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Physico-Chemical Studies on The Seeds of Some Wild Plants (Jojoba, Milk Thistle and Chia Seeds) as a Rich and New Source of Oil

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ABSTRACT

This study was conducted to evaluate the seeds of some wild plants jojoba, milk thistle, and chia as rich and important sources of oil. The chemical composition of the seeds and the amino acid composition of their meals were determined. Oil was extracted, and its physicochemical characteristics, fatty acid profile, COX (calculated oxidative stability), AI (atherogenicity index), and PI (peroxidability index) were assessed as indicators of stability. In addition, the unsaponifiable matter fraction and bioactive components were analyzed. The results showed that jojoba seeds had the highest oil content (50.68%), followed by chia seeds (33.13%) and milk thistle seeds (21.35%). The meal of jojoba seeds also recorded the highest total amino acid content (21.32%), followed by chia (18.51%) and milk thistle (15.26%). Gas-liquid chromatography of jojoba oil revealed high contents of C20:1 alcohol (20.68%), followed by C22:1 alcohol (4.96%) and C24:1 alcohol (1.27%). The results also showed that jojoba oil is a rich source of omega-9 fatty acid (C20:1, 54.01%), chia oil is an excellent source of omega-3 (linolenic acid, 64.52%), and milk thistle oil is rich in omega-6 (linoleic acid, 55.59%). β-sitosterol was the predominant sterol in chia and milk thistle oils (79.64% and 66.05%, respectively), while *ficosem1-old,cis* (52.09%) and 13-docosenoic alcohol (Z) (47.89%) were major sterols in jojoba oil.

1. Introduction

Milk thistle is considered a safe and well-tolerated herbal product, with no known health hazards or side effects (Shaker et al., 2010). Flowering begins in spring, and the plant is typically harvested in early summer. Milk thistle seeds contain about 22% total lipids, which is comparable to many other vegetable oil seeds (El-Mallah et al., 2003). Milk thistle belongs to the Asteraceae (Compositae) family, also known as the aster, daisy, or sunflower family the largest family of flowering plants. Sunflower is an annual plant of the same family, Asteraceae (The Plant List, 2016). The predominant fatty acids in milk thistle seed oil are linoleic acid (C18:2), oleic acid (C18:1), palmitic acid (C16:0), and stearic acid (C18:0) (Malekzadeh et al., 2011). In Egypt, milk thistle is commonly found and widely spread in the Nile Delta region, along roadsides, in wastelands, and as a troublesome weed in cereal crops. It typically grows in dry, sunny areas during the winter and spring seasons. The plant has a glabrous or slightly downy, erect, and branched stem ranging from 40 to 200mm in the upper part. Milk thistle seed oil is rich in essential nutrients and unsaturated fatty acids, making it suitable for both food and industrial uses, similar to cottonseed, sunflower, and soybean oils (Abd-El-Hady and Arafa, 2019). Silymarin, a compound found in milk thistle, has protective effects against oxidative damage in the liver, brain, and heart. It is also used in treating liver and bile tract diseases, viral hepatitis, and toxin-induced liver damage, and it helps replenish glutathione levels (Abenavoli and Milic, 2017). Consequently, milk thistle seeds are commercially cultivated for their remarkable medicinal properties (Alemardan et al., 2013). Milk thistle oil is affordable, nutritious, and beneficial for human consumption (Haudolin et al., 2001). The plant (*Silybum marianum* L.) grows well in Egypt.

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Research has shown that its oil can be extracted in high quality, comparable to soybean and sunflower oil. Although precise commercial production statistics are unavailable, studies confirm its potential for both food and industrial applications (Abd-El-Hady et al., 2019). Jojoba (*Simmondsia chinensis*) is a desert shrub that grows wild in the American Southwest and northwestern Mexico. It is cultivated as a specialty oil crop due to its high content of long-chain wax esters. Jojoba seeds contain over 50% by weight of a liquid wax ester mixture, used in lubricants and personal care products. Minor components in jojoba oil include sterols and fatty alcohols (Van Boven et al., 2000). The main molecular species in jojoba oil is *cis*-13-docosenyl *cis*-11-eicosenoate (C20:1), which ranges from 31% to 45% of the extracted seed oil. Other alcohol-acid combinations contribute to the C42 molecular chain length, forming 41% to 57% of the total wax ester content (Thomas, 1984). Jojoba oil has a unique chemical structure and shows great commercial promise. Its saponification and iodine values are relatively low compared to other vegetable oils like soybean and rapeseed, indicating better oxidative stability (Allawzi et al., 1998). In Egypt, agricultural trials for jojoba are limited due to its desert climate requirements, and production remains on a small scale.

This unusual chemical structure closely resembles natural human skin sebum, explaining its many skin-related benefits. Traditionally, Native Americans used jojoba wax for skin and hair care, including the treatment of cuts, sores, bruises, burns, sunburns, and windburns (Tietel, 2024). Chia (*Salvia hispanica* L.), an herbaceous annual plant from the Lamiaceae family, is currently the only domesticated species of its genus. Wild and cultivated forms differ very little. Chia is one of the richest botanical sources of linolenic acid (cis-C18:3, omega-3) and does not contain any antinutritional compounds (Ricardo and Coate, 2005). Omega-3 fatty acids play an essential role in human physiology, especially during fetal and infant development (Maira et al., 2014). The European Union has recognized chia seeds as a novel food, while in the United States, chia seeds are generally recognized as safe (GRAS). However, no such designation currently exists for chia seed oil. In Canada, both chia seeds and their oil are listed as ingredients in natural health products (Parker et al., 2018). Liver cancer is the third leading cause of cancer-related deaths worldwide. Doxorubicin (DOX) is one of the most effective chemotherapy agents used in cancer treatment. It is an anthracycline antibiotic administered intravenously every 21 to 28 days at a dose of 60 to 75mg/m^2 of body surface area. However, the widespread use of DOX is limited due to its multiple adverse effects and the development of resistance. These adverse effects include hepatotoxicity, cardiotoxicity, and nephrotoxicity. Doxorubicin-induced hepatotoxicity is primarily attributed to the generation of reactive oxygen species (ROS) during hepatic metabolism, which disrupts redox homeostasis and leads to mitochondrial dysfunction, oxidative stress, inflammation, decreased antioxidant enzyme levels, and apoptosis (Tawfik, 2023). The aim of this study is to evaluate the seeds of selected wild plants jojoba, milk thistle, and chia as rich and valuable sources of oil.

2. Materials and Method

Materials

Milk thistle (*Silybum marianum* L.), jojoba (*Simmondsia chinensis* L.), and chia seeds (*Salvia hispanica* L.) were obtained from the Desert Research Center, Cairo, Egypt.

Solvents

All solvents used in this study were of analytical grade and obtained from Merck.

Methods

Oil Extraction from Jojoba, Milk Thistle, and Chia Seeds. The seeds of jojoba, milk thistle, and chia were crushed separately using a grinder. The crushed seeds were soaked in pure *n*-hexane for 24 hours. The micella (oil-solvent mixture) was then collected and filtered. This extraction process was repeated three times using fresh solvent each time. The solvent was removed under reduced pressure using a rotary evaporator at 40–45°C. The extracted oil was dried over anhydrous sodium sulfate, filtered, and stored in dark bottles at –5°C in a freezer until further analysis. The procedure followed was according to AOCS (1981).

Chemical Composition of Seeds

Moisture, oil, crude protein, ash, and total carbohydrate contents of jojoba, milk thistle, and chia seeds were determined according to the standard methods described by AOAC (2000). The fiber content was calculated by difference using the following equation: Fiber contents (%) = 100% - (moisture oil + protein + ash + total carbohydrates) %

Amino Acids Composition of Seed Meal

The amino acid composition of the meal obtained from jojoba, milk thistle, and chia seeds was determined according to the official methods of AOAC (2016).

Physical and chemical properties of extracted

Refractive Index (RI)

The refractive index of the extracted oils was measured at 25°C using a refractometer (Model NYRL-3, Poland) according to AOAC (2012).

Color

Oil color was determined following the method described by Lee et al. (2004). A 5% (w/v) solution of each oil in chloroform was prepared, and absorbance was measured at 420 nm using a Pye-Unicam double-beam recording spectrophotometer (Model SP1600).

UV Absorbance at 230 and 270 nm (K230 and K270)

The presence of conjugated dienes and trienes in the oil samples was assessed by measuring absorbance at 230 and 270 nm (K230 and K270) according to EC Regulation No. 2568/91 (1991) for virgin olive oil.

Free Fatty Acids (Acidity %), Peroxide Value, and Sterol Compounds

Free fatty acids (acidity %), peroxide value (meq/kg oil), and sterol compound contents (%) were determined according to the methods described in AOAC (2012).

Saponification and iodine values (SV and IV):

SV and IV were calculated from the fatty acid composition of the oils using the equations described by Susana and Nelson (1995):

IV (iodine value) = (%C16:1×0.950) + (% C18:1× 0.860) + (%C18:2×1.732) + (%C18:3×2.616) + (% C20:1×0.785) + (%C22:1×0.723) (g I_2/100g of sample)

SV (saponification value) =

$$\frac{3 \times 56.1 \times 1000}{(\text{Mean molecular weight} \times 3) + 92.09 - (3 \times 18)}$$

(mg KOH per g of sample)

Where, 3 = number of fatty acids per triacylglycerol 56.1 = MW of KOH (g/mol), 1000 = conversion of units (mg/g), 92.09 = MW of glycerol (g/mol), 18 = MW of water (g/mol)

Fatty Acid Composition

The fatty acid profile of the oil samples was determined using a gas chromatograph (GC) equipped with a DB-23 capillary column (60m × 0.32mm × 0.25µm film thickness), following the method described by the International Olive Oil Council (IOOC, 2001).

Determination of AI, COX, and PI Factors

The following indices were calculated based on fatty acid composition:

- AI (Atherogenicity Index) – as described by Idamokoro et al. (2019)
- COX (Calculation of Oxidative Stability) – as described by Cao et al. (2015)
- PI (Peroxidability Index), as described by Yun and Surh (2012). These indices serve as indicators of oil stability and potential health effects.

AI = [C12+ 4 (C14) + C16]:(sum of unsaturated FA).

$$COX = \frac{1*X1+10.3*X2+21.6*X3}{100}$$

Whereas:

x_1, x_2, and x_3 are the percentages of C18:1, C18:2, and C18:3 acids in total fatty acids of an oil sample, respectively.

PI= (%monoenoic FA×0.025)＋(% dienoic FA×1)＋(%trienoic FA×2)＋(%tetraenoic FA×4)＋(% pentaenoic FA×6) ＋(%hexaenoic FA×8).

Total Polyphenols and Tocopherols

The total polyphenol content and tocopherol content of the oil samples were determined according to the methods described by Gutfinger (1981) and Wong et al. (1988), respectively.

Determination of Pigment Contents (Chlorophylls and β-Carotene)

Chlorophyll and carotenoid contents (ppm) were estimated according to the method of Isabel et al. (1991).

Identification of Sterol Compounds

The unsaponifiable matter in the analyzed oil samples was determined by gas chromatography–mass spectrometry (GC-MS), following the method reported by AOAC (2016).

3. Results and Discussion

Chemical Composition of Seeds

A proximate analysis of seeds obtained from Jojoba, Milk Thistle, and Chia plants covering moisture content, crude protein, oil content, crude fiber, ash content, and available total carbohydrates is presented in Table 1. The results showed that the moisture content of the aforementioned seeds was 5.00%, 4.94%, and 7.94%, respectively. These values are lower than the 15% moisture limit recommended for the safe storage of plant food materials. According to the same table, it can be observed that the seeds had a high oil content: 50.68%, 21.35%, and 33.13%, respectively. This suggests that these seeds may have potential as sources for oil production. Fiber plays a crucial role in a healthy, well-balanced diet. It supports gut health and helps prevent heart disease, diabetes, weight gain, and certain types of cancer, as mentioned by Shokrg (2017). In general, the analyzed samples exhibited high fiber content: 6.21%, 26.52%, and 19.82%, respectively. Regarding the ash content, the seeds had values of 3.20%, 4.83%, and 3.19%, respectively, indicating they are a good source of minerals. Additionally, the available total carbohydrate contents were relatively high: 10.31%, 26.46%, and 25.33%, respectively, which enhances the nutritional value of the resulting meal, making it suitable for use in both human food and animal feed.

Table 1. Chemical composition of seeds (w/w)

Chemical composition (%)	Seeds of		
	Jojoba	Milk thistle	Chia
Moisture content	5.00	4.94	6.76
Crude oil	50.68	21.35	33.13
Crude protein	24.6	15.9	11.87
Crude fiber	6.21	26.52	19.82
Ash content	3.2	4.83	3.19
Available carbohydrate	10.31	26.46	25.23

Physicochemical Characteristics of Extracted Oils

The physicochemical properties of oils play a crucial role in determining their quality and consumer acceptability. These properties are also closely related to health and safety criteria. Table 2 presents the analysis results of oils extracted from seeds of three wild plants: Jojoba, Milk Thistle, and Chia. The parameters evaluated include refractive index (RI at 25°C), color (at 420nm), acidity (as free fatty acids, FFA%), peroxide value (PV, meq O_2/kg oil), specific extinction coefficients (K_{230} and K_{270} nm), iodine value (IV, g I_2/100g oil), and saponification value (SV, mg KOH/100g oil). The refractive index (RI) is a significant physical property as it can be measured quickly and accurately with a small sample size. It is commonly used to identify oils and estimate their degree of unsaturation. The data in Table 2 revealed RI values of 1.4650, 1.4600, and 1.4780 for jojoba, milk thistle, and chia oils, respectively. The higher RI value observed for chia oil may be attributed to its higher content of polyunsaturated fatty acids, as will be discussed further in Table 3. Regarding color, the values at 420nm were 0.054 for jojoba oil, 0.237 for milk thistle oil, and 0.025 for chia oil. The color of oil is primarily due to the presence of natural pigments such as chlorophylls and carotenoids, which are powerful antioxidants and serve as important visual indicators of product quality, as reported by Awed (2015). Acidity is a key quality parameter that can indicate the age and degradation of the oil. The acidity values of the aforementioned oils were found to be 0.09% for jojoba oil, 4.08% for milk thistle oil, and 0.201% for chia oil. The relatively low free fatty acid (FFA) values, especially in jojoba and chia oils, suggest better oxidative stability and a longer potential shelf life. The peroxide value (PV), expressed in meq O_2/kg oil, is one of the most critical indicators of oxidative rancidity in oils and fats. The results showed that jojoba oil had the lowest PV at 2.26meq O_2/kg, indicating minimal oxidation. In contrast, milk thistle and chia oils exhibited higher PVs, at 38.72 and 10.36 meq O_2/kg, respectively, suggesting a higher degree of oxidation. Regarding sterol compounds, jojoba oil contained a significantly higher percentage (30.94%) compared to milk thistle (1.65%) and chia oils (2.18%). Sterols are known for their health benefits and antioxidant properties. The saponification values (SV) for jojoba, milk thistle, and chia oils were 111.82, 200.06, and 200.26mg KOH/100g oil, respectively. SV gives an indication of the average molecular weight (chain length) of the fatty acids in the oil lower SV suggests longer-chain fatty acids. The iodine values (IV), which reflect the degree of unsaturation, were 48.57, 122.43, and 207.73g I_2/100g oil for jojoba, milk thistle, and chia oils, respectively. A higher IV denotes a greater proportion of unsaturated fatty acids. Finally, the specific extinction coefficients at 230nm (K_{230}) and 270nm (K_{270}), which are used to assess secondary oxidation products, were as follows:

- K_{230}: 0.313 (jojoba), 1.59 (milk thistle), and 0.89 (chia)
- K_{270}: 0.173 (jojoba), 0.86 (milk thistle), and 0.443 (chia)

These values provide additional insights into the oxidative stability and overall quality of the oils.

Table 2. Physical and chemical characteristics of oils

Physical properties	Extracted oils from seeds of		
	Jojoba	Milk thistle	Chia
Color at 420nm	0.054	0.237	0.025
RI at 25°C	1.4650	1.4600	1.4780
State at room temperature	Liquid	Liquid	Liquid
Chemical properties			
Acidity (%)	0.09	4.08	0.201
Peroxide value (meqo_2/kg oil)	2.26	38.72	10.36
($K_{230\ nm.}$)	0.313	1.591	0.890
($K_{270\ nm.}$)	0.173	0.86	0.443
Sterol compounds (%)	30.94	1.65	2.183
(IV) Iodine value (I_2/100g oil)	48.57	122.43	207.73
(SV) Saponification value (mgKOH/100g oil)	111.82	200.06	200.26

Fatty Acid Composition of Oils

Data presented in Table 3 show that jojoba oil contains a low amount of total saturated fatty acids (TSFA), at 1.05%, and a high amount of total unsaturated fatty acids (TUSFA), at 60.70%, along with a significant proportion of fatty alcohols (38.25%). Regarding milk thistle and chia oils, their TSFA contents were 20.66% and 9.84%, respectively. Among the three, chia oil had the highest proportion of TUSFA at 90.16%, followed by milk thistle oil at 79.34%, and jojoba oil at 60.70%. The major unsaturated fatty acids (USFA) identified were:

- In jojoba oil: C20:1 (54.01%) as the dominant component, followed by C20:1 alcohol (20.68%), C22:1 (8.52%), and C22:1 alcohol (4.96%).
- In milk thistle oil: C18:2 acid (55.59%) was predominant, followed by C18:1 acid (22.73%).
- In chia oil: C18:3 acid (64.52%) was the most abundant, followed by C18:2 acid (19.15%).

The presence of essential fatty acids namely linolenic acid (C18:3) and linoleic acid (C18:2) in chia and milk thistle oils suggests high nutritional value and potential health benefits, including improvements in blood lipid profiles, regulation of blood pressure, and reduction of cholesterol levels. These findings are supported by Cheikh-Rouhou et al. (2008), who

who indicated that essential fatty acids contribute to lowering blood cholesterol levels, while Gombo and Dau (2014) noted an inverse relationship between cholesterol levels and essential fatty acid intake.

Table 3. Fatty acids composition of oils

Fatty acids composition (%)	Extracted oils from seeds		
	Jojoba	Milk thistle	Chia
$C_{14:0}$	0.02	0107	0.03
$C_{16:0}$	0.78	8.68	6.67
$C_{16:1}$	0.14	0.102	0.09
$C_{17:0}$	0.07	0.082	0.04
$C_{17:1}$	0.03	0.036	0.16
$C_{18:0}$	0.03	5.49	2.76
$C_{18:1}$(ω -9)	6.59	22.73	6.22
$C_{18:2}$(ω-6)	0.05	55.59	19.15
$C_{18:3}$(ω-3)	0.68	0.145	64.52
$C_{20:0}$	0.05	3.52	0.27
$C_{20:1}$	54.01	1.097	0.16
$C_{22:0}$	0.1	2.78	0.06
$C_{22:1}$	8.52	-	-
$C_{24:1}$	0.68	-	-
$C_{18:1\ alcohol}$	0.19	-	-
$C_{20:0alcohol}$	0.07	-	-
$C_{20:1alcohol}$	20.68	-	-
$C_{22:0alcohol}$	0.03	-	-
$C_{22:1alcohol}$	4.96	-	-
$C_{24:1alcohol}$	1.27	-	-
TSFA	1.05	20.66	9.84
TUSFA	60.70	79.34	90.16
TU/TS	26.18	3.84	9.16
T alcohol acids	38.25	-	-

Natural Antioxidants in Oils

Many vegetable seed oils contain phenolic compounds and tocopherols that act as natural antioxidants. Due to their redox properties, these compounds play a crucial role in scavenging free radicals and inhibiting oxidative reactions, including the decomposition of peroxides, as reported by Osawa (1994). Results in Table 4. show the contents of total polyphenols, total tocopherols, carotenoids, and chlorophylls in oils extracted from jojoba, milk thistle, and chia seeds. According to the data, chia oil exhibited significantly higher levels of these antioxidant compounds, with values of 88.74ppm (polyphenols), 72.41ppm (tocopherols), 230ppm (carotenoids), and 0.136ppm (chlorophyll). The oils extracted from jojoba and milk thistle seeds also showed considerable amounts of natural antioxidants:

- Jojoba oil: 23.23ppm (polyphenols), 10.12ppm (tocopherols), 0.38ppm (carotenoids), and 0.098ppm (chlorophyll).

Milk thistle oil: 5.90ppm (polyphenols), 47.95ppm (tocopherols), 0.35 ppm (carotenoids), and 0.146ppm (chlorophyll). These results indicate that the examined oils, especially chia oil, are rich in natural antioxidants, which contribute to their nutritional quality and oxidative stability. The Atherogenicity Index (AI), Calculated Oxidative Stability (COX), and Peroxidability Index (PI) of oils extracted from jojoba, milk thistle, and chia seeds are presented in Table 5. As shown, there were significant differences among the oils in terms of COX and PI values. Specifically, the COX values were 0.743, 5.95, and 14.764, while the PI values were 2.91, 56.41, and 149.74 for jojoba, milk thistle, and chia oils, respectively. The high variation in COX and PI values among the oils is attributed to differences in their unsaturated fatty acid compositions, as illustrated in Table 4. Both COX and PI indices are

calculated based on the content and type of major unsaturated fatty acids, and secondary lipid oxidation tends to be more pronounced in oils with higher COX and PI values (Cao et al., 2015; Yun and Surh, 2012).
In contrast, the Atherogenicity Index (AI) values did not show substantial differences among the oil samples. The AI values were 0.110, 0.013, and 0.075 for jojoba, milk thistle, and chia oils, respectively. A lower AI is considered favorable for cardiovascular health, whereas diets with high AI are considered potentially harmful (Idamokaro et al., 2019).

Table 4. Some natural antioxidant of oils

Bioactive compounds (ppm)	Extracted oils from seeds		
	Jojoba	Milk thistle	Chia
T. polyphenols (ppm.)	23.23	5.9	88.74
T.tocopherols (ppm.)	10.12	47.95	72.41
Carotenoids (ppm.)	0.38	0.35	0.230
Chlorophyll (ppm.)	0.98	0.146	0.163

Table 5. COX, PI and AI factors of oils

Factors of oils	Extracted oils from seeds of :		
	Jojoba	Milk thistle	Chia
COX	0.740	5.95	14.764
AI	0.110	0.013	0.0753
PI	2.909	56.41	149.74

AI, COX, and PI Factors of Oil Samples

The Atherogenicity Index (AI), Calculated Oxidative Stability (COX), and Peroxidability Index (PI) of oils extracted from jojoba, milk thistle, and chia seeds are presented in Table 5. As shown, there were significant differences among the oils in terms of COX and PI values. Specifically, the COX values were 0.743, 5.95, and 14.764, while the PI values were 2.91, 56.41, and 149.74 for jojoba, milk thistle, and chia oils, respectively. The high variation in COX and PI values among the oils is attributed to differences in their unsaturated fatty acid compositions, as illustrated in Table 4. Both COX and PI indices are calculated based on the content and type of major unsaturated fatty acids, and secondary lipid oxidation tends to be more pronounced in oils with higher COX and PI values (Cao et al., 2015; Yun and Surh, 2012).

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Amino Acid Composition of Seed Meals

The amino acid profiles of jojoba seed meal (JSM), milk thistle seed meal (MTSM), and chia seed meal (CSM) were analyzed to determine the types and levels of both essential and non-essential amino acids. This analysis aimed to assess the potential use of these oil-extracted seed meals as feed for livestock or poultry, thereby maximizing the value of these by-products. As presented in Table 6, seventeen amino acids were identified across all samples: Aspartic acid (ASP), Threonine (THR), Serine (SER), Glutamic acid (GLU), Glycine (GLY), Alanine (ALA), Valine (VAL), Isoleucine (ISO), Leucine (LEU), Tyrosine (TYR), Phenylalanine (PHE), Histidine (HIS), Lysine (LYS), Arginine (ARG), Proline (PRO), Cysteine (CYS), and Methionine (METH).

Among the three samples, JSM exhibited the highest total amino acid content at 21.32%, followed by CSM (18.51%) and MTSM (15.26%). Glutamic acid (GLU) was the most abundant amino acid in all samples, with concentrations of 2.65% (JSM), 3.17% (MTSM), and 3.12% (CSM). In JSM, the next most abundant amino acids were: ASP (2.51%), GLY (1.91%), ARG (1.62%), LEU (1.53%).

In MTSM: ASP (1.51%), ARG (1.22%), LEU (1.04%)

In CSM: ARG (1.98%), ASP (1.61%), LEU (1.26%)

On the other hand, Methionine (METH) and Histidine (HIS) recorded the lowest values in all samples:

- JSM: METH (0.26%), HIS (0.49%)
- MTSM: METH (0.26%), HIS (0.31%)
- CSM: METH (0.60%), HIS (0.54%)

These results highlight the potential nutritional value of the seed meals, particularly jojoba seed meal, for use in animal feed formulations.

Table 6. Amino acids composition of seeds meal

Amino acids composition %	Meal		
	Jojoba seed	Milk thistle seed	Chia seed
Aspartic (ASP)	2.15	1.51	1.61
Therionin (THR)	1.07	0.62	0.62
Serine (SER)	0.92	0.68	0.71
Glutamic (GLU)	2.65	3.17	3.12
Glycine (GLY)	1.91	0.94	0.91
Alinin (ALA)	0.91	0.68	0.91
Valine(VAL)	1.22	0.82	0.94
Isoleucine (ISO)	0.83	0.66	0.70
Leucine (LCY)	1.53	1.04	1.26
Tyrosine (TYR)	1.14	0.76	0.79
Phenylalanine(PHE)	1.11	0.71	1.05
Hisidine(HIS)	0.49	0.31	0.54
Lysine (LYS)	1.12	0.55	0.93
Argnin (ARG)	1.62	1.22	1.98
Proline (PRO)	1.25	0.76	0.78
Cystim (CYS)	1.09.	0.51	0.97
Methionine (METU)	3.26	0.26	0.60
Total amino acids	21.32	15.26	18.51

Separation of Sterol Compounds from Oils

Table 7 presents the sterol compounds identified in the oils extracted from jojoba, milk thistle, and chia seeds. According to the data, 3, 14, and 13 sterol-related compounds were identified in jojoba, milk thistle, and chia oils, respectively. The results indicate that jojoba oil contained the highest percentages of Eicosen-1-ol (Z) and cis-9- and 13-Docosen-1-ol (Z), accounting for 52.09% and 47.89%, respectively. In contrast, the predominant sterol compound in both milk thistle and chia oils was beta-sitosterol trimethylsilyl (TMS), with values of 66.05% and 71.64%, respectively. Furthermore, campesterol-TMS was present at a higher percentage in chia oil (6.63%) compared to milk thistle oil (2.81%). The concentration of stigmasterol-TMS was 4.53% in milk thistle oil, whereas it was lower in chia oil, recorded at 2.02%. These findings highlight the variability in sterol composition among the oils, which could influence their functional and nutritional properties.

Table 7. Sterol compounds of oils

Sterol compounds (%)	Extracted oil from seeds of:		
	Jojoba	Milk thistle	Chia
Eicosen-1-ol, cis-9-	52.09		
9-Octadecen-1-ol, (Z)-, TMS derivative	0.02	0.12	
13-Docosen-1-ol, (Z)-	47.89		
Hexadecanoic acid, methyl ester		0.02	0.38
Hexadecanoic acid, ethyl ester		0.89	1.28
Palmitic Acid, TMS derivative		2.04	1.01
13-Octadecenoic acid, methyl ester			2.46
9,12-Octadecadienoic acid (Z,Z)-, TMS derivative			1.66
.alpha.-Linolenic acid, TMS derivative			5.43
Stearic acid, TMS derivative		0.99	0.39
1-Monopalmitin, 2TMS derivative		0.05	0.55
Campesterol, TMS derivative		2.81	6.63
Stigmasterol, TMS derivative		4.53	2.02
.beta.-Sitosterol, TMS		66.05	71.64
Isofucosterol, O-TMS			4.07
Palmitelaidic acid, TMS		0.01	0.2
Cholesterol, TMS derivative		1.96	
.beta.-Amyrin, TMS derivative		0.85	
.5.alpha.-Stigmast-7-en-3.beta.-ol, O-TMS		3.64	
9,19-Cyclolanostan-3-ol, 24-methylene-, (3.beta.)-, O-TMS		1.27	

Recommendation

It is essential to domesticate and cultivate these wild crops in Egypt's desert regions, particularly due to their low water requirements and high seed productivity. Additionally, their seeds contain a high oil content, which can be utilized for food, cosmetic, and medicinal industrial purposes. Consequently, crops such as chia and milk thistle could significantly contribute to bridging the edible oil gap in Egypt.

4. Conclusion

This study demonstrated that wild jojoba, chia, and milk thistle seeds cultivated in Egypt possess high oil content and represent promising alternative sources of vegetable oil. The analysis revealed that jojoba oil is particularly rich in fatty alcohols and eicosenoic acid (C20:1), whereas chia and milk thistle oils are abundant in unsaturated fatty acids, notably α -linolenic acid (C18:3, ω-3) and linoleic acid (C18:2, ω-6). Chia oil also exhibited a high level of natural antioxidants. β-Sitosterol was identified as the predominant sterol in both chia and milk thistle oils, while ficosem1_old, cis-, and 13-docosenoic acid (Z) were the major sterol constituents in jojoba oil.

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