

Natural variability in yield and properties of *Balanites aegyptiaca* (L.) Delile kernel oil from different locations in Nigeria

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Abstract. *Balanites aegyptiaca* known as the desert date is an underutilized and neglected wild fruit tree/shrub of the arid and semi-arid zones with high economic potential. This study, therefore, was conducted to investigate the yield, physico-chemical and phytochemical properties, proximate and mineral composition of desert date kernel oil from different locations. Oil was extracted using the soxhlet apparatus, while hexane served as solvent. Standard procedures were used to determine the yield and properties of desert date kernel oil. The data obtained were subjected to the analysis of variance ($p < 0.05$). Oil yield (%) was found to range from 21.09 ± 1.04 - 43.95 ± 1.85 and varied significantly among the locations. Acid and saponification values (mg KOH/g) increased significantly from 2.11 ± 0.07 to 1.36 ± 0.07 and 76.35 ± 0.22 to 179.85 ± 0.90 , respectively. The refractive index ranged from 1.36 ± 0.15 to 1.48 ± 0.06 , while the iodine value (mg KOH/g) varied significantly from 67.07 ± 1.53 to 85.33 ± 2.52 . Saponins, tannins, and phenol were discovered to vary significantly among the locations, and range from 3.82 ± 0.30 - 5.83 ± 0.45 (mg/100 g), 1.31 ± 0.10 - 1.68 ± 0.03 (mg/100 g) and 1.51 ± 0.05 - 2.09 ± 0.06 (mg/100 g), respectively. The broad variability observed in the properties of desert date kernel oil among locations indicates the feasibility of improving kernel oil yield and properties through selection

Keywords: Desert date, underutilized tree species, physico-chemical properties, phytochemical properties, proximate composition, kernel oil

1. Introduction

The potential use of neglected and underutilized seed oil-bearing trees is yet to be exploited to its fullness. According to Ajayi (2010), underutilized seed kernels have the potential to supply a significant amount of oil for domestic and industrial use. Seed oils provide some of the major ingredients used in pharmaceutical and other industries (Nzikou et al., 2010). The quality and application of seed oil are determined by its physico-chemical properties, while the mineral elements are some of the major components of a healthy diet (Zahir et al., 2017). Physico-chemical and phytochemical properties, oil yield, proximate and mineral composition depend on the seed oil, and these properties are not evenly distributed, they are reported to vary based on location and species.

The physico-chemical properties of the seed oil of some indigenous and underutilized forest tree species were reported to significantly vary among species in Nigeria (Ajayi, 2010), while in Mexico the chemical composition among the nuts of five populations of *Pinus cembroides* was observed to differ significantly (Valero-Galván et al., 2019). The oil yield, protein, and mineral content of desert date kernel were reported to vary based on locations in Sudan (Elfeel, 2010). While it might not be possible to identify all the drivers responsible for these differences, several factors such as environmental conditions and silvicultural practices applied to the trees while growing (Beltrán et al., 2021) and genotype (Simsek et al., 2013) could be regarded as some of the major factors responsible for this variation. In China for instance, some mineral elements such as Fe, Zn, and Ca in the Kernel of *Juglans mandshurica* were reported to correlate positively with some important geo-climatic factors (Li et al., 2022) signifying the influence of the environment on seed oil properties.

Balanites aegyptiaca which is commonly called desert date is one of the important wild fruit trees in the arid and semi-arid regions of the world. This species is distributed in many African, Asian, and Middle East countries (Orwa et al. 2009). The tree has nutritional, medicinal, and economic benefits (Okia et al., 2013; Al-Maliki et al., 2016). However, despite the economic potential of this species, it remains underutilized and neglected. Oil extraction from the kernels of desert date for subsistence domestic use was reported in some countries in Africa (Okia, 2010). However, inadequate information on the oil properties has hindered its full exploitation for both domestic and industrial use.

Though some studies have been carried out on the oil properties of Desert date (Chapagain and Wiesman, 2005; Elfeel, 2010; Hassan et al., 2021), we are not aware to the best of our knowledge of any study that investigated the effect of kernel source (locations) on the yield, physico-chemical and phytochemical properties, proximate and mineral composition of desert date kernel oil. This study was therefore conducted to provide information on the effect of kernel sources (locations) on the yield and properties of desert date oil that could aid in the full exploitation of the oil products as well identifying the location(s) (source (s)) that could serve as potential germplasm for improving yield and other properties of the oil.

2. Methods

Ten (10) trees were randomly selected at a minimum of distance of 100 m apart from the natural population of the species (Abasse et al., 2011; Ivetić et al., 2016) in eight locations (Table 1). This was done in order to avoid selecting close relatives during selection and to preserve the genetic variability of the population. Five (5) kg of ripe fruits were collected from each tree in each location during the fruiting season of 2022. The fruits were soaked overnight in water and de-pulped the next day by hand washing to obtain the nuts. The nuts were broken manually using a hammer to obtain the kernels. The kernels in each location were bulked to ensure an equal representation of the variability of the kernel in the location after which drying and blending into powder form was done using a blender (Figure 1).

Table 1. Geographic characteristics of the source of kernels

Location	Longitudes	Latitudes	Elevation
Baure	008°43.496	12°50.407	403.7
Buratai	012°02.535	11°01.488	537.8
Dumsai	010°33.325	12°51.615	344
Gamawa	010°35.661	12°11.397	355.5
Gashua	011°00.770	12°52.496	334.1
Guri	010°24.755	12°45.313	347.9
Kirikasama	010°20.296	12°40.213	387.2
Mashi	007°56.316	12°57.681	507.2

Note: Latitude, longitude, and elevation are averaged of 10 sampling points.

2.1. Oil extraction

500g of the kernel powder (M1) from each location was placed in a thimble and loaded into a soxhlet apparatus for extraction. Hexane was used as a solvent for the extraction. After the extraction, the solvent was separated from the oil with the aid of a rotary vapourator. The resulting oil was weighed (M2) and Oil yield (%) was determined gravimetrically and expressed in percentage using the formulae below:

$$\text{Yield (\%)} = \frac{M2}{M1} \times 100\% \quad (1)$$

Where: M2 = weight of kernel power, M2 = weight of oil exacted



Figure 1. (a) *Balanites aegyptiaca* fruits, (b) Toast kernels of *Balanites aegyptiaca*, (c) Grinded kernel of *Balanites aegyptiaca* (d) Samples of oil extracted from *Balanites aegyptiaca* kernels

2.2. Assessment of physico-chemical properties

The physico-chemical properties were analysed using standard methods described by (AOAC, 1990)

Refractive index (RI): Refractometer was used to measure RI in the kernel oil.

Viscosity (VI): Viscometer was used to determine VI

Acid value (AV): AV was calculated using the equation given below:

$$AV \text{ (mgKOH/g oil)} = \frac{56.1 \times V \times C}{W} \quad (2)$$

Where; V = Volume of standard potassium hydroxide used, C = Concentration of potassium hydroxide used, W = Weight of oil (g)

Saponification value (SV): SV was determined from the relationship given below:

$$SV \text{ (mgKOH/g oil)} = \frac{56.1 \times C \times (V_0 - V)}{W} \quad (3)$$

Where C = Concentration of HCl used, V₀ = Volume of HCl used for blank, V = Volume of HCl used for oil sample, W = Weight of oil (g)

Iodine value (IV): IV was computed according to the formulae below:

$$IV \text{ (mgKOH/g oil)} = \frac{(B - S) \times M \times 12.69}{W} \quad (4)$$

Where; B= volume of Na₂S₂O₃ used for blank titration, S= volume of Na₂S₂O₃ used for oil sample, M= molarity of Na₂S₂O₃ (0.1), 12.69 = constant (meq weight of iodine)

2.3. Proximate composition

The proximate composition of the oil was determined according to standard laboratory procedures (AOAC, 1990)

Moisture content: The oven dehydration method was employed. Oil samples of known weight were dehydrated between 95-100°C for 5hr. Moisture content was computed according to the formula given below:

$$MC (\%) = \frac{W_1 - W_2}{W} \times 100 \quad (5)$$

Where; W1 = weight of the empty crucible, W2 = weight of crucible + sample, W3 = weight of crucible + sample after, W = Weight of oil (g)

Crude protein

The Kjeldahl method for protein analysis was used to determine protein contents. Nitrogen content was calculated using the volume of standardized acid used during the titration and then converted to crude protein using the conversion factor of 6.25 (Nielsen, 2006).

2.4. Mineral composition

The mineral contents were analysed by dry ashing samples as described by Atasie and Akinhanmi (2009). A flame photometer was used to determine calcium (Ca), sodium (Na), and potassium (K) while the atomic absorption spectrophotometer was used for determining magnesium (Mg), iron (Fe), copper (Cu), and zinc (Zn).

2.5. Phytochemical analysis

Phytochemicals are screened and quantified according to the standard procedures described by Obadoni and Ochuko (2001)

2.6. Data analysis

The data were subjected to ANOVA ($p < 0.05$), Duncan multiple range test was used to separate means where necessary.

3. Result and Discussion

3.1. Percentage oil yield (OY) of desert date from different locations

The source of desert date kernel had a significant influence on the percentage of oil yield. Kernel oil was highest (43.95) in Guri and least (21.09) in Buratai (Figure 2). The significant variation in oil yield among locations observed in this study was in agreement with that of Ajayi (2010) who reported a significant variation in the seed oil yield of some underutilized indigenous crops of Nigeria. The yield of 23.11 - 43.95 % recorded in this study was higher than 19.8 - 40 % reported in desert date kernel oil from Sudan by (Elfeel 2010) but lower than 39.20 - 50.22 % recorded by Chapagain and Wiesman (2005) in desert date kernel oil sourced from different countries. According to AOAC (1990), an oil yield of ≥ 32 % is the standard range of yield accepted for commercial production. This implies that Guri could serve as a good source of the kernel for the commercial production of desert date oil.

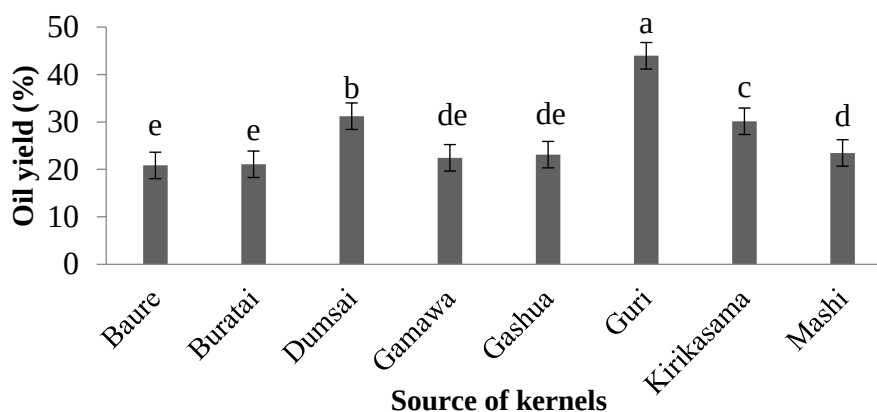


Figure 2. Oil yield among sources of desert date kernel

Note: : Mean carrying the same alphabet did not vary significantly $p < 0.05$. The error bars indicate the standard error.

3.2. Physico-chemical properties of desert date kernel oil from different locations

The RI and VI of the kernel oil were not significantly different among locations (Table 2). The RI of oil among the locations ranged from 1.36 ± 0.15 (Mashi) to 1.48 ± 0.06 (Gamawa). The VI varied from 41.33 ± 2.08 cP (Gashua) to 48.67 ± 2.52 cP (Buratai). A significant variation in the AV, SV, and IV of desert date oil was observed among sources (Table 2). The AV was highest (2.11 ± 0.07 mg KOH/g) in Baure and least (1.36 ± 0.07 mg KOH/g) in Dumsai. The SV increased from 76.35 ± 0.22 mg KOH/g (Guri) to 179.85 ± 0.90 mg KOH/g (Kirikasama). The IV varied from 67.07 ± 1.53 mg KOH/g in Gamawa to 85.33 ± 2.52 mg KOH/g in Baure. The CV in physico-chemical properties among the sources of kernel oil was highest in RI (9.12). VI, AV, IV, and SV had a CV of 6.91, 5.28, 1.83, and 0.55, respectively (Table 2).

Table 2. Physico-chemical properties of desert date kernel oil from different locations in Nigeria

	RI	VI	AV	SV	IV
Baure	1.39 ± 0.06^a	42.33 ± 4.93^a	2.11 ± 0.07^a	129.85 ± 0.65^e	85.33 ± 2.52^a
Buratai	1.43 ± 0.0^a	48.67 ± 2.52^a	1.96 ± 0.07^{ab}	107.74 ± 1.42^e	71.43 ± 1.59^{bc}
Dumsai	1.45 ± 0.26^a	44.0 ± 2.65^a	1.36 ± 0.07^e	114.31 ± 0.37^d	67.93 ± 1.10^d
Gamawa	1.48 ± 0.06^a	36.67 ± 2.52^a	1.92 ± 0.15^{bc}	154.48 ± 0.77^b	67.07 ± 1.53^d
Gashua	1.45 ± 0.03^a	41.33 ± 2.08^a	1.62 ± 0.06^d	89.55 ± 0.45^f	70.80 ± 1.37^{bc}
Guri	1.44 ± 0.05^a	45.0 ± 5.0^a	1.64 ± 0.11^d	76.35 ± 0.22^g	72.11 ± 1.39^b
Kirikasama	1.46 ± 0.04^a	41.67 ± 2.52^a	1.84 ± 0.09^{bc}	179.85 ± 0.90^a	69.06 ± 0.65^{cd}
Mashi	1.36 ± 0.15^a	44.67 ± 1.53^a	1.76 ± 0.13^{cd}	108.06 ± 0.54^e	71.65 ± 0.54^{bc}
CV (%)	9.12	6.91	5.28	0.55	1.83
F-Stat	1.07	3.55	16.92	6112.7	46.27
Sig	0.43 ^{ns}	0.02*	0.00*	0.00*	0.00*

Note: Mean carrying the same alphabet did not vary significantly $p < 0.05$. Mean values are followed by the standard deviation. F= test value in the ANOVA table, ns = non-significant, * = significant. OY = Oil yield (%), RI = Refractive index, VI = Viscosity (cP), AV = Acid value (mg KOH/g), Iodine value (mg KOH/g), SV = Saponification value (mg KOH/g).

The value of the RI in this study is within the acceptable range of 1.45 to 1.48 according to ASTM International (2002). Similar values were reported in some popular seed oil such as groundnut oil 0.15-1.47 (Andrew et al. 2012) and sesame oil 1.46 (Njoku et al. 2010). The VI recorded in this study is similar to the value of 49 cP reported by Chapagain et al. (2009). The AV recorded from all the locations in this study is within the acceptable value of 4 mg/KOH/g at the maximum recommended for consumption by Codex Stan 19-(1993). The edibility of oil can be determined by its acid value (Tesfaye and Abebaw 2016). This implies that desert date kernel oil in all the locations could be used as edible oil for cooking. The SV in this study was lower than the recommended value of ≥ 180 mgKOH/g for use as raw material for soap production (AOAC, 1990). However, it was higher than the SV of corn oil (153.8 mg KOH/g) and mustard oil (125.6 mg KOH/g) according to Zahir et al. (2017). The IV in this study was within the value of 80 to 100gI₂/100g considered the standard according to (AOAC, 1990). The kernel oil in this study could be considered non-drying based on Ouattara et al. (2015) classification. This implies that desert date kernel oil in all the locations could be suitable for the production of vegetable oil-based ice cream. The IV recorded in this study was less than what was reported by Okia (2010) in Uganda where a value of 98.20 – 103.32 I₂ g/100 g was recorded. Variations in physico-chemical properties observed in this study and other studies could be attributed to environmental factors and the genotype of the tree crops.

3.3. Proximate and mineral composition of desert date kernel oil from different locations

The proximate and mineral composition of the kernel oil varied significantly among the locations (Table 3). The moisture content (MC) increased from 3.11 ± 0.01 (Baure) to 8.10 ± 0.02 (Gamawa). The ash content ranged from 0.32 ± 0.02 g/100g (Mashi) to 0.49 ± 0.01 g/100g (Gamawa). The protein content was highest (12.38 ± 0.07 g/100g) in Baure and least (10.61 ± 0.06 g/100g) in Mashi location. Ca, Na and K ranged from 2.12 ± 0.08 mg/100g (Baure) to 6.60 ± 0.16 mg/100g (Guri), 6.18 ± 0.11 mg/100g (Gashua) to 7.97 ± 0.12 mg/100g (Guri) and 12.5 ± 0.53 mg/100g (Mashi) to 3.83 ± 0.16 mg/100g (Gamawa), respectively. Mg varied from 0.68 ± 0.01 mg/100g in Buratai to 1.11 ± 0.02 mg/100g in Baure. Cu content was highest (0.17 ± 0.01 mg/100g) in Kirikasama and least (0.08 ± 0.01 mg/100g) in Guri and Mashi (Table 3). Mineral elements such as Ca, K, Na, Mg, Cu, and Zn in the kernel oil in this study vary in quantity depending on the location.

Table 3. Proximate and mineral composition of desert date kernel oil from different locations in Nigeria

	MC	Ash	Pro	Ca	Na	K	Mg	Cu	Zn
Baure	3.68±0.01g	0.37±0.02 ^{cd}	12.38±0.07 ^a	2.12±0.08 ^e	6.94±0.10 ^{cd}	10.75±0.58 ^b	1.11±0.02 ^a	0.12±0.0 ^c	0.18±0.0 ^e
Buratai	3.87±0.03 ^f	0.43±0.02 ^b	12.13±0.07 ^b	2.93±0.07 ^d	6.92±0.10 ^{cd}	10.23±0.07 ^{bc}	0.68±0.01 ^e	0.14±0.0 ^b	0.10±0.0 ^h
Dumsai	7.29±0.02 ^b	0.46±0.02 ^{ab}	11.59±0.06 ^c	2.84±0.07 ^d	7.95±0.12 ^a	7.85±0.11 ^e	0.86±0.01 ^c	0.12±0.0 ^c	0.10±0.0 ^g
Gamawa	8.10±0.02 ^a	0.49±0.01 ^a	12.20±0.12 ^b	5.23±0.13 ^b	6.81±0.12 ^d	3.83±0.16 ^g	1.02±0.01 ^b	0.10±0.01 ^d	0.14±0.0 ^e
Gashua	3.11±0.01 ^h	0.35±0.01 ^{de}	11.36±0.06 ^d	3.24±0.10 ^e	6.18±0.11 ^e	9.60±0.44 ^c	0.77±0.0 ^d	0.09±0.0 ^e	0.19±0.0 ^a
Guri	5.98±0.01 ^d	0.39±0.01 ^c	11.57±0.06 ^c	6.60±0.16 ^a	7.97±0.12 ^a	6.33±0.26 ^f	0.69±0.02 ^e	0.08±0.01 ^e	0.19±0.0 ^a
Kirikasama	4.14±0.01 ^e	0.39±0.02 ^c	10.94±0.06 ^e	3.21±0.08 ^c	7.20±0.11 ^b	8.81±0.61 ^d	0.79±0.01 ^d	0.17±0.01 ^a	0.13±0.0 ^f
Mashi	7.25±0.02 ^c	0.32±0.02 ^e	10.61±0.06 ^f	2.88±0.07 ^d	7.11±0.11 ^{bc}	12.5±0.53 ^a	1.04±0.05 ^b	0.08±0.01 ^e	0.17±0.0 ^d
CV	0.25	4.51	0.60	2.72	1.56	3.93	1.90	4.47	0.43
F-Stat	48.23	22.60	3.40	660.94	86.76	137.59	172.35	118.94	5233.4
Sig.	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00

Note: Mean carrying the same alphabet did not vary significantly $p < 0.05$. Mean values are followed by the standard deviation. MC = Moisture content (%), Ash = Ash content (g/100g),

Pro = Protein (g/100g), Ca = Calcium (mg/100g), Na = Sodium (mg/100g), K = Potassium (mg/100g), Mg = Magnesium (mg/100g), Cu = Copper (mg/100g), Zn = Zinc (mg/100g)

This result agreed with that of Li et al. (2022) who reported a significant variation in Fe, Zn, Ca, and Mg among *Uglans mandshurica* Kernel in China. Similar quantities of mineral elements were also observed in desert date kernel oil in Jos, Nigeria (Zang et al., 2017). However, higher mineral values were reported by Atasie and Akinhanmi (2009) in common edible oils in Nigeria (palm ke rnel oil). The MC of the kernel oil was similar to 8.73% reported by Jauro and

Adams (2011) in desert date kernel oil. The low MC of the kernel oil recorded in this study could be an indication of long shelf life and therefore signify the ability of the oil to be stored for a long without getting spoilt.

3.4. Phytochemical properties of desert date kernel oil from different locations

The quantity of tannins, phenol, and saponins in the oil differed significantly among the sources (Table 4) Tannin content ranged from 1.31 ± 0.10 mg/100g (Baure) to 1.68 ± 0.03 mg/100g (Dumsai). The highest quantity of saponins (5.83 ± 0.45) mg/100g was recorded in Dumsai, while Guri source had the least (3.82 ± 0.30 mg/100g). Phenol content decreased from 2.09 ± 0.06 mg/100g in Buratai to 1.51 ± 0.05 mg/100g in Baure. The CV of phenol compound among the locations was very high (26.82) compared with saponins and tannin (Table 4).

Phenol, saponin, and tannin were present in the kernel oil of all the locations. Hassan et al. (2021) also reported the presence of saponins, flavonoids, and alkaloids in the kernel oil of desert date. However, Zang et al. (2017) reported the absence of these phytochemicals. The contradictions among the results could be a function of oil extraction methods used and screening techniques used for identifying the phytochemicals. The source or locations where the kernel was sourced could also affect the availability of these photochemical. Photochemical contents have been reported to vary widely among and within different sources (Lutz et al., 2016). The high phenol and saponin content recorded in Buratai implies that kernel from Buratai could serve as a good source of phenol and saponin. The presence of saponin is an indication that the oil can produce lathering products like soap and hair shampoos.

Table 4. Phytochemical properties of desert date kernel oil from different locations in Nigeria

Sources	Phenol (mg/100g)	Saponins (mg/100g)	Tannin(mg/100g)
Baure	1.51 ± 0.05^c	5.27 ± 0.40^{ab}	1.31 ± 0.10^b
Buratai	2.09 ± 0.06^a	5.20 ± 0.40^b	1.64 ± 0.02^a
Dumsai	2.01 ± 0.19^{ab}	5.83 ± 0.45^a	1.68 ± 0.03^a
Gamawa	1.68 ± 0.01^c	4.2 ± 0.21^{cd}	1.64 ± 0.04^a
Gashua	1.97 ± 0.09^{ab}	5.52 ± 0.34^{ab}	1.66 ± 0.07^a
Guri	1.90 ± 0.06^{ab}	3.82 ± 0.30^d	1.66 ± 0.07^a
Kirikasama	1.89 ± 0.03^b	4.50 ± 0.20^c	1.64 ± 0.05^a
Mashi	1.15 ± 0.18^d	4.07 ± 0.25^{cd}	1.64 ± 0.03^a
CV (%)	5.23	6.59	3.27
F-Sta	26.82	15.09	14.30
Sig	0.00	0.00	0.00

Note: Mean sharing different alphabet vary significantly $p < 0.05$ Mean values are followed by standard deviation

4. Conclusions

Yield, physico-chemical and phytochemical properties, proximate and mineral composition of desert date kernel oil from different locations in Nigeria were investigated. The oil yield was discovered to vary among the locations with a percentage yield suitable for commercial production. The physico-chemical and phytochemical properties and proximate and mineral composition vary widely among kernel locations, indicating the feasibility of improvement in kernel oil properties through selection. The RI, AV, and IV in this study were within the acceptable range recommended. This supported the feasibility of the utilisation of kernel oil for domestic and industrial purposes. Saponins, phenols, and tannins were present in kernel oil as well as mineral elements such as Ca, K, Na, Mg, Cu, and Zn. The variation in yield and the properties of desert date kernel oil from different locations signifies the possibility of improving kernel oil yield and properties through germplasm selection

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