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Valorization of Date Sorting Rejects and Date Pits from Mejhoul, Boufeggous, and Jihel Varieties: Processing, Product Development, and Physicochemical Characterization

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Abstract

Date sorting rejects, corresponding to fruits with visual defects and low market value, together with date pits, are agro-food by-products that remain underutilized despite their nutritional and technological potential. This study focused on the valorization of these by-products from three Moroccan date varieties (Mejhoul, Boufeggous, and Jihel) for the development of innovative food products. First, the raw materials were characterized in terms of their physicochemical and microbiological properties. Based on these characteristics, several value-added products were developed, including date syrup, date paste, date powder, date-enriched biscuits, and a coffee substitute produced from roasted date pits. The results showed that date sorting rejects present favorable characteristics for valorization, with low water activity (0.303–0.342), high soluble solids content (61.6–78 °Brix), and good microbiological stability. The produced date syrups exhibited high yields (>80%), total soluble solids ranging from 69.9 to 72.8 °Brix, pH values between 4.25 and 4.53, and viscosities from 2,924 to 7,929 cP, comparable to commercial products. Date pastes showed yields above 100%, total soluble solids of 63.4–65.6 °Brix, and water activity between 0.55 and 0.70. Date powders were characterized by low moisture content (<10%) and very low water activity (<0.18), ensuring good storage stability. The powder from the Jihel variety proved particularly suitable for biscuit formulation, allowing complete replacement of sucrose and up to 50% substitution of wheat flour while maintaining acceptable sensory quality. In contrast, coffee substitutes produced from date pits exhibited satisfactory physicochemical properties but limited consumer acceptance. Overall, these findings highlight the strong potential of date sorting rejects and date pits as sustainable raw materials for the development of value-added food products, contributing to the reduction of post-harvest losses and the promotion of a circular economy in the date palm sector.

Keywords: *Date sorting rejects; valorization; syrup; paste; Biscuit formulation; coffee substitutes*

Introduction

The phoeniculture sector in Morocco plays a significant socio-economic role, particularly in oasis regions where date palm cultivation (*Phoenix dactylifera* L.) represents a key source of income and rural stability. Moroccan dates are recognized as an important terroir product due to their nutritional richness in natural sugars, dietary fibers, and bioactive compounds, making them highly suitable for value addition through processing (Harrak et al., 2019; El Janati et al., 2022).

However, a considerable proportion of the production consists of sorting by-products, including downgraded dates and date pits, which remain underutilized despite their promising potential for agro-food applications. These by-products can be effectively valued through the development of diversified products such as syrups, pastes, bakery products, functional flours, and coffee substitutes, thereby contributing to post-harvest loss reduction and increased economic value of the supply chain (Harrak et al., 2019).

Previous studies have highlighted the technological and nutritional potential of dates and their by-products in food formulation, particularly as partial or total substitutes for sugar and wheat flour, as well as producing functional beverages from roasted date pits (Elkatry et al., 2024; Farag et al., 2019). Nevertheless, product quality and consumer acceptance remain strongly dependent on processing conditions and formulation parameters, highlighting the need for further optimization and characterization.

In Morocco, research efforts conducted by the National Institute of Agricultural Research (INRA) have contributed to the development of date-based products and post-harvest technologies (Harrak et al., 2018; Noutfia et al., 2019). However, further work is still required to standardize processing techniques and to improve the physicochemical and sensory quality of the derived products.

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In this context, the valorization of dates and their by-products through transformation into innovative food products represents a sustainable approach to enhance the competitiveness of the date palm sector and meet the growing demand for natural and functional foods.

Materials and Methods

Plant Material

Sorting rejects of three Moroccan date varieties, namely Mejhoul, Boufeggouss, and Jihel (with two textures: normal and hard), were collected from a date storage and packing unit located in the Drâa–Tafilalet region. Upon arrival at the laboratory, the samples were subjected to physicochemical analyses, including moisture content, ash content, water activity, pH, titratable acidity, total soluble solids (°Brix), and hardness, as well as microbiological analyses involving the determination of total aerobic mesophilic flora and fungal microflora. The samples were then stored at 4 °C until processing.

Physicochemical Characterization

Determination of Moisture Content

Moisture content, corresponding to the wet fraction of dates, was determined according to AOAC method No. 920.151 by drying a 10 g sample of dates in an oven (WiseVen®) at 70 °C to avoid sample caramelization, until constant crucible weight was reached (AOAC, 1990). Measurements were performed in triplicate for each variety.

Determination of Ash Content

The dry matter previously obtained from date samples was incinerated at 500 °C for 5 h in a muffle furnace (Ney® VULCAN D-550) until a whitish ash of constant weight was obtained (NF V05-113, 1972). Measurements were performed in triplicate for each sample.

Determination of Water Activity

Water activity (aw) was measured using an aw-meter (Labswift, Novasina AG®). Five grams of dates cut into small pieces were placed in a sample cup and introduced into the measuring chamber. The aw value was displayed once the air inside the chamber reached thermodynamic equilibrium with the sample (Chirife and Fontan, 1982). Measurements were performed in triplicate for each sample.

Determination of pH

pH was determined using a pH meter (AD1030 - Adwa®) according to AOAC method No. 981.12 (AOAC, 1990), using a date/distilled water weight ratio of 0.2. Three replicates were carried out for each sample.

Determination of Titratable Acidity

Titratable acidity (expressed as g of malic acid per 100 g fresh weight of dates) was determined according to the acid–base titration method described by the French standard NF V05-101 (AFNOR, 1974). Titration was performed using 0.1 N sodium hydroxide (NaOH) in the presence of phenolphthalein as an indicator. Analyses were conducted in triplicate for each variety.

Determination of Total Soluble Solids (°Brix)

Total soluble solids content, expressed as degrees Brix (1 °Brix corresponding to 1% sugars), was determined using a digital refractometer (ATAGO® model PR-201α) according to AOAC method No. 932.12 (AOAC, 1990). Analyses were conducted in triplicate for each variety.

Hardness Measurement

Date firmness was determined using a CT3-4500 texture analyzer (Brookfield®) equipped with a cylindrical puncture probe (6 mm diameter) moving at a speed of 30 mm/min to a depth of 5 mm. The compression force exerted by the probe on the date pulp was expressed in Newtons (Hazbavi et al., 2014). Analyses were performed in ten replicates for each variety.

Microbiological Characterization

A 25 g sample of dates from each variety was suspended in 225 mL of sterile distilled water. Subsequently, a series of decimal dilutions was prepared from stock suspension. Then, 0.1 mL of each dilution was spread onto the surface of two agar media (PCA and PDA), using two Petri dishes per dilution and per medium. PCA medium was used for the enumeration of total aerobic mesophilic flora, with incubation at 37 °C for 24 h, whereas PDA medium was used for fungal microflora enumeration, with incubation at 30 °C for 72 h. Results were expressed as colony-forming units per gram (CFU g^{-1}).

Processing of Dates and Characterization of Derived Products

Processing

The date sorting rejects analyzed, including their pits, were used as raw materials to produce several value-added products, namely date syrup, date paste, date flour, and a coffee substitute prepared from date pits. The different processing steps involved in the production of these products are summarized in Figure 1.

The date powder from the Jihel variety (hard texture) was used to prepare a dry biscuit according to the formulation detailed in Table 1, with the aim of substituting sucrose and partially replacing soft wheat flour. Baking was carried out at 180 °C for 10 min.

Table 1. Formulation used for the preparation of dry biscuits based on Jihel date flour

Ingredients	*Control biscuit 1 (100% soft wheat flour)*	*Biscuit with 10% date powder*	*Biscuit with 30% date powder*	*Biscuit with 50% date powder*	*Biscuit with 70% date powder*	*Control biscuit 2 (100% date powder)*
Soft wheat flour	250g	225g	175g	125g	75g	0
Date powder	0	25g	75g	125g	175g	250g
Sugar	125g	0	0	0	0	0
Butter	125g	125g	125g	125g	125g	125g
Egg	1	1	1	1	1	1
Salt	1 pinch	1 pinch	1 pinch	1 pinch	1 pinch	1 pinch

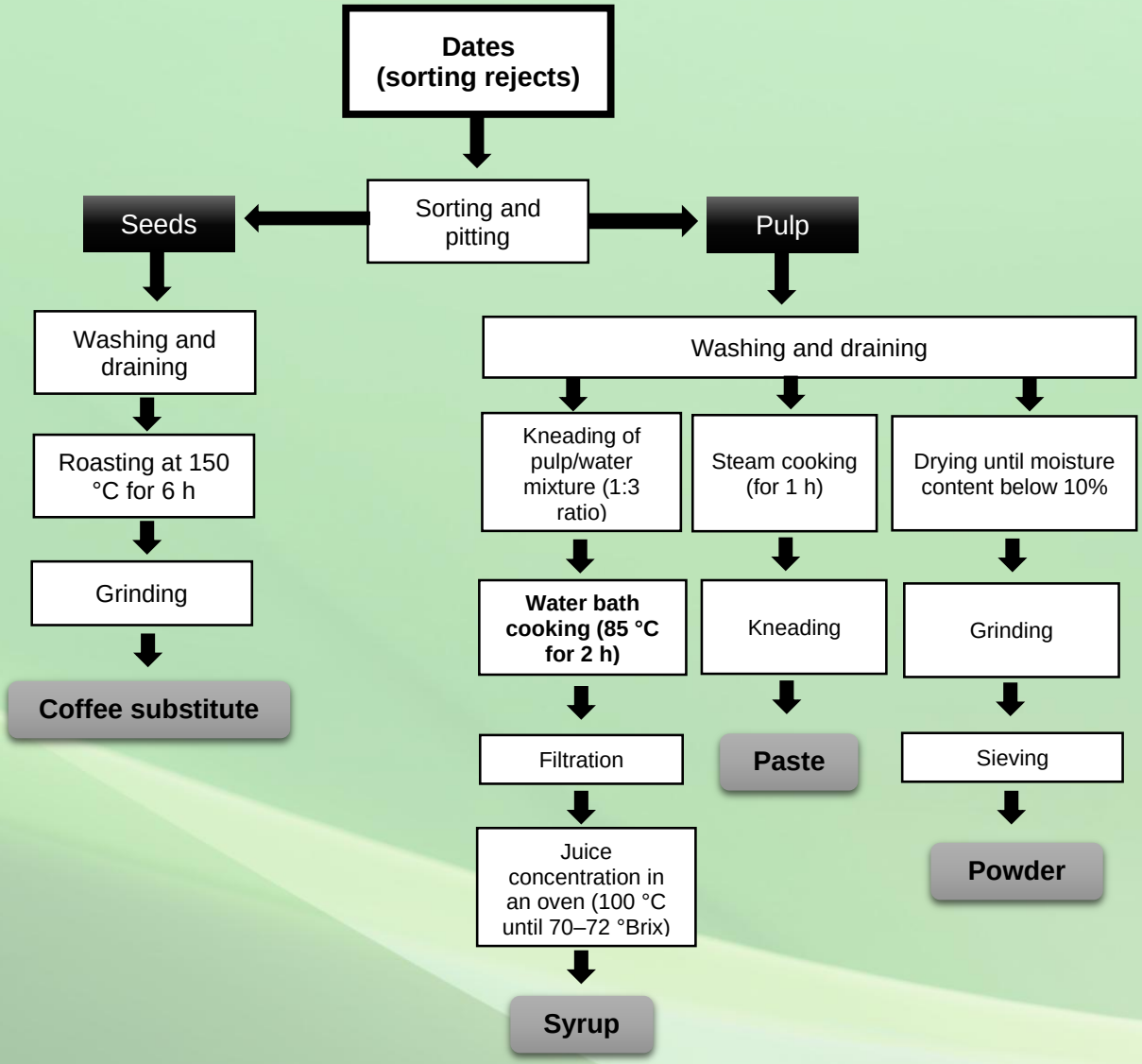

Figure 1. Operational steps to produce date-derived products

Characterization and Sensory Analysis

The syrups, pastes, coffee substitutes, and powders were subjected to the physicochemical analyses described above, namely moisture content, ash content, water activity (aw), pH, and total soluble solids (°Brix), in addition to color indices L* (lightness), a* (green–red), and b* (blue–yellow), using a spectrocolorimeter (HunterLab, MiniScan EZ) in ten replicates (Al-Hooti et al., 1997).

For the date syrups obtained, density and viscosity were also measured in ten replicates. Kinematic viscosity (in cSt) was determined using a rotational viscometer (Fungilab Smart Series) (Yücel et al., 2013), equipped with an L2 spindle rotating at 2.5 rpm at approximately 25 ± 2 °C. Results were expressed in centipoise (cP).

Regarding the formulated date pastes, firmness was determined in ten replicates using a CT3-4500 texture analyzer (Brookfield®), as previously described.

Finally, a sensory panel composed of 10 assessors evaluated the manufactured products (syrup, paste, coffee substitute, and biscuits) using evaluation sheets based on taste, odor, color, and texture, on a global 20-point scale.

Some quality attributes of syrups and pastes obtained from the three date varieties were monitored over a two-month storage period at 4 °C. Hermetically sealed glass bottles and plastic trays were used as packaging for the syrups and pastes, respectively.

Statistical Analysis

Statistical analyses were carried out using GraphPad Prism software (version 8.0.2 for Windows). The physicochemical parameters were analyzed by one-way ANOVA followed by Tukey's post hoc test for multiple comparisons. Statistical significance was set at $p < 0.05$.

Results

Quality of Date Sorting Rejects

Physicochemical Characterization

The mean values of the physicochemical parameters determined for date sorting rejects from the three varieties Mejhoul, Boufeggouss, and Jihel (normal and hard textures) are presented in Table 2. The aim of this characterization was to assess the initial quality of the dates and to guide their processing and valorization.

Table 2. Physicochemical characteristics of sorting rejects from the three date varieties studied

Parameter	*Mejhoul*	*Boufeggous*	*Jihel (normal texture)*	*Jihel (hard texture)*
Moisture (%)	18,54 ± 1,22 ^{b}	22,95 ± 0,725 ^{a}	16,09 ± 1,24 ^{b}	11,67 ± 0,827 ^{c}
Asch (%)	2,41 ± 0,388 ^{a}	2,56 ± 0,544 ^{a}	2,01 ± 0,06 ^{a}	2,4 ± 0,108 ^{a}
a_w	0,338 ± 0,001 ^{a}	0,342 ± 0,0015 ^{a}	0,321 ± 0,0025 ^{b}	0,303 ± 0,0023 ^{c}
pH	6,26 ± 0,005 ^{b}	6,42 ± 0,011 ^{a}	5,68 ± 0,011 ^{c}	5,35 ± 0,005 ^{d}
Titratable acidity (g malic acid/100 g of dates)	0,201 ± 0,0096 ^{b,c}	0,247 ± 0,029 ^{a,b}	0,195 ± 0,005 ^{c}	0,285 ± 0,019 ^{a}
Total soluble solids (°Brix)	78 ± 0,6 ^{a}	63,8 ± 0,346 ^{c}	69,2 ± 0,346 ^{b}	61,6 ± 0,346 ^{d}
Firmness (N)	4,31 ± 0,146 ^{c}	2,84 ± 0,0819 ^{d}	12,16 ± 0,149 ^{b}	35,93 ± 0,098 ^{a}

Values are presented as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test. Means in the same row bearing different superscript letters differ significantly at $p < 0.05$.

Physicochemical Quality of Date Sorting Rejects

The moisture contents obtained for the three studied date varieties allowed classifying Boufeggous as a semi-soft date (20% < moisture < 30%) and Mejhoul and Jihel as dry dates (moisture < 20%) according to Lobo et al. (2014). These values are lower than those reported by Bouhlali et al. (2017) for the same varieties from the same region. Several factors may influence date moisture content within the same variety, including maturity stage (Al-Shahib and Marshall, 2003), geographical origin (Elhoumaizi et al., 2023), climatic conditions (Hasnaoui et al., 2011; Outghouliast et al., 2019), and storage duration and conditions (Hazbavi et al., 2015; Aleid et al., 2014). In the present study, and according to Harrak et al. (2005), Boufeggous, being the most humid variety, is the most suitable for syrup extraction and paste production, whereas Jihel (hard texture, lowest moisture content) is the most appropriate for flour production. It has been reported that one of the main criteria for selecting date varieties for syrup extraction is fruit consistency, which should be soft, semi-soft, or capable of becoming so after soaking (Houssni et al., 2022). In a previous study, Harrak et al. (2018) used sorting rejects and semi-soft Moroccan date varieties of medium commercial quality (Bouittob and Bousthammi) for paste production. Moreover, other researchers used Mejhoul sorting rejects to develop a stable paste for potential incorporation into food products (Sánchez-Zapata et al., 2011). The suitability of Jihel for flour production has also been confirmed in a previous study by Harrak and Jaouan (2010).

Regarding water activity (aw), values ranged from 0.303 (hard Jihel) to 0.342 (Boufeggous). These values are lower than those reported by Hasnaoui et al. (2011), who also showed that aw can vary depending on maturity stage and climatic conditions. This is likely due to dehydration resulting from water evaporation during storage. Noutfia et al. (2018) reported that some Moroccan date varieties spontaneously lose part of their moisture/weight depending on initial water content and storage conditions (temperature, relative humidity, packaging, etc.).

Ash content reflects the total mineral content of a sample. The results showed values ranging from 2.01% to 2.56%, consistent with literature data (Hasnaoui et al., 2010; Harrak, 2022). Mineral content depends on soil type, fertilizers, irrigation water quality, and cultivation practices (Ismail et al., 2006). However, ash content is not a strong varietal marker but may help characterize geographical origin (Harrak and Boujnah, 2012).

All three varieties exhibited slightly acidic pH values. Boufeggous showed the highest pH, followed by Mejhoul and Jihel. Mejhoul dates are reported to have a pH close to neutrality, indicating good commercial quality (Harrak and Hamouda, 2005).

Titratable acidity ranged from 0.195 to 0.285 g malic acid/100 g dates, consistent with previous studies (Noutfia et al., 2019; Harrak, 2022). Some authors reported that malic acid content increases during storage due to continued postharvest ripening (Al-Qurashi and Awad, 2011; Mahmood et al., 2012).

Total soluble solids were highest in Mejhoul (78%), while the other varieties ranged from 61.6% to 69.2%. Differences among varieties were significant ($p < 0.05$). Previous studies on 20 Moroccan date varieties reported values ranging from 63.9% to 82.8% (Harrak et al., 2005). These values may increase during storage due to continued ripening, moisture loss, or polysaccharide hydrolysis into simple sugars (Hazbavi et al., 2015; Noutfia et al., 2019). High sugar content is technologically valuable for syrup and sugar extraction (Harrak and Boujnah, 2012).

Regarding texture, Jihel was the hardest variety (35.93 and 12.6 N for hard and normal texture batches, respectively), followed by Mejhoul (4.31 N) and Boufeggous (2.84 N), with $p < 0.05$. Strong correlations have been reported between texture properties and date chemical composition (Singh et al., 2015). Fruit firmness is generally negatively correlated with moisture content; thus, moisture loss leads to fruit hardening (Afoakwa and Sefa-Dedeh, 2001).

Overall, the physicochemical characterization indicates that the studied sorting rejects are of medium quality and suitable for transformation into paste and syrup, while Jihel (hard texture) appears most appropriate for flour production.

Microbiological Characterization

Microbial enumeration of Mejhoul, Boufeggous, and Jihel date samples revealed a complete absence of yeasts and molds on PDA medium, and the presence of only a few bacterial colonies (not exceeding 30 CFU) on PCA plates corresponding to the 10^{-1} dilution. These results indicate that the date sorting rejects exhibit very good hygienic quality. Due to their richness in phenolic compounds (AlFaris et al., 2021), dates are generally protected against microbial contamination. In addition, the microbiological safety of the raw materials used in this study is ensured by their slightly acidic pH and low water activity (aw).

It should be noted that the processing methods applied in this study include thermal treatments, which further contribute to the high hygienic quality of the derived products**.**

Yield, Quality, Evaluation and Stability of Derived Products

Date Syrup

Date syrups obtained from the three varieties Mejhoul, Boufeggous, and Jihel are illustrated in Figure 2. The results of date syrup yields and their physicochemical properties are presented in Table 3.

The three date varieties used in this study yielded syrups comparable to commercial products, with densities ranging from 1.15 to 1.26. These results are consistent with those reported by Djafri et al. (2021) but lower than those obtained by other authors (Mimouni and Siboukeur, 2011; Boussaid et al., 2020; Laouar et al., 2021) for Algerian date syrups. The yields obtained exceeded 80% and were higher than those reported by Djafri et al. (2021). Significant differences were observed among the three syrups.

The Mejhoul syrup showed the highest moisture content (47.12%), followed by Boufeggous (45.72%) and Jihel (39.68%) ($p < 0.05$). These values are in agreement with those reported by Bouhlali et al. (2020), who found moisture contents ranging from 30.4% to 45.9% in Moroccan date syrups. Moisture content depends on variety, processing conditions, added water volume, temperature, and cooking time (Laouar et al., 2021). It is a key factor affecting syrup stability and susceptibility to fungal spoilage (Bellaouchi et al., 2017). Despite high moisture levels, the high sugar content reduces water availability, as reflected by water activity (aw). Mejhoul syrup showed the highest aw (0.735), followed by Jihel (0.631) and Boufeggous (0.602) ($p < 0.05$). These values inhibit most bacterial and fungal growth, which generally require aw > 0.9 and 0.7, respectively (Tapia et al., 2020).

Total soluble solids (°Brix) were consistent with values reported for Algerian date syrups (64–75%) (Laouar et al., 2021). A °Brix range of 70–75% is considered optimal for high-quality syrups (Mimouni and Siboukeur, 2011). Syrup pH values ranged from 4.25 to 4.53, in agreement with previous studies (Boussaid et al., 2020; Bouhlali et al., 2020). The low pH, combined with low aw and phenolic compounds, contributes to microbial inhibition and extends shelf life (Hamad, 2012).

Boufeggous syrup exhibited the highest ash content (2.45%) ($p < 0.05$), likely due to greater mineral diffusion during extraction. However, ash contents were lower than those reported for Moroccan date syrups (3.66–5.21%) (Bouhlali et al., 2020).

Table 3. Physicochemical characterization of the three obtained date syrups

	Mejhoul	*Boufeggous*	*Jihel*
Yield (%)	86,75	80,23	86,14
Density	1,16	1,15	1,26
Moisture (%)	47,12 ± 0,01 [a]	45,72 ± 0,29 [b]	39,68 ± 0,05 [c]
Ash (%)	1,68 ± 0,07 [b]	2,45 ± 0,43 [a]	1,81 ± 0,037 [b]
a_w	0,735 ± 0,003 [a]	0,602 ± 0,014 [c]	0,631 ± 0,005 [b]
pH	4,53 ± 0,015 [a]	4,25 ± 0,02 [b]	4,49 ± 0,01 [a]
Total soluble solids (°Brix)	70,8 ± 0,2 [b]	69,86 ± 0,11 [c]	72,8 ± 0,2 [a]
L*	9,88 ± 1,13 [b]	7,21 ± 2,07 [c]	12,8 ± 1,04 [a]
b*	12,9 ± 0,81 [b]	6,99 ± 0,62 [c]	14,53 ± 0,8 [a]
a*	11,99 ± 0,86 [a]	5,91 ± 0,7 [c]	9,87 ± 0,51 [b]
Viscosity (Cps)	2924,45 ± 126,26 [c]	7929,44 ± 839,57 [a]	3729,76 ± 9,33 [b]

Values are presented as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test. Means in the same row bearing different superscript letters differ significantly at $p < 0.05$.

Figure 2. Date syrups of (1) Mejhoul, (2) Boufeggous, and (3) Jihel

Mineral content varies widely depending on variety and extraction techniques (Mimouni and Siboukeur, 2011; Boussaid et al., 2020; Djafri et al., 2021). Date syrups are generally richer in minerals than high-fructose syrups (~0.3%) (Mimouni and Siboukeur, 2011).

Viscosity is a key property for syrup quality and application. Boufeggous syrup showed the highest viscosity (7929.44 cP), followed by Jihel (3729.76 cP) and Mejhoul (2924.45 cP) ($p < 0.05$). These values are higher than those reported by Djafri et al. (2021) (419.01–803.7 cP). Viscosity is inversely related to moisture content and depends on soluble solids and temperature (Guérin et al., 1978; Gabsi et al., 2013). Enzymatic treatments can significantly reduce viscosity by degrading polysaccharides (Julai et al., 2023).

Color is a key quality attribute. Boufeggous syrup was the darkest (L* = 7.21), likely due to raw material color and browning reactions during concentration (Julai et al., 2023). Jihel syrup showed the highest lightness (L* = 12.8) and yellowness (b* = 14.53), consistent with previous findings (Bouhlali et al., 2020). Mejhoul syrup exhibited the highest redness (a* = 11.99), possibly due to carotenoids and anthocyanins (Al-Qarni et al., 2020).

Some quality attributes of the syrups obtained from the three date varieties were monitored over a two-month storage period at 4 °C. The samples were stored in hermetically sealed glass bottles. The results are presented in figure 3.

During storage, moisture content decreased in Mejhoul syrup from the first month, while changes appeared from the second month for Boufeggous and Jihel ($p < 0.05$). Water activity remained stable in Boufeggous but decreased in Mejhoul and increased in Jihel. These results differ from Naknean et al. (2013) and Hajmeer et al. (2000), who reported stable moisture and aw during storage. Variations may be attributed to packaging permeability (glass bottles) and initial moisture content.

pH decreased during storage, in agreement with Naknean et al. (2013), likely due to sugar degradation and organic acid formation. °Brix decreased in Mejhoul and Boufeggous but increased in Jihel, consistent with previous studies (Hajmeer et al., 2000; Chauhan et al., 2018). Viscosity decreased over time, as also reported by Hajmeer et al. (2000), due to polysaccharide degradation.

Color changes indicated progressive browning during storage, associated with Maillard reactions (Naknean et al., 2013). Variations in a* and b* values depended on variety and storage conditions.

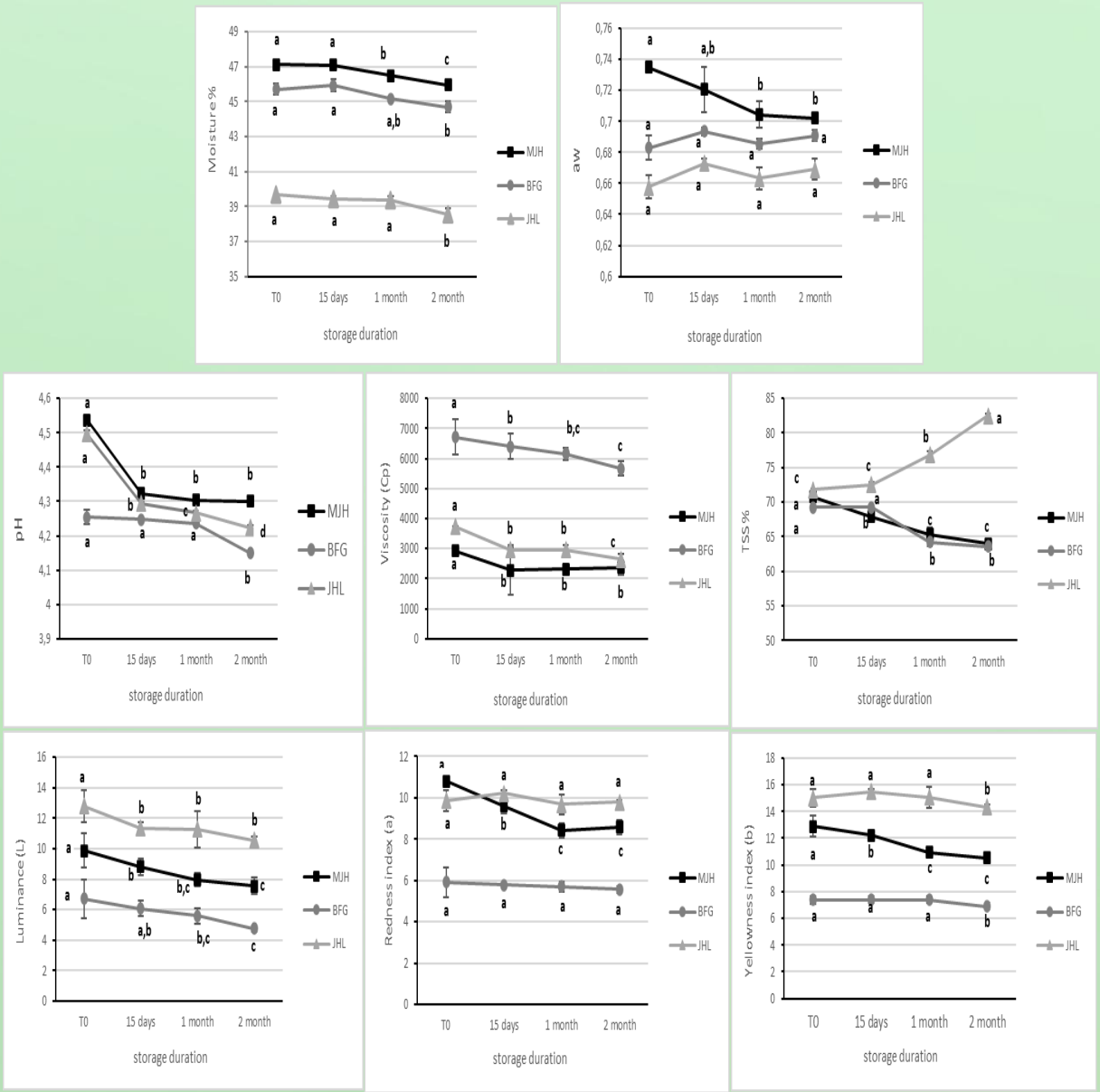

Figure 3. Evolution of quality attributes of the three syrups extracted from Mejhoul, Boufeggous, and Jihel dates

Date Paste

Date pastes obtained from the three varieties Mejhoul, Boufeggous, and Jihel are illustrated in Figure 4. The results of the yields obtained for date paste from the three studied varieties and their physicochemical properties are presented in Table 4.

The adopted process allows the production of date pastes with yields exceeding 100%, which can be explained by the hygroscopic nature of dates during steam cooking. No significant difference ($p > 0.05$) was observed in the moisture content between the paste of the Mejhoul variety (30.98%) and that of the Boufeggous variety (31.18%). However, the Jihel variety paste exhibited a lower moisture content (26.08%). These values exceed the limit specified by the Codex Standard (2013) and the Moroccan Ministerial Decree (MAPMDREF, 2018), which is around 20%. This highlights the need for incorporating other ingredients such as flours and oils, which could both improve the quality of the paste and adjust its moisture content. Indeed, Harrak et al. (2017) reported acceptable moisture levels in date pastes derived from two Moroccan varieties (Bouittob and Bousthammi) when using an improved formulation incorporating cereal flours, olive oil, and citric acid. However, it should be noted that the addition of additives in date paste is restricted by Moroccan standards.It has also been reported that the moisture content of date pastes depends on both the date variety and the cooking conditions (Al-Abid et al., 2007).The three pastes exhibited a slightly acidic pH and a moderate water activity (aw), in agreement with the findings of Ahmed and Ramaswamy (2006). Moreover, the three formulated pastes showed statistically similar lightness (L*), whereas redness (a*) and yellowness (b*) values were significantly higher in the Jihel variety paste.Similar L*

values have been reported for pastes prepared from Emirati date varieties (Khalas, Lulu, and Bumaan), with values of approximately 25, 21, and 22, respectively. However, the a* and b* values reported in that study were considerably higher than those obtained in the present work. These differences can be attributed to varietal effects as well as to the initial colour characteristics of the raw date material used for paste preparation (Ahmed and Ramaswamy, 2006). Although the developed pastes were well accepted by consumers, with sensory scores of 15.4, 14.2, and 13.4/20 for Mejhoul, Boufeggous, and Jihel, respectively, their rheological and textural properties still require improvement. Indeed, it has been reported that hardness decreases after processing dates into paste (Ahmed and Ramaswamy, 2006) and is negatively correlated with moisture content (Rahman and Al-Farsi, 2005).

During the two-month storage period at 4 °C (Figure 5), the date pastes of the three varieties showed a progressive decrease in weight, attributed to water loss during storage, which is confirmed by the decrease in moisture content. Water activity showed a slight decrease, with no statistically significant difference ($p > 0.05$), suggesting limited changes in water availability within the sugar-rich matrix during storage. Indeed, total soluble solids increased, likely due to a concentration effect resulting from water loss. An increase in hardness was also observed, indicating a progressive hardening of the date pastes, a phenomenon generally associated with reduced moisture content and the decrease in the plasticizing effect of water in sugar-rich matrices (Alhamdan and Hassan, 1999; Karazhiyan & Razavi, 2012). Finally, colour indices changed during storage, reflecting progressive modifications in the visual properties of the date pastes over the storage period.

Table 4. Physicochemical characterization of the pastes obtained from the three date varieties

	Mejhoul	*Boufeggous*	*Jihel*
Yield (%)	105,51	108,12	107,64
Moisture (%)	30,98 ± 0,204 ^{a}	31,18 ± 0,85 ^{a}	26,08 ± 0,52 ^{b}
Ash (%)	2 ± 0,05 ^{a}	1,99 ± 0,12 ^{a}	2,03 ± 0,002 ^{a}
a_w	0,697 ± 0,013 ^{a}	0,571 ± 0,003 ^{b}	0,551 ± 0,003 ^{b}
pH	5,36 ± 0,03 ^{b}	5,58 ± 0,02 ^{a}	5,12 ± 0,02 ^{c}
Titratable acidity (g malic acid/100 g of dates)	0,041 ± 0,04 ^{b}	0,094 ± 0,03 ^{a}	0,134 ± 0,02 ^{a}
Total soluble solids (°Brix)	64,8 ± 0,34 ^{b}	63,4 ± 0,35 ^{c}	65,6 ± 0,35 ^{a}
L*	21,98 ± 1,34 ^{a}	21,87 ± 0,8 ^{a}	22,33 ± 0,82 ^{a}
b*	3,77 ± 0,34 ^{b}	3,47 ± 0,59 ^{b}	4,86 ± 0,72 ^{a}
a*	6,94 ± 0,51 ^{b}	6,25 ± 0,57 ^{c}	8,67 ± 1,05 ^{a}
Firmness (N)	0,606 ± 0,081 ^{b}	0,9208 ± 0,11 ^{a}	0,889 ± 0,12 ^{a}

Values are presented as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test. Means in the same row bearing different superscript letters differ significantly at $p < 0.05$.

Figure 4. Date pastes prepared from (1) Mejhoul, (2) Boufeggous, and (3) Jihel

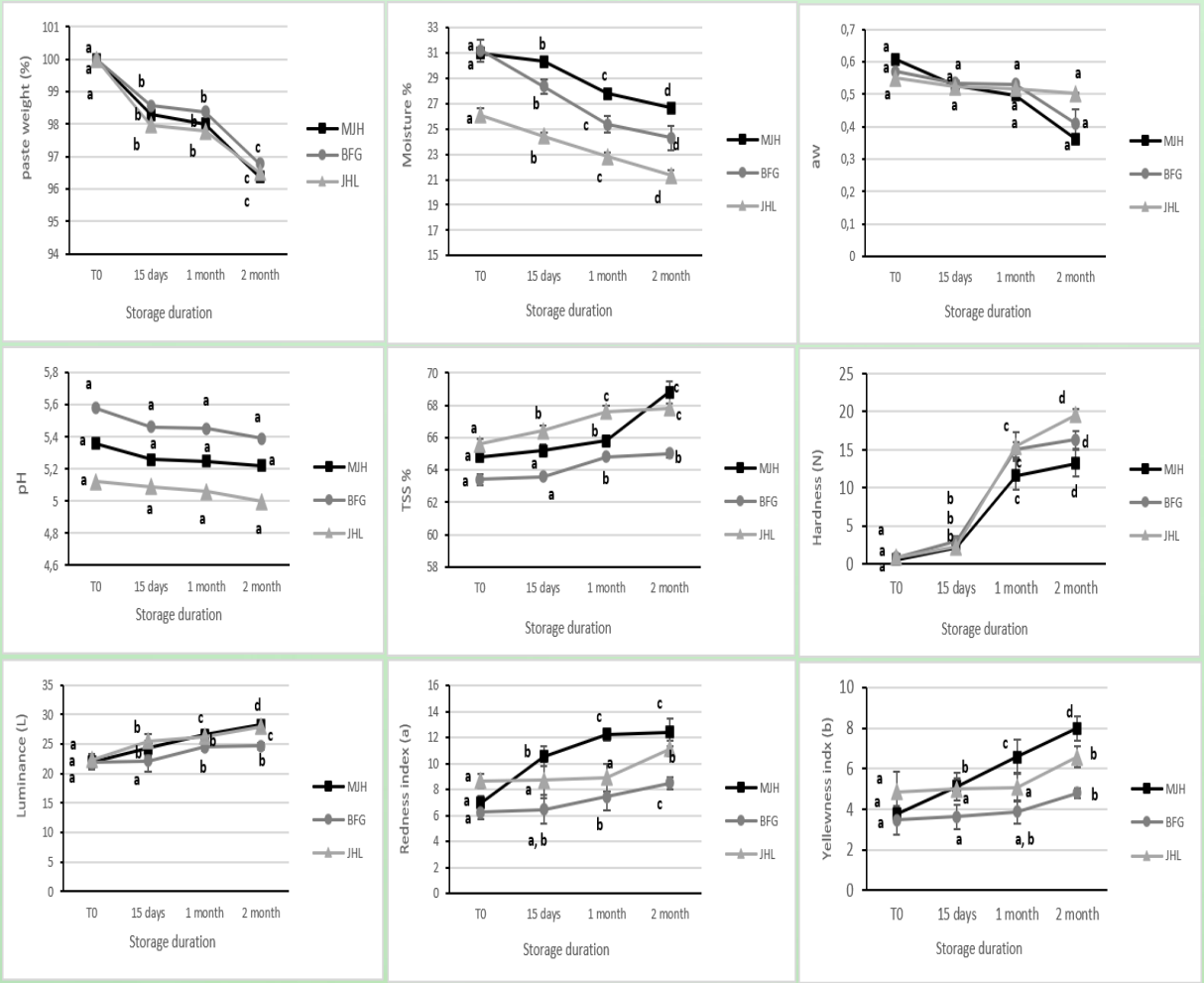

Figure 5. Evolution of quality attributes of the three pastes prepared from Mejhoul, Boufeggous, and Jihel dates

Date powder

Figure 6 illustrates the powders obtained from the date samples Mejhoul, Boufeggous, Jihel (normal texture), and Jihel (hard texture). The results of yields obtained for date powder and physicochemical properties of the powders produced from the three studied date varieties are summarized in Table 5. The date powders obtained in this study exhibited a high content of soluble sugars (70.8 to 83 °Brix), reflecting their natural richness in sugars such as glucose and fructose. They were also slightly acidic, with pH values ranging from 4.29 to 4.81, which is typical of date-derived products and contributes to their microbiological stability. In addition, these powders were characterized by a low moisture content (below 10%), associated with a very low water activity (aw < 0.18), which strongly limits microbial growth and ensures good long-term storage stability. Regarding colour, only the flour obtained from the Jihel variety with hard texture (batch 2) showed satisfactory visual characteristics, with a luminance (L*) of 56.5 ± 0.69, indicating a lighter colour and therefore better acceptability for food applications. Consequently, this flour was selected and used as an ingredient in the formulation of dry biscuits at different proportions. Several studies have also highlighted the influence of extraction and processing methods on the physicochemical, nutritional, and technological properties of date powders, particularly in terms of sugar composition, water-holding capacity, and functional properties (Manickavasagan et al., 2015; Moghbeli et al., 2019; Assous et al., 2021; Sourki et al., 2022; Muñoz-Bas et al., 2025).

Dry Biscuit Based on Date Powder

Date powder obtained from the Jihel variety (characterized by its hard texture) was used in the preparation of a dry biscuit as a substitute for both sucrose and white flour. Figure 7 illustrates the biscuits formulated with different substitution levels. Sensory evaluation of the prepared biscuits showed that replacing 50% of the white flour and 100% of the sucrose with date flour was highly effective. Elkatry et al. (2024) demonstrated the effectiveness of substituting sugar with Khalas date flour at a level of 25% in dry biscuit formulations. They reported that the addition of date powder significantly increased the polyphenol and flavonoid contents as well as the antioxidant activity, thereby slowing the rancidity process and extending the shelf life of the biscuits. Due to their high fiber content, these biscuits may represent a nutritionally suitable option for diabetic individuals.

Table 5. Physicochemical characterization of the prepared date powders

	Mejhoul	*Boufeggous*	*Jihel (normal texture)*	*Jihel (hard texture)*
Yield (%)	83,63	71,57	75,24	87,67
Moisture (%)	8,12 ± 0,01 ^{a}	8,89 ± 0,02 ^{b}	6,97 ± 0,05 ^{c}	5,81 ± 0,32 ^{d}
Ash (%)	2,55 ± 0,05 ^{b}	2,76 ± 0,12 ^{a}	2,3 ± 0,03 ^{c}	2,34 ± 0,02 ^{c}
a_w	0,145 ± 0,001 ^{d}	0,183 ± 0,004 ^{a}	0,173 ± 0,003 ^{b}	0,155 ± 0,002 ^{c}
pH	4,41 ± 0,005 ^{c}	4,29 ± 0,00 ^{d}	4,57 ± 0,00 ^{b}	4,81 ± 0,005 ^{a}
Acidity (g of malic acid / 100 g of dates)	0,402 ± 0,01 ^{b}	0,482 ± 0,02 ^{a}	0,317 ± 0,00 ^{c}	0,402 ± 0,01 ^{b}
TSS°	83 ± 0,35 ^{a}	75,2 ± 0,35 ^{b}	70,8 ± 0,6 ^{d}	73,4 ± 0,35 ^{c}
L*	24,86 ± 1,02 ^{c}	26,07 ± 0,04 ^{c}	38,41 ± 0,51 ^{b}	56,5 ± 0,69 ^{a}
b*	20,49 ± 0,58 ^{c}	21,15 ± 0,16 ^{c}	34,59 ± 0,44 ^{b}	35,75 ± 0,48 ^{a}
a*	16,26 ± 0,31 ^{b}	15,96 ± 0,05 ^{b}	17,84 ± 0,13 ^{a}	12,4 ± 0,16 ^{c}

Values are presented as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test. Means in the same row bearing different superscript letters differ significantly at $p < 0.05$.

Table 6. Physicochemical characterization of coffee substitutes prepared from date pits

	Mjehoul	*Boufeggous*	*Jihel*
Yields (%)	83,18	83,29	80,26
Moisture (%)	1,35 ± 0,003 ^{b}	1,876 ± 0,04 ^{a}	0,88 ± 0,1 ^{c}
Ash (%)	1,28 ± 0,01 ^{b}	1,34 ± 0,02 ^{a,b}	1,4 ± 0,02 ^{a}
a_w	0,103 ± 0,008 ^{a,b}	0,108 ± 0,003 ^{a}	0,054 ± 0,007 ^{b}
pH	3,74 ± 0,005 ^{c}	3,78 ± 0,005 ^{b}	3,82 ± 0,006 ^{a}
Acidity (g of malic acid/ 100g of dattes)	0,308 ± 0,023 ^{a}	0,335 ± 0,023 ^{a}	0,322 ± 0,00 ^{a}
TSS°	3,8 ± 0,35 ^{a,b}	4,4 ± 0,35 ^{a}	3,6 ± 0,00 ^{b}
L*	24,75 ± 0,34 ^{b}	25,79 ± 0,15 ^{a}	20,65 ± 0,301 ^{c}
b*	17,87 ± 0,19 ^{b}	18,62 ± 0,15 ^{a}	13,62 ± 0,22 ^{c}
a*	14,1 ± 0,07 ^{b}	15,46 ± 0,14 ^{a}	12,56 ± 0,05 ^{c}

Values are presented as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test. Means in the same row bearing different superscript letters differ significantly at $p < 0.05$.

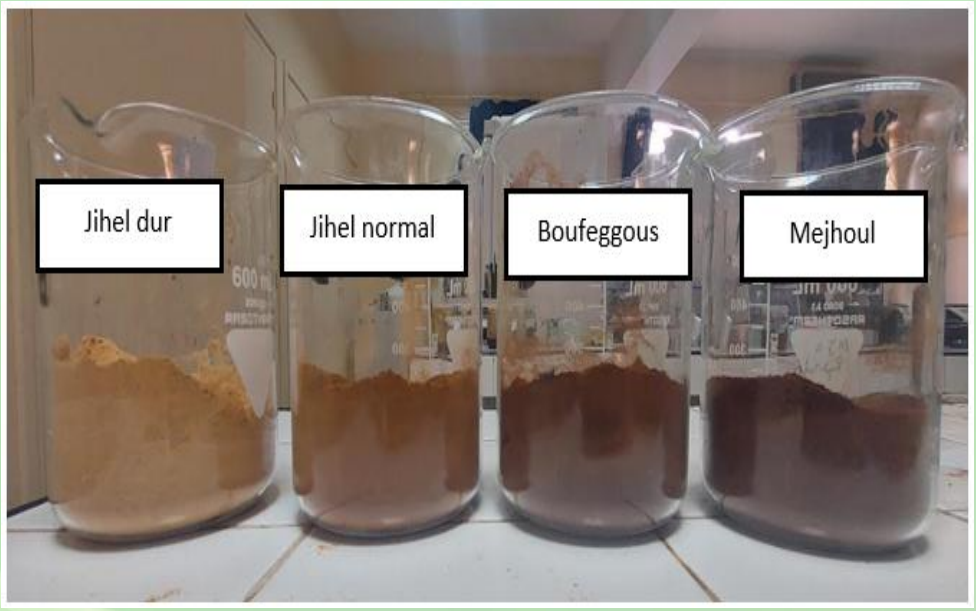

Figure 6. Powders obtained from the four date samples studied

Similarly, Latif and Pik Wan (2023) showed that date powder can be incorporated into biscuit formulations as a substitute for sucrose, improving nutritional quality and extending shelf life. These authors also demonstrated that incorporation levels above 30% negatively affected the sensory properties of the final product, particularly in terms of color and taste.

Coffee Substitute from Date Pits

The coffee substitutes produced from the date pits of the three varieties, Mejhoul, Boufeggous, and Jihel, are illustrated in figure 8. The results of the yields obtained for coffee substitutes from date pits of the three varieties, as well as their physicochemical properties, are presented in Table 6.

Although these products exhibited desirable physicochemical quality characteristics like those of real coffee, they were not well accepted by consumers. The latter reported that the taste was far from what would justify the designation "coffee substitute" and suggested emphasizing the potential therapeutic benefits of this beverage to encourage its consumption as an infusion rather than as a coffee substitute.

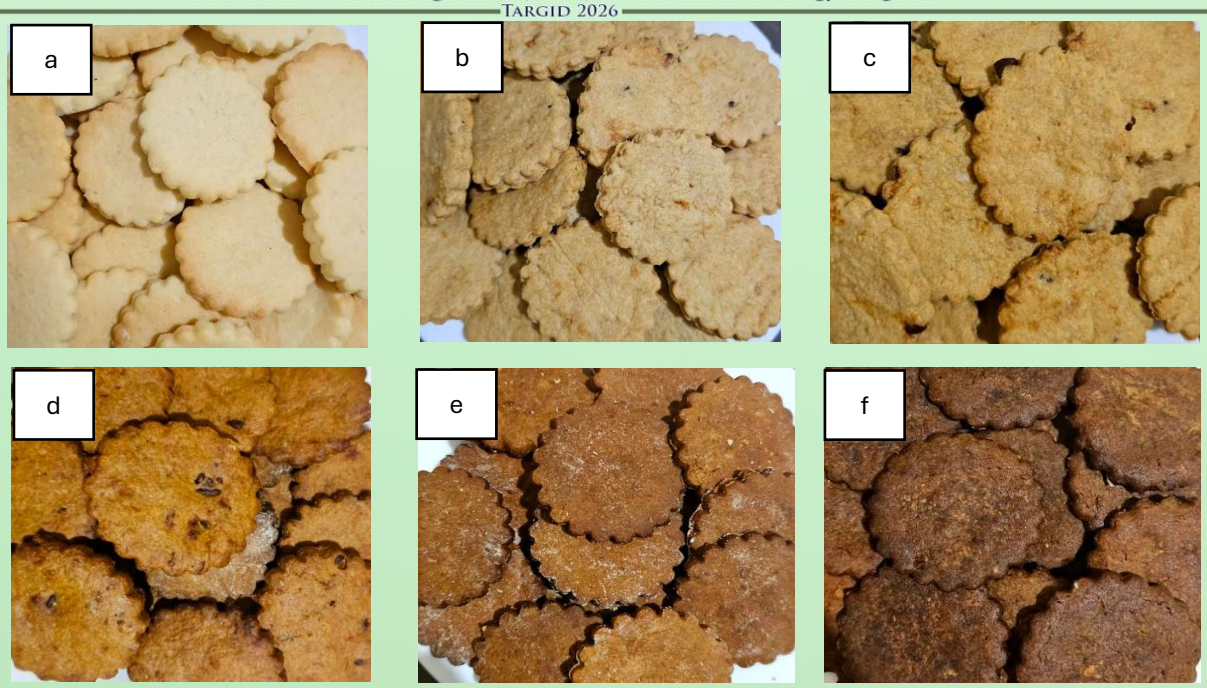

Figure 7. Appearance of dry biscuits prepared with (a) wheat flour (control), (b) 10% date powder, (c) 30% date powder, (d) 50% date powder, (e) 70% date powder, and (f) 100% date powder.

Figure 8. Coffee substitutes prepared from the date pits of the Mejhoul, Boufeggous, and Jihel varieties.

Indeed, Farag et al. (2019) highlighted the abundance of furans, pyrones, terpenoids, and sulfur-containing compounds in roasted date pits, whereas pyrroles and caffeine—typical metabolites of roasted coffee—were absent. Other authors have demonstrated the potential use of roasted date pit powder as a healthy coffee alternative (Venkatachalam & Sengottian, 2016). However, Ghnimi and Almansoori (2015) called for further studies on the composition of this product before recommending it for human consumption and emphasized the need to improve its manufacturing process.

Conclusion

The results of this study demonstrate that date sorting by-products and date pits represent a promising and sustainable resource for the development of high-value-added food products. The different date varieties exhibited distinct technological potentials, with Boufeggous showing suitability for syrup and paste production, while the hard-texture Jihel proved to be the most appropriate for date powder manufacturing and bakery applications. The

developed products displayed satisfactory physicochemical and microbiological qualities, as well as good storage stability.The valorization of these underutilized by-products contributes to reducing post-harvest losses, enhancing the sustainability and competitiveness of the Moroccan date palm sector, and diversifying agro-food products derived from dates. Furthermore, the incorporation of date powder into biscuits demonstrated its potential as a natural alternative to refined sugar and wheat flour, offering opportunities for the development of nutritionally improved food products. Nevertheless, further research is required to optimize processing conditions and improve the sensory acceptability of certain products, particularly date-pit coffee substitutes and date pastes. Such efforts would strengthen the commercial viability of these products and support the wider adoption of date by-product valorization strategies within a circular and sustainable agri-food economy.

Declarations

Author Contribution Statement

MISBAH Asmae: Conceptualization, methodology design, supervision, data analysis and interpretation, statistical analysis, valorization of results, and writing of the original draft. The author also contributed to the review and editing of the manuscript.

ZYADI Fatimzehra and AZIZ Siham: Equal contribution. Both authors performed laboratory experiments, sample preparation, and data collection as part of their internship work.

BENAMAR Houria: Provided technical assistance, laboratory support, and contributed to the execution of experimental procedures.

OUHEJJOU Bouchra: Critical review and revision of the manuscript, validation of the methodology and results, and contribution to the improvement of the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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