Pharmacogn J. 2024; 16(1): 156-166
A Multifaceted Journal in the field of Natural Products and Pharmacognosy
www.phcogj.com

Research Article

A Comparative Study of the Biometric, Germinative, and Physicochemical Characteristics of Fruits and Oils of Three Cannabis Strains (*Cannabis sativa* L.var indica) Cultivated in the Rif Region of Morocco

Abdelhak Chergui*, El Amine Ajal, Imane Zakaria, Rachid Nejjari

Abdelhak Chergui*, El Amine Ajal, Imane Zakaria, Rachid Nejjari

Laboratory of Pharmacognosy, Mohammed V University, Faculty of Medicine and Pharmacy, Av. Mohammed Belarabi El Alaoui, BP 6203- Rabat institut-Rabat, MOROCCO.

Correspondence

Abdelhak Chergui

Laboratory of Pharmacognosy, Mohammed V University, Faculty of Medicine and Pharmacy, Av. Mohammed Belarabi El Alaoui, BP 6203- Rabat institut-Rabat, MOROCCO.

E-mail: Chergui74@yahoo.fr

History

- Submission Date: 29-11-2023;
- Review completed: 05-01-2024;
- Accepted Date: 09-01-2024.

DOI : 10.5530/pj.2024.16.22

Article Available online

http://www.phcogj.com/v16/i1

ABSTRACT

Background: *Cannabis sativa* var indica is the variety grown in the northern reliefs of Morocco, exclusively for resin and narcotics production. Despite the extensive research on the botany, phytochemistry, and pharmacology of Rif's cannabis, there is limited comparative research on the fruits and oils of different strains cultivated in the region. **Objective**: This study examined the biometric, germinative and physicochemical properties of three cannabis strains grown in the Western Rif region of Morocco. **Materials and methods**: three cannabis strains (Beldiya, Khardala and Critical) were characterized by their biometric parameters (weight, length and width), germinative and physicochemical properties. **Results**: The study revelated that there are notable differences in the biometric properties and germination rates of the achenes of the strains studied. Additionally, significant variations were observed between the strains with regards to their oil yield, as well as the levels of polyphenols and flavonoids. The results also revealed a correlation between biometric parameters, germination rate and phytochemical content. **Conclusion:** The oils of all strains studied were extra virgin, and the Beldiya strain's fruit oil was found to be particularly rich in polyphenols and flavonoids, making it a potentially useful ingredient in nutrition and health applications. Overall, this study provides useful information for researchers and growers interested in the cultivation and use of cannabis fruits and oils in various industries.

Key words: Biometry, Cannabis strains, fruit, germination, oil, Rif.

INTRODUCTION

Cannabis sativa L, also known as hemp, is an annual herb belonging to the Cannabaceae family.[1,2] It has an upright stem, simple leaves with caducous stipules, and actinodromous venation, with 5 to 7 unequal elongated and toothed segments.[3,4] The plant is dioecious, with male flowers gathered into panicles, and female flowers grouped into compact cyms. The bracts of the female flowers are rich in glandular trichomes, which secrete resin. The fruit, also known as an achene, is a smooth ovoid oilseed.[5] Currently, 538 natural substances have been identified in Cannabis sativa, with over 100 being cannabinoids, including Δ9-tetrahydrocannabinol (THC) and cannabidiol (CBD).[6-9]

Hemp is a polymorphic species that adapts to a wide variety of ecological conditions[10], exhibiting plasticity at the botanical, chemical, and pharmacological levels.[11] The number of species in the genus Cannabis is a subject of controversy, with some considering it to be polytypic with several species, while others suggest that there is only one species with high polymorphism and several varieties, such as *Cannabis sativa* var. sativa (hemp fiber) and *Cannabis sativa* var. indica (Indian hemp).[12-18]

Cannabis is a versatile crop cultivated for its oil, fiber, and diverse applications in agro-food, cosmetic, and pharmaceutical industries.[19,20] Pharmacologically, cannabis is known for its psychotropic properties attributed mainly to THC. Several studies have reported the antiemetic, aperitif, and therapeutic effects of cannabinoids in treating neurological disorders such as epilepsy and multiple sclerosis.[21] Cannabis oil is a rich source of unsaturated fatty acids, notably linoleic and linolenic acid [2,22,23], which provide high nutritional value to humans.[24,25] Moreover, several studies have demonstrated the hypotensive, cholesterol-lowering, and cardiovascular disease preventive properties of cannabis oil.[21,25,26,27] Cannabis achenes are also rich in polyphenols possessing antioxidant properties.[28] In fact, polyphenols, especially flavonoids, stabilize cell structures by neutralizing the free radicals responsible for lipid peroxidation.[29-31]

In Morocco, hemp is predominantly cultivated in the Rif region, located in the north, and is commonly known as "Kif." The term "Kif" refers to the dried and chopped plant that is mixed with tobacco and smoked traditionally by the locals, while "Hashish" specifically refers to the resin obtained from flowered tops.[6,10] Morocco holds the distinction of being the world's largest producer and exporter of Hashish.[32]

The Cannabis sativa var indica is the variety grown in the northern reliefs of Morocco, such as Al-Hoceima, Tetouan, Chaouen, Taounate, and Larache provinces, exclusively for resin and narcotics production.[10] Traditionally cultivated "Beldiya" strains and newly introduced hybrid cultivars like "Khardala," "Critical," and "Amnizya" are also grown in the Rif. Despite the extensive research on the

Cite this article: Chergui A, Ajal EA, Zakaria I, Nejjari R. A Comparative Study of the Biometric, Germinative, and Physicochemical Characteristics of Fruits and Oils of Three Cannabis Strains (*Cannabis sativa* L.var indica) Cultivated in the Rif Region of Morocco. Pharmacogn J. 2024;16(1): 156-166.

botany, phytochemistry, and pharmacology of Rif's cannabis, there is limited comparative research on the fruits and oils of different strains cultivated in the region.

Therefore, the objective of this study is to conduct a biometric, germinative, and physicochemical characterization of the achenes and oils of three cannabis strains (*Cannabis sativa* var. indica) grown in the Western Rif region of Morocco, which falls in the northwest part of the country.

MATERIALS AND METHODS

Plant material and study area

The present study focuses on the fruit characterization of three strains of Cannabis sativa. var indica, which are cultivated in the Western Rif of Morocco. These strains include the traditionally cultivated Moroccan strain called "Beldiya" (Bad berred, Chefchaouen province), as well as two hybrid cultivars named "Khardala" (Sedd El kharroub, Larache province) and "Critical" (Bab berred, Chefchaouen province) (Figure 1).

The Rif is a mountain range bordering the Mediterranean in the north of Morocco and extending over a length of 360 km, from Tangier in the west to the Moulouya Embouchure in the east.[33] The climate in the Rif is Mediterranean and more humid in the western Rif because of its geographical location between the Atlantic Ocean and the Mediterranean Sea.[34] The soils are generally classified as red or brown Mediterranean soils and most of them are fragile and unstable.[33]

Sampling plan

The fruits were collected in the 2021 season (by local farmers of the region) according to a random sampling plan: 3 repetitions with 500g of fruit for each strain.

Study of the fruit biometric parameters

The three cannabis strains were characterized by their weight, length and width. These biometric measurements are made using a digital slide foot and an analytical balance. Each parameter is measured in triplicate on 30 fruits samples of each strain.

Seeds germination rates

100 fruits of each strain are initially disinfected with a 30% bleach solution for 4 minutes, and then rinsed with distilled and sterile water for 30 minutes.[35] The seeds are deposited in sterile Petri dishes containing two layers of filter paper soaked in distilled water. Petri dishes are incubated at 25°C in a dark dry oven. After 48 hours, the germinated seeds are counted. A seed is considered germinated when the radicle breaks through the seed coat.[36] The results of germination are expressed in rate of germination, which is the ratio of the number of germinated seeds to the total number of seeds sown. Each germination test is performed in triplicate.

Figure 1: Achenes and oils of *Cannabis sativa* var. indica strains.

Physiochemical parameters of oils and fruits

The fruits of the three strains were ground into powder (using an Arzum AR 1034 clipper grinder). These samples are used for all subsequent physicochemical analyzes.

Oil yield

The total oil content of hemp seeds (20g of powder of each hemp strain) is extracted with hexane (ratio of 1:10) in Sohxlet extractor for 5 hours and the solvent is removed with rotary vacuum evaporator at 50°C, then the mass of oil is weighed. The oil yield is calculated using the equation 1:

$$\text{Oil yield in \%: } \frac{\text{Mass of oil collected in g.100}}{\text{Mass of the sample in g}} \quad (1)$$

Each test is repeated 3 times.

Relative density of oil

The relative density was determined at 20° C according to the standard NF ISO 279:1999 (T 75-111)/ISO 279:1998.[37] Each test is repeated 3 times.

Refractive index of oil

The refractive index was determined at 20°C according to the standard NF ISO 280:1999 (T 75-112)/ISO 280:1998[38], using a Carl Zeiss refractometer. Each test is repeated 3 times.

Acid value of oil

The principle is to determine the percentage of free fatty acids in the oil. The method consists of dissolving a test sample of the fat in a mixture of ethanol and diethyl oxide followed by titration of the free fatty acids with a basic solution of potassium hydroxide in the presence of phenolphthalein as indicator. The analysis is carried out according to NF ISO 660-2009 standards.[39] The result is expressed in g of oleic acid per 100 g of oil. Each test is repeated 3 times.

Peroxide value of oil

The determination of this parameter consists of an iodometric analysis, which involves dissolving the oil in a chloroform-acetic acid mixture and adding an excess of the potassium iodide solution. The iodine released is determined with a standard solution of sodium thiosulfate. The analysis is done according to NF ISO 3960-2017 standards.[40] Each test is repeated 3 times.

Extraction of polyphenols

The extraction was performed according to the protocol described by Frassinetti et al., (2018).[41] Briefly, in a centrifuge tube, 10 ml of the ethanol/water solution (80:20, v/v) was added to 1 g of sample. The solution is stirred for 3hours in the dark at 4°C, and then centrifuged for 20 min at speed of 4000 rpm. The ethanol phase is removed by rotary vacuum evaporator at 40°C. The dried extracts are dissolved in 5 ml of distilled water. Each extraction is repeated 3 times.

Determination of the total polyphenolic content

Total polyphenolic content was determined using a spectrophotometry at 760 nm (Shimadzu UV 1800, Kyoto Japan) according to the Folin-Ciocalteu (FC) method.[42] The results are expressed in mg equivalent of gallic acid per g of fresh matter (mg EAG/g FM). The calibration curve was established using Gallic acid. Each test is repeated 3 times.

Determination of the total flavonoid content

Total flavonoid content was determined using a spectrophotometry at 510 nm (Shimadzu UV 1800, Kyoto Japan) according to the protocol described by Hogan et al., (2009).[43] The flavonoid content is expressed in mg equivalent of quercetin per g of fresh matter (mg EQ/g FM). The calibration curve was established using quercetin. Each test is repeated 3 times.

Statistical analysis

The statistical analyses are made by the SPSS software (25). These included the One-way analysis of variance (One-way ANOVA and error threshold of 5%), principal component analysis (PCA), and linear regression.

RESULTS

The biometric parameters of fruits

Achene weight

The weight of the cannabis fruit varies depending on the strain, as depicted in Figure 2. This is confirmed by the One-way ANOVA analysis, which indicates a significant effect (at a threshold of α=0.05) of the cannabis strain on fruit weight. Specifically, the Khardala strain exhibits the maximum weight (19,67 mg), whereas the Beldiya strain has the minimum weight (11,74 mg). The Critical strain displays an intermediate weight (13,73 mg).

Achene length

Similarly, the length of the fruit varies according to the cannabis strain, as shown in Figure 3. The One-way ANOVA confirms a significant effect (with a threshold of α=0,05) of the cannabis strain on fruit length. The Khardala strain shows the longest fruit (4,49 mm), while the Beldiya strain has the shortest fruit (3,83 mm). The Critical strain has an intermediate length (4,10 mm).

Achene width

The size of the fruit also varies among the strains of cannabis, particularly in terms of their width (Figure 4). This is confirmed by the One-way ANOVA, which reveals a significant effect (at α=0,05) of the cannabis strain on the width of the fruit. The Khardala strain displays the widest fruit (3,48 mm), while the Beldiya strain has the narrowest (2,95 mm). The Critical strain has an intermediate width (3,13 mm).

Seeds germination rates

The germination rate of achenes varies significantly among the cannabis strains (Figure 5).

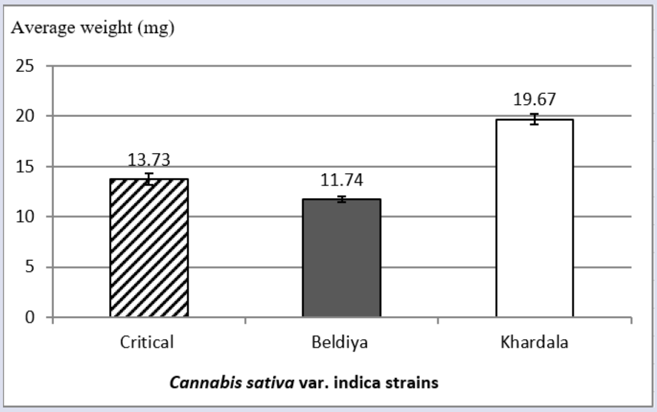


Figure 2: Average achene weight of *Cannabis sativa* var. indica strains.

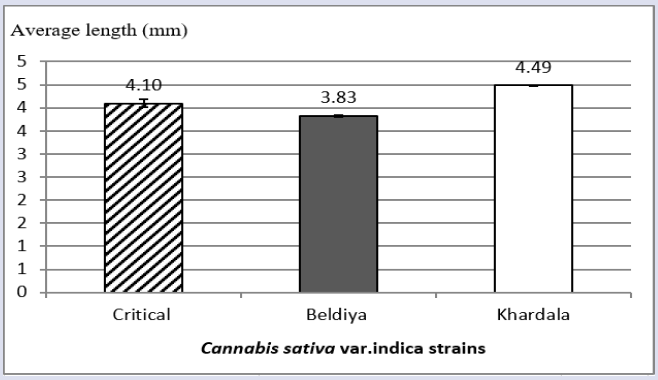


Figure 3: Average achene length of *Cannabis sativa* var. indica strains.

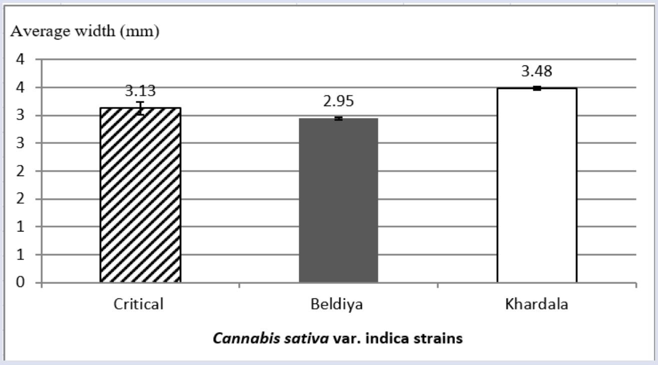


Figure 4: Average achene width of *Cannabis sativa* var. indica strains.

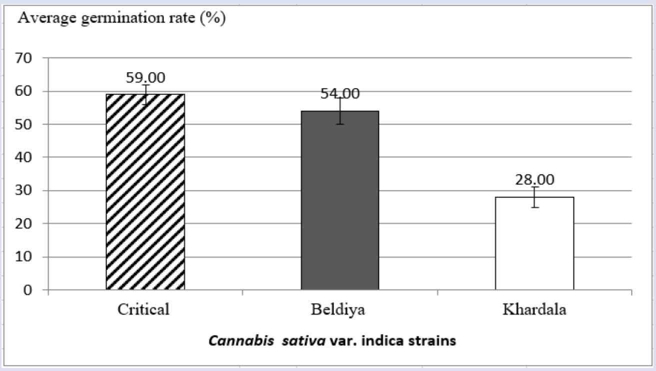


Figure 5: Average germination rate of *Cannabis sativa* var. indica strains.

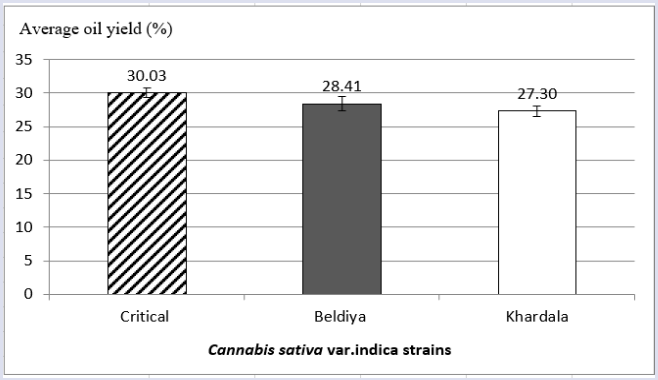


Figure 6: Average oil yield of achene of *Cannabis sativa* var. indica strains.

There was a significant effect (at α=0,05) of cannabis strain on the germination rate. The Beldiya and Critical strains display moderate germination rates (54% and 59%, respectively), while the Khardala strain has a lower germination rate (28%).

Physiochemical parameters of oils and fruits

Oil yield

The oil yield of the achenes varies depending on the strain of cannabis (Figure 6). A significant effect (at α=0,05) of the cannabis strain on the oil yield is demonstrated. The oil yield ranges from 27,30% to 30,03%.

Relative density of oil

The density of the oils extracted from the three cannabis strains is nearly identical (Figure 7). There was no effect (at α=0,05) of the cannabis strain on the relative density of the oil. The densities of the oils obtained from the Critical, Beldiya, and Khardala strains are quite similar, with values of 0,8634, 0,8583, and 0,8677, respectively.

Refractive index of oil

The oils of the three cannabis strains show a substantially identical refractive index (Figure 8). This is confirmed by the One-way ANOVA which shows that the cannabis strain has an insignificant effect (at the α=0,05 threshold) on the refractive index. The refractive indices of the oils obtained from the Critical, Beldiya, and Khardala strains are very similar, with values of 1,4752; 1,4753 and 1,4753, respectively.

Acid value of oil

The acid value varies slightly according to the strain (Figure 9), and this is confirmed by the One-way ANOVA which shows that there is an insignificant effect (at threshold α=0,05) of cannabis strain nature on the acid value. Indeed, the acid value are very similar (0,30 ; 0,31 and 0,33, respectively Khardala, Critical and Beldiya).

Peroxide value

The peroxide value shows variations depending on the strain of cannabis (Figure 10). This is confirmed by the One-way ANOVA which shows that there is a significant effect (at threshold α=0,05) of the cannabis strain on the peroxide index.

The highest peroxide value is reported in Critical strain (6,64) and the lowest in Beldiya (6,20), Khardala has an intermediate value (6,58).

Polyphenol and flavonoid contents

The content of polyphenols and flavonoid varies according to the strain of cannabis (Figure 11 and Figure 12). This is confirmed by the One-way ANOVA which shows that there is a significant effect

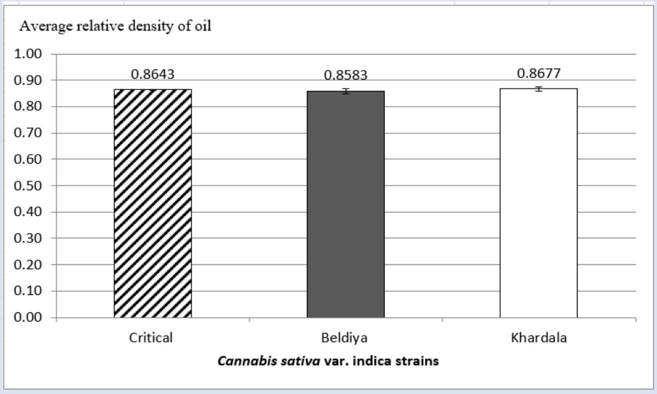


Figure 7: Average relative density of achene oil of *Cannabis sativa* var. indica strains.

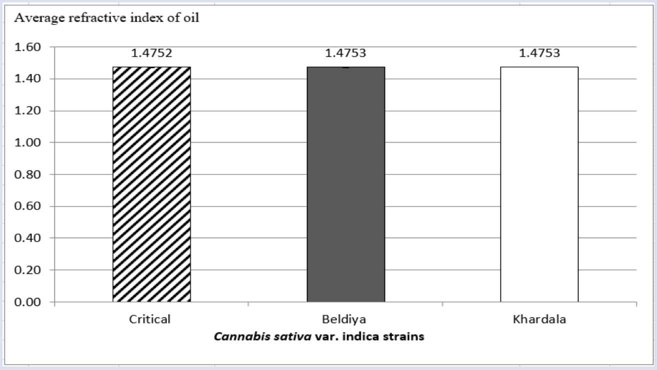


Figure 8: Average refractive index of achene oil of *Cannabis sativa* var. indica strains.

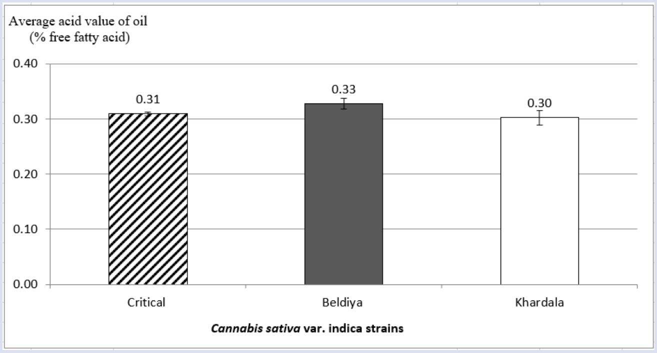


Figure 9: Average acid value of achene oil of *Cannabis sativa* var. indica strains.

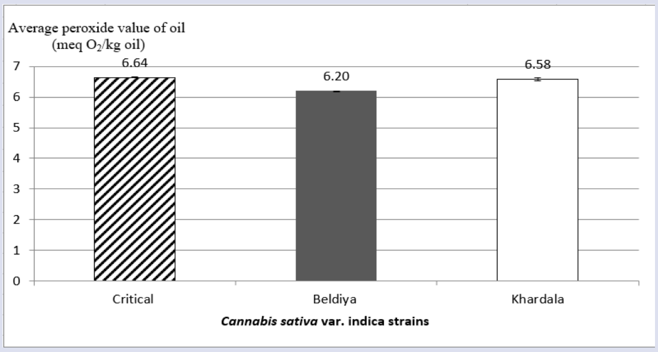


Figure 10: Average peroxide value of achene oil of *Cannabis sativa* var. indica strains.

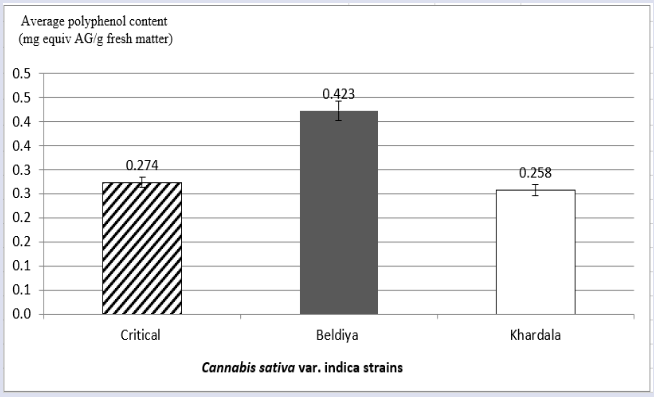


Figure 11: Average polyphenol content in fruit of *Cannabis sativa* var. indica strains.

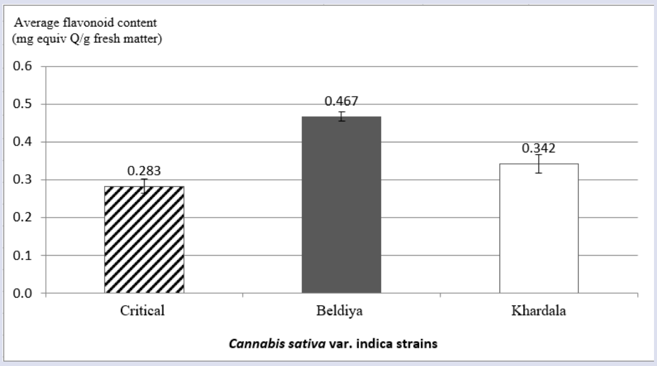


Figure 12: Average flavonoid content in fruit of *Cannabis sativa*.var indica strains.

(at threshold α=0,05) of the cannabis strain on the polyphenol and flavonoid contents. The highest content of polyphenol is reported in Beldiya strain (0,423 mg equi AG/g FM), while Critical and Khardala show relatively low levels; 0,274 mg equi AG/g FM and 0,258 mg equi AG/g FM respectively.

The flavonoid profile is similar to that of polyphenol: Beldiya has the highest content (0,467 mg equiv Q/g FM) while Critical and khardala have relatively low levels (0,283 mg equal Q/g FM and 0,342 mg equiv Q/g FM respectively).

DISCUSSION

The weight of the achenes shows a significant fluctuation, ranging from 11,73 to 19,67mg. This range is wider than the one reported by Merzouki et al., (1996)[33] for cannabis achenes cultivated in the Rif (12,13 to 13,73mg). However, the Critical strain's average weight (13,73mg) is similar to that reported by Merzouki et al., (1996)[33] for cannabis achenes cultivated in Ketama (Al Hoceima Province) (13,73mg).

In terms of length, the achenes' average length ranges from 3,83 to 4,49mm, which is higher than what was reported by Merzouki et al., (1996)[33] for cannabis cultivated in the Rif (4,01 to 4,19mm). Wider range has been also reported in some Iranian cannabis varieties[44] with ranges between 3,81 to 4,61mm. However, the length range of the studied strains is close to that of wild varieties. According to Small (1975 a & b)[13,14], the average length of wild cannabis achenes from various regions (South Asia, Africa, China, North America, and Russia) varies between 3,66 and 4,39mm.

Interestingly, the achenes of the hybrid strains (Critical and Khardala) are longer than those of traditionally cultivated Beldiya strains. This could be attributed to active selection of cultivated varieties, aimed at increasing the achenes' length and facilitating their disarticulation during harvest, making it easier for humans.[13,14,33] The average length of the Critical strain's achenes (4,10mm) is similar to that cited by Merzouki et al., (1996)[33] for cannabis achenes cultivated in Jebha (Chefchaouen Province) (4,09mm). Additionally, the average length of the Beldiya strain's achenes (3,83mm) is very similar to that of the North American wild variety (3,89mm).[13,14]

The achenes' average width ranges from 2,95 to 3,48 mm. However, Asadi et al., (2019)[44] reported a higher range of widths in Iranian achenes, fluctuating between 2,72 and 3,70mm. The Beldiya strain displays the smallest biometric parameters (weight, length, and width), while the Khardala strain presents the highest values. The Critical strain shows intermediate values. The biometric parameters of the Beldiya strain seem to characterize wild strains adapted to extreme ecological conditions.[13,14,33]

The germination rate presents a large variation and is under genetic control[45], depending on several parameters, such as varieties[45,46], seed origin[47,48], age, storage conditions, temperature, and soil water content.[49]

The Beldiya and Critical strains display a moderate germination rate (54% and 59% respectively), while the Khardala strain has a low germination rate (28%). Similar rates have been reported for cannabis fibers of European and Chinese origin. Islam et al., (2022)[50] report a germination rate of 28% in the European variety 'Santhica,' and 54% and 58% in Chinese varieties 'Yuma1' and 'Han COLD' , respectively.

A negative correlation appears to exist between biometric parameters and germination rate. The Beldiya strain, despite having the weakest biometric parameters, has a higher germination rate (54%) than the Khardala strain (28%). Small seeds of Indian white sandalwood (*Santalum album*) have a higher germination rate than medium and large seeds[45,51], showing similar behavior to the Beldiya strain. Comparable results were obtained for hemp achenes from China, where the small achenes of the 'Han FNQ' variety exhibited a higher germination rate than the large achenes of the 'SI 1' variety.[50]

The oil content of cannabis achenes is influenced by several factors, including the variety, geographical origin, environmental conditions, extraction method, solvent, cultivation technique, storage conditions, and maturation period.[52,53,54] The oil yield ranges from 27,30% to 30,03%, which is consistent with findings from other studies. For instance, Anwar et al., (2006)[55] report rates of 26,90% to 31,50% in Pakistani cannabis, and Abdollahi et al., (2020)[56] report oil yields of 29,92% and 30,80% in native cannabis populations from Fars and Yazd regions of Iran, respectively. However, Deferne and Pate (1996)[57], Oomah et al., (2002)[58], Callaway, (2004)[59], Da Porto et al., (2012)[21], report slightly higher oil contents of 25% to 35%. Stambouli et al., (2006)[60] report relatively high yields of up to 34,6% in cannabis from northern Morocco.

The Beldiya and Khardala strains have similar yields of 28,41% and 27,30%, respectively, which is comparable to the oil yield of cannabis achenes in markets in Turkey (27,80%) reported by Babiker et al., (2021).[61] The Critical strain has the highest yield (30,03%), similar to that of cannabis cultivated in Canada (30,5%)[58] and native cannabis populations in Iran.[56] This strain may be of interest due to its high oil yield, which is rich in polyunsaturated fatty acids[62,63,64], especially linoleic and linoleic acid [21,22], known for their nutritional and health benefits.[25,58,61,65] Moreover, the contents of oleic and linoleic acid are similar to those of oilseeds such as soybean.[60]

A positive relationship exists between oil yield and germination rate. In fact, the Critical strain, which is richer in oil than the Khardala strain (30,03% and 27,30%, respectively), has a higher germination rate (59% and 28%, respectively).

Reserve fats in oilseeds, such as cannabis, are primarily composed of triglycerides.[66,67] These lipids are stored in the oleosomes[68,69,70] and may represent up to 95% of cannabis oil.[71] During germination, these reserves are mobilized for the benefit of the embryo in the formation of the new seedling.[72] This mobilization involves the hydrolysis of triacylglycerols to glycerol and fatty acids. These fats are a source of energy available for embryonic development.[66,70] Fatty acids are converted by the glyoxylic cycle into sucrose, which is then used directly by the seed embryo.[73] Additionally, unsaturated fatty acids are a source of elements for the synthesis of phospholipids involved in the structure of newly formed cell membranes.[74]

The density increases with an increasing length of fatty acid chains and decreases with increasing unsaturation.[75] Compared to wild cannabis, the observed densities are relatively low. Anwar & al. (2006) reported densities between 0,9180 and 0,9270 in wild cannabis from Marghazar (Pakistan). Compared to other vegetable oils, the density of cannabis oil also remains relatively low, i.e., 0,9 for Argan oil of southwestern Morocco[76] and 0,92 for walnut oil.[77]

The refractive index is similar (1,4750) to that reported for wild cannabis from Marghazar Pakistan.[55] This index is also within the limits of other vegetable oils such as almond oil (1,468-1,475) and linseed oil (1,472-1,487).[77]

One of the parameters that determine the stability and quality of vegetable oils is the acid value.[78] In all the strains studied, the acid value of the oils remains below 0,8%, which indicates the extra virgin quality of the oil[79] according to Moroccan standards[80] and also below 0,4%, which is the limit value recommended for a food oil by Codex Alimentarius.[77] The acid value is significantly lower than that of cannabis varieties cultivated in Italy, where the acid value varies between 0,81 and 5,43% in the 'Monoica' and 'Diana' varieties, respectively.[28]

The peroxide index is a qualitative criterion used to evaluate the degree of oxidative deterioration of oils.[81,82] Temperature and light are two factors that promote peroxide formation.[81,83]

In all the strains studied, the peroxide index remains around 6 meq O2/kg oil, which is less than 15 meq O2/kg oil, indicating the oil's extra virgin quality[79] according to Moroccan standards.[80] The peroxide indices obtained remain much lower than the limit values indicated for a food oil by Jacobs (1958)[84] and Wolff (1991)[85], which are 70 and 20 meq O2/kg oil, respectively. Similarly, this index remains below the limit value (125 meq O2/kg of oil) recommended for a food oil by Codex Alimentarius.[77]

The polyphenol content ranges from 0,258 to 0,423 mg equiv AG/g of FM. These contents are higher than those reported by Babiker et al., (2021)[61] in cannabis achenes sold in Turkey (0,167 mg equiv AG/g FM) and those reported by Haddou et al., (2023)[2] in cannabis cultivated in Ketama (Rif, province of Tangier-Tetouan-Al Hoceima) (0,130 mg equiv AG/g of extract). Compared to the other two strains, Beldiya is richer in polyphenols, which is beneficial for nutrition and human health. These phenolic compounds are antioxidants that play a crucial role in the stability of cell structures by neutralizing free radicals and reactive forms of oxygen responsible for the oxidation of lipids.[29,30,31] These polyphenols are mainly represented by gallic acid, 3,4-dihydroxybenzoic acid, catechin, 1,2-dihydroxybenzene, and syringic acid.[61,62] These phenolic acids contribute significantly to the antioxidant activity of the hydrophilic fraction of cannabis fruits.[28]

The flavonoid content of the Critical strain is similar to that of the cannabis achenes sold in Turkey.[61] Oils of cannabis achenes may also contain up to 2780,4 mg equiv of quercetin/100 g of total flavonoids in the "Finola" variety. These flavonoids are mainly flavanones, flavonols, flavanols, and isoflavones.[28]

The observed differences in concentrations of polyphenols and flavonoids between the strains studied are related to genetic, climatic, and other factors that affect the nutritional quality of the plant.[86,87] Plants of the same species cultivated under different environmental conditions show variations in the production and accumulation of secondary metabolites.[88] These differences can be summarized by the term "terroir," which refers to the combination of soil type, climate (sun, temperature, and precipitation), and topography.[89,90]

Table 1: Correlation coefficient (R), determination coefficient (R^2) and Durbin-Watson test for the linear regression model.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,877[a]	,770	,769	2,3799115	1,755

a. Predictors: (Constant), Achene width

b. Dependent Variable : Achene weight

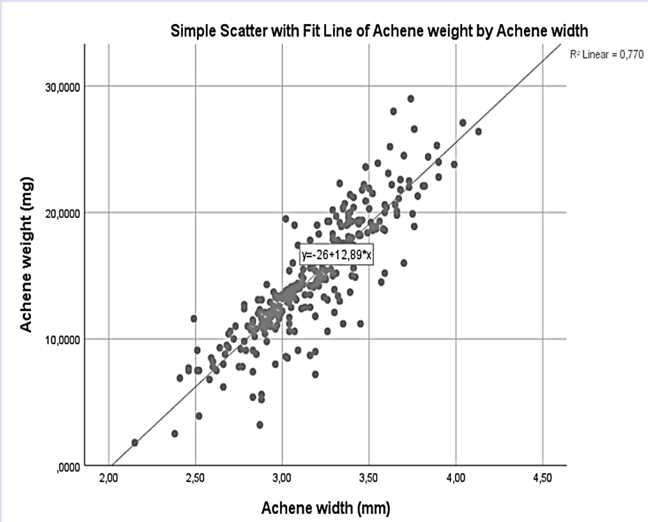


Figure 13: Linear regression curve and equation of fruit weight by fruit width.

Table 2: Coefficients of simple linear regression equation.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound
1	(Constant)	-25,996	1,378		-18,859	,000	-28,710	-23,282
	Achene width	12,885	,430	,877	29,941	,000	12,038	13,732

a. Dependent Variable : Achene weight

The Durbin-Watson test (Table 1) showed the possibility of establishing a linear regression between fruit width and weight, based on the analysis of the different biometric parameters. The test yielded a value of 1,755 (within the range of 1,5 and 2,5), indicating a positive linear correlation between the two variables. This correlation was also observed in cannabis fruits from Iran.[44] The correlation coefficient (R) was 0,87, indicating a strong positive correlation between the two variables. The coefficient of determination R^2 (0,77) suggests that the width of the fruit contributes 77% to the explanation of the fruit's weight. Therefore, there is a good linear regression between these two variables.

The analysis of the coefficients of the simple linear regression equation (Table 2) showed that the constant and the regression coefficient were significantly different from 0.

Thus, the model of the simple linear regression can be formulated by the equation 2

Fruit weight = 12,885*fruit width-25,996 (2)

The simple linear regression curve is graphically shown in Figure 13. Knowing the width of the fruit, this model allows predicting its weight, with an accuracy of 77%.

Statistical analysis of the different quantitative variables (with a positive definite correlation matrix) studied by the PCA, indicated that there is a statistically acceptable factorial solution (Kaiser-Meyer-Olkin Index = 0,767, Table 3). Also, the Bartlett's test of sphericity suggested the highly significant correlation between variables (Table 3). This correlation was also confirmed by the correlation matrix (Table 4).

The matrix shows that there is a strong negative correlation between biometric parameters and germination rate and a strong positive correlation between germination rate and oil yield (Table 4). A good

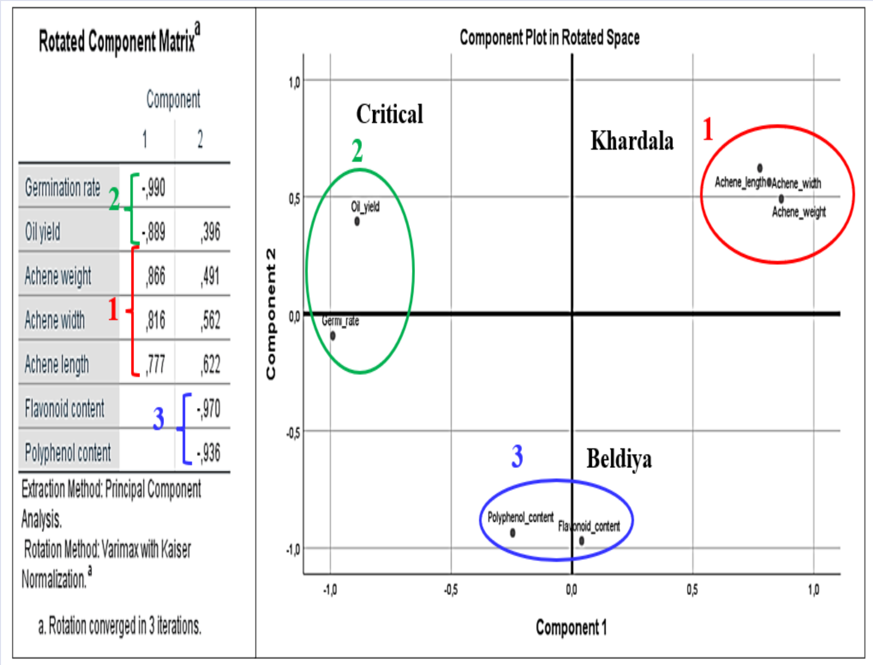


Figure 14: Components plot in rotated space and rotated component matrix.

Table 3: KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,767
Bartlett's Test of Sphericity	Approx. Chi-Square	83,690
	df	21
	Sig.	,000

Table 4: Correlation matrix.

		Achene weight	Achene length	Achene width	Germination rate	Flavonoid content	Polyphenol content	Oil yield
Correlation	Achene weight	1,000	,977	,978	-,907	-,428	-,680	-,564
	Achene length	,977	1,000	,987	-,830	-,576	-,758	-,436
	Achene width	,978	,987	1,000	-,860	-,517	-,704	-,492
	Germination rate	-,907	-,830	-,860	1,000	,037	,331	,823
	Flavonoid content	-,428	-,576	-,517	,037	1,000	,856	-,383
	Polyphenol content	-,680	-,758	-,704	,331	,856	1,000	-,146
	Oil yield	-,564	-,436	-,492	,823	-,383	-,146	1,000

Table 5: Eigen values of different components

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,767	68,097	68,097	4,767	68,097	68,097	3,851	55,021	55,021
2	2,010	28,709	96,806	2,010	28,709	96,806	2,925	41,785	96,806
3	,120	1,718	98,525						
4	,080	1,142	99,667						
5	,013	,187	99,854						
6	,006	,088	99,942						
7	,004	,058	100,000						

Extraction Method: Principal Component Analysis.

negative correlation also exists between the biometric parameters (in particular the length of the fruit) and the polyphenol content (Table 4).

However, the biometric parameters remain moderately negatively correlated with the oil yield (Table 4). This negative correlation was also observed in cannabis achenes cultivated in Italy.[28] A weak correlation between biometric parameters and oil yield was also observed in sunflower achenes[91] and cannabis achenes from Iran.[44]

The factorization operation identified 7 components, 2 of which have eigenvalues greater than 1 and cumulate 96,806% of the explained total variance (Table 5). The component 1, after rotation, could explain 55,021% of the total variance.

The projection of the different variables in the two dimensions formed by the two factorial axis (Figure 14) after rotation, allowed to distinguish 3 groups:

Component 1: this axis explains 55,021% of the total variance observed and summarizes 5 variables forming 2 opposite groups: Group 1 consists of the 3 biometric variables (weight, length and width of the fruit) and Group 2 consists of 2 variables (oil yield and germination rate). Group 2 is negatively correlated with group 1. Indeed, the germination rate and the oil yield show a negative correlation with the biometric variables (Table 4).

Component 2: this axis explains 41,785% of the total variance. This group is represented by 2 phytochemical variables (polyphenol and flavonoid contents).

The studied cannabis fruits can be characterized according to two sets of criteria:

- Biometric criteria (length, width and weight of fruit), physiological criteria (germination rate) and physical criteria (oil yield).
- Phytochemical criteria (polyphenol and flavonoid contents).

Thus, Critical strain will be characterized mainly by its good oil yield and high germination rate, the Beldiya strain will be marked by its high polyphenol and flavonoid content, while the Khardala strain will be characterized by its high weight and size.

CONCLUSION

In conclusion, this study provides valuable insights into the characteristics of three strains of cannabis fruits and oils cultivated in the Rif of Morocco. The fruits were characterized based on biometric, physiological, physical, and phytochemical criteria, with the Beldiya strain being rich in polyphenols and flavonoids that act as antioxidants and the Critical strain having a high oil content with good germination rate could be of interest in the nutrition and cosmetic field. The results also revealed a correlation between biometric parameters, germination rate and phytochemical content. The oils of all strains studied were extra virgin, and the Beldiya strain's fruit oil was found to be particularly rich in antioxidants, making it a potentially useful ingredient in nutrition and health applications. Overall, this study provides useful information for researchers and growers interested in the cultivation and use of cannabis fruits and oils in various industries.

ACKNOWLEDGMENT

We would like to express our very sincere thanks to all the authors (El Amine Ajal, Imane Zakaria and Rachid Nejjari) who are collaborating with us on this project.

DATA AVAILABILITY

All the data supporting the findings of this study are included in this article.

COMPETING INTEREST

The author(s) declare that they have no competing interests.

FUNDING SOURCES

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Ylenia P, Roberta A, Valentina T, Luisa P, Guido F, Laura B, et al. Essential Oil of *Cannabis sativa* L: Comparison of Yield and Chemical Composition of 11 Hemp Genotypes.Molecules.2021;26 (13):4080.
2. Salima H, El Hassania L, Asmae H, Abdelkrim C, Belkheir H. Phytochemical study using HPLC-UV/GC-MS of different of *Cannabis sativa* L seeds extracts from Morocco. Materials Today: Proceedings.2023;72:3896-3903.
3. Patrick M, Veronique DT. Chapitre 11. Monographies : *Cannabis sativa* varièté indica. Traité de toxicologie médico-judiciaire. Paris : Elsevier-Masson SAS, p.229-320 ; 2012.
4. Vijayasankar R, Hemant L, Suman C, Ikhlas AK, Mahmoud AE. *Cannabis sativa* L, Botany and Biotechnology.. S. Chandra *et al.* (eds.), Morpho-Anatomy of Marijuana (*Cannabis sativa* L.). Switzerland : Springer International Publishing, p.123-136; 2017.
5. Michel B. Botanique systématique et appliquée des plantes à fleur. Paris : Ed. Tec & Doc ; 2010.
6. Jean B. Pharmacognosie : Phytochimie, Plantes médicinales,4[ième] édition. Paris: Lavoisier; 2009.
7. Natasha RR, David JR, Ethan BR. Cannabis roots: a traditional therapy with future potential for treating inflammation and pain. Cannabis and cannabinoid research.2017;2(1):210-216.
8. Sara AB, Marika P, Simone T, Amit K, Giuseppina M, Maurizio M, et al. *Cannabis sativa*: a comprehensive ethnopharmacological review of a medicinal plant with a long history.J. Ethnopharmacol. 2018; 227: 300-315.
9. Ismail EB, El Hassan S, Aboubakr B, Mohamed K, Abderrahmane M. A comparative phytochemical profiling of essential oils isolated from three hemp (*Cannabis sativa* L.) cultivars grown in central-northern Morocco. Biocatalysis and Agricultural Biotechnology.2022;42:102327.
10. Jamal B. La pharmacopée marocaine traditionnelle : Médecine arabe ancienne et savoirs populaires. Casablanca : Editions Le Fennec ; 2020.
11. Gilbert F, Christine RD, Jean D, Jean M, Mda RP. Identification of a new chemotype in *Cannabis sativa*: cannabigerol-dominant plants, biogenetic and agronomic prospects. PMID.1987; 3628560.
12. William AE. Cannabis, a polytypic genus. Econ Bot.1974; (28):304-310.
13. Ernest S. Morphological variation of achenes of Cannabis. Canadian Journal of Botany.1975a; 53(10):978-987.
14. Ernest S. American law and the species problem in Cannabis. Sci Semant Bull Narc.1975b; 27:1-20.
15. Simon G, Rod P, James R. Short tandem repeat (STR) DNA markers are hypervariable and informative in *Cannabis sativa*: implications for forensic investigations. Forensic Sci Int.2003;131: 65-74.
16. Karl WH. Genetic evidence for speciation in Cannabis (Cannabaceae). Genet Resour Crop Evol. 2005;52: 161-180.
17. Robert CC, Mark DM. Cannabis: evolution and ethnobotany. Los Angeles: University of California Press; 2013.
18. Ernest S. Evolution and classification of *Cannabis sativa* (marijuana, hemp) in relation to human utilization. Bot Rev.2015; 81: 189-294.

19. Elma MJS, Qingying Z, Stefano A, Ming Y, Luisa MT. New developments in fiber hemp (*Cannabis sativa* L.) breeding. Industrial Crops and Products. 2015;68:32-41.

20. Vibha D, Shabina K. Comparative study of different extraction processes for hemp (*Cannabis sativa*) seed oil considering physical, chemical and industrial-scale economic aspects. Journal of Cleaner Production. 2019; 207: 645-657.

21. Ella JB, Elizabeth AM, Graham CB, Parveen Y, Philip CC. Progress in Lipid Research Metabolism and functional effects of plant-derived omega-3 fatty acids in humans. JPLR.2016; 64: 30-56.

22. Carla DP, Deborha D, Franco T. Fatty acid composition and oxidation stability of hemp (*Cannabis sativa* L.) seed oil extracted by supercritical carbon dioxide. Industrial Crops and Products. 2012; 36: 401-404.

23. Antonella S, Enza MG, Maria TM, Francesco L, Valeria D, Clara C. Polyphenolic compounds and antioxidant activity of cold-pressed seed oil from Finola cultivar of *Cannabis sativa* L. Phytotherapy Research.2016; 30: 1298-1307.

24. Eleonora S, Christopher DB. Omega-3 fatty acids, hepatic lipid metabolism, and nonalcoholic fatty liver disease. Annual Review of Nutrition.2013; 33: 231-248.

25. Qi Z, Fenghong H, Chang Z, Pingmei G, Wenlin L, Changsheng L, et al.Physicochemical properties and volatile terpene of hempseed oils in Bama region. Oil Crop Science. 2017; 1(1):13-22.

26. Nalini K, Renee K, Alejandro JA, Melanie NR, Andrea E, Elena D, et al. Comparison of fish oil, flaxseed oil, and hempseed oil supplementation on selected parameters of cardiovascular health in healthy volunteers. Journal of the American College of Nutrition.2008; 27: 51-58.

27. Prociuk MA, Andrea E, Richard MN, Gavel NT, Ander B P, Dupasquier CMC, et al.Cholesterol-induced stimulation of platelet aggregation is prevented by a hempseed-enriched diet. Candian Journal of Physiology and Pharmacology. 2008;86:153-159.

28. Davide C, Gabrielle R, Luigi L, Stefano A. The variety, terroir, and harvest types affect the yield and the phenolic and sterolic profiles of hemp seed oil. Food Research International. 2021; (142): 110212.

29. Saskia VR, Emad SS, Patrick AM. Influence of methanolic extracts of soybean seeds and soybean oil on lipid oxidation in linseed oil. Food Chemistry. 2001; 75:177-184.

30. José LQ, Carmen RT, Alfonso GJ, Jesùs RH, Josés M.Role of vitamin E and phenolic compounds in the antioxidant capacity, measured by ESR, of virgin olive, olive, and sunflower oils after frying. Food Chemistry. 2002; 76: 461-468.

31. Anna K, Satu P, Anu H, Kristiina W, Marina H. Processing of rapeseed oil: Effects on sinapic acid derivative content and oxidative stability. European Food Research and Technology. 2003; 217: 110-114.

32. UNODC. Enquête sur le cannabis au Maroc. Vienne : United Nations Office on Drugs and Crime ; 2003.

33. Abderrahmane M, Manuel CP, Joaquin MM, Etude morphologique des akènes de 4 « variétés climatiques » du cannabis du rif (Nord du maroc). Ars Pharmaceutica.1996 ; 37 (2) : 239-251.

34. Abdelmalek BA. Etude phytoécologique, Biogéographique et dynamique des associations et séries sylvatiques du Rif occidental (Maroc). Thèse, Faculté des Sciences et Techniques St. Jérôme, Marseille, Maroc, 1982.

35. Abdelhak C, Latifa EH, L, Mohammed M. Characteristics of Marram Grass (*Ammophila arenaria* L.), Plant of The Coastal Dunes of The Mediterranean Eastern Morocco: Ecological, Morpho-anatomical and Physiological Aspects. Journal of Materials and Environmental Sciences. 2017; 8 (10): 3759-3765.

36. Daniel C. Les obstacles de la germination. Lyon : Masson ; 1970.

37. M'Barek B, Abdelaziz C, Mohamed O, Brahim B, Ahmed R. Étude physicochimique de l'huile essentielle de *Tetraclinis articulata* (vahl) masters du plateau central marocain. Les technologies de laboratoire.2015 ; 9 (37).

38. NF ISO 280:1999 (T 75-112)/ISO 280:1998. Essential oils-Determination of refractive index.

39. NF ISO 660 :2009. Corps gras d'origine animale et végétale-Détermination de l'indice d'acide et de l'acidité ; 2009.

40. NF ISO 3960:2017 Corps gras d'origine animale et végétale-Détermination de l'indice de peroxyde ; 2017.

41. Stefania F, Eleonora M, Leonardo C, Morena G, Vincenzo, Lorenza B, et al.Nutraceutical potential of hemp (*Cannabis sativa* L.) seeds and sprouts. Food Chemistry.2018; 262: 56-66.

42. Nathalie B, Jean PC.Méthode rapide d'évaluation du contenu en composés phénoliques des organes d'un arbre forestier. Cah. Tech. INRA.2006; numéro special: 79-82.

43. Shelly H, Lei Z, Janrong L, Bruce Z, Kequan. Antioxidant properties and bioactive components of Norton (*Vitis aestivalis*) and Cabernet Franc (*Vitis vinifera*) wine grapes. LWT-Food Science and Technology.2009;42 (7):1269-1274.

44. Sadegh A, Hosein M, Hasanali NB, Mohammed RN, Seyed AS. Evaluation of phenotypic properties and seed oil content of hemp (*Cannabis sativa* L.) ecotypes in Iran. Paris: 9th International Conference on Science, Engineering and Technology (WICSET2019) Organizers: Scientific Society of Paris Universities and WICSET Scientific Society Holding, p.11-13;2019.

45. Manonmani V, Vanangamudi K. Effect of seed source and size on seed germination and seedling vigour of sandal (*Santalum album*). J. Trop. For. Sci.2002;14:150-155.

46. Paulina C, Ramiro B, Carolina H. The effect of seed size on germination and seedling growth of *Cryptocarya alba* (Lauraceae) in Chile. Rev. Chil. Hist. Nat. 1998; (71): 189-197.

47. Claudia RD, Leandro DDS, Ademir G, Thamiris GD. Seed origin, storage conditions, and gibberellic acid on in vitro germination of *Campomanesia adamantium* (Cambess.) O.Berg, Afr. J. Biotechnol.2016 ; (15) : 1731-1737.

48. Renato TB, Cibele CM, Givanildo ZS, Dagoberto M. Origin and temperature on the germination of beggartick seeds. Rev. Bras. Eng. Agrícola Ambient. 2017; 21: 448-453.

49. Suman C, Hemant L, Ikhlas AK, Mahmoud AE.*Cannabis sativa* L, Botany and Biotechnology.. S. Chandra *et al*. (eds.), Botany and Horticulture. Switzerland : Springer International Publishing, p. 79-100; 2017.

50. Mohammad MI, Zed R, Paul S, Khadambot HMS, Zakaria MS.Industrial Hemp (*Cannabis sativa* L.) Varieties and Seed Pre-Treatments Affect Seed Germination and Early Growth of Seedlings. Agronomy. 2022;12 (6).https://doi.org/10.3390/agronomy12010006.

51. Nagaveni HC, Ananthapadmanabha HS. Seed polymorphism and germination in *Santalum album* L. Van vigyan. 1986 ;24 : 25-28.

52. Christoph M, Vito M. Factors influencing the yield and the quality of hemp (*Cannabis sativa* L.), essential oil. J. Int. Hemp Assoc.1998 ; 5(1) :16-20.

53. Afsaneh S, Maryam G, Ebrahim HS. Chemical evaluation of oil extracted from hemp seed. Food Technology and Nutrition. 2011; 8(2):52-60.

54. IF Garcia T, Victor HDZ, R Pérez A, Hernández A, Salvatore C, Michelle M, et al. Impact of plant density and irrigation on yield of hemp (*Cannabis sativa* L.) in a Mediterranean semi-arid environment. Journal of Agricultural Science and Technology. 2014;16 (4): 887-895.

55. Farooq A, Sajid L, Muhammad A. Analytical characterization of hemp (*Cannabis sativa*) seed oil from different agro-ecological zones of Pakistan. Journal of the American Oil Chemists' Society.2006; 83(4): 323-329.

56. Mahnaz A, Fatemeh S, Mohsen C, Amir M, Mohamad FM.Impact of four hemp (*Cannabis sativa* L.) varieties and stage of plant growth on yield and composition of essential oils. Industrial Crops & Products. 2020; 152: 112397.

57. Jean LD, David WP. Hemp seed oil: A source of valuable essential fatty acids. Journal of the International Hemp Association.1996; 3: 4-7.

58. B Dave O, Muriel B, David VG, John CGD. Characteristics of hemp (*Cannabis sativa* L.) seed oil. Food Chemistry. 2002; 76 (1): 33-43.

59. James C. Hempseed as a nutritional resource: An overview. Euphytica.2004; 140(582): 65-72.

60. Hamid S, Aziz EB, Taoufik B, Ahmed B. Caractérisation de l'huile de graines de *Cannabis sativa* L. cultivé au nord du Maroc. Annales de Toxicologie Analytique.2006 ; 18 (2) :119-125.

61. El Fadil EB, Nurhan U, Fahad AJ, Isam AMA, Kashif G, Mehmet MO, et al. Effect of roasting on antioxidative properties, polyphenol profile and fatty acids composition of hemp (*Cannabis sativa* L.) seeds. LWT, Food Science and Technology. 2021; 139:110537.

62. Milica P, Aleksendra M, Marijina S, Tamara DH, Bojana S, Ivan M et al. Characterization of byproducts originating from hemp oil processing. Journal of Agricultural and Food Chemistry. 2014; 62 (51): 12436-12442.

63. Eliana V, Marie-Pier A, Philippe S, Arif M, Jean-Benoit C. Seed composition of ten industrial hemp cultivars approved for production in Canada. Journal of Food Composition and Analysis. 2015; 39 (10): 8-12.

64. Marek V, Barbora S, Simona K, Petra T, Eva T, Ales Z. Comprehensive sterol and fatty acid analysis in nineteen nuts, seeds, and kernel.SN Applied Sciences.2019; 1(12). https://doi.org/10.1007/s42452-019-1576-z, 1531.

65. Bertrand M, Ludger B. Virgin hemp seed oil: An interesting niche product. European Journal of Lipid Science and Technology. 2008;110 (7): 655-661.

66. Jean-Louis G. Biochimie végétale. Paris : Dunod ; 2000.

67. Said G. Contribution à la valorisation de l'huile d'argane : Influence de l'origine du fruit (terroir, forme) et de la méthode d'extraction sur la composition chimique, les caractéristiques organoleptiques et la stabilité de l'huile d'argane. Thèse, Faculté des Sciences, Université Mohammed V, Rabat, Maroc, 2012.

68. Jean-Claude K, Benoit B, Michèle G, Anne-Marie G, Anne-Marie H, Alain J et al.Biologie moléculaire de la biogenèse des lipides des plantes. Acta Bot. Gallica. 1993; 104: 735-754.

69. William GH. Physiologie végétale. Bruxelles : De Boeck université ; 2003.

70. Sébactien B, Loïc L. Compared analysis of the regulatory systems controlling lipogenesis in hepatocytes of mice and in maturing oilseeds of Arabidopsis. in Comptes Rendus Biologies.2008; 331(10): 737-45.

71. Christelle L, Bruno N, Hanitra R, Magalie W, Thierry C, Marc A. Deciphering the properties of hemp seed oil bodies for food applications: Lipid composition, microstructure, surface properties and physical stability. Food Res. Int.2021; 150: 110759.

72. Paul M, Françoise T. Installation et utilisation des réserves lipidiques dans les graines oléagineuses. Bull. Soc. bot. Fr. Actual. bot. 1983;130: (3/4), 49-56.

73. Jean-Louis G, Louis C, Max H. Abrégé de phytochimie. Paris : Masson ; 1985.

74. Khaled S, Sadok B, Habib K. Évolution des tocophérols en relation avec les acides gras insaturés au cours de la maturation des graines de colza de printemps (*Brassica napus* L.). C. R. Biologies. 2007 ;330 : 55-61.

75. Aldo U. Olive et huile d'olive, In : Manuel des corps gras. Paris : Lavoisier,p. 221 - 228 ; 1992.

76. Zoubida C, Dominique G. Ethnoeconomical, ethnomedical, and phytochemical study of Argania spinosa (L.) Skeels. Journal of Ethnopharmacology. 1999; (67): 7-14.

77. Codex alimentarus. CXS-210 ; 1999.

78. Ernandes RA, Lêda RDF, Luis AP, Marco TCDS, André RC. Influence of soybean storage conditions on crude oil quality. Revista Brasileira de Engenharia Agrícolae Ambiental.2010; 14(3): 303-308.

79. Saïd G, Hicham H, Dominique G, Aziza H, Bertrand M, Zoubida C. Oxidative stability of edible argan oil: A two-year study. LWT - Food Science and Technology. 2011; 44:1-8.

80. Moroccan Industrial Standardization Service (SNIMA). Moroccan Standards 08.5.090 Argan Oil Specifications. Rabat: Minister of Industry, Energy and Mines, Morocco; 2003.

81. Eunok C, David BM. Mechanisms and Factors for Edible Oil Oxidation. Food Sci. and Food Saf.2006; 5 (4): 169-186.

82. Gloria MR, Manuel MP, Joaquin V, Carmen MD.Formation of oxidation compounds in sunflower and olive oils under oxidative stability index conditions. Eur. J. Lipid. Sci. Technol.2008;110: 465-471.

83. Imène B, Mnasser H. Etude de la stabilité oxydative de l'huile d'olive vierge extra tunisienne au cours de son stockage. Oléagineux, Corps Gras, Lipides. 2005 ; 12 (5-6) : 447-454.

84. Morris BJ. Chemical analysis of foods, third ed. D. New York: Van Nostrand; 1958.

85. Jean PW. Analyse et dosage des lipides. In Techniques d'analyse et de contrôle dans les industries agro-alimentaires. IV: analyse des constituants alimentaires. Paris : Lavoisier ; 1991.

86. Guilles F, Mehmet MO, Jean-Claude C. Effect of harvest years on chemical composition of essential oils of bitter fennel (*Foeniculum vulgare* Mill. subsp. piperitum) fruits. Journal of Food Biochemistry.2011; (35): 1223-1230.

87. Salvatore F, Simona P, Maura S, Luigia P, Giuseppina C, Gian MB, et al. Can agronomic practices and cold-pressing extraction parameters affect phenols and polyphenols content in hempseed oils?, Industrial Crops and Products.2019;130:511-519.

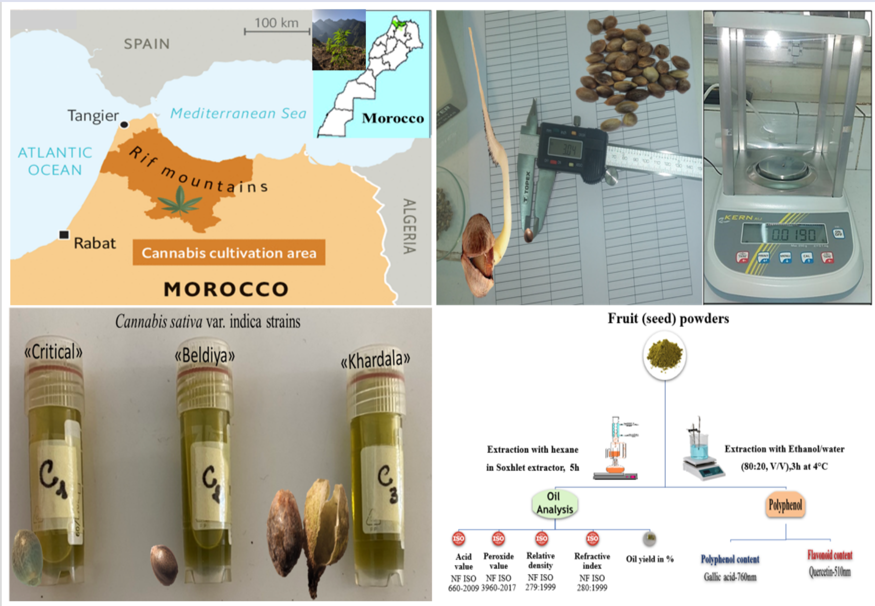
88. Bruno LS, RuAngelie EE, Fernando BDC. Effect of the environment on the secondary metabolic profile of Tithonia Diversifolia: A model for environmental metabolomics of plants. Scientific Reports.2016; 6: 29265.

89. Maria IFM, Raùl FG, Maria CGP, Belen P, Pilar RP, Emma CV,2013. Terroir and variety: Two key factors for obtaining stilbene-enriched grapes. Journal of Food Composition and Analysis. 2013; 31(2): 191-198.

90. Luigi L, Gabriele R, Marco T. Extending the concept of terroir from grapes to other agricultural commodities. An overview. Current Opinion in Food Science.2020; 31: 88-95.

91. Mario B, GianPaolo V, Mario M, Enrico B. Genotype and environmental effects on hullability in sunflower. Results of three years of experimentation. In Proceedings of the 14 th International Sunflower Conference; 1996, Beijing-Shenyang, China; 1996.

GRAPHICAL ABSTRACT



ABOUT AUTHORS

Abdelhak CHERGUI, Professor-Researcher: Professor at the Faculty of Medicine and Pharmacy of Rabat (Morocco). The author Abdelhak CHERGUI is Professor-Researcher at the Faculty of Medicine and Pharmacy at Mohammed V University in Rabat (laboratory of Pharmacognosy). He is specialist in Plant Biology & Ecophysiology and Systematic Botany of Aromatic and Medicinal Plants. He is also associate Professor in Biology & Geology and Teacher trainer in Pedagogy and Didactics of Life and Earth Sciences. The author has published several research papers and books in reviewed international journals relating to Plant Ecophysiology and Pharmacognosy.

El Amine AJAL, Professor-Researcher: Professor at the Faculty of Medicine and Pharmacy of Rabat (Morocco). Specializing in biodiversity, natural products chemistry, and Food Sciences and Technology. Dr AJAL now works as Professor-Researcher at Pharmacognosy Department within the Faculty of Medicine and Pharmacy of Rabat. His field of expertise refers to the development and optimization of analytical methods and their application for the evaluation of different aspects of food quality and authenticity, in particular in the field of olive oil and pomegranate. Moreover, Professor AJAL is the author or co-author of multiple research papers in reviewed international journals relating to Food Science.

Imane ZAKARIYA, Professor-Researcher: Professor at the Faculty of Medicine and Pharmacy of Rabat (Morocco). The author Imane ZAKARIYA is Associate Professor Researcher at the Faculty of Medicine and Pharmacy-Rabat (Pharmacognosy laboratory). Her focus is based on the use of natural compounds to have application in health field. She was awarded her PhD in 2007 from the University Mohammed V Morocco, afterwards in 2012, she obtained her specialty diploma in Clinical and Hospital Pharmacy from the same faculty. She has published many articles in international journals, with interest of Clinical Pharmacy and Pharmacognosy.

Rachid NEJJARI, Professor-Researcher: Professor at the Faculty of Medicine and Pharmacy of Rabat (Morocco). The author Rachid NEJJARI is Professor-Researcher at the Faculty of Medicine and Pharmacy at Mohammed V University in Rabat (laboratory of Pharmacognosy). He is Pharmacist Specialist on Clinical Pharmacy and Director of Pedagogy and Research Units of Pharmacognosy. Professor Rachid NEJJARI is also the Head of Hospital Pharmacy Department at the Souissi Maternity Hospital (SMH) of the Ibn Sina University Hospital Center-Rabat (ISUHC). The author has supervised several doctoral theses and authored several scientific articles and books.

Cite this article: Chergui A, Ajal EA, Zakaria I, Nejjari R. A Comparative Study of the Biometric, Germinative, and Physicochemical Characteristics of Fruits and Oils of Three Cannabis Strains (*Cannabis sativa* L.var indica) Cultivated in the Rif Region of Morocco. Pharmacogn J. 2024;16(1): 156-166.