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Characterization of Majhoul Dates from Different Geographical Sites of the Drâa-Tafilalet Area

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Abstract

This study provides a comprehensive characterization of "Majhoul" dates (*Phoenix dactylifera* L.) from four major growing regions of Drâa-Tafilalet area Morocco (Boudnib, Erfoud, Goulmima, and Zagora). The research aimed to evaluate the impact of local conditions on fruit quality through integrated physicochemical, biochemical, and microbiological analyses. Significant variations were observed across localities: moisture content ranged from 20.59 % to 25.00 %, water activity (a_w) from 0.618 to 0.766, and total sugars from 72.23% to 75.87%. These compositional differences directly influenced microbial stability, with higher moisture correlating with increased microbial risks. Biochemically, protein content varied significantly (1.74%-1.98 %), while lipid content remained consistently low (0.1 %). Microbiological assessment revealed excellent hygienic quality with the absence of pathogenic bacteria (*E. coli*, *Salmonella, Listeria*) but showed elevated fungal mesophilic aerobic thermophilic loads in Zagora samples (4×10^6 colony-forming units per gram (CFU)/g), indicating the need for optimized postharvest management. The findings demonstrate that local factors significantly determine Majhoul date quality and underscore the importance of controlled drying and storage conditions for enhancing preservation, safety, and marketability of this economically important variety.

Keywords: Biochemical, Food safety, Majhoul dates, *Phoenix dactylifera*, Physicochemical, Postharvest.

Introduction

Date palm (*Phoenix dactylifera* L.) is a perennial crop in arid and semi-arid regions, including North Africa, the Middle East, as well as parts of Europe and arid areas in the U.S., Mexico, Peru and Chile. It is distinguished by its remarkable adaptability to desert

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environments, where it resists extreme temperatures and water scarcity (Aziz Elhoumaizi et al., 2023).

Date palm (*Phoenix dactylifera* L.) is one of the oldest fruit trees cultivated in arid regions of the Arabian Peninsula, North Africa, and the Middle East. This crop is highly valued for its ecological, economic, and social importance. Dates are known for their high sugar content (fructose, glucose, and sucrose), dietary fiber, and essential vitamins and minerals (Jdaini et al., 2022).

In Morocco, the date palm represents about 4.5% of the world's date palm population. The country ranks seventh worldwide in terms of land area devoted to date cultivation, eleventh in the number of date palms, and twelfth in date production. Date production in Morocco, reaching approximately 100,000 tons per year in favorable seasons, plays a key role in income generation, contributing 40–60% of the livelihood of nearly two million people living in oasis ecosystems (Morad et al., 2024).

The Moroccan date palm sector covers about 50,000 hectares, representing nearly five million palm trees. The palm groves of the Tafilalet and Drâa regions account for almost 90% of national date production. However, current production remains insufficient to meet national market demands in both quality and quantity (Refrigeration preservation of Moroccan dates: Inventory and evaluation of physical and sensory criteria for quality). In 2020, total date production reached approximately 140,000 tons, encompassing more than 220 varieties, including a large proportion of Khalts (45%), mainly originating from seed propagation. Several high-quality cultivars such as Boufeggous, Majhoul, Bouskri, and Aziza Bouzid are also cultivated. Morocco imports around 80,000 tons of dates annually, primarily from Tunisia, with the Deglet Nour variety accounting for nearly 90% of dates marketed in Europe. Dates are widely consumed in eastern and southeastern oases, where they constitute a staple food, while in urban areas consumption peaks during Ramadan and Ashura(Jdaini et al., 2022).

Many recent studies have explored the morphological and chemical aspects of different parts of the date palm. The date fruit has attracted particular attention because both the pulp and seeds are consumed and contain various nutrients, including proteins, sugars, lipids, vitamins, magnesium, iron, potassium, and a significant amount of calcium (Hachani et al., 2018).

More specifically, recent research has contributed to a deeper characterization of the Majhoul cultivar at different levels. Genetic studies based on next-generation sequencing have revealed plastid genome polymorphisms that enable cultivar discrimination and authentication of Majhoul dates (Sadder et al., 2025)-. At the morphological and agronomic levels, fruit quality has been shown to vary significantly according to flowering phases, fruit load, and pollination conditions, which influence parameters such as fruit weight, dimensions, and the occurrence of external defects (Salomón-torres et al., 2025; Cohen et al., 2025). In addition, postharvest studies have demonstrated that storage and processing techniques, including freezing and drying, affect several physicochemical attributes of Majhoul dates, such as water activity, texture, phenolic compounds, and color, while sugars remain relatively stable, highlighting the importance of postharvest handling in preserving fruit quality (Noutfia et al., 2025a; b).

In the Drâa-Tafilalet region, several studies on the Majhoul variety have reported significant variations in fruit morphological and chemical characteristics across production conditions. In particular, flowering phases strongly influence fruit morphological traits such as weight, size, and volume, with early flowering associated with superior morphological quality (Arba, Berjaoui, and Sabri, 2023). Other studies have shown that certain cultural practices can modulate chemical and organoleptic parameters of Majhoul dates, including pH, sugar content, and ripening dynamics, while titratable acidity remains relatively stable (Arba, Elladi, and Ouachouo, 2025).

Dates produced in Morocco, such as Majhoul, Elkhalsse, and Tarzawa, are mainly classified according to their geographical origin to meet consumer preferences. Their nutritional value is largely attributed to their high sugar content (glucose, fructose, sucrose), and to a lesser extent maltose and galactose, with proportions varying depending on the cultivar and dry matter content (Essebbahi et al., 2023).

While several studies have investigated the Majhoul cultivar, most have focused on genetic, agronomic, or technological aspects, or on the effects of specific cultivation practices and postharvest treatments. However, studies providing an integrated characterization combining physicochemical, compositional, and microbiological analyses of Majhoul dates from the Drâa-Tafilalet region remain limited. The objective of the present study is therefore to perform a comparative characterization of Majhoul dates from several representative areas of this region (Boudnib, Erfoud, Goulmima, and Zagora) to assess the influence of geographical origin on overall fruit quality and to generate scientific data to support the valorization of this cultivar.

Material and Methods

Dates samples

Four date samples of the Majhoul variety were collected in October 2024 at the tamar stage (full maturity) from the Drâa-Tafilalet region (Morocco), including Boudnib, Erfoud, Goulmima, and Zagora. For each region, three subsamples of 1 kg each were collected from different trees within the main production area to ensure representativeness. Fruits were harvested at full maturity, when dates reached their optimal texture, placed in sterilized bags, and transported under controlled conditions to avoid contamination.

Physicochemical analyses

Water activity

The water activity (a_w) is determined by preparing the sample at a constant temperature, typically 25°C, and placing it in an airtight container to prevent vapor exchange. Water activity is measured using a water activity meter that evaluates the water vapor balance in a closed system. Before each series of measurements, the device is calibrated using standard salt solutions. The water activity obtained is between 0 (dry product) and 1 (pure water) and allows for microbiological stability of food(Aziz Elhoumaizi et al., 2023) .

Total titratable acidity

The total titratable acidity was measured in the juice by titration with a 0.1 N solution of sodium hydroxide, using phenolphthalein as an indicator. Results were expressed as a percentage of citric acid. To do this, 25 g of fruit pulp was mixed with 50 ml of distilled water, boiled, in a blender and then filtered. A volume of 25 ml of the resulting filtrate was used for titration, following the procedure described by Alahyane et al. (2022), and all measurements were performed in triplicate to ensure accuracy.

Moisture content

Moisture content was determined by placing samples in a vacuum oven set at 70°C for 48 hours. This method removes all water from the samples, ensuring accurate measurement of residual moisture (Hasnaoui et al., 2010).

Brix

Soluble solids (SS) were measured in Brix fruit juice using a manual refractometer. To do this, 10 g of date pulp was dissolved in 100 mL of distilled water, then the juice was separated, centrifuged at 4000 tr/min for 15 minutes and filtered through filter paper. The°Brix of the juice was then measured with the refractometer(Younés Noutfia, Alem, and Filali Zegzouti, 2019).

Ash content

Ash content was measured by burning samples in a muffle oven at an elevated temperature of 600°C for 8 hours. This process destroys all organic matter, leaving only the minerals as residues, which allows us to quantify their proportion in the sample(Hasnaoui et al., 2010).

Dry matter

The determination of dry matter (DM%) is done in two stages. First, the moisture content (H%) of the fruit is measured by comparing the fresh weight and dry weight of the fruit after drying at 105°C. Then, the dry matter is obtained by subtracting 100% water content. This allows for an estimate of the proportion of fruit composed of non-aqueous substances, expressed as a percentage(Elmejhed et al., 2024).

Biochemical analyses

Lipid content

Approximately 30 g of pulp was used to extract the raw fat using a Soxhlet extractor with n-hexane as solvent. After evaporation of the solvent, the lipid content was expressed in g/100 g dry pulp (Alahyane et al., 2022).

Protein content

The protein content was determined by the Kjeldahl method. After total nitrogen was measured, protein content was calculated using the conversion factor of 6.25, as per AOAC (1997)(Hasanaoui et al., 2010).

Carbohydrate Content

The total carbohydrate content was estimated by calculation, using the difference method recommended for nutritional analyses. This method involves subtracting the sum of the percentages of the main components (proteins, fats, moisture, ash, and dietary fiber) from 100. This approach provides the proportion of total carbohydrates present in the sample, expressed as a percentage of the fresh matter. The results thus represent the total carbohydrate content, including simple sugars, complex sugars, and any non-fibrous polysaccharides (Alahyane et al., 2022).

Determination of Energy Value

The energy value of the date fruit varieties and clones was calculated by multiplying the percentage of crude protein, fat, and carbohydrate by their respective factors, then summing the results, according to the formula provided by Crisan and Sands (1978):

Energy value (Kcal / 100 g) = (2.62 × % protein) + (8.37 × % fat) + (4.2 × % carbohydrate) (Alahyane et al., 2022)

Microbiological analysis

Ten grams of each sample were homogenized with 90 mL of sterile peptonic water using a stomacher (Lab-Blender 400 circulator, Seward Medical). The suspensions obtained were successively diluted to decimal places, and 0.1 mL of each dilution was used for the enumeration of target microorganisms. All analyses were performed in three replicates, and the results are expressed as the logarithm of colony-forming units (log CFU).

Microbiological analyses were performed using standard methods. Total aerobic mesophilic flora (TMF) was analyzed according to the NM ISO 4833 standard. Total coliforms were enumerated at 30°C in accordance with NM ISO 4831, while Escherichia coli was evaluated at 40°C in accordance with NM ISO 16649-2. Yeasts and molds were counted according to NF V 08-059, and enterobacteria were determined in accordance with NF V 08-054.

Coagulase-positive staphylococci were detected using NM ISO 6888-2. Salmonella spp. was performed according to NM ISO 6579-1, and Listeria monocytogenes according to NM ISO 11290-2. These protocols ensure the reliability and reproducibility of results in accordance with international standards (Aziz Elhoumaizi et al., 2023; Hasnaoui et al., 2010).

Statistical analyses

Statistical analysis of data was carried out using the Minitab 18 software. The ANOVA (Analysis of variances) was applied to determine the effect of the different studied factors on the measured parameters. This method made it possible to verify the significance of the differences between the averages of the compared groups. In addition, the standard errors of the measurements were calculated in order to estimate the accuracy of the experimental data and better interpret the results(Aziz Elhoumaizi et al., 2023).

Results and Discussion

Physicochemical parameters

The physicochemical results are presented in Table 1 and revealed significant differences among the studied localities for all measured parameters, as confirmed by the analysis of variance (ANOVA). The highest moisture content was recorded in dates from the Goulmima region (25.00%), followed by Zagora (20.60%), while similar values were observed in Boudnib (20.59%) and Erfoud (20.68%). Likewise, water activity was highest in Goulmima (0.766), followed by Zagora (0.678), Erfoud (0.633), and Boudnib (0.618).

Table 1. Physicochemical parameters of Majhoul dates in the region of Boudnib, Goulmima,Erfoud and Zagora, Tafilalet area, Morocco.

		Parameters					
		Moisture content (%)	**Water activity**	**Dry matter content (%)**	**Acidity (méq/kg)**	**Total ash content (%)**	**Brix (%)**
Localities	**Boudnib**	20.590 ^{c} ±0.008	0.618 ^{d} ±0.001	79.40 ^{a} ±0.03	15.00 ^{a} ±0.35	1.63 ^{a} ±0.01	67.00 ^{a} ±0.11
	Goulmima	25.000 ^{a} ±0.006	0.766 ^{a} ±0.001	75.00 ^{d} ±0.03	14.00 ^{b}±0.34	1.02 ^{c} ±0.01	66.40 ^{b} ±0.11
	Erfoud	20.680^{b} ±0.006	0.633 ^{c} ±0.001	79.30 ^{b} ±0.03	15.00 ^{a} ±0.35	1.61 ^{a} ±0.01	66.00 ^{c} ±0.11
	Zagora	20.600 ^{c} ±0.008	0.678^{b} ±0.001	76.00 ^{c} ±0.03	14.00 ^{b}±0,36	1.20 ^{b} ±0.01	66.20 $^{b\,c}$ ±0.11

The averages that do not share the same letter (a, b, c, and d) are significantly different

Dry matter content was inversely proportional to moisture content, with the highest values recorded in Boudnib (79.40%) and Erfoud (79.30%), followed by Zagora (76.00%) and Goulmima (75.00%). Titratable acidity was higher in Boudnib and Erfoud (15.00 méq/kg), compared to 14.00 méq/kg in Goulmima and Zagora.Ash content was highest in Boudnib and Erfoud, with 1.63% and 1.61%, respectively, while Goulmima and Zagora showed lower values (1.02% and 1.20%, respectively). Regarding total soluble solids, Boudnib recorded the highest value (67.00%), followed by Goulmima (66.40%), Zagora (66.20%), and Erfoud (66.00%).

The findings of the present study align with those of recent studies on date varieties (Nabily et al., 2020). reported that moisture content and water activity are critical factors influencing the shelf life and microbial stability of dates, with lower a_w values (<0.65) being ideal for long-term storage. In a similar vein emphasized the pivotal role of dry matter content and Brix values in determining date quality, with elevated values frequently linked to enhanced nutritional and sensory attributes (Alam et al., 2023; Hazbavi et al., 2015).The findings of this study are in alignment with the observations made by Hamdi et al. (2016), Amadou (2016), Al-Karmadi et al. (2024), and Al-Karmadi and Okoh (2024). who reported that acidity levels in dates are generally low and consistent across diverse varieties. The variations in total ash content may be attributed to differences in soil mineral composition, as suggested by Alahyane et al.(2022) (Alahyane et al., 2022). in their study on Moroccan date varieties. These findings underscore the importance of regional factors, such as soil type, climate, and agricultural practices, in shaping the physico-chemical properties of dates.

Nutritional Value

The biochemical analysis of Majhoul dates from the studded four regions (Boudnib, Goulmima, Erfoud, and Zagora) (Table 2) revealed notable variations in their nutritional composition. The lipid content was low across all samples and did not show any significant differences between the studied localities (0.100%). In contrast, significant variations were observed in the protein content of dates. Dates from Erfoud had the highest protein level

(1.98%), while those from Goulmima showed the lowest (1.74%). Carbohydrates, which constitute the major component of the dates, did not differ significantly among the samples, with values ranging from 72.23% to 75.87%. The energy value of the dates was relatively stable and high, ranging from 296 to 311 Kcal/100 g, reflecting their richness in carbohydrates.

Table 2. Biochemical characters of Majhoul dates from the regions of Boudnib, Goulmima, Erfoud, and Zagora, Tafilalet area, Morocco

		Parameters			
		Lipids(%)	**Protein(%)**	**Total sugars (%)**	**Energy values (Kcal/100g)**
Localities	**Boudnib**	$0.100^{a} \pm 0.014$	$1.90^{b} \pm 0.02$	$75.87^{a} \pm 04.30$	$311.00^{a} \pm 02.90$
	Goulmima	$0.100^{a} \pm 0.011$	$1.74^{c} \pm 0.03$	$72.23^{a} \pm 02.85$	$296.00^{a} \pm 09.30$
	Erfoud	$0.100^{a} \pm 0.011$	$1.98^{a} \pm 0.02$	$75.72^{a} \pm 03.42$	$311.00^{a} \pm 08.43$
	Zagora	$0.100^{a} \pm 0.012$	$1.95^{a\ b} \pm 0.01$	$73.20^{a} \pm 05.20$	$310.00^{a} \pm 06.23$
The averages that do not share the same letter (a, b, c, and d) are significantly different					

These results are consistent with those of recent studies on date varieties Al-Karmadi et al.,(2024) reported carbohydrate contents of 70%–80% in date varieties from the Middle East, emphasizing the role of sugars such as glucose and fructose in contributing to the high energy density of dates (Al-Karmadi and Okoh, 2024). In a similar vein, Ghazzawy et al., (2022) underscored the pivotal influence of geographical and climatic factors, including temperature, soil type, and irrigation practices, on the biochemical composition of dates. This observation potentially elucidates the observed regional variations in protein and carbohydrate content(H.S. et al., 2022). The strong correlation between carbohydrate content and energy value in this study is consistent with observations that have identified dates as an excellent source of energy due to their high sugar content (Meenakshi and Misra, 2023).The minimal lipid content (0.1%) observed in this study is consistent with the findings of other studies reporting low lipid content in Moroccan date varieties(Alahyane et al., 2022)**,** thereby reinforcing the notion that dates are not a significant source of fats (Fernández-López et al., 2022).

Microbiological analysis

The microbiological results of date samples (Erfoud, Goulmima, Bodnib, and Zagora) are summarised in Table 3. This section discusses the detected microbial loads, their implications for food safety, and their compliance with established microbiological standards.The total viable count, measured as coliforms at 30°C, exhibited minimal presence across the samples. Specifically, samples from Goulmima, Bodnib, and Zagora exhibited values below 1 UFC/g, while the Erfoud sample presented a slightly higher but acceptable level of 10^2 UFC/g. These results comply with the Codex Alimentarius microbiological guidelines, which specify a limit of $\leq 10^2$ UFC/g for coliforms in ready-to-eat food products (Fallis, 2013).The low levels of coliforms observed in this study are indicative of effective hygienic practices during harvesting, processing, and storage, as previously reported in studies on postharvest management(Wong, Motomura, and Paull, 2018).

Table 3. Microbiological parameters of Majhoul dates from the regions of Boudnib, Goulmima,Erfoud, and Zagora, Tafilalet area, Morocco

Parameters	Analysis method	Unit	Criteria	Erfoud	Goulmima	Bodnib	Zagora
Total coliforms at 30°C	NM ISO 4831	UFC/g	$\leq 10^2$	10^2	<1	<1	<1
E. coli 40°C	NM ISO 16649-2	UFC/g	≤ 10	ND	ND	ND	ND
FMAT	NM ISO 4833	UFC/g	$\leq 10^5$	$5*10^3$	$4*10^4$	$5*10^2$	$4*10^6$
Yeasts and molds	NF V 08-059	UFC/g	$\leq 10^4$	$3*10^3$	$8*10^3$	10^3	$7*10^2$
Enterobacteriaceae	NF V 08-054	UFC/g	$\leq 10^2$	ND	ND	ND	ND
Coagulase positive staphylococci	NM ISO 6888-2	UFC/g	≤ 10	ND	ND	ND	ND
Salmonella	NM ISO 6579-1	UFC/25g	Absence	ND	ND	ND	ND
Listeria	NM ISO 11290-2	UFC/25g	Absence	ND	ND	ND	ND

Escherichia coli, a key indicator of fecal contamination, was not detected (ND) in any of the samples, demonstrating the absence of significant contamination from human or animal sources. Enterobacteriaceae, which are considered general indicators of unsanitary conditions, were also absent in all samples, thus further confirming the hygienic quality of the dates (Table 3). Conforming with the findings of previous research, which indicated that adequate sanitation measures during the production process lead to a substantial reduction in E. coli prevalence in date fruits (Zamir et al., 2018).

The fungal mesophilic aerobic thermophilic (FMAT) load varied among the samples. Notably, Zagora exhibited the highest FMAT level at $4*10^6$ UFC/g, far exceeding the acceptable limit of 10^5 UFC/g. This elevated level indicates potential contamination due to environmental factors, such as high humidity during storage or insufficient drying of the dates. In contrast, samples from the other regions showed FMAT levels within the permissible range, ranging from 5.10^3 UFC/g in Erfoud to 4.10^4 UFC/g in Goulmima. These results underscore the importance of optimizing storage and drying processes (Van Eck and Puchta, 2019).Yeast and mould counts ranged between 10^3 and $8*10^3$ UFC/g, with the highest level recorded in Goulmima and the lowest in Zagora. All samples complied with the recommended threshold of $\leq 10^4$ UFC/g. These findings suggest effective control measures against fungal growth, though periodic monitoring remains critical. High yeast and mold counts can compromise the sensory and nutritional quality of dates and pose spoilage risks, as highlighted in studies on fungal contamination in dried fruits (Zamir et al., 2018)**.** No pathogenic bacteria, such as Salmonella or Listeria monocytogenes, were detected in any of the samples. This is a critical finding as these pathogens pose serious risks to human health and are considered key indicators of food safety in the context of international trade. The absence of these pathogens highlights the effectiveness of food safety protocols in date production across the studied regions. The findings align with the FAO guidelines (2020) for pathogen-free dried fruit production (Van Eck and Puchta, 2019).These microbiological results align well with the physico-chemical properties and biochemical results previously discussed. The moisture content of dates ranged from 20.59% in Boudnib to 25% in Goulmima, with Goulmima exhibiting the highest moisture level, which typically promotes microbial growth. Despite this, the Samples with lower moisture and water activity (a_w), such as Boudnib (a_w = 0.618), showed minimal coliform presence (≤1 UFC/g), which corresponds with the ideal moisture and a_w conditions for microbial stability. The consistent acidity (pH 14-15) of the samples further inhibits microbial growth, maintaining hygienic quality. The biochemical characteristics of the samples, including carbohydrate content, ranged from 72.23 % in Goulmima to 75.87% in Boudnib, with higher sugar content in Boudnib and Erfoud supporting yeast and mold growth. However, yeast and mold counts remained within the acceptable threshold of ≤10^4 UFC/g (ranging from 10^3 to 8.10^3 UFC/g), indicating effective control during postharvest handling. The total ash content, ranging from 1.02% in Goulmima to 1.63% in Boudnib, contributed to the overall quality and microbial resistance. In terms of fungal contamination, Zagora showed an elevated FMAT count (4.10^9 UFC/g), suggesting that higher humidity or inadequate drying practices contributed to microbial proliferation, while other samples like Boudnib and Erfoud maintained FMAT levels within permissible limits (5.10^3 to 4.10^4 UFC/g). The absence of *E. coli*, enterobacteria, and pathogenic bacteria like *Salmonella* in all samples reflects the effectiveness of hygienic practices, aligning with the low moisture, stable acidity, and adequate postharvest handling.

Conclusions

The comprehensive analysis of Majhoul dates from four distinct Moroccan growing regions (Boudnib, Goulmima, Erfoud, and Zagora) highlights significant variations in physico-chemical, biochemical, and microbiological properties, emphasizing the impact of regional factors on date quality. Moisture content and water activity (a_w) played a crucial role in microbial stability, with lower a_w values in Boudnib correlating with minimal microbial presence, while higher moisture in Goulmima indicated a greater risk of microbial proliferation. The biochemical composition, particularly carbohydrate and protein levels, confirmed the nutritional value of dates, with higher sugar content in Boudnib and Erfoud supporting potential yeast and mold growth, though microbial loads remained within acceptable limits due to effective postharvest control measures. The microbiological assessment revealed the absence of pathogenic bacteria such as E. coli and Salmonella, affirming the effectiveness of hygienic handling practices. However, the elevated fungal mesophilic aerobic thermophilic (FMAT) count in Zagora indicated that optimizing drying and storage conditions is essential for microbial safety. These results highlight the importance of the present research, which is distinguished by an integrated approach linking physicochemical and microbiological parameters with the hygroscopic behavior of Majhoul dates. The study emphasizes the key role of moisture control and storage conditions, supported by sorption isotherms, in improving the safety, quality, and shelf life of dates intended for local consumption and international trade.

References

1. Al-Karmadi, A. and Ifeanyin Okoh, A. 2024. "An Overview of Date (*Phoenix Dactylifera* L.) Fruits as an Important Global Food Resource." *Foods*, **13(7):** 1–19.
2. Alahyane, A., H. Harrak, I. Elateri, J. Ayour, A. Ait-Oubahou, M. Benichou, and M. E. Abderrazik. 2022. "Evaluation of Some Nutritional Quality Criteria of Seventeen Moroccan Dates Varieties and Clones, Fruits of Date Palm (*Phoenix dactylifera* L.)." *Braz. J. Biol.*, **82**: 1–12.
3. Alam, M. Z., Al-Hamimi, S., Ayyash, M., Rosa, C. T., Yahia, E. M., Haris, S., Al-Marzouqi, A. H. and Kamal-Eldin, A. 2023. "Contributing Factors to Quality of Date (*Phoenix dactylifera* L.) Fruit." *Sci. Hortic.*, **321:** 112256.
4. Amadou, I. 2016. Date Fruits: Nutritional Composition of Dates (*Balanites aegyptiaca* Delile and *Phoenix dactylifera* L.). Chapter 10. In: "*Nutritional Composition of Fruit Cultivars*", (Eds.): Simmonds, M. and Preedy, V. Elsevier, Academic Press, Cambridge, PP. 215–33.
5. Arba, M., Berjaoui, I. and Sabri, A. 2023. "Study on the Evolution of the Fruit Morphological and Physico-Chemical Parameters of 'Majhoul' Date Palm during Fruit Growth". *Acta Agric. Slov.,* **119(3):** 1–8.
6. Arba, M., Elladi, A. and Ouachouo, H. 2025. "Effect of Chemical Thinning on the Fruit Organoleptic Parameters of ' Ma- Jhoul ' Date Palm during the Ripening Stage". *Acta Agric. Slov.,* **121(1):** 1–9.
7. Elhoumaizi, M. A., Jdaini, K., Alla, F. and Parmar, A. 2023. "Variations in Physicochemical and Microbiological Characteristics of 'Majhoul' Dates (*Phoenix dactylifera* L.) from Morocco and New Countries of Its Expansion." *J. Saud. Soc. Agric. Sci.*, **22(5):** 318–26.
8. Cohen, Y., Sadowsky, A., Nusinow, M., Morris, N. and Tikochinsky, T. 2025. "Large-Scale

Study on the Influence of Thinning Practices on Yield and Fruit Quality Attributes in ' Majhoul ' Dates." *J. Agric. Food Res.*, **24**: 102346.

9. van Eck, J. and Puchta, H. 2019. Food and Agriculture. *In: "Chemistry and Industry"*. London, **83(2)**: 22–25.

10. Elmejhed, B., Derraji, H., Terouzi, W. and Kzaiber, F. 2024. "Assessment of the Physico-Chemical and Sensory Qualities of Moroccan Date Syrup: Optimization of Extraction and Conservation." *IOSR J. Biotechnol. Biochem.,* **7(2):** 35–45.

11. Essebbahi, I., Ouazzani, C., Moustaghfir, A., Er-Ramly, A., El Baroudi, Y., Dami, A. and Balouch, L. 2023. "Nutritional Qualities and Fluoride Content of Different Date (*Phoenix dactylifera* L.) Varieties Consumed in Morocco." *J. Appl. Nat. Sci.*, **15(1):** 9–14.

12. Fallis, A. G. 2013. *Commission Du Codex Alimentarius*. *J. Chem. Inf. Model.*, **53:** 1689–1699.

13. Fernández-López, J., Viuda-Martos, M., Sayas-Barberá, E., Navarro-Rodríguez de Vera, C., and Pérez-Alvarez, J. A. 2022. "Biological, Nutritive, Functional and Healthy Potential of Date Palm Fruit (*Phoenix dactylifera* L.): Current Research and Future Prospects." *Agronomy*, **12(4):** 1-30.

14. Ghazzawy, H. S., Alhajhoj, M. R., Ali-Dinar, H. M., Munir, M. and Alqahtani, N. 2022. "Impact of Geographical Distribution on the Variation of Morphological and Biochemical Properties in Two Date Palm Cultivars." *Ecol. Environ. Conserv.*, **28(01s):** S73-S81.

15. Hachani, S., Hamia, C., Boukhalkhal, S., Silva, A. M. S., Djeridane, A. and Yousfi, M. 2018. "Morphological, Physico-Chemical Characteristics and Effects of Extraction Solvents on UHPLC-DAD-ESI-MSn Profiling of Phenolic Contents and Antioxidant Activities of Five Date Cultivars (*Phoenix Dactylifera* L.) Growing in Algeria." *NFS J.*, **13**: 10–22.

16. Hasanaoui, A., Elhoumaizi, M. A., Hakkou, A., Wathelet, B. and Sindic, M. 2010. "Physico-Chemical Characterization, Classification and Quality Evaluation of Date Palm Fruits of Some Moroccan Cultivars." *J. Sci. Res.*, **3(1):** 139.

17. Hasnaoui, A., Elhoumaizi, M. A., Asehraou, A., Sindic, M., Deroanne, C. and Hakkou, A. 2010. "Chemical Composition and Microbial Quality of Dates Grown in Figuig Oasis of Morocco." *Int. J. Agric. Biol.*, **12(2):** 311–14.

18. Hazbavi, I., Khoshtaghaza, M. H., Mostaan, A. and Banakar, A. 2015. "Effect of Postharvest Hot-Water and Heat Treatment on Quality of Date Palm (Cv. Stamaran)." *J. Saudi Soc. Agric. Sci.,* **14(2)**: 153–59.

19. Jdaini, K., Alla, F., M'hamdi, H., Guerrouj, K., Parmar, A. and Elhoumaizi, M. A. 2022. "Effect of Harvesting and Post-Harvest Practices on the Microbiological Quality of Dates Fruits (*Phoenix dactylifera* L.). *J. Saudi Soc. Agric*. Sci., **21(8)**: 552-559.

20. Meenakshi, S. and Misra, A. 2023. "Effect of Dates on Blood Glucose and Other Metabolic Variables: A Narrative Review. *Diabetes Metab. Syndr.: Clin. Res. Rev.,* **17(2): 1-7.**

21. Morad, O., Yassine, Z.- eddine, Nouhaila, A., Fouzia, K., Abdelkhalek, O., Mohammed, E. and Khalid, B.2024. "The Effect of Water Activity and Temperature on the Water Content during the Preservation of Dates 'MAJHOUL Variety'. *Appl. Chem. Eng.*, **7(3)**: 1–8.

22. Nabily, Mohamed, Abdelkader Nabili, Ahmed Namsi, Hatem Majdoub, and Atf Azzouna. 2020. Shelf Life Prediction and Storage Stability of Deglet Nour Dates (*Phoenix Dactylifera* L.): Microbiological and Organoleptic Properties. *Chem. Afr.*, **3(1):** 189–97.

23. Noutfia, Y., Alem, C. and Filali Zegzouti, Y. 2019. "Assessment of Physico-Chemical and Sensory Properties of Two Date (Phoenix Dactylifera L.) Cultivars under Commercial Cold Storage C*onditions. J. Food Process. Preserv*., **43(12)**: 1–7.

24. Noutfia, Y., Ropelewska, E., Szwejda-Grzybowska, J., Jóźwiak, Z., Mieszczakowska-Frąc, M. and Rutkowski, K. P. 2025a. Impact of Prolonged Frozen Storage on 'Mejhoul' Date Palm Cultivar Based on Selected Qualitative Characteristics. *Horticulturae*, **11(7):** 1-16.

25. Noutfia, Y., Ropelewska, E., Szwejda-Grzybowska, J., Mieszczakowska-frac, M., Siarkowski, S., Rutkowski, K. F. and Konopacka, D. 2025b. Effects of Mild Infrared and Convective Drying on Physicochemical Properties , Polyphenol Compounds , and Image Features of Two Date Palm Cultivars : ' Majhoul ' and ' Boufeggous'. *Food Sci. Technol.,* **218**: 1-11.

26. Sadder, M. T., Alashoush, A., Alsmairat, N. and Haddad, A. 2025. The Complete Plastome of 'Mejhoul' Date Palm: Genomic Markers and Varietal Identification. *Int. J. Mol. Sci.*, **26(23):** 1-14.

27. Salomón-Torres, R., Elhoumaizi, M. A., Zambrano-Reyes, C., Zaid, A. A., Ruisanchez-Ortega, Y., Peña-Yam, L. P. and Gutiérrez-Pacheco, M. M. 2025. Effect of Pollen Storage Duration on Stainability , Fruit Set , and Physical Traits in Date Palm (*Phoenix Dactylifera* L .) Cultivar ' Majhoul. *Plants*, **14(20):** 1-15.

28. Wong, K., Motomura, S. and Paull, R. E. 2018. *Postharvest Handling and Food Safety-Layers of Protection.* Food Safety and Technology Series, FST-66, 9 PP. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/FST-66.pdf

29. Zamir, R., Nazmul Islam, A. B. M., Rahman, A., Ahmed, S. and Omar Faruque, M. 2018.

Microbiological Quality Assessment of Popular Fresh Date Samples Available in Local Outlets of Dhaka City, Bangladesh. *Int. J. Food Sci.,* **Volume 2018, Article ID 7840296,** 4 PP.