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Characterization of the Moroccan saffron in relation to climate, soil, and water in its main production zones

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ABSTRACT

Purpose: Moroccan saffron is considered among the best quality produce worldwide. Its main production zones in Morocco are Taliwine and Taznakht administrative districts, located in the semiarid and arid bioclimatic ranges. The present study objective is the chemical characterization of Moroccan saffron from the main producing counties in relation with climatic conditions, altitude, soil, and irrigation water. **Research method:** Saffron, soil and water samples were taken from 10 counties representing 80% of the production areas and underwent analysis using standard methods. **Findings:** Results showed that 80% of saffron samples are classified in category I, regarding crocin, picrocrocin, and safranal contents, according to the international standard ISO 3632-1. Soils supporting saffron cultivation are coarse and low in organic matter; their pH is alkaline and the EC low. Irrigation water is generally alkaline with low to very low EC. Statistical analysis showed that moderate altitude (1650-1900m) in the semiarid bio-climatic range had a positive effect on saffron quality (higher picrocrocin and crocin contents). Safranal was not influenced by altitude or by the bio-climate. Water and soil did not show any influence on saffron quality. **Research limitations:** As some cooperatives had organizational problems, it was not possible to get saffron samples from high altitude in the arid bioclimatic range in 2017 and 2018. **Originality/Value:** The most important value of the present work is the large number of samples distributed over three years and covering 80% of the production territory, which enabled to distinguish an effect of bio-climate and altitude on picrocrocin and crocin.

INTRODUCTION

Saffron (*Crocus sativus* L.) is the most expensive spice in the world principally used for culinary purposes but it has also medicinal properties (Cavusoglu & Erkel, 2009; Kumar, 2009). It is mainly produced in Iran, India, Greece, Morocco, Spain, China, Turkey, Azerbaijan and Italy. It is adapted to arid and semiarid lands and to temperate and subtropical climates. The crop can be cultivated on soils ranging from sandy to well-drained clay-loam (Lage & Cantrell, 2009). Worldwide, Iran is the biggest saffron producer with 405 tons dried stigma per year, and 115,000 ha (Golmohammadi, 2019). Morocco is the 4th saffron producer in the world and the first in Africa. In 2019, the total area cultivated with this crop was 1,860 ha with a yield of 6.5 tons produced by over 4,300 farmers (Moroccan Ministry of Agriculture, 2020). The main production zones are located in the mountainous areas of Taliwine and Taznakht administrative districts, historically considered as the origin of the cultivation of this produce (Ait Oubahou & El Otmani, 1999).

Saffron stigma quality depends on the content of its three main secondary metabolites: crocin and its derivatives responsible for the colour, picrocrocin, responsible for the slightly bitter taste, and safranal, responsible for the characteristic aroma of this spice. The concentration of these three metabolites can be evaluated using several techniques such as UV-vis spectrophotometry (ISO 3632-2, 2010), high performance liquid chromatography, gas chromatography, thin layer chromatography (Tarantilis et al., 1995; Zougagh et al., 2005; Caballero-Ortega et al., 2007; Zalacain et al., 2005).According to the international standard ISO 3632-1 (2011), saffron in filaments or powder is classified in categories I, II or III according to its physical (water content) and chemical criteria (volatile matter, crocin, picrocrocin and safranal contents).

The quality of saffron also depends on environmental conditions such as climate (temperature, rainfall patterns), altitude, soil type, and irrigation water. These conditions constitute factors related to the ecological characteristics of the cultivation zone (Behdani et al., 2006).

The objective of this study is to investigate Moroccan saffron quality (crocin, picrocrocin and safranal contents) in relation to the *Terroir*, a term designating a specific geographical location. The *"Terroir"* is defined as a particular geographical location where an agricultural produce draws its originality, directly from the specificities of its production area (INAO, 2016). As such, the *Terroir* is a delimited space in which a human community builds, over the course of its history, collective production know-how, based on a system of interactions between the physical and biological environments, and a set of human factors.

MATERIALS AND METHODS

Study area

The study area is located within the administrative districts of Taliwine and Taznakht, two towns at the junction of the High and Anti-Atlas Mountains of Central Morocco (Fig. 1). These districts comprise several counties where saffron is cultivated. In this paper focus is made on counties that have relatively substantial production. For Taliwine, these are: Agadir Melloul, Askawn, Assays, Sidi Hsayn, Tassousfi and Zagmuzen. In Taznakht, counties producing saffron are: Iznaguen, Khuzama, Sirwa and Wisselsate (Fig. 2). Official Moroccan topographical maps were digitized using Autocad 2021 software for geographical location of counties and samples as well as altitudes (Fig. 3).

Table 1. Number of saffron samples received from farmers according to counties of Taliwine and Taznakht

	AM	Ask	Ass	Izn	Khu	SH	Sir	Tas	Wis	Zag	Total
2016	12	23	22	3	13	13	10	30	3	7	136
2017	17	22	24	4	6	9	5	55	3	0	145
2018	18	59	22	20	4	20	4	62	21	9	239
Total	47	104	68	27	23	42	19	147	27	16	520

AM=Agadir Melloul, Ask=Askawn, Ass=Assays, Izn=Iznaguen, Khu=Khuzama, SH=Sidi Hsayn, Sir=Sirwa, Tass=Tassousfi, Wiss=Wisselsate, Zag=Zagmuzen.

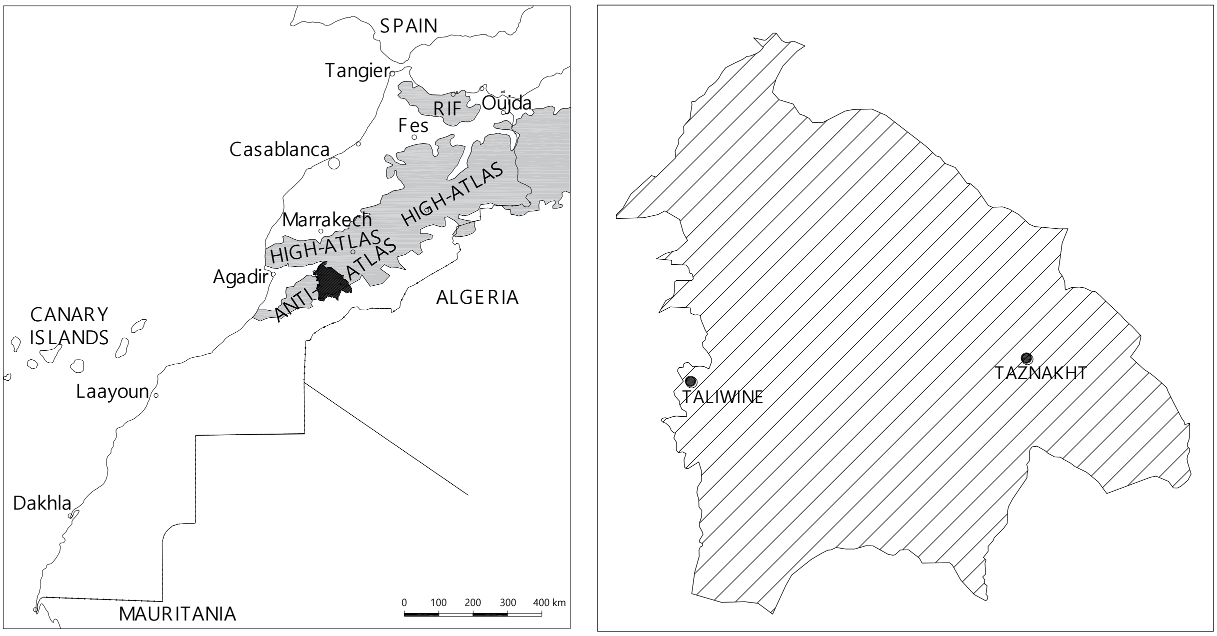

Fig. 1. Location maps of Saffron production area in Morocco.

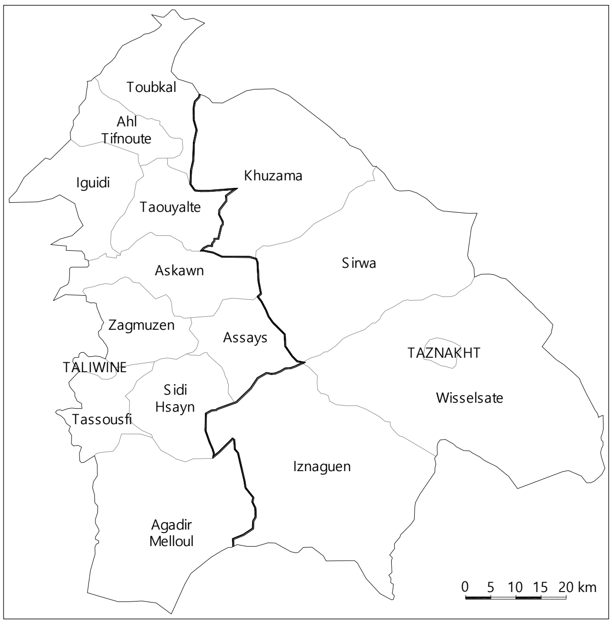

Fig. 2. Counties constituting the administrative districts of Taliwine and Taznakht.

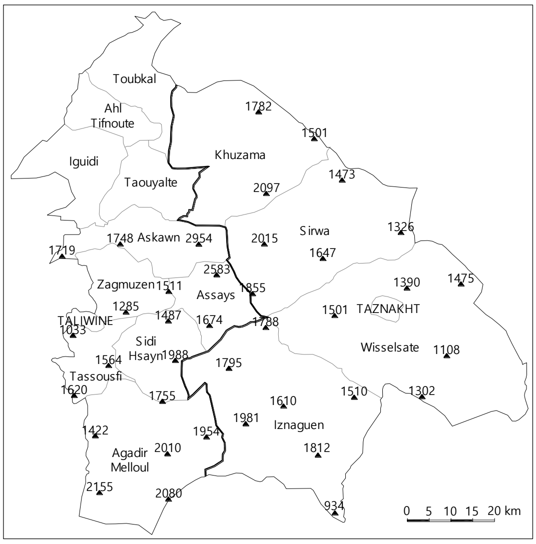

Fig. 3. Altitude points in saffron producing counties of Taliwine and Taznakht.

Saffron, soil, and water sampling

Dry saffron stigma samples were brought to the laboratory of Dar Azaafarane (Taliwine) by several farmers cultivating this crop in Taliwine and Taznakht administrative districts as follows: 136 in 2016, 145 in 2017 and 239 in 2018 (Table 1). These farmers wanted to investigate the quality of their produce. Each saffron sample was labelled with information about location in terms of county and geographical coordinates including altitude using a Garmin 64 sx-GPS.

In 2021, soil and irrigation water were sampled from locations representative of the different production areas of Taliwine and Taznakht for physicochemical characterization and possible correlation with saffron quality, climate and altitude. Soil samples were taken at an average depth of 25 cm. Water samples were taken from irrigation wells after at least 15 minutes of pumping. Ten soil and 10 water samples were taken and geographically referenced by GPS coordinates (Garmin 64 sx-GPS).

Saffron chemical analysis

For crocin, picrocrocin and safranal analysis, one-gram saffron sample was taken in different places of the batch brought back by each farmer (in the top, in the middle and in the bottom). It was kept in a clean glass bottle and stored in the dark at room temperature. Measurements were just after harvest done in November of each sampling year (2016, 2017 and 2018).

Physicochemical analysis was performed according to ISO 3632 standards whose tests include moisture, volatile matter, crocin, picrocrocin, and safranal contents. Moisture and volatile matter were evaluated after samples drying in an oven at 103°C± 2°C for 16 hours (ISO 3632-2, 2010). Samples with moisture content higher than 12% were discarded because they did not conform to the standards. The physicochemical properties of saffron were measured by a spectrophotometer (Biobase BK-UV1000) according to the standard ISO 3632-1 (2011). Picrocrocin, safranal and crocin contents were measured in 257, 330 and 440nm wavelengths, respectively.

Physicochemical analysis of soil and water

Saffron production soil samples were sieved through a 2 mm mesh to separate gravel form fine particles. Components of the fine fraction were determined using Robinson pipette method. The pH was measured by a Jenway 3310 pH-meter and the EC by an Adwa 3000

EC-meter. Organic matter was measured by Walkley Black method (Chapman & Pratt, 1962). Calcium carbonate ($CaCO_3$) was determined through a direct reaction with chlorhydric acid. Nitrates were obtained by colorimetry and available phosphorous by Olsen's method (Chapman & Pratt, 1962). Sodium and potassium were measured by a Wagtech flame photometer. Calcium, magnesium, and trace elements (Cu, Fe, Mn, Zn) were determined by a Thermo Scientific iCE 3000 series Atomic Absorption spectrometer. Carbonate, bicarbonate and chloride were measured by titration (Chapman & Pratt, 1962).

Climate data

Climate data of the area in terms of rainfall and temperature were obtained from Climate Toolbox website (2021). For this paper, only climate data of 2016, 2017 and 2018 are studied with the aim of investigating possible correlations with saffron chemical characteristics.

Statistical analysis

To assess the effect of bioclimatic range and altitude on saffron chemical parameters, data were submitted to statistical analysis using Statistica (version 6) software. When analysis of variance (ANOVA) revealed significant differences, mean comparisons were performed using Newman-Keuls test.

RESULTS AND DISCUSSION

Categorization of saffron from Taliwine and Taznakht administrative districts

Out of the 520 saffron samples brought by farmers, 17 were discarded for non-compliance with ISO 3632-1 (2011) due to moisture and volatile matter content that was higher than 12%. The other samples were analyzed for crocin, picrocrocin and safranal content. Almost 80 % of the samples were classified as category I, 15 % as category II, and 4.4 % as category III. Five samples only were found non-compliant with the ISO 3632-1 (2011) standards (Table 2).

Saffron samples distribution according to altitude

Altitudinal ranges of saffron production in Taliwine and Taznakht districts have been set by Birouk (2009) in 3 levels: low altitude (1450 to 1650 m), moderate altitude (1650 to 1900 m) and high altitude (1900 to 2200 m). According to these intervals, the samples investigated in this paper are distributed as follows: 212 in low altitude, 168 in moderate altitude and 122 in high altitude.

Table 2. Saffron samples classification according to ISO 3632-1 (2011) standards

Harvest year Categories	2016		2017		2018		Total	
	Samples number	Percentage of total	Samples number	Percentage of total	Samples number	Percentage of total	Samples number	Percentage of total
Category I	94	76.4	125	88.7	181	75.7	400	79.5
Category II	21	17.1	11	7.8	44	18.4	76	15.1
Category III	8	6.5	4	2.8	10	4.2	22	4.4
Non-compliant	0	0	1	0.7	4	1.7	5	≈ 1
Total	123	100	141	100	239	100	503	100

Table 3. Altitudinal ranges of saffron producing counties in Taliwine and Taznakht districts

	AM	Ask	Ass	Izn	Khu	SH	Sir	Tas	Wis	Zag
Altitude min. (m)	1422	1200	1387	934	1501	1169	1326	1033	1108	1167
Altitude max. (m)	2080	2954	2583	1981	2263	1988	2015	1620	1827	1955

AM=Agadir Melloul, Ask=Askawn, Ass=Assays, Izn=Iznaguen, Khu=Khuzama, SH=Sidi Hsayn, Sir=Sirwa, Tass=Tassousfi, Wiss=Wisselsate, Zag=Zagmuzen.

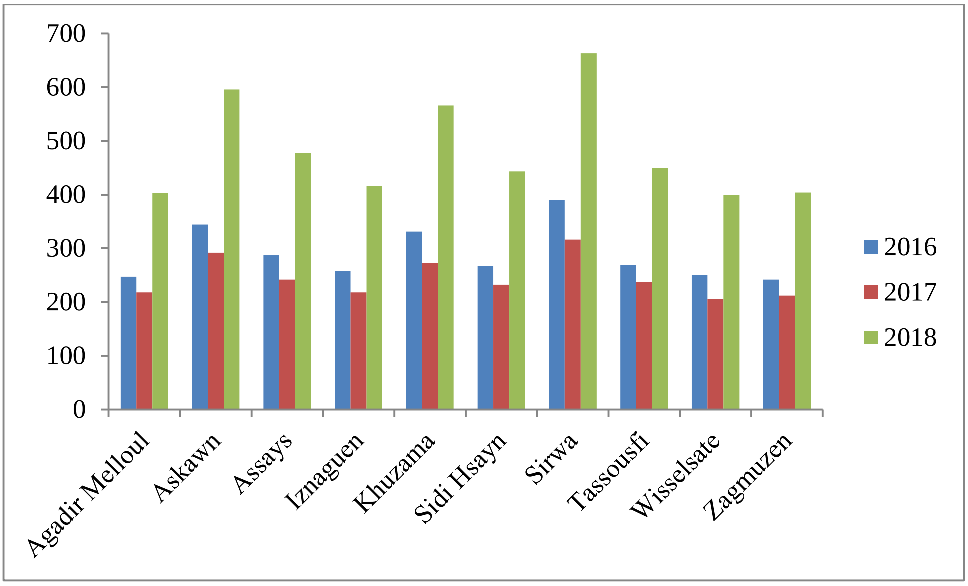

Fig. 4. Annual rainfall (mm) for the 10 counties studied (2016-2018).

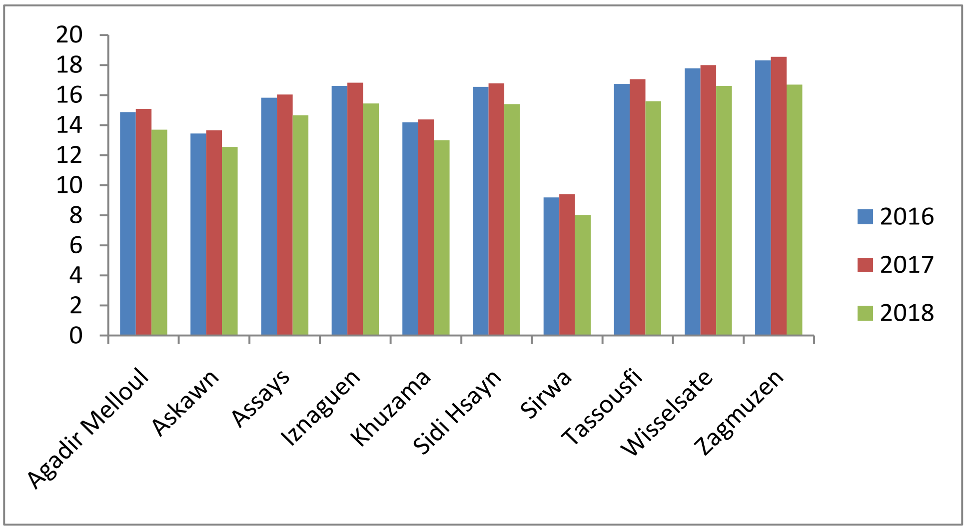

Fig. 5. Mean annual temperature (°C) for the 10 counties studied (2016-2018).

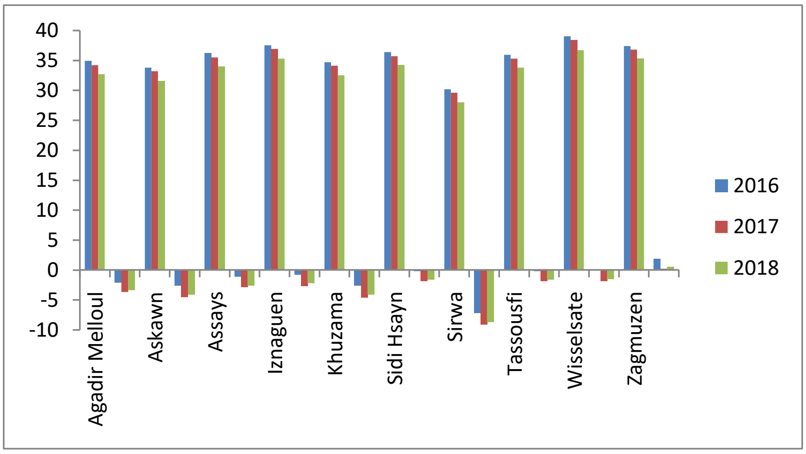

Fig. 6. Absolute maximum (July) and minimum (January) temperatures (°C) for the 10 counties studied (2016-2018).

Climate characterization of saffron production counties in Taliwine and Taznakht districts

Climate data were compiled for the 3 years corresponding to the harvest of saffron samples studied. As climate is also influenced by altitude, Table 3 shows the altitudinal ranges for each county. Apart from Tassousfi and Wisselsate, all counties have altitudes that range from low to high, according to the subdivision set by Birouk (2009).

Figure 4 presents rainfall data for the 10 counties from which saffron samples were obtained. It clearly shows the irregularity of rain during the 3 years, 2018 being exceptionally rainy for the climate of this region. Askawn, Khuzama and Sirwa counties had the highest rainfall during the 3 years of study (Fig. 4).

Mean temperature calculated as the average of maximum and minimum temperatures ranged from 9 to 18 °C indicating that the climate can be considered as mild (Fig. 5). However, while absolute maximum temperatures registered during the 3 years was not particularly high ranging from 28 to 39 °C, absolute minimum temperatures were all below zero reaching -9 °C registered in 2017 in Sirwa (Fig. 6).

Emberger (1955) who described the Moroccan vegetation in relation to the climate established subdivisions combining rainfall and maximum and minimum temperatures. According to these parameters, 2 bio-climates can be distinguished in the Taliwine-Taznakht saffron production districts. A semiarid bio-climate comprising Askawn, Khuzama, and Sirwa and an arid bio-climate for the other counties.

In Tables 4 and 5, saffron quality is combined with altitude and bio-climates to detect any correlations between chemical contents and these parameters. Tables 4 to 6 show that almost all samples from the semiarid bio-climate comply with category I classification. In fact samples from the moderate altitude (1650-1900 m) and high altitude (1900-2263 m) were category I according to ISO 3632-1 (2011) standard, at 100 and 95% rates respectively. In the arid bio-climate samples were classified category I at rates of 66.67%, 82.78% and 66.98% in high, moderate and low altitudes respectively. Statistical analysis revealed a significant effect of the bioclimatic range and altitude on picrocrocin and crocin (Tables 4 and 5). There was a positive effect of the bio-climate on the quality of saffron. Globally the 137 saffron samples from the semiarid bio-climate had picrocrocin and crocin levels higher than the 366 samples taken from the arid bio-climate. In 2017 and 2018 picrocrocin and crocin values were remarkably higher in the moderate altitudinal range (1650-1900 m). Absorbance readings revealed that in 2017, the highest values for picrocrocin (101.7) and crocin (260.8) were found in Askawn saffron samples at 1796 and 1811 m altitudes respectively under semiarid bio-climate. On the other hand, safranal content was not affected by the bioclimatic range or by altitude. Birouk (2009), Lage and Cantrell (2009) and Lage et al. (2010) concluded that there was a positive correlation between the altitude where saffron is produced and crocin content. However, Aboudrare et al. (2012) who worked on 20 samples and Atyane *et al.* (2016) who analyzed 8 samples concluded that crocin absorbance at low altitude (1500-1600 m) was higher than at higher altitude. Nevertheless, the small number of samples on which these authors have worked makes it difficult to draw any sound conclusions. Birouk (2009) argued that the impact of altitude on saffron chemical quality reported in several studies may not be only attributed to this factor but also to others such as drying process and storage conditions. In the present study we made sure that the drying process and storage conditions were similar for the investigated samples as farmers had to respect them for commercial purposes. We can therefore assert that moderate altitude in the semiarid bio-climatic range of Taliwine and Taznakht districts positively affected the quality of saffron.

Characterization of saffron production soils and water in Taliwine and Taznakht districts

Physical and chemical properties of soils are shown in Tables 7 and 8. Soil texture is coarse with gravel values globally higher than 30% (Table 7). The coarseness is also expressed in the fine fraction as clay is always lower than 10 %. These soils can be classified as well draining. The pH is alkaline in almost all samples and the EC is rather low. Organic matter content is well below 1% except for one sample that had 1.26%. To remedy the low organic matter content, each year farmers add manure to their fields as organic fertilizer amendment to improve saffron production conditions. Low organic matter content was also found in saffron production soils in Iran for which Kafi et al. (2006) reported values below 1 %.

Chemical analysis of saffron production soils revealed that they are low in lime except the soil of Tassousfi that had high calcium carbonate content. In spite of that, the concentrations of active calcium are within acceptable ranges with the exception of the sample from Assays at 1747 m altitude (Table 8).

Several studies have shown that saffron can be successfully grown on a wide range of soil textures provided they are well drained. In Spain, saffron was successfully cultivated on a well-drained clay-limestone soil type. In Italy, the best saffron yields were obtained on well-drained clay soils or on alluvial sediments. In India, farmers cultivate saffron on soils with a clay upper layer but with good drainage at the lower layers (Shahandeh, 2020). In the studies carried out in these countries, the main factor for saffron cultivation is good soil drainage (Shahandeh, 2020).

Lage and Cantrell (2009) found that the clay content was positively correlated with safranal absorbance. Birouk (2009) who studied the perception of the characteristics of saffron by 49 producers and 14 sellers in the administrative district of Taliwine also concluded that the clay content and the appreciation of the intensity of the aroma in the different rural communities were correlated. Husaini et al. (2010) suggested that increasing the clay content had a dominant influence on soil water supply, nutrient uptake and the quality of saffron as far as safranal content was concerned. Nevertheless, in accordance with the results of Lambert and Karra (2016), the present study has revealed that the 10 soil samples analyzed did not have clay contents higher than 10 %. Given that saffron of this region is internationally renowned, it can be concluded that its chemical quality depends on factors other than soil characteristics.

Table 4. Effect of bio-climate and altitude on the quality of saffron in Taliwine and Taznakht districts (Single year values)

		Harvest year								
		2016			2017			2018		
Bio-climate	Altitude (m)	P	S	C	P	S	C	P	S	C
Semi-arid	1900-2263	89.43 b	30.70 a	213.04 b	91.07 b	29.89 a	223.38 b	90.78 b	31.15 a	220.88 b
	1650-1900	92.81 a	28.56 a	226.19 a	98.36 a	29.89 a	238.03 a	97.40 a	31.20 a	250.81 a
Average values		91.12 a	29.63 a	219.62 a	94.72 a	29.89 a	230.71 a	94.09 a	31.18 a	235.85 a
Arid	1900-2263	76.09 c	32.21 a	203.00 b	NSA	NSA	NSA	NSA	NSA	NSA
	1650-1900	90.75 a	30.85 a	215.73 a	92.58 a	30.40 a	217.51 a	85.15 a	31.11 a	208.71 a
	1399-1650	86.78 b	31.09 a	209.16 b	93.84 a	33.49 a	216.17 a	87.89 a	34.74 a	213.76 a
Average values		84.54 b	31.38 a	209.30 b	93.21 a	31.95 a	216.84 b	86.52 b	32.93 a	211.24 b

Values are mean of total saffron samples from each altitude regarding P: Picrocrocin, S: Safranal, and C: Crocin contents expressed as $E^{1\%}$ values. NSA=No samples available. In each column, values with the same letter are not significantly different at p<0.05.

Table 5. Effect of bio-climate and altitude on the quality of saffron in Taliwine and Taznakht districts

Bio-climate	Altitude (m)	Picrocrocin	Safranal	Crocin
Semi-arid	1900-2263	90.43 b	30.58 a	219.10 b
	1650-1900	96.19 a	29.88 a	238.34 a
	Average values	93.31 a	30.23 a	228.72 a
Arid	1900-2263	*	*	*
	1650-1900	89.49 a	30.79 a	213.98 a
	1399-1650	89.50 a	33.11a	213.03 a
	Average values	89.50 b	31.95 a	213.50 b

(Average values for 2016, 2017 and 2018 harvest years) *= Data not available. For each component and in each bio-climate, values with the same letter are not significantly different at p<0.05. For the 2 bio-climates and for each component, average values with the same letter are not significantly different at p<0.05.

Table 6. Effect of bio-climate and altitude on the quality of saffron in Taliwine and Taznakht districts

	Semiarid bio-climate			Arid bio-climate		
	High altitude	Moderate altitude	Low altitude	High altitude	Moderate altitude	Low altitude
	(1900-2263)	(1650-1900)	(1399-1650)	(1900-2263)	(1650-1900)	(1399-1650)
Category I	94.96%	100%	NSA	66.67%	82.78%	66.98%
Category II	3.36%	NSA	NSA	33.33%	11.26%	25.47%
Category III	1.68%	NSA	NSA	NSA	3.31%	7.08%
Non-Compliant					2.65%	0.47%

NSA: No samples available

Table 7 Texture, pH, EC and organic matter content of saffron production soils in Taliwine and Taznakht districts

		Texture (%)								
Bio-climate	County (sample altitude)	Gravel (>2mm)	Coarse sand (200µ-2mm)	Fine sand (50-200µ)	Coarse silt (20-50µ)	Fine silt (2-20µ)	Clay (<2µ)	pH	EC dS/m	Organic matter (%)
Semi-arid	Askawn (1929 m)	35.7	30.4	8.6	11.1	9.8	4.4	7.58	0.12	0.741
	Askawn (1927 m)	34.3	41	10.7	7.7	2.9	3.4	7.09	0.05	0.566
	Askawn (1796 m)	21.5	32.7	27.4	0.4	11.9	6.1	7.52	0.11	0.352
	Khuzama (2244 m)	38.0	40.5	6.9	5.6	3.8	5.2	7.62	0.05	0.148
	Sirwa (2016 m)	57.8	5.6	6.8	18.9	0.2	10.6	8.11	0.08	0.695
	Sirwa (2016 m)	37.9	20.8	14.4	8.1	14.6	4.2	8.46	0.11	0.792
	Sirwa (2016 m)	60.0	8.9	7.7	15.8	6.8	0.8	7.34	0.06	0.234
Arid	Assays (1747 m)	35.4	16.5	19.2	11	14.1	3.8	7.98	0.06	0.481
	Assays (1392 m)	36.0	7.6	40.7	2.9	9.6	3.2	8.32	0.17	1.264
	Iznaguen (1783 m)	39.5	1.3	9.4	27.4	18.9	3.5	8.17	0.08	0.573
	Tassousfi (1467 m)	50.4	12.4	11.2	11.4	8.7	5.9	8.33	0.13	0.449
	Wisselsate (1399 m)	39.2	7.8	11.2	31.8	5.9	3.9	8.52	0.69	0.298

Table 9 shows the chemical characteristics of water used for the irrigation of saffron fields in the producing counties of Taliwine and Taznakht. Electrical conductivity is very low in altitudes higher than 1500 m presumably due to the geological type of the substratum generally of metamorphic origin. In samples presenting ECs higher than 1 dS/m, the concentration of some elements is higher compared to the other samples. The pH ranged from 6 to 8 depending on the location. Bicarbonates are higher in water with high EC and Ca or K contents or both (Table 9). Nitrates are low with the exception of the Iznaguen county sample that exceeds the acceptable limit for drinking water. This situation may be due to contamination by sanitation cesspools. Koocheki et al. (2020) reported that the best growth and yield of saffron were obtained when irrigation water is low in salt-induced ions. Yarami and Sepaskhah (2016) reported that water with an EC of 3 dS/m reduced crocin, picrocrocin and safranal contents by 9, 13 and 18 % respectively compared with a control treatment.

Table 8. Chemical composition of saffron production soils in Taliwine and Taznakht districts

		Chemical parameters										
Bio-climate	County (sample altitude)	$CaCO_3$ %	CaO ‰	P ppm	NO_3 ppm	Na_2O ppm	K_2O ppm	MgO ppm	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Semi-arid	Askawn (1929 m)	3.1	3.26	90.8	26	959	770	741	0.44	3.4	1.7	0.34
	Askawn (1927 m)	3.2	2.16	84.6	26.2	594	660	566	0.42	4.9	1.2	0.33
	Askawn (1796 m)	1.1	1.44	54.6	19.5	972	660	352	1.28	2.8	1.1	0.32
	Khuzama (2244 m)	5.9	1.82	78.8	6.6	635	320	148	0.18	1.4	1.6	0.34
	Sirwa (2016 m)	3.9	1.84	72.7	13.1	608	510	234	0.87	4.4	1.4	0.48
Arid	Assays (1747 m)	0.4	7.98	54.4	13.2	351	600	481	0.22	5.9	1.4	0.33
	Assays (1392 m)	11.6	2	72.6	6.5	1025	600	1264	0.22	3.9	1.5	0.31
	Iznaguen (1783 m)	2.3	3	48.4	9.8	824	870	573	0.31	1.2	1	0.27
	Tassousfi (1467 m)	50.1	2.54	78.8	6.4	297	940	449	0.24	7.1	1.3	0.28
	Wisselsat (1399 m)	5.8	1.76	30.4	25.9	338	700	298	0.21	3.5	1.8	0.3

Table 9. Characterization of saffron irrigation water in Taliwine and Taznakht districts

		Chemical parameters								
Bio-climate	County (sample altitude)	EC (dS/m)	pH	NO_3 (ppm)	H_2CO_3 (ppm)	Cl (ppm)	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Semi-arid	Askawn (1929 m)	0.28	7.29	5.62	90.2	6.2	4.14	76.8	36.2	18.1
	Askawn (1927 m)	0.2	7.88	6.91	73.2	2.5	7.59	114.3	45.1	7.9
	Askawn (1796 m)	0.25	7.52	4.74	91.5	2.48	11.04	72.9	14.4	18.4
	Khuzama (2244 m)	0.22	7.56	31.2	105.6	3.7	2.3	62.4	40.6	1.3
	Sirwa (2016 m)	0.15	6.55	28.1	97.6	3.72	3.22	20.7	28.8	4.6
Arid	Assays (1747 m)	0.44	7.22	3.2	184.2	6.2	3.91	24.6	50.1	7
	Assays (1392 m)	1.04	8.28	8.82	488.1	9.9	27.37	89.3	120.4	23.6
	Iznaguen (1783 m)	0.77	6.13	102.8	427.6	4.97	17.94	56.2	80.2	18.8
	Tassousfi (1467 m)	1.02	8.02	15.6	478.6	4.9	27.37	186.2	128.9	19.4
	Wisselsate (1399 m)	1.1	7.97	14.4	439.2	11.2	35.19	41.7	110.2	23.7

CONCLUSION

The present study, based on a substantial number of samples collected over 3 harvest years (2016, 2017 and 2018), suggests that the Moroccan saffron owes its distinct chemical quality to the *Terroir* of its production counties in Taliwine and Taznakht administrative districts. The investigation was undertaken to characterize the Moroccan saffron in relation to climate, soil and irrigation water. Crocin, picrocrocin and safranal, the secondary metabolites responsible for saffron quality, were investigated according to ISO 3632-1 (2011). The results indicate that, over the 3 years of study, 80 % of saffron samples from these counties are classified as Category I. They also indicate that the contents of secondary metabolites (crocin and picrocrocin) were higher in saffron produced in the semiarid bio-climatic range, especially at moderate altitude (1650-1900 m). They also show that neither the soil type nor the quality of irrigation water had an effect on chemical saffron quality. The semiarid and arid bio-climate ranges and altitude seem to give this produce its distinct quality. These assets may be considered among the main reasons for Morocco to introduce the label "Protected Designation of Origin (PDO)" for this saffron, with the aim of promoting its marketing at the national and international levels.

Conflict of interest

There is no conflict of interest by the authors.

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