to improve its sustainable use.

It is from this angle that our study is situated, which aims to contribute to a better understanding of *B. aegyptiaca*. Specifically, the biochemical quality of *B. aegyptiaca* is analysed across three provenances.

## 2. Materials and Methods

### 2.1. Presentation of the Ferlo

The study was carried out in the Ferlo, more specifically in the communes of Doundodji, Dodji and Labgar (**Figure 1**), in the department of Linguère, Louga region (Senegal).

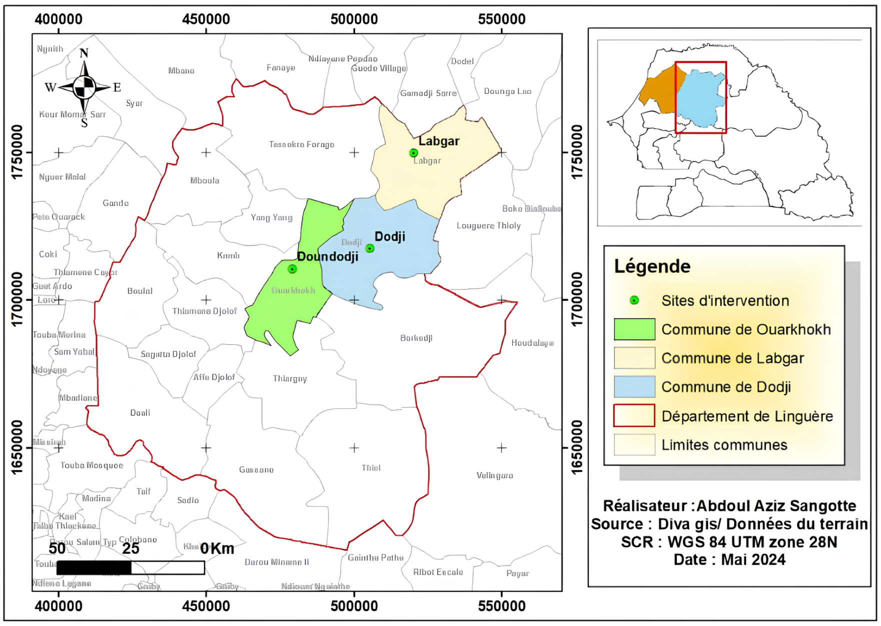


**Figure 1.** Geographical location of the study sites.

These communes have similar characteristics to Ferlo, which is a silvopastoral area located in northern Senegal. It is semi-desert [15] and belongs to the Sahelian bioclimatic zone [16]. Indeed, the Ferlo is located between latitudes 16˚15 and 14˚30 North and longitudes 12˚50 and 16˚ West, with an area of about 70,000 $km^2$. It is the largest eco-geographical region in Senegal. From an administrative point of view, this agro-ecological region covers part of the regions of Saint-Louis and Louga and the entire Matam region [5].

The Ferlo is a region in the Sahelian zone, with a dry season lasting nine months and a rainy season lasting three months. It is part of the semi-arid Sahelian domain and experiences variability in precipitation, with an average annual rainfall ranging from 300 mm in the north to 500 mm in the south [15]-[19]. The climate is characterized by low relative humidity of 35% per year and strong evaporation from 1800 to 2200 $mm \cdot year^{-1}$ [6] [8] [20]. The flora in the Ferlo is ordered according to rainfall gradient, with a zonal arrangement of phytogeographical domains interrupted by a few azonal groups at the Ferlo valley level. The main types of flora are shrubby pseudo-steppes and shrub to treed savannahs, which are deciduous, open, and often spiny, with *Acacia raddiana* and *Balanites aegyptiaca* predominating [7] [18].

The Ferlo region is home to spiny trees, rich woody flora, and a transition zone between silvo-pastoral zones and groundnut basins. The region has developed into silvopastoral reserves and classified forests, with higher frequency of *B. aegyptiaca*. The herbaceous mat includes species like *Aristida mutabilis*, *Schoenefeldia gracilis*, and *Cenchrus biflorus* [17]. Two types of soil are distinguished in Ferlo: sandy dune systems with neutral to weakly acidic subarid reddish-brown soils and tropical ferruginous soils with a sandy to sandy-clay texture. Soils evolve according to latitude, from subarid brown to tropical ferruginous, with sandy-clay soils with clay accumulation in deep horizons. The area is characterized by flat, monotonous relief, often found in dune plateaus called "seno" in Fulani [17] [18].

### 2.2. Choice of Sites

The study was carried out in the communes of Dodji, Labgar and Doundodji. These sites were chosen in a participatory manner but also on the basis of the important statistics available to the Linguère forestry service in terms of the availability of the resource.

### 2.3. Identification and Collection of *B. aegyptiaca* Nuts

Due to poor fruit production during the sampling season, nuts were collected from animal enclosures, where livestock such as goats had ingested and excreted intact seeds. Collection was carried out with the support of local residents and forest agents. Only nuts with intact morphology (no cracks, breaks, or insect damage) were retained. In each site, 10 kg of seeds were collected and transported in labeled bags to the Zootechnical Research Center (CRZ) in Dahra for further analysis.

## 2.4. Agromorphometric Characterization of Nuts

At the laboratory, the nuts were cleaned and labeled. Individual nut weight was measured using a precision balance (Mettler Toledo), and length and diameter were recorded with a digital caliper (**Table 1**). Based on these measurements, a multivariate analysis was used to classify the nuts into three size categories: small, medium, and large (**Figure 2**). From each site, 750 nuts per category were randomly selected, totaling 2250 nuts.

**Table 1.** Agromorphometric characteristics of nuts.

| Calibre | Weight | Small axis | Major axis |
|---|---|---|---|
| Small | 1.94 ± 0.03 | 11.50 ± 0.08 | 20.85 ± 0.17 |
| Medium | 1.31 ± 0.03 | 12.09 ± 0.08 | 22.84 ± 0.17 |
| Big | 1.94 ± 0.03 | 13.38 ± 0.08 | 24.13 ± 0.17 |

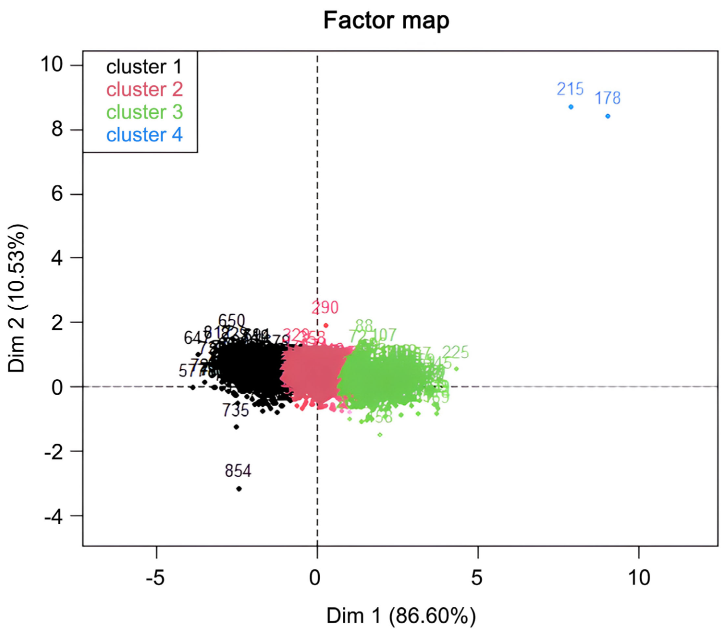


**Figure 2.** Calibration of *Balanites aegyptiaca* nuts according to agromorphometric traits (weight, minor and major axes).

## 2.5. Biochemical Characterization

Almond samples were categorized based on size and site, and biochemical analyses were conducted to determine dry matter, moisture, organic matter, fat, and crude fibers content.

To determine the organic matter, 2.5 g of ground material was weighed in a crucible previously dried and tared and then put in the oven at 550˚C for 3 hours. At a temperature of 100˚C, the crucibles are transferred to a desiccant for 30 minutes, and then weighed with the calcinations residue.

For crude fibers, the test portion is 1 g of ground material. Two successive hot extractions are carried out, with 150 ml of $H_2SO_4$, then 150 ml of KOH, the reagents being boiling when they are added to the sample. Each attack lasts 30 minutes from the time the boil resumes. The heating is first set to maximum and decreased as soon as the boil returns. After each attack, the product is rinsed with boiling distilled water. After the two hot extractions, rinse 3 times with acetone using a wash bottle. After rinsing, the bags were dried in the crucibles in a ventilated oven at 105˚C for 16 hours. The bags were taken out of the oven, cooled in a desiccant containing blue silica gel for 1/2 h. The contents were poured into bags in the crucibles and then weighed without letting them regain moisture. They were then charred for 3 hours at 550˚C.

### 2.6. Data Processing

Data were subjected to analysis of variance (ANOVA), followed by post-hoc comparison using the Least Significant Difference (LSD) test at a significance level of $p < 0.05$. Statistical analyses were performed using Statistix 8.1 software.

## 3. Results and Discussion

### 3.1. Analysis of Variance

The analysis of variance (ANOVA) revealed that most biochemical parameters—dry matter, moisture, fat, and organic matter—did not significantly vary across provenance or size categories. However, a significant interaction effect between provenance and nut size was observed for crude fiber content ($p = 0.0364$), indicating that fibre levels were not uniform across the different size-provenance combinations. This interaction suggests the influence of local environmental conditions and possibly post-harvest handling practices on fiber accumulation (Table 2).

**Table 2.** Test of the significance of the biochemical parameters studied between the origins and the sizes (p values).

| Variables | MB | CB | H | MSA | MG |
|---|---|---|---|---|---|
| Origin | 0.216 | 0.573 | 0.119 | 0.119 | 0.184 |
| Calibre | 0.216 | 0.573 | 0.119 | 0.119 | 0.184 |
| Provenance × Calibre | 0.415 | 0.0364 | 0.471 | 0.471 | 0.639 |

OM: organic matter, CB: crude fibre, H: moisture, MSA: analytical dry matter, fat: fat.

### 3.2. Biochemical Parameter Trends

The biochemical characteristics of the samples analyzed depend on the origin (Table 3). The dry matter is relatively similar for medium and small sizes, averaging around 95%. On the other hand, for large calibers, Labgar and Dodji have the highest values, 94.99% and 94.91% respectively, while Doundodji is at 91.01%. As for humidity, it has similarities for medium and small sizes between all sites (Table 4), but shows disparities at the level of large sizes, where Doundodji records the highest value at 8.99%, compared to Labgar (5.01%) and Dodji (5.03%).

**Table 3.** Variations in the biochemical parameters of *Balanites* nuts according to size and origin and sites (%).

| Sites | Labgar (LAB) | | | Dodji (DOD) | | | Doundodji (DDJ) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Big | Medium | Small | Big | Medium | Small | Big | Medium | Small |
| Dry matter | 94.99 | 94.92 | 95.02 | 94.97 | 95.14 | 95.25 | 91.01 | 95.09 | 95.22 |
| Humidity | 5.01 | 5.08 | 4.98 | 5.03 | 4.86 | 4.75 | 8.99 | 4.91 | 4.78 |
| Fat | 44.20 | 45.00 | 44.40 | 45.20 | 45.00 | 44.60 | 45.60 | 44.80 | 41.40 |
| Crude fibers | 13.80 | 13.98 | 13.51 | 13.40 | 13.11 | 14.73 | 14.80 | 16.42 | 18.32 |
| Organic matter | 97.20 | 97.10 | 97.00 | 97.10 | 97.10 | 97.00 | 96.80 | 96.90 | 96.70 |

**Table 4.** Variables of the different biochemical parameters according to the sites (%).

| Sources | MO | CB | H | MSA | MG |
|---|---|---|---|---|---|
| Doundodji | 96.000 ± sA | 15.000 ± $\sigma$A | 4.000 ± $\sigma$A | 95.000 ± sA | 43.000 ± sA |
| Labgar | 96.667 ± sA | 13.333 ± $\sigma$A | 6.000 ± $\sigma$A | 93.000 ± $\sigma$A | 44.667 ± $\sigma$A |
| Come | 96.667 ± sA | 14.000 ± sA | 4.333 ± $\sigma$A | 94.667 ± sA | 44.667 ± $\sigma$A |
| Average | 96.444 | 14.111 | 4.7778 | 94.222 | 44.111 |
| CV | 0.49 | 13.15 | 22.06 | 1.12 | 2.51 |

Dry matter content was high across all samples, with an average above 94%, confirming the dry nature of *B. aegyptiaca* kernels. However, large nuts from Doundodji showed a notably lower DM (91.01%) compared to Labgar and Dodji (both near 95%). These differences might stem from variable soil conditions, local microclimates, or the fact that nuts in Doundodji were collected from animal enclosures, potentially leading to moisture uptake from fecal matter or environmental humidity.

Although not statistically significant, higher moisture content was observed in large nuts from Doundodji (8.99%) almost double that of other provenances. This discrepancy might reflect inadequate post-harvest drying or ambient humidity during collection, corroborating findings from [21] and [22] that emphasize the importance of harvest and storage conditions on seed moisture and storability. The moisture values in this study remain lower than those reported for other indigenous fruits such as *Tamarindus indica* (14% - 18%) or *Adansonia digitata* (11% - 24%), supporting the classification of *B. aegyptiaca* as a dry-seeded species.

Fat content ranged from 41.40% to 45.60%, with Doundodji's small-sized nuts displaying the lowest values. These results are slightly lower than the 52% reported by Ndiaye [21], suggesting either varietal differences or possible degradation of lipids due to storage or environmental conditions. Nevertheless, the high and consistent fat content in medium and large sizes supports *B. aegyptiaca*'s potential as an oilseed crop. The literature suggests that lipid biosynthesis in dryland species is strongly influenced by genotype and water availability during kernel development.

Crude fiber content showed significant variation only in interaction between provenance and size. The highest values were found in small and medium nuts from Doundodji (18.32% and 16.42%), indicating that fiber accumulation might be driven by environmental stressors such as soil compaction, grazing pressure, or nutrient deficiency, as shown in studies on similar Sahelian species [23]. These findings align with the hypothesis that stress can increase lignin and structural carbohydrate content in plant tissues.

Organic matter levels remained above 96% across all samples, suggesting a generally high nutritional density. The minor variations among sites and sizes point to a relatively uniform biochemical profile, possibly due to shared genetic material or similar agronomic practices, as described by Garcia *et al.* [24].

### 3.3. Correlation between Parameters

Correlation analysis (**Table 5**) confirmed a strong negative correlation between fat and crude fibre (r = −0.84, p < 0.01), implying that as lipid content increases, structural carbohydrate levels decline. This inverse relationship suggests a physiological trade-off between energy storage (lipid accumulation) and structural reinforcement (fiber), which is typical in seeds adapting to arid environments. These results are consistent with those from dryland crops like *Ziziphus mauritiana*, where high-fat varieties also showed lower structural carbohydrate content [25].

**Table 5.** Pearson correlation matrix of biochemical parameters.

| | MO | CB | H | MG |
|---|---|---|---|---|
| CB | −0.59 (0.08) | | | |
| H | −0.02 (0.95) | −0.20 (0.59) | | |
| MG | 0.47 (0.19) | −0.84 (0.004) | 0.39 (0.29) | |
| MS | 0.02 (0.95) | 0.20 (0.59) | −1 (0) | 0.39 (0.29) |

### 3.4. Principal Component Analysis (PCA)

PCA was conducted to reduce dimensionality and assess the clustering of samples based on biochemical traits. The first two components accounted for 94.34% of the variance (48.35% and 45.99% respectively). The PCA plot (**Figure 3**) highlights a clear separation of Doundodji samples, particularly those of small and medium size, along the fiber-fat axis, supporting the statistical findings of size-provenance interactions.

### 3.5. Discussion

This study on the biochemical characterization of *Balanites aegyptiaca* kernels provided insights into the variability of key biochemical traits across three geographic provenances. While the analysis of variance showed no statistically significant main effects of provenance or size on most parameters, a significant interaction between these two factors was observed for crude fiber content (p < 0.05). This interaction suggests that the effect of nut size on fiber content depends on the origin, and vice versa.

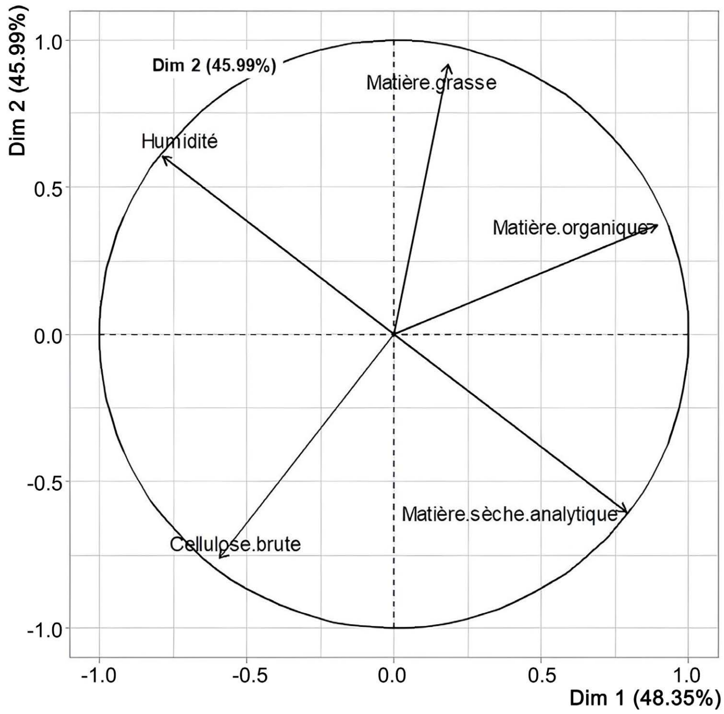


**Figure 3.** Correlation analysis in biochemical parameters according to provenances and caliber.

Dry matter content remained relatively stable in medium and small-sized nuts, with average values around 95%, indicating consistency in water-extractable content across these categories. However, in large-sized nuts, a marked difference was noted: Labgar and Dodji recorded the highest values (approximately 95%), whereas Doundodji presented a substantially lower value (91.01%). This variation may be attributed to genetic differences or localized agronomic practices, as supported by [24], who documented agromorphological diversity among *B. aegyptiaca* individuals from different provenances.

Regarding moisture content, although not statistically significant, large-sized nuts from Doundodji had markedly higher moisture (8.99%) compared to Labgar (5.01%) and Dodji (5.03%). This discrepancy likely stems from post-harvest conditions, particularly the collection of nuts from animal enclosures, which can expose them to ambient humidity and biological degradation. These findings are consistent with studies indicating that storage environment and handling practices significantly affect moisture retention and, ultimately, the shelf life of agricultural products. The moisture values obtained in this study differ substantially from those reported by [25], which ranged from 14.6% to 24.1%. These lower values reinforce the classification of *B. aegyptiaca* as a dry-seeded fruit species, as suggested by [26]. The fruit's quality index, estimated at 2.6, places it in the semi-dry category according to [27]. Together, these indicators support its high storage potential under ambient conditions, with reduced risk of microbial spoilage [26]

[27].

Fat content showed relative uniformity across large and medium sizes at all sites, with values between 44% and 45%. However, for small-sized nuts, Dodji (44.59%) and Labgar (44.42%) had higher fat levels than Doundodji (41.43%). In contrast, [21] reported significantly higher values (up to 52%), suggesting potential regional variability or differences in extraction protocols. The uniformity observed in our results may reflect the predominance of genetic control over fat synthesis, with environmental factors playing a secondary role. Furthermore, the data reveal an inverse relationship between fat and crude fibre content kernels with higher fat content tend to have lower fiber levels a relationship further explored in the correlation analysis.

Although crude fibre content did not vary significantly with size or provenance alone (CV = 13%), the significant interaction indicates complex dynamics. Doundodji samples, particularly small-sized nuts, showed the highest fiber levels (18.32%). These results are lower than those reported by [5] in Téssékéré, despite both areas being ecologically similar. Differences in collection, storage, and processing methods may explain these discrepancies. It is also worth noting that fiber accumulation can be influenced by physiological stress, nutrient availability, and maturity stage, factors that may vary among sites.

Moreover, the nutritional value of *B. aegyptiaca* pulp has been contextualized by [5], who compared its sugar content with other Sudano-Sahelian fruit species. According to their findings, *B. aegyptiaca* pulp has a sugar content comparable to *Ziziphus mauritiana* (37.6%) [28], but lower than *Phoenix dactylifera* (69.9%) [29], *Detarium microcarpum* (64.47%) [30], and *Maerua pseudopetalosa* (67.72%), yet higher than *Adansonia digitata* (7.2% - 11.8%) and *Tamarindus indica* (14.4% - 18.6%) [25]. This suggests that *Balanites* fruits possess a favorable nutritional profile and may be suitable for broader dietary use by local populations.

The findings of [31] confirm that crude fiber content can vary according to growing conditions and cultivation practices, which aligns with our observation of variability among the sites studied. Such variation underscores the importance of localized agronomic management and the need for standardizing post-harvest practices if biochemical quality is to be preserved or improved.

Finally, organic matter content was remarkably consistent across all sizes and origins, with values generally exceeding 96%. This consistency suggests biochemical stability and supports the hypothesis that well-managed environmental and agricultural conditions promote uniform quality. The work of [32] has shown that stability in organic matter is often associated with controlled cultivation systems and minimal external disturbances, which may be the case in the sampled regions.

## 4. Conclusions

This study assessed the biochemical characteristics of *Balanites aegyptiaca* kernels from three communes in Senegal (Dodji, Labgar, and Doundodji) across different size categories. The results showed that provenance and size had no significant effect on the contents of dry matter, organic matter, fat, moisture, and crude fiber, with the exception of a significant interaction between provenance and size for crude fiber. Notably, Doundodji small-sized nuts had the highest fiber content, while fat content was relatively stable, especially in medium and large nuts across sites.

These findings highlight the biochemical stability of the species and its potential for valorization, particularly in oil production and food applications. The strong negative correlation between fat and fiber also offers insights for varietal selection. This study emphasizes the value of indigenous species like *B. aegyptiaca* for sustainable use, suggesting promising opportunities for agro-industrial development, local processing, and future breeding strategies in arid regions.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] Sarr, O., Diatta, S., Gueye, M., Ndiaye, P.M., Guissé, A. and Akpo., L.E. (2013) Importance des ligneux fourragers dans un système agropastoral au Sénégal (Afrique de l'ouest). *Revue de Medecine Veterinaire*, **164**, 2-8.

[2] Fall, A. (2017) Du Ferlo au Bassin arachidier (Sénégal): Analyse de la composition floristique de la végétation envisagée comme ressource et comme indicatrice des changements socio-environnementaux. *Physio-Géo*, **11**, 65-91. https://doi.org/10.4000/physio-geo.5265

[3] Bost, F. (2019) Sahel. Encyclopædia Universalis, 6.

[4] Lebel, T. and Le Barbé, L. (1997) Rainfall Monitoring during HAPEX-Sahel. 2. Point and Areal Estimation at the Event and Seasonal Scales. *Journal of Hydrology*, **188**, 97-122. https://doi.org/10.1016/s0022-1694(96)03325-2

[5] Sagna, M.B., Niang, K.S., Guisse, A. and Goffner, D. (2014) *Balanites aegyptiaca* (L.) Delile: Geographical Distribution and Ethnobotanical Knowledge by Local Populations in the Ferlo (North Senegal). *Biotechnologie Agronomie Société Environnement*, **18**, 503-511.

[6] Bakhoum, A. (2013) Dynamique des ressources fourragères: Indicateur de résilience des parcours communautaires de téssékéré au ferlo (nord-sénégal). Thèse de doctorat unique en en Biologie, Productions et Pathologies Animales, Option Ecologie pastorale, Faculté des Sciences et Techniques-Université Cheikh Aanta DIOP (FST-UCAD), 115.

[7] Sarr, M.A. (2008) Variabilité pluviométrique en Afrique de l'Ouest: Dynamique des espaces végétaux à partir des images satellites. Exemple du bassin versant du Ferlo (Sénégal). *Journées de Climatologie-Nantes-Climat et société*: *Climat et végétation*, **13**, 57-76.

[8] Ndong, A.T., Ndiaye, O., Sagna, M.B., Diallo, A., Galop, D. and Guisse, A. (2016) Caractérisation de la végétation ligneuse sahélienne du Sénégal: Cas du Ferlo. *International Journal of Biological and Chemical Sciences*, **9**, 2582-2594. https://doi.org/10.4314/ijbcs.v9i6.6

[9] Belem, B., Smith, O.C., Theilade, I., Bellefontaine, R., Guinko, S., Lykke, A.M., Diallo, A. and Boussim, J.I. (2008) Identification des arbres hors forêt préférés des populations du Sanmatenga (Burkina Faso). *Bois et Forêts des Tropiques*, **298**, 53-64.

[10] Mapongmetsem, P.M, Tsingsabe, O., Keumeze, V. and Damba A. (2010) Utilisation et commercialisation des produits forestiers non ligneux par les communautés locales en zone soudanienne. Artile, Faculté des Sciences, Université de Ngaoundéré, 12.

[11] Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009) Agro-Forestree Database: A Tree Reference and Selection Guide Version 4.0.

[12] Djagoun, A.J.M. (2018) Estimation de la variabilité morphologique des plantes du sahel à partir des herbiers en lien avec les changements globaux. Mémoire Master, en Agroforesterie Écologie et Adaptation (AFECA), Université Cheikh Anta DIOP de Dakar (UCAD), 54.

[13] Kieffer, M., Boëtsch, G., Demelin, M. and SaЇchi, N. (2012) Le dattier du désert et la grande muraille verte. Fondation d'entreprise pour la protection et la valorisation du patrimoine végétal. Institut Klorane, 40.

[14] Hiernaux, P. and Houérou H.N. (2006) Les parcours du Sahel. *Sécheresse*, **17**, 51-71.

[15] Sy, O. (2009) Rôle de la mare dans la gestion des systèmes pastoraux sahéliens du Ferlo (Sénégal). *Cybergeo*: *European Journal of Geography*, **440**, 1-10.

[16] Faye, A. (2015) Balanites (*Balanites aegyptiaca*) Del., Multipurpose Tree a Prospective Review. *International Journal of Modern Chemistry and Applied Science*, **2**, 189-194.

[17] Diatta, B.D., Niass, O., Gueye, M., Houël, E. and Boëtsch, G. (2022) Diversité et activité antimicrobienne des plantes impliquées dans le traitement des affections dermatologiques chez les Peul et les Wolof du Ferlo Nord (Sénégal). *European Scientific Journal*, **18**, 73-97. https://doi.org/10.19044/esj.2022.v18n8p73

[18] Fall, A. (2014) Le Ferlo sénégalais: Approche géographique de la vulnérabilité des anthroposystèmes sahéliens. Thèse de Doctorat, en Géographie, UFR Lettres Sciences de l'Homme et des Sociétés, Université Paris 13 Sorbonne Paris Cité, 378.

[19] Barral, H. (1982) Le Ferlo des forages: Gestion ancienne et actuelles de l'espace pastoral. Étude de géographie humaine. ORSTOM, 85 p.

[20] Diallo, A., Faye, M., Ndiaye, O. and Guisse, A. (2011) Variations de la composition de la végétation herbacée des plantations de *Acacia senegal* (L.) Willd de la zone de Dahra (Ferlo). *International Journal of Biological and Chemical Sciences*, **5**, 1250-1264. https://doi.org/10.4314/ijbcs.v5i3.72273

[21] Ousmane, N., Aly, D., Bassimbé, S.M. and Aliou, G. (2013) Diversité floristique des peuplements ligneux du Ferlo, Sénégal. *VertigO—La Revue Électronique en Sciences de L'environnement*, **13**, 1-12. https://doi.org/10.4000/vertigo.14352

[22] Thiam, R. (2015) Étude photochimique et détermination d'indices chimiques des huiles de graines de *Balanites aegyptiaca* (L.) DELILE (Balanitaceae) et de *Hibiscus sabdariffa* L. (Malvaceae).

[23] Diouf, P., Diedhiou, S., Goudiaby, A.O.K., Ndoye, I. and Koita, B. (2019) Etude de la Variabilité Morphologique de Saba Senegalensis (A. DC.) Pichon en Casamance (Sénégal). *European Scientific Journal ESJ*, **15**, 500-517. https://doi.org/10.19044/esj.2019.v15n9p500

[24] Sarr, A. (2020) Caractérisation de trios populations de *Balanites aegyptiaca* (L) Del, en zone sahélienne: Cas du ferlo. Mémoire de fin d'études pour l'obtention du diplome d'ingénieur agronome, specialisé en foresterie, départeement des productions végétales, Ecole nationale Supérieure d'Agriculture (ENSA), Thies, 48 p.

[25] Soloviev, P., DaoudaNiang, T., Gaye, A. and Totte, A. (2004) Variabilité des caractères physico-chimiques des fruits de trois espèces ligneuses de cueillette récoltés au

Sénégal: *Adansonia digitata*, *Balanites aegyptiaca* et *tamarindus Indica*. *Fruits*, **59**, 109-119. https://doi.org/10.1051/fruits:2004011

[26] Ben Salah, M. and Hellali, R. (2011) Composition chimique des fruits de 15 cultivars tunisiens de palmier dattier (*Phoenix dactylifera* L.). *FAO*, **148**, 19-25.

[27] Reynes, M., Bouabidi, H., Piombo, G. and Risterucci A.M. (1994) Caractérisation des principales variétés de dattes cultivées dans la région du Djerid en Tunisie. *Fruits*, **49**, 289-298.

[28] Danthu, P., Soloviev, P., Totté, A., Tine, E., Ayessou, N., Gaye, A., *et al.* (2002) Caractères physico-chimiques et organoleptiques comparés de jujubes sauvages et des fruits de la variété Gola introduite au Sénégal. *Fruits*, **57**, 173-182. https://doi.org/10.1051/fruits:2002016

[29] Favier, J.C., Ireland-Ripert, J., Laussucq, C. and Feinberg, M. (1993) Répertoire général des aliments, tome 3. Table de composition des fruits exotiques, fruits de cueillette d'Afrique. Tec Doc Lavoisier, INRA, ORSTOM, 242.

[30] Kouyaté, A.M., Van Damme, P., De Meulenaer, B. and Diawara, H. (2008) Contribution des produits de cueillette dans l'alimentation humaine. Cas de Detarium microcarpum. *Afrika Focus*, **22**, 77-88. https://doi.org/10.1163/2031356x-02201007

[31] Smith, P., Soussana, J., Angers, D., Schipper, L., Chenu, C., Rasse, D.P., *et al.* (2019) How to Measure, Report and Verify Soil Carbon Change to Realize the Potential of Soil Carbon Sequestration for Atmospheric Greenhouse Gas Removal. *Global Change Biology*, **26**, 219-241. https://doi.org/10.1111/gcb.14815

[32] Martínez-García, L.B., Korthals, G., Brussaard, L., Jørgensen, H.B. and De Deyn, G.B. (2018) Organic Management and Cover Crop Species Steer Soil Microbial Community Structure and Functionality along with Soil Organic Matter Properties. *Agriculture*, *Ecosystems & Environment*, **263**, 7-17. https://doi.org/10.1016/j.agee.2018.04.018