Article

Wild plants of the center-north of Mexico with potential for oil production

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Abstract

Mexico has a wide variety of wild plant species that could be used in a sustainable way to obtain oil and high added value products or be used as raw material in the industrial, cosmetological, pharmaceutical and / or bioenergy production sectors. The objective of this study was to determine the productive potential, perform the physical, chemical and morphological characterization of seeds from wild plants in the regions of Aguascalientes, San Luis Potosí and Zacatecas in order to determine their potential in oil production. Refractive index, saponification, acidity, iodine and peroxide were determined as established in the Mexican Standard (NMX). According to the results obtained, Agave sp., Presented the highest potential seed yield of 24305 kg ha-1, however, it has a long fruiting period. And for oil yield, A. undulata showed the greatest potential with 1315 kg ha-1. Regarding the morphological parameters C. ficifolia obtained the highest values (mm) in length and width dimensions and J. dioica the highest value in thickness (mm) and weight of 100 seeds. The seeds with high oil content corresponded to the species C. foetidissima (33.9%) and P. louisianica (33.6%) and J. diodica (32.86%). The variation between the studied characteristics allowed the identification of species of interest for the production of oil for industrial and / or bioenergetic use.

Keywords: Oil, bioenergetics, wild plants, oil quality, morphology.

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Introduction

The detection of plant species with agroindustrial and bioenergetic potential has become a subject of great socioeconomic interest worldwide. Countries with great ecological diversity play an important role in the search for these species. In this sense, Mexico has a great ecological variability: in the north and part of the center of the country there are arid, semi-arid and dry sub-humid zones characterized by xerophilous thickets, pastures and thorny forests; in areas of the Pacific and the center of the Gulf of Mexico are dry and semi-dry tropical forests; in more humid areas (> 900 meters above sea level) the evergreen tropical forests are located, and at higher altitudes the cloud forests; finally, in the mountains they inhabit the forests of conifers and oaks (CONABIO, 2006).

The dry areas occupy more than half of the Mexican territory with 101.5 million hectares, of this surface, the arid zones represent 15.7%, the semiarid 58% and the rest corresponds to the dry subhumid zones (UACH, 2011). According to the above, in the arid and semi-arid zones there is a great variety of vegetation with characteristics adapted to this type of habitat, natural resources that could be used in a sustainable manner in the generation of high added value products or as raw material in the industrial, medicinal, cosmetological and / or bioenergy production sector. Given the growing interest in the production of bioenergy, it is necessary to consider new strategies such as focusing attention on crops, which include short-cycle forest trees, perennial and herbaceous herbs, which are alternative sources of energy such as natural gas, biodiesel or bioethanol (Díaz-Ramírez et al., 2013).

Although, Mexico has a great variety of natural resources, its incorporation into the bioenergetic field is incipient and is being driven by the implementation of productive programs and projects in the medium term. In this way, the search and identification of endemic plant species and introduced with high oil content could be used in the manufacture of biodiesel. Among the wild plants with potential for oil production that have been studied in the country are: castor (Perdomo et al., 2013; Mosquera-Artamonov et al., 2016; Vasco et al., 2018), piñón (García et al. al., 2017), chicalote and cuernitos (Reveles et al., 2010), gatuña (Ortega-Nieblas and Vázquez-Moreno, 1995), among others; However, other species have yet to be explored, in order to identify wild plants adapted to the agro-environmental conditions of the central-northern region of Mexico that could produce bioenergy oil.

Taking into account that both native and introduced species already adapted to each region, could be used for energy purposes in those soils unfit for agriculture, without displacing food production and also require little input, this research aims to collect wild species from the center -north of Mexico, determine its productive potential, analyze its oil content and its physical-chemical characteristics, and identify plant species of interest for the production of oil.

Materials and methods

Selection and collection of seed

The collection of seeds was carried out through field trips between the months of June 2014 to May 2015, considering the annual availability of wild plants, in 18 sites belonging to the states of Aguascalientes (AGS), San Luis Potosí (SLP) and Zacatecas (ZAC), Mexico. The following criteria were used for the selection of the species in the field: 1) abundance, 2) seed availability, 3) accessibility to the sites, and 4) use history. The 19 species collected in the study area were: Argemone mexicana chicalote, Cucurbita foetidissima crazy gourd, Cucurbita ficifolia chilacayota, Apodanthera undulata, melon, Bidens odorata, Leónotis nepetifolia, Datura inoxia toloache, Datura ferox thistle, Xanthium strumarium, toritos Proboscidea louisianica, mostacilla Brassica sp., Saramago Eruca sativa, blood grade Jatropha dioica, huizache Acacia farnesiana, mesquite Prosopis glandulosa, governor Larrea tridentata, maguey Agave sp., Pirul Schinus molle and sunflower Helianthus annuus. For each collection site, geo-positioning coordinates, plant characteristics and agro-environmental conditions were recorded; these are described in Table.

Table 1. Characteristics and location of the species collected in the study.

State	Municipality	Latitude (North)	Length (West)	Altitude (m)	Wild plant
AGS	Cosío	22º23´39.8"	102º18´23.4"	2008	*Datura inoxia*
AGS	San José de Gracia	22º08´36.9"	102º21´26.4"	1980	*Helianthus annuus, Apodanthera undulata*
AGS	Tepezalá	22º13´33.2"	102º14´14.2"	1887	*Xanthium strumarium, Datura ferox, Bidens odorata*
SLP	Ahualulco	22º19´38.8"	101º12´15.3"	1862	*Proboscidea louisianica*
SLP	Salinas	22º43´56.0"	101º42´40.0"	2096	*Bidens odorata, Eruca sativa*
SLP	Salinas	22º37´32.6"	101º41´15.0"	2110	*Proboscidea louisianica, Helianthus annuus, Eruca sativa, Bidens odorata, Xanthium strumarium*
SLP	Salinas	22º37´10.3"	101º43´58.9"	2079	*Acacia farnesiana*
SLP	Salinas	22º35´59.9"	101º42´07.0"	2115	*Larrea tridentata, Jatropha dioica*
SLP	Mexquitic	22º19´38.8"	101º12´15.0"	1870	*Bidens odorata, Brassica sp, Proboscidea louisianica*
SLP	Mexquitic	22º16´23.4"	101º05´35.0"	1980	*Leonotis nepetifolia*
SLP	Venado	22º55´54.3"	101º04´25.6"	1755	*Bidens odorata, Xanthium strumarium*

Table 1. Characteristics and location of the species collected in the study.(Continuation)

State	Municipality	Latitude (North)	Length (West)	Altitude (m)	Wild plant
ZAC	Pánfilo Natera	22º40´22.9"	102º06´28.4"	2127	*Proboscidea louisianica*
ZAC	Zacatecas	22º45´26.9"	102º33´51.1	2418	*Bidens odorata, Helianthus annuus, Datura inoxia*
ZAC	Zacatecas	22º45´51.4"	102º38´21.2"	2325	*Jatropha dioica*
ZAC	Zacatecas	22º46´00.3"	102º35´03.8"	2444	*Argemone mexicana*
ZAC	Guadalupe	22º45´04.2"	102º27´10.4"	2193	*Cucurbita foetidissima*
ZAC	Loreto	22º16´19.3"	101º57´30.4"	2047	*Schinus molle*
ZAC	Guadalupe	22º40´53.5"	102º33´27.1"	2376	*Prosopis glandulosa Agave sp.*
ZAC	Genaro Codina	22°29´13.65"	102°27´48.52"	2176	*Cucurbita ficifolia*

Estimation of productivity in the field

To determine its productivity in the field, once the plant was located, the methodology proposed by Mostacedo and Fredericksen (2000) was followed, who recommend the sampling method by square plot of 1 mx 1 m for herbaceous plants, of 5 mx 5 m for creepers and 10 mx 10 m for shrubs and trees. In each of the plots the coverage, density and frequency of plants, as well as the number of seeds per plant, of all the plants contained in the respective plot was estimated. The variables density and number of seeds per plant were used to estimate the potential yield of seed extrapolated to one hectare under natural conditions.

Morphological characterization of the seeds

The clean seeds were dried at 60 ° C for a period of 18 h. Subsequently, the weight (g) of 100 seeds taken at random, from each of the species considered in the study, was recorded by means of an analytical balance (Vlab V300®). To 100 seeds of each the species collected were measured length, width and thickness (cm) using a vernier, according to the methodology proposed by Pérez et al. (2006).

Extraction and physicochemical characterization of oils

The chemical extraction of oil was carried out using a grease and oil determinant (Soxtec System HT 1043), according to the technique proposed by Loredo et al., (2012). Once the oils were extracted, the determination of the following parameters was carried out, taking into consideration the Mexican Standards (NMX): refractive index (NMX-F-074-S 1981), saponification index (NMX-F- 174-S-1981), acid number (NMX-F-101-1987), iodine number (NMX-F-408-S-1981) and peroxide index (NMX-F-154-1987).

Statistic analysis

The results obtained were expressed as the mean of three independent experiments ± standard deviation. For potential seed and oil yield, variance analysis was performed, the experimental design was completely randomized and the Tukey test ($p \leq 0.05$) was applied using the SAS program (Statiscal Analysis Software, V9.1).

Results and Discussion

Seed collection

Field trips were conducted in different sites of the central-northern highlands of the country, in search of plant species that had potential for oil production. The species collected were distributed at altitudes from 1755 to 2444 meters above sea level. It was observed that most of the seeds of the collected plants present ruderal characteristics of annual cycle, which were found at the edge of the road, uncultivated lands or as invaders of agricultural fields.

Potential seed and oil yield

The statistical analysis performed shows that there is a statistical difference for the potential seed yield and oil yield, depending on the vegetable species under study ($p \leq 0.05$). Agave sp., Was superior and statistically different (DSH = 2457) to the rest of the species, registering a potential seed yield of 24305 kg ha-1. However, this represents a special case given that in tall species of this type of plants maturation can occur between 10 and 25 years, while in the low-bearing species of this species can occur between four and five years (García-Mendoza, 2002). Figure 1 shows that four species registered potential seed yields greater than 1000 kg ha-1, but they excel, in addition to Agave sp., A. mexicana, A. undulata and P. louisianica.

On the other hand, seven species presented values of seed yield lower than 100 kg ha-1, with L. tridentata standing out among them with only 0.8 kg ha-1, despite having registered one of the highest densities. An important group of species were located with potential intermediate seed yields, with the exception of P. glandulosa, all of them are medium-low, herbaceous and creeping.

Regarding B. odorata, it highlights that despite registering a high density per unit area and having a high number of seeds, it was not reflected in its potential yield due to its low weight. Similar behavior was observed with L. tridentata since its seeds are very light. In X. strumarium its reduced yield could be associated with the presence of a low number of seeds (two seeds per fruit); however, it is a species to consider since its seed contains 20.4% oil. In the particular case of Brassica sp., Its low yield could be the result of its low density and reduced seed size; however, it has a high percentage of oil (30.3%), which is interesting, especially if it is considered that it can be cultivated intensively in order to increase its seed yield. In other cultivated oleaginous species, very contrasting results have been observed as regards yields, especially considering that many of them have been obtained under experimental conditions.

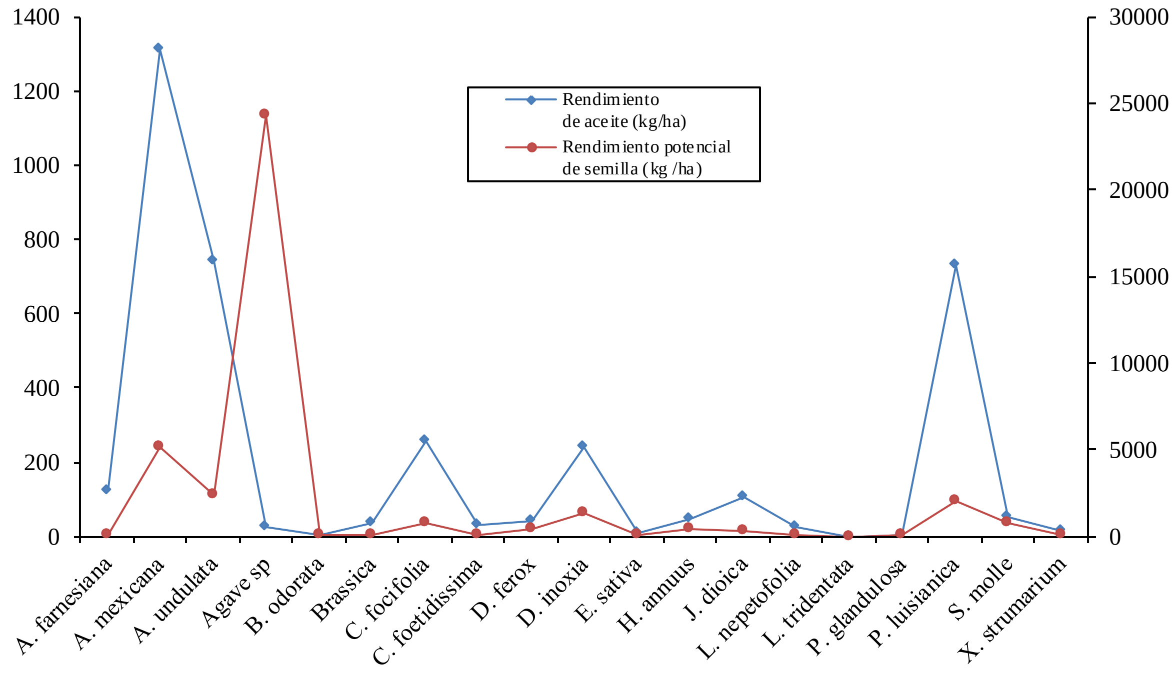

Figure 1. Relationship between potential seed yield and oil content.

The results obtained for oil yield of the species studied are shown in Figure 1. A. mexicana was the species with the highest oil yield with 1315 kg ha-1, statistically different from the rest of the species (DSH = 773.2) , this species was as competitive or better than some commercial crops currently used in the production of biodiesel, such as soybean Glycine max (335 kg ha-1), sunflower Helianthus annuus (568 kg ha-1), arachis hypogaea peanut (712 kg) ha-1), Brassica napus rape (832 kg ha-1), jatropha curcas (950 kg ha-1), castor oil castor Ricinus communis (1133 kg ha-1), tung Aleurites fordii (1204 kg ha-1) as register Martínez-Valencia et al., (2011). A. undulata and P. lousianica showed interesting oil yields of 743 and 730 kg ha-1, these are derived from their large number of fruits, size and quantity of seeds and above all of their oil contents greater than 30%.

Physical characterization and weight of seeds

The results obtained for the physical characterization and weight of the seeds under study are presented in Table 2.

Table 2. Physico-chemical characteristics of vegetable oils.

seeds	Long (mm)	Width (mm)	Thickness (mm)	Weight 100 seeds (g)
A. mexicana	1.85 ± 0.11	1.73 ± 0.01	1.67 ± 0.10	0.26 ± 0.01
A. undulata	10.72 ± 0.75	8.34 ± 0.59	3.69 ± 0.54	10.60 ± 0.21
A. farnesiana	6.35 ± 0.18	5.86 ± 0.56	4.12 ± 0.23	12.64 ± 1.26
Agave sp.	10.34 ± 0.27	7.30 ± 0.43	0.01 ± 0.03	0.83 ± 0.05
B. odorata	10.22 ± 2.27	0.84 ± 0.15	0.59 ± 0.12	0.14 ± 0.01
Brassica sp.	1.51 ± 0.18	1.36 ± 0.70	1.20 ± 0.30	0.08 ± 0.08
C. ficifolia	17.32 ± 0.30	10.73 ± 0.25	2.65 ± 0.26	3.70 ± 0.04
C. foetidissima	9.62 ± 0.68	2.28 ± 0.36	1.58 ± 0.44	17.31 ± 0.04
D. ferox	3.74 ± 0.31	2.91 ± 0.26	1.49 ± 0.15	0.80 ± 0.03
D. inoxia	4.52 ± 0.63	3.31 ± 0.42	1.31 ± 0.01	0.94 ± 0.02
E. sativa	1.56 ± 0.11	1.24 ± 0.11	0.77 ± 0.14	0.07 ± 0.01
H. annuus	5.64 ± 0.68	2.28 ± 0.36	1.58 ± 0.44	0.63 ± 0.06
J. dioica	11.61 ± 0.92	10.17 ± 0.85	9.66 ± 0.53	154.60 ± 1.95
L. nepetifolia	3.91 ± 0.31	1.48 ± 0.14	1.01 ± 0.18	0.18 ± 0.01
L. tridentata	5.41 ± 0.71	1.59 ± 0.29	2.26 ± 0.33	0.51 ± 0.03
P. louisianica	8.75 ± 0.58	5.10 ± 0.36	2.90 ± 0.37	3.20 ± 0.08
P. glandulosa	5.56 ± 0.30	4.28 ± 0.40	2.40 ± 0.18	3.53 ± 0.06
S. molle	4.51 ± 0.48	4.27 ± 0.45	4.01 ± 0.63	2.65 ± 0.02
X. strumarium	13.75 ± 2.45	4.11 ± 0.61	2.21 ± 0.43	5.61 ± 0.04

The results are expressed as the mean of three replicates ± standard deviation.

Regarding the “long” parameter of the seeds evaluated, the average values (mm) range from 1.51 ± 0.18 for Brassica sp., To 17.32 ± 0.30 for C. ficifolia. In relation to the “width” of the seeds, the lowest average (mm) was determined in B. odorata with 0.84 ± 0.15 and C. ficifolia the highest value (mm) with 10.73 ± 0.25. Regarding the characteristic “thickness”, J. dioica presented the highest average (9.66 ± 0.53 mm) with respect to the seeds of the other species under study such as Agave spp (0.01 ± 0.03), B. odorata (0.59 ± 0.12). mm) and E. sativa (0.77 ± 0.14). Finally, the "weight of 100 seeds" presented a great variability between the species under study, J. dioica seeds were the heaviest, registering an average value of 154.60 ± 1.95 g, while the rest showed values that oscillated between 0.26 and 17.31 g per 100 seeds. For all cases, the registered standard deviation values were low, which confirms that in the three parameters evaluated (length, width and thickness) there is no high variability in the dimensions of the seeds of the same species. However, it is appreciated in the dimensions of the seeds of the different species.

Oil content of the seeds under study

In Figure 2, the percentages of oil obtained from the seeds collected are presented. It is highlighted that six species recorded contents greater than 30%, among which are: C. foetidissima (33.9%), P. louisanica (33.6%), J. diodica (32.86%), C. ficifolia (31.8%), A undulata (31.40%) and Brassica sp. (30.33%). Likewise, it is appreciated that six of the collected species obtained an oil percentage between 10 and 30% and seven resulted with oil values less than 10%. These contents, in general, are lower than those recorded by Martínez-Valencia et al. (2011) for commercially grown oilseeds such as: sunflower Helianthus annuus (45-55%), canola Brassica napa (40-44%), palm Elaeis guineensis (44-57%), coconut Cocus nucifera (65-75%), peanut Arachis hypogaea (48-50%) and safflower Carthamus tinctorius (35-40%); or to the oil content of, 41.52 to 51.04% obtained by Vasco-Leal et al. (2017) in twelve accessions of castor bean from the states of Aguascalientes, Jalisco, San Luis Potosí and Zacatecas, Mexico.

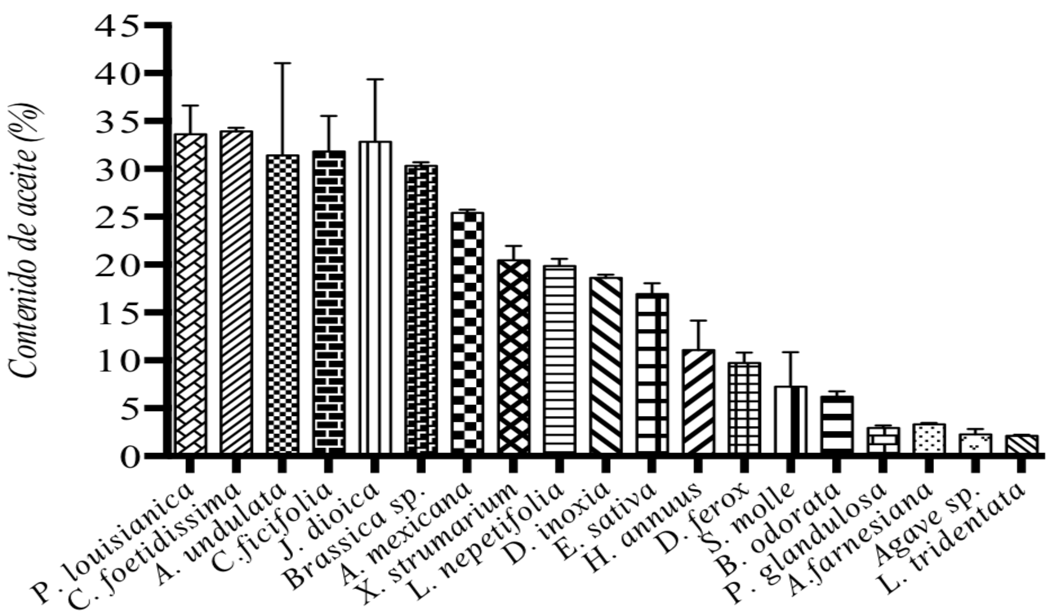

Figure 2. Percentage of oil obtained from the species of plants collected.

Physicochemical characterization of oils

The quality and efficiency of biodiesel depend on the process and the quality of the oil generated by the raw material; that is, oils with a low concentration of free fatty acids, high in monounsaturated fatty acids and without gums and impurities, among other physicochemical properties (Martínez-Valencia et al., 2011). On the other hand, Martínez-Sánchez et al. (2015) point out that the chemical characteristics most used for the classification and determination of the commercial quality of the oils are: iodine index, saponification, peroxides and acidity; Physical characteristics include specific gravity, refractive index, density and melting point. Table 3 presents results of the physicochemical characteristics of the oils studied.

Table 3. Main fatty acids present in the oils of the species studied.

Species	IR	IS (mg KOH g^{-1})	IY (g I_2 100 g^{-1})	IP (meq kg^{-1})	IA (% oleic acid)
A. farnesiana	1.4768	ND	60.68 ± 2.78	ND	ND
A. mexicana	1.4730	119.31 ± 1.42	117.94 ± 1.75	0.39 ± 0.10	11.71 ± 0.02
A. undulata	1.4870	141.48 ± 0.24	123.80 ± 4.54	0.75 ± 0.10	11.25 ± 0.17
Agave sp.	1.4762	ND	ND	0.74 ± 0.05	ND
B. odorata	1.4725	149.81 ± 3.43	96.57 ± 0.86	1.62 ± 1.41	ND
Brassica sp.	1.4715	174.17 ± 0.37	93.82 ± 0.32	0.79 ± 0.04	3.13 ± 0.01
C. ficifolia	1.4748	ND	73.12 ± 1.34	1.08 ± 0.01	0.68 ± 0.22
C. foetidissima	1.4750	180.02 ± 0.05	141.26 ± 22.79	0.47 ± 0.05	11.51 ± 0.03
D. ferox	1.4700	142.31 ± 2.42	ND	ND	29.66 ± 0.19
D. inoxia	1.4720	146.22 ± 0.34	114.95 ± 1.11	1.06 ± 0.01	8.70 ± 0.43
E. sativa	1.4780	129.64 ± 3.37	97.59 ± 0.16	ND	4.24 ± 0.01
H. annuus	1.4723	152.27 ± 3.20	122.29 ± 2.95	0.77 ± 0.05	7.69 ± 0.01
J. dioica	1.4725	ND	113.49 ± 2.58	ND	ND
L. nepetifolia	1.4658	149.93 ± 2.08	88.47 ± 1.20	0.47 ± 0.05	36.17 ± 0.72
P. glandulosa	1.4757	ND	ND	ND	ND
P. louisianica	1.4735	182.83 ± 4.43	116.65 ± 0.32	0.72 ± 0.05	3.50 ± 0.01
S. molle	1.4850	ND	99.40 ± 0.85	0.79 ± 0.05	26.80 ± 0.55
X. strumarium	1.4750	ND	126.63 ± 2.23	0.67 ± 0.05	1.79 ± 0.37

The results are expressed as the mean of three replicates ± standard deviation.
IR = Refractive index, IS = Saponification index, IY = Iodine index,
IA = acidity index, IP = peroxides index, ND = not determined.

Refractive index (IR)

Table 3 shows the refractive index determined for the oils of the species under study, which show values between 1.4658 and 1.4870; These are within the range of the following results obtained in oils from other oilseeds: castor oil (1.4764 - 1.4778), soybeans (1.466 - 1.47) and higher average values compared with the following oil raw materials : pine nuts (1.4680), cotton and

peanuts (1,460 - 1,465), sunflower (1,467 - 1,469), sesame (1,465 - 1,469), babassu (1,448 - 1,451) according to the literature (Anvisa, 1999; Pinhão manso, 2005, Proquinor, 2003).
Saponification index (IS)

According to the obtained results, the species with the highest saponification index showed values of 182.83, 180.02 and 174.17 mg KOH g-1 (P. louisiana> C. foetidissima> Brassica sp.), While the values of the species with the lowest index were 119.31 and 129.64 (A. mexicana <E. Sativa). Danlami et al., (2015) observed similar average values or R. communis oil (174.6 mg KOH g-1). Similarly, Yong and Salimon (2006) obtained values for Elateriospermum tapos of 150.90 mg KOH g-1. Similar results were obtained in this study for the species of B. odorata, H. annuus and L. nepetifolia. On the other hand, in the cosmetics industry, Ruiz and Huesa (1991) observed IS values for Shea butter oil (Butyruspermum parki) of 180-190 mg KOH g-1; these values are similar with the oils of C. foetidissima and P. louisianica, which makes possible their potential use in the cosmetics industry. Likewise, Cruz et al. (2015) obtained in J. curcas, one of the oils most used in obtaining biodiesel with averages that ranged between 192 and 196 mg KOH g-1, only P. louisianica recorded these values in our study.

Iodine Index

The iodine index (IY) evaluated in the oils of the collected species ranged from 60.68 to 141.26 g I2 100 g-1 (Table 3). When comparing these averages with those vegetable oils from other oilseeds, Freire (2001) determined averages in R. communis oil, between 81 to 91 g I2 100 g-1 and Cecchi (2003) in Glycine max oil recorded values between 120 to 141 g I2 100 g-1; in this way it is evident that each species has a characteristic value, which could depend on the variety and the method used in its determination. According to Saraf and Thomas (2007), this parameter directly influences the quality of biodiesel, because high values of this index in the oil, can translate into a greater tendency to oxidation, contribute to the formation of gums in the engine and the decrease in lubricity.

Peroxide index

Peroxides are known as compounds of the primary decomposition of the oxidation of fats and oils (Gómez, 2010), so that those values of peroxide index (IP) close to 0 meq kg-1, are related to a level of low rancidity; that is, they oxidize slowly allowing the oil to retain its quality for a longer time, giving them an advantage for possible later use. A high IP value indicates the presence of oxidation; In this study, it is worth noting that the oils of most of the plant species studied had an IP less than 1. According to Luna-Guevara and Guerrero-Beltrán (2012) the IP and the AI are considered quality indicators and freshness of oils

Acidity index

In Table 3, it can be seen that the oil of species with IA less than 5% oleic acid are C. ficifolia (0.68%), X. strumarium (1.79%), Brassica sp. (3.13%), P. louisianica (3.50%) and E. sativa (4.24%), while S. molle, D. ferox, L. nepetifolia, present values of 26.80, 29.66 and 36.17% respectively. This determination is essential for the production of biodiesel and oils for food or industrial use.

Conclusions

The wild species studied had distinctive agroproductive characteristics in terms of seed productivity and oil content. Six species (C. ficifolia, C. foetidissima, A. undulata, J. dioica, P. louisianica and Brasica sp) obtained percentages higher than 30%, which is why they are considered of interest in oil production. Considering the physical and chemical characteristics of the oils, its potential use is suggested not only in the biofuels industry, but also its possible use in the food, pharmaceutical and cosmetological industries, as well as in the obtaining of higher added value products.

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