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Variations in physicochemical and microbiological characteristics of 'Mejhoul' dates (*Phoenix dactylifera* L.) from Morocco and new countries of its expansion

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ABSTRACT

'Mejhoul' date cultivar originated from Morocco and largely spread around the world. It is of high commercial value and is considered to be one of the best-exported dates concerning its fruit quality and size in comparison with other cultivars. This study aims to investigate variations within the physicochemical and microbiological characteristics of 'Mejhoul' dates sampled from its original growing areas in Morocco and other countries, where the cultivar is expanded in the recent years. Dates samples were collected from the most important production areas of the 'Mejhoul' cultivar in Morocco (Figuig, Bouanane, Boudnib, Difat Ziz, Rissani and Zagora) and the United States of America, Kingdom of Saudi Arabia, Jordan and Palestine. Variance analysis of pH, moisture, ash and sugar content show a significant difference ($p < 0.05$) within 'Mejhoul' cultivar samples. Statistical analysis (Principal Component Analysis "PCA") allows the classification of samples into three groups. The first group holds 'Mejhoul' samples from Morocco, including Figuig, Boudnib and Difat Ziz, characterized by high water content and high density of TVC and Yeasts. The second group is composed of all international samples (Palestine, Jordan, USA and KSA) in addition to samples from Rissani (Morocco), presents reverse characteristics compared to the first group. The third group includes 'Mejhoul' from Bouanane and Zagora (Morocco). Despite the availability of favorable conditions, making Morocco an ideal area for 'Mejhoul' production. However export of this date cultivar remains limited from Morocco due to uncontrolled production techniques and environmental factors.

1. Introduction

Date palm (*Phoenix dactylifera* L.) is the main perennial crop in arid and semiarid areas, especially in North Africa and the Middle East as well as in some regions of Europe and the arid regions of the USA, Mexico, Peru and Chile. It is characterized by its high adaptation to desert environments; extreme temperatures and water deficiency (Chao and Krueger,2007). Approximately, 60 cultivars are widely grown and have important national and international markets (Zaid and Arias-Jimenez, 2002).

In Morocco, date palm covers 61,332 ha, concentrated mainly in the province of Draâ - Tafilalet (77 %), followed by the region of Sous Massa (15 %), Oriental (5 %) and finally Guelmim Oued Noun (4 %). Date production in 2020 is estimated at 143,160 (t) (MAPMDREF, 2019) which comprises over 220 cultivars including a high proportion of Khalts (mainly originated from seed) and other cultivars such as 'Boufeggous', 'Mejhoul', 'Bouskri', and 'Aziza Bouzid' (Hasnaoui et al., 2011). Morocco's date exports remain low compared to other countries.

'Mejhoul' cv is a well-known cultivar and one of the highest quality dates in the market. The large size, soft flesh and attractive appearance, have made it very popular among growers and consumers. 'Mejhoul' command the highest market prices, which helps to recover additional production costs. 'Mejhoul' date originates from Morocco, it was introduced into many regions, such as the USA (Arizona, California), Mexico, South Africa (Namibia),

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Fig. 1. Studied 'Mejhoul' date s from; (a): Jordan, (b): Palestine, (c): USA, (d): KSA, (e): Figuig, (f): Bouanane, (g): Boudnib, (h): Difat Ziz, (i): Rissani, (j): Zagora.

the Middle East (Jordan, Israel, and Palestine), and Arabian Gulf countries (Kingdom of Saudi Arabia) (Zaid and Oihabi, 2022).

Date palm is propagated either by the use of conventional technique namely offshoots or the use of micro-propagation techniques that allows for large-scale production of healthy, disease-free, true-to-type plants (Abahmane, 2011). The expansion of 'Mejhoul' dates cultivation from its original growing area in Morocco to other countries induces divergences in production and fruit quality. However, several elements affect the production and quality of date palms, such as edaphic and climatic conditions in addition to harvest and postharvest practices (Al-Khayri al., 2015).

Fruit quality is governed by many factors including climatic conditions such as light, relative humidity, and temperature, in addition to the quality and availability of water, which control the synthesis and accumulation of several compounds of fruits (Hewett, 2006). According to Woolf and Ferguson (2000) and Tahir et al., (2007), light exposition, increases fruit size, total soluble solids, and flesh firmness. Fruit quality is also affected by nutrient rates in the soil (Hudina and Štampar, 2005). Eventually, harvesting methods and postharvest activities, including drying, sorting, grading, packing and packaging materials, storage, transportation, and marketing conditions act on fruit quality variation (Bekele, 2018).

The 'Mejhoul' characterization was a subject of many studies. In Morocco, Bouhlali et al. (2015) revealed that the 'Mejhoul' cultivar from Errachidia was characterized by 2.30 %, ash and 30 % of moisture. They also reported that total sugar, glucose, and fructose, respectively are 71.76, 33.96, and 37.79 g/100 g DW. Hasnaoui (2013) indicated that the 'Mejhoul' dates from Figuig and Tafilalet varied between 2.41 and 2.88 and the less total sugar content was recorded for Mejhoul Tafilalet, 65.30 g/100 g DW and the higher for 'Mejhoul' Figuig 68.45 g/100 g DW. The 'Mejhoul' dates from Mexico were the subject of a study carried out by Salomón-Torres et al., (2018) which indicated that protein, ash and total sugar were in the range of 3.00 %, 2.58 % and 70.04 g/100 g DW, respectively. Several studies have investigated the physicochemical and microbiological properties of the 'Mejhoul' cultivar. However, no research has been carried out on the variation of these characteristics according to the ecological plasticity of the 'Mejhoul' cultivar.

Consequently, the aims of this work is to find out the variation of physicochemical parameters and microbiological characteristics of the 'Mejhoul' cultivar depending on their ecological plasticity and to determine the factors likely responsible for these variations.

2. Material and methods

2.1. Plant material

Ten samples of 'Mejhoul' dates (One kg of dates was taken for each) were collected at the tmar stage (fully ripened) in October 2018 at the International Exhibition of Dates (Erfoud, Morocco) (Fig. 1). Out of these samples, eight are originated from most important production areas of 'Mejhoul' cultivar in Morocco (Figuig, Bouanane, Boudnib, Difat Ziz, Rissani, and Zagora), while four samples are from USA, Jordan, KSA and Palestine. Fruits were recovered in sterilized bags, transported to the laboratory, and stored at (- 20 °C) until analysis.

2.2. Physicochemical analysis

2.2.1. Colour characteristics

Fruit's colour properties were determined according to the CIE-LAB colour space system defined by International Commission on Illumination (CIE) in 1976. L* defines lightness, a* corresponds red, and green ratio and b* indicate the ratio of yellow and blue.

2.2.2. pH, Moisture, ash and protein

Moisture content and pH were determined following the Association of Official Analytical Chemists method. pH was measured using an electronic pH-meter (pH211, Hanna instrument). Total nitrogen was determined following the Kjeldahl method, and then protein amount was calculated using the factor of 6.25 (AOAC, 1997).

2.2.3. Sugar composition

Sugar profile (sucrose, glucose and fructose) was determined using the high-performance liquid chromatography (HPLC) method, as elaborated by (Alasavar et al., 2003). The separation of sugar was performed with a Carbopac PA 10; Lichrosorb NH2 Analytical HPLC Column (4.6 × 250 mm). The mobile phase was an isocratic acetonitrile and water solution 80/20. Injection capacity and flow speed were respectively 10 µL and 1 mL/min. Identified sugars were quantified basing on peak areas of external standards consisting of glucose (2 %), fructose (2 %) and sucrose (2 %) solutions.

2.3. Microbiological analysis

Ten grams of each sample were aseptically weighed into a sterile stomacher and homogenized with 90 mL of sterile peptone water for 30 s in a stomacher (Lab-Blender 400 circulator, Seward Medical, England). Samples were then serially diluted up and 0.1 mL of each dilution was plated out onto the culture medium surface (Spread plate method) and incubated for 48 h. Total viable counts were counted on Plate Count Agar (BIOKAR, France) incubated at 30 °C. *Staphylococcus aureus* was enumerated using Baird Packer Agar medium (BIOKAR, France) at 37 °C. Violet Red Bile Lactose Agar (BIOKAR, France) was used to enumerate total coliforms incubated at 37 °C and fecal coliforms at 44 °C. *Bacillus* was counted using *Bacillus* Cereus Agar (BIOKAR, France) at 37 °C. Lactic acid bacteria enumeration was done using Man Rogosa and Sharpe medium (BIOKAR, France) at 37 °C. Yeast and moulds were enumerated on Oxytetracycline Glucose Agar medium (BIOKAR, France), at 30 °C. Results of three repetitions were expressed as colony-forming units per gram (log CFU.g^{-1}).

2.4. Statistical analysis

Data analysis was performed using the SPSS Statistics 19.0 package (IBM, 2019). The ANOVA and Duncan's multiple range tests were conducted to determine significant differences between means and to separate groups of means with a probability of $p \leq 0.05$. Values were expressed as an average of four determinations ± standard deviation. Principal component analysis (PCA) was performed on physical and chemical data set to verify whether it was possible to differentiate samples according to their growing area and to elucidate variable which impacts the quality of 'Mejhoul' dates.

3. Results and discussion

3.1. Physicochemical results

Physicochemical results are given in (Table 1). Analysis of variance of pH, moisture, ash, protein and sugar content revealed significant differences ($p < 0.05$) among samples.

Table 1
Physicochemical characteristics of 'Mejhoul' dates.

		Color			pH	Ash (g/ 100 g DW)	Moisture (%)	Total Sugar (g/ 100 g DW)	Protein (g/ 100 g DW)	r
		L*	a*	b*						
International 'Mejhoul'	Jordan	27.01 ± 0.41^{abc}	5.10 ± 5.1^{b}	5.39 ± 0.78^{b}	6.23 ± 0.13^{bc}	3.10 ± 0.10^{d}	25.79 ± 0.4^{ab}	79.03 ± 0.01^{e}	3.12 ± 0.10^{bc}	3.06
	Palestine	26.57 ± 1.12^{a}	3.56 ± 0.27^{a}	2.84 ± 0.81^{a}	6.21 ± 0.07^{bc}	3.03 ± 0.03^{d}	23.96 ± 1.01^{a}	82.29 ± 0.32^{g}	3.33 ± 0.15^{bc}	3.43
	USA	27.02 ± 0.8^{cd}	9.75 ± 1.45^{e}	7.24 ± 0.6^{bcd}	6.55 ± 0.05^{de}	3.24 ± 0.04^{d}	25.53 ± 3.3^{ab}	71.56 ± 0.14^{c}	3.32 ± 0.19^{bc}	2.80
	KSA	27.50 ± 0.23^{bcd}	8.23 ± 0.33^{d}	6.25 ± 0.37^{bc}	6.44 ± 0.04^{d}	3.24 ± 0.23^{d}	24.16 ± 0.54^{a}	76.50 ± 0.21^{d}	3.10 ± 0.10^{bc}	3.17
Moroccan 'Mejhoul'	Figuig	30.28 ± 1.33^{e}	7.51 ± 1.79^{d}	10.18 ± 3.3^{f}	6.34 ± 0.02^{e}	2.50 ± 0.16^{c}	34.43 ± 4.03^{c}	76.25 ± 0.89^{d}	2.98 ± 0.40^{b}	2.21
	Bouanane	26.85 ± 2.03^{ab}	7.67 ± 0.46^{d}	6.48 ± 1.49^{def}	5.93 ± 0.23^{a}	2.41 ± 0.06^{c}	34.25 ± 3.17^{c}	66.24 ± 1.05^{b}	3.11 ± 0.19^{bc}	1.93
	Boudnib	27.38 ± 0.53^{abc}	6.4 ± 1.52^{c}	13.75 ± 0.9^{bc}	6.17 ± 0.20^{b}	2.12 ± 0.39^{b}	35.46 ± 1.44^{c}	79.91 ± 0.76^{f}	3.52 ± 0.23^{c}	2.25
	Difat Ziz	29.61 ± 1.27^{abc}	7.21 ± 1.22^{cd}	10.07 ± 3.2^{de}	6.21 ± 0.06^{bc}	1.75 ± 0.13^{a}	35.66 ± 8.23^{c}	72.00 ± 0.04^{c}	2.51 ± 0.18^{a}	2.02
	Rissani	28.80 ± 1.14^{d}	6.23 ± 0.78^{c}	8.16 ± 1.5^{cde}	6.40 ± 0.13^{cd}	2.51 ± 0.06^{c}	31.08 ± 0.5^{bc}	75.71 ± 0.02^{d}	3.39 ± 0.51^{bc}	2.43
	Zagora	29.95 ± 0.97^{e}	8.13 ± 0.47^{d}	10.82 ± 2.65^{f}	6.53 ± 0.04^{de}	2.50 ± 0.06^{c}	33.01 ± 1.30^{c}	59.70 ± 0.65^{a}	3.17 ± 0.15^{bc}	1.80

Values are average (n = 5) ± standard deviation. Different litters (a-f) show significant differences in the same raw.
DW: Dry Weight.

3.2. Colour characteristics

Fruit skin colour is an excellent quality indicator; it is correlated to the synthesis and accumulation of secondary metabolites, such as phenolic and terpenoid compounds. Colour parameters of 'Mejhoul' samples are reported in (Table 1). Comparing 'Mejhoul' samples from Morocco, their origin with those from other transplanting countries, such as Palestine, Jordan, KSA and USA, we noted significant variations in lightness, redness, and yellowness values ($P < 0.05$). L* of Figuig (Morocco) samples (30.28) was significantly higher than those of Palestine samples (26.57), in contrast, a* values decreased from 9.75 for 'Mejhoul' USA to 3.56 for 'Mejhoul' Palestine. The highest b* value was found within Boudnib (Morocco) dates, and the lowest value was attributed to Palestine dates samples. These results are in agreement with (Hasnaoui, 2013), which reports that date cultivars from the United Arab Emirates have less light shade and lower values of a * and b * compared to those from Morocco. The variation of 'Mejhoul' colouration, maybe due to the variation in climatic condition as temperature and light radiation. The less lightness, redness and yellowness observed for 'Mejhoul' from Palestine and Jordan probably owing to the climate characterizing these countries and favouring intense browning. High temperatures induce poor fruit colouration, however, low temperatures enhance peel colour development (Koshita, 2015).

The difference in the pre-harvest, harvest, and post-harvest techniques used by Moroccan farmers and those from other countries may also be a major factor influencing the colour variance of the 'Mejhoul' samples. According to Arakawa et al., 1985, to enhance the exposure of apple fruit to light which increase its colouration, it is necessary to adopt good agricultural practices such as pruning or training, leaf thinning and bagging. Fertilizer application may also affect the colour variation of fruits. Kassem, (2012) indicate that potassium and Sulphur fertilization significantly increased dates fruit weight, length, width and colour.

Several authors have reported that storage conditions affect colour properties. Noutfia, et al. (2019) revealed that colour was significantly impacted by storage duration for the 'Mejhoul' cultivar. The increase of the b* value is correlated to enzymatic and no enzymatic reactions (Achour and Bagga, 2005). However, recent studies reported that b* and a* values decrease under cryogenic, storage conditions (Alhamdan et al., 2016). According to Aleid et al. (2014), packing type affects the colour properties of date fruits. Carton packages showed large lightness, redness and yellowness values compared to those in basket packages, it might be due to high inhibition of oxidant reactions in carton packing.

3.2.1. pH, moisture and ash content

In this study, the potential of hydrogen (pH) varied between 5.93 for samples from Bouanane (Morocco) to 6.55 for 'Mejhoul' from the USA. Similar results were obtained by Hasnaoui (2013) and (Bouhlali et al., 2015). The significant pH variation between Moroccan 'Mejhoul' and those from USA, KSA, Jordan, and Palestine might be due to the differences in climate. Barnuud et al. (2014), report that despite variations in a range of factors potentially affecting the pH of berry, the climate is the dominant factor. The low pH found in certain Moroccan 'Mejhoul' dates might be owing to farmers in some oasis still storing and transporting the dates in improper condition, as well as poor packing. Hazbavi et al., (2015) indicate that the pH of date fruits (cv. Stamaran) treated with hot water and dried at different temperatures decreased as storage duration increased (0–6 months). Aleid et al., (2014a) and Aleid et al., (2014b) explored the effect of storage duration on the pH of 'Sukkary' and 'Khalas' cultivars. They found that the date's pH decreased during storage, either kept within cold or frozen conditions. Baloch et al., (2006) study on 'Dhakki' dates, demonstrate that both oxidative and no-oxidative mechanisms, as well as water activity of dates, induces a fall of pH during storage under a controlled atmosphere. Conforming to Cheraghi and Hamdani, (2012), the type of packaging used for the 'Kabab' cultivar had a significant effect on total soluble solids, titratable acidity, and pH.

As for most agricultural products, the moisture content of dates fruits is a crucial qualitative characteristic. Table 1 presents water content of studied samples. Analysis of variance revealed significant differences ($p < 0.05$) between samples from Morocco, and Jordan, Palestine, and the USA. The highest moisture content was recorded within samples from Difat Ziz (Morocco) (35.66 %) while the lowest values were assigned to 'Mejhoul' from Palestine (23.96 %). Referring to the CEE-ONUDF-08 standard and the CODEX standard (CODEX STAN 143–1985), concerning marketing and commercial quality control of dates, all Moroccan dates present a moisture content surpassing limits preconized for date's international commercialization (30 %). According to Dowson and Atten, (1963), variation of moisture content may be related to relative atmospheric humidity.

Irrigation technique and fertilization can increase of 'Mejhoul' Moisture. A study carry on the effects of irrigation on dates fruit quality at Aswan (Egypt) has reported that increasing the frequency of irrigation improves moisture content, however, during the full maturation stage, it is recommended to minimize the amount and frequency of irrigation to reduce crop moisture (FAO, 2008). As reported by Soliman et al. (2018), the addition of Potassium fertilizer increased moisture content. Trees supplied with 400 g of K_2O produced fruits with high water content compared to control.

The variability of techniques considered by Moroccan farmers for drying 'Mejhoul' dates can also impact moisture content. Alsmairat et al. (2015) report that drying dates at trees give high moisture content compared to methods based on the fan, and forced warm air. Several studies have proved the effect of storage conditions and packing type on the moisture content of fruits. Kulkarni et al., (2008) report that at low-temperature storage, moisture content levels of fruits remain more or less constant, however, prolonged storage often leads to its decrease (Afoakwa and Sefa-dedeh, 2001).

Ash content ranged from 1.75 for 'Mejhoul' from Difat Ziz (Morocco) to 3.52 from Boudnib (Morocco) (Table 1). Analysis of variance of mineral content revealed high significant variation. Differences observed between samples can be explained by the effect of environmental conditions (type of soil and type of irrigation water), agronomic practices (application of fertilizers or other chemical substances), and geographical origin. Al-hooti et al., (1997) report that soil fertility status reflects mineral concentrations of dates. High temperatures and/or direct sunlight also affected mineral accumulation (Woolf and Ferguson, 2000).

Protein content shows significant variability between 'Mejhoul' samples. The highest amount of protein was registered in 'Mejhoul' from Palestine (3.33 g/100 g DW) and the lowest value was assigned to 'Mejhoul' from Difat Ziz (Morocco) (2.51 g/100 g DW). These results are similar to those obtained by (Bouhlali et al., 2015).

The ratio of total sugars and water content is expressed as an Index of quality "r" or the hardness. This index lead to classify dates at soft "r" <2, half-soft for 2 <"r" <3.5, and dry fruits "r"greater than 3.5 (Munier, 1973). All 'Mejhoul's samples studied ranged as half-soft dates, except 'Mejhoul' from Zagora (Morocco) and Bouanane (Morocco) ranged as soft dates (r = 1.80 and 1.93 respectively). These differences can be explained by storage conditions and environmental factors, especially atmospheric humidity (Hasnaoui, 2013).

3.2.2. Sugars composition

Significant variations were found among 'Mejhoul' dates sampled from different locations. The total sugar content of studied

'Mejhoul' ranges between 59.70 g/100 g DW (Zagora/Morocco) and 82.29 g/100 g DW (Palestine). Reducing sugar was predominant in all samples, while sucrose was not detected (Fig. 2). High content of inverted sugars within studied samples can be attributed to high invertase enzyme activity (Cheikh-Rouhou et al., 2006). (Table 2) shows that 'Mejhoul' from Palestine has the highest level of Fructose (44.31 g/100 g DW) and 'Mejhoul' from Boudnib (Morocco) shows the highest glucose content (38.36 g/100 g DW), while the lowest values were assigned to 'Mejhoul' from Zagora (Morocco). Those results are in agreement with those of Osman (2008), working on Egyptian cultivars 'Samany' and 'Zaghloul'.

The high concentration of total sugar content registered for Palestine 'Mejhoul' compared to 'Mejhoul' from Morocco (Bouanane, Zagora and Difat Ziz), may be due to fertilization techniques used. Soliman et al. (2018) report that the application of organic fertilizers alone or combined with NPK mineral fertilizer produced fruits with higher content of non-reducing and total sugars than mineral fertilization alone (NPK or N mineral alone). Reducing sugars percentage in fruits is increased by Potassium fertilization without depending on fertilizer concentration, while, non-reducing sugars present in fruits were positively affected by Potassium treatments during the second season (Soliman et al., 2018).

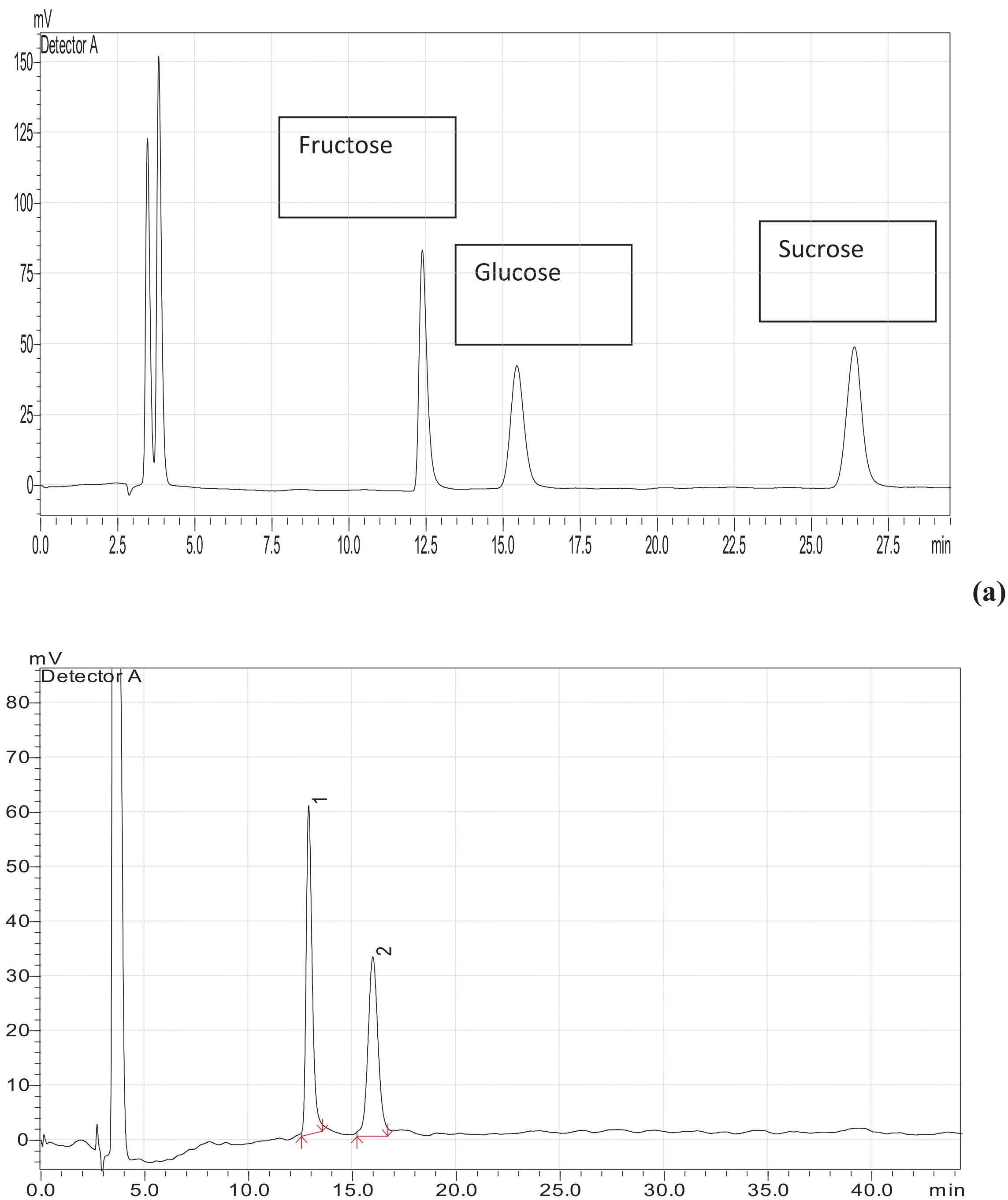

Fig. 2. (a) Chromatogram mixture of standard soluble sugars: Fructose, glucose and sucrose, (b) Soluble sugars chromatogram of 'Mejhoul' Cultivar.

Table 2
Sugar composition (Fructose, Glucose, Sucrose) of 'Mejhoul' dates.

Area	Glucose	Fructose	Sucrose	Fructose/glucose	
International 'Mejhoul'	Jordan	36.08 ± 0.02^{d}	42.95 ± 0.01 ^{g}	ND	1.19
	Palestine	37.98 ± 0.20^{e}	44.31 ± 0.13 ^{h}	ND	1.16
	USA	34.35 ± 0.09^{c}	37.21 ± 0.05^{b}	ND	1.08
	KSA	35.91 ± 0.45^{d}	40.60 ± 0.66^{e}	ND	1.13
Morocco 'Mejhoul'	Figuig	37.71 ± 0.85^{e}	38.52 ± 0.05 ^{cd}	ND	1.02
	Bouanane	30.73 ± 0.18^{b}	38.62 ± 0.88 ^{cd}	ND	1.25
	Boudnib	38.36 ± 0.79^{c}	41.55 ± 0.03^{f}	ND	1.08
	Difat Ziz	34.27 ± 0.32^{f}	37.78 ± 0.28^{bc}	ND	1.1
	Rissani	36.41 ± 0.17^{d}	39.30 ± 0.14^{d}	ND	1.08
	Zagora	27.45 ± 0.64^{a}	32.25 ± 0.01^{a}	ND	1.17

Values are average (n = 5) ± standard deviation. Significant differences in the same row are shown by different litters (a-f).
ND: No Determine.

According to Kassem (2012), the content of reducing sugars and total sugar in fruits was greater within trees treated with ammonium sulfate and ammonium nitrate.

In this study, irrigation techniques and quality of irrigation water can be considered as factors controlling variations in the total sugars of 'Mejhoul' dates sampled from different locations. Several studies report the existence of a significant influence of irrigation system on the sugars compositions of dates (Ismail et al., 2006; Nadeem and Anjum, 2011; Mirabad et al., 2013). According to Mattar et al. (2021), total sugars and non-reducing sugars contents in fruits decreased with the combination of saline water irrigation and 150 % evapotranspiration (ETc), whereas 50 % ETc irrigation level caused an increment in both parameters. Water-stressed 'Mazafati' and 'Khalas' dates are characterized by an increased sugar content (Al-yahyai and Al-kharusi, 2012; Alikhani-koupaei et al., 2018).

As reported by Krid (2018), polyethene bagging of 'Deglet Noor' fruits bunch increases reducing sugars (fructose and glucose), compared to unbegged dates. Packaging types could also affect sugar composition (fructose, glucose, and sucrose). Confirming to Alsawmahi et al. (2018), dates packaged in polypropylene present a higher amount of fructose and glucose contents than those packaged in polyethylene. Reducing sugars are affected by storage conditions. Glucose contents increased within high storage temperatures, whereas, Fructose contents increased no matter freezing temperatures (Ismail et al., 2008).

3.3. Microbiological analysis

The microbiological analysis shows that 'Mejhoul' sampled from Moroccan palm groves and different international locations contain a variable amount of mesophilic aerobic bacteria, yeasts and moulds. Pathogenic microorganisms, coliforms, *Bacillus sp* and *Staphylococcus* were not detected on any samples (Table 3). Globally, microbial values obtained did not fall within acceptable limits, according to the microbiological standard given by the French federation of commerce and distribution (FCD, 2020).

Microbial load enumeration of mesophilic aerobic bacteria for 'Mejhoul' samples ranged between 4.02 log CFU.g^{-1} for 'Mejhoul' from Figuig (Morocco) and 1.90 log CFU.g^{-1} for 'Mejhoul' from the USA. Yeasts were<1 log CFU.g^{-1} for 'Mejhoul' from KSA, Rissani (Morocco) and Zagora (Morocco) and higher than 2.85 log CFU.g^{-1} for 'Mejhoul' from Boudnib (Morocco). The Higher moulds content was recorded within samples from Difat Ziz (Morocco) (2.36 CFU. g^{-1}), while the lowest was accorded within samples from Zagora (Morocco) (1.02 log CFU.g^{-1}) (Table 3). Variation found within Microbial load could be contributed to physicochemical properties, pH, water activity, moisture content, nature and amounts of sugars within dates, to external environmental conditions (temperature, humidity), or storage conditions and production practices (harvest, and postharvest processing) (Kalia and Gupta, 2006).

Elevated High counts of mesophilic aerobic bacteria, yeast, and moulds found within 'Mejhoul' from Figuig (Morocco) may be owing to inadequate hygienic conditions considered during harvest, deficient storage conditions, and inappropriate date packaging. Jdaini et al. (2022), indicate that the major causes of microbial deterioration are the use of improper date harvesting and post-harvesting practices. Proper storage techniques are essential for maintaining product quality and preventing date deterioration before selling to consumers (Al Jawally, 2010). According to Hamad (2012), samples packaged and maintained at refrigeration temperatures present low contamination levels. Minor microbial load registered within international 'Mejhoul'can be assigned to strict sanitary standards required by importers,

Table 3
Microbiological results of 'Mejhoul' dates.

	TVC	Yeasts	Molds	*S. aureus*	LAB	*Bacillus* sp.	Coliforms	
International 'Mejhoul'	Jordan	3.07	2.46	1.85	<1.0	<1.0	<1.0	<1.0
	Palestine	2.23	1.60	1.90	<1.0	<1.0	<1.0	<1.0
	USA	1.90	1.48	1.70	<1.0	<1.0	<1.0	<1.0
	KSA	2.04	<1.0	1.60	<1.0	<1.0	<1.0	<1.0
Moroccan 'Mejhoul'	Figuig	4.02	2.66	1.95	<1.0	<1.0	<1.0	<1.0
	Bouanane	2.84	2.48	1.00	<1.0	<1.0	<1.0	<1.0
	Boudnib	3.15	2.85	1.00	<1.0	<1.0	<1.0	<1.0
	Difat Ziz	2.93	1.95	2.36	<1.0	<1.0	<1.0	<1.0
	Rissani	2.20	<1.0	1.85	<1.0	<1.0	<1.0	<1.0
	Zagora	2.15	<1.0	1.02	<1.0	<1.0	<1.0	<1.0

*Results are expressed as log CFU.g^{-1} of dates.

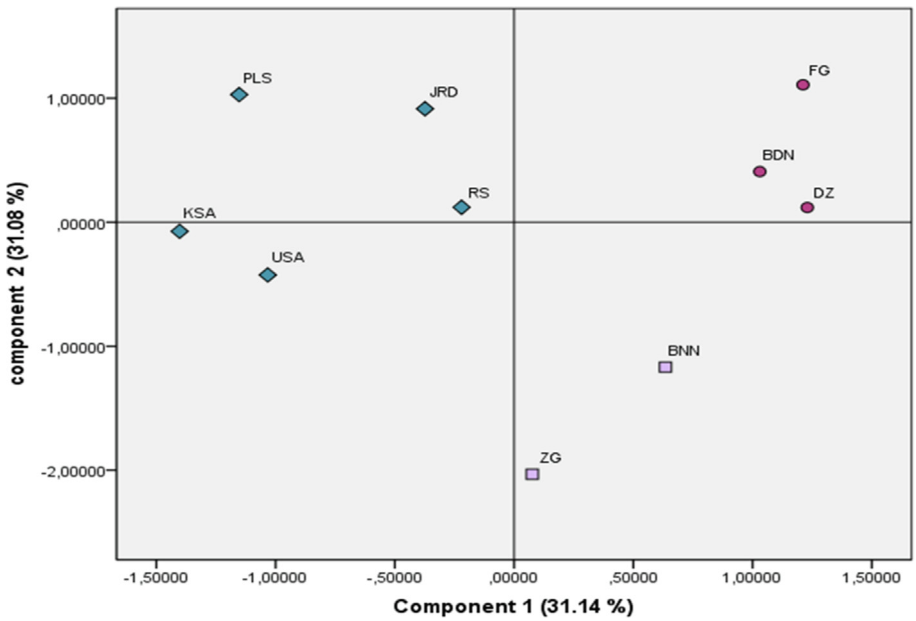

Fig. 3. Projection of the variables of the ten studied 'Mejhoul' dates samples in the plane defined by two principal components; **KSA**: kingdom of Arabia Saudi,**USA**: United State of America, **JRD**: Jordan, **PLS**: Palestine, **RS**: Rissani, **FG**: Figuig, **BND**: Boudnib, **DZ**: Difat Ziz, **BNN**: Bouanane, **ZG**: Zagora.

and suitable agricultural practices applied from production to marketing.

3.4. Principal component analysis of physic-chemical and microbiological characteristics.

Principal component analysis (PCA) was conducted to classify studied 'Mejhoul' and to provide easy visualization of relationships among the growing area of 'Mejhoul' samples and their physico-chemical and microbiological characteristics. Fig. 3 sum-up PCA results of 10 studied 'Mejhoul' samples. The factorial map showed clear discrimination between studied samples and approved interpretations elaborated above. Results obtained allowed the establishment of two main components PC1 and PC2, explaining more than 76 % of the total information. PC1 explained 31.14 %, with high contribution of moisture (0.950), ash (-0.889), hardness index (-0.827), TVC (0.778) yellowness (0.685) and Yeasts (0.520). PC2 explained 31.08 % and represented by fructose content (0.933) total sugar (0.929), glucose (0.799), Molds (0,631) and redness (-0.576). Based on PC1 and PC2, the studied 'Mejhoul' samples could be divided into three groups. The first group consists of samples from Figuig, Boudnib and Difat Ziz (Morocco), which is correlated positively to Moisture, TVC, yellowness and yeasts and negatively to Ash and quality index. The second group is composed of samples from Palestine, Jordan, USA and KSA, with opposition to the first group, and respect to PC1. The third group include 'Mejhoul' from Bouanane and Zagora (Morocco). For principal component 2, the most distinct variables were total sugar, fructose, glucose and moulds. According to factorial maps, the effect of growing areas on physic-chemical characteristics and microbiological proprieties was mainly manifested, exhibiting that expansion of 'Mejhoul' dates cultivation from their original growing area in Morocco into other international production locations has induced variations within their characteristics.

4. Conclusion

Expansion of 'Mejhoul' dates cultivation from its original growing area in Morocco to other countries brings on different variations in physical, chemical, and microbiological Parameters. Historically 'Mejhoul' dates palm trees originated in Morocco, known as the best dates grown anywhere, where all the favourable conditions are regrouped to produce a good and exceptional quality of dates. This makes Morocco the perfect place for cultivating dates and the leading fruit 'Mejhoul' dates exporting country. Despite all these profitable advantages, we find out that Morocco is not among the chief exporting countries that newly introduced 'Mejhoul' in their lands. In this study, we tried to hypothesize the different causes of Moroccan date's low quality compared to other countries such as the USA, KSA, Jordan and Palestine. As we know dates are exposed to all kinds of contaminants and deteriorations consequently; they lose their value and their quality. We think that this low quality is due to multiples reasons. Environmental factors (drought and scarcity of water resources) come first. On the other hand, the main production techniques are neglected by most farmers who are still confined to their ancestral farming practices. However, the main exporting countries are not content only with traditional method but also with good agricultural practices such as:

- Adequate supply of fertilizer
- Thinning and bagging of bunches
- Fruits drying to maintain a humidity level below 28 %
- Sorting and grading fruits
- Store fruits under adequate conditions to maintain fruits quality and prevent deterioration of dates before selling them to consumers
- Using of appropriate packaging such as modified atmosphere and vacuum packaging

5. Author agreement

All the authors of the manuscript titled Variations in physico-chemical and microbiological characteristics of 'Mejhoul' dates (*Phoenix dactylifera* L.) from Morocco and new countries of its expansion, has seen and approved the contents of the submitted manuscript to Journal of the Saudi Society of Agricultural Sciences.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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