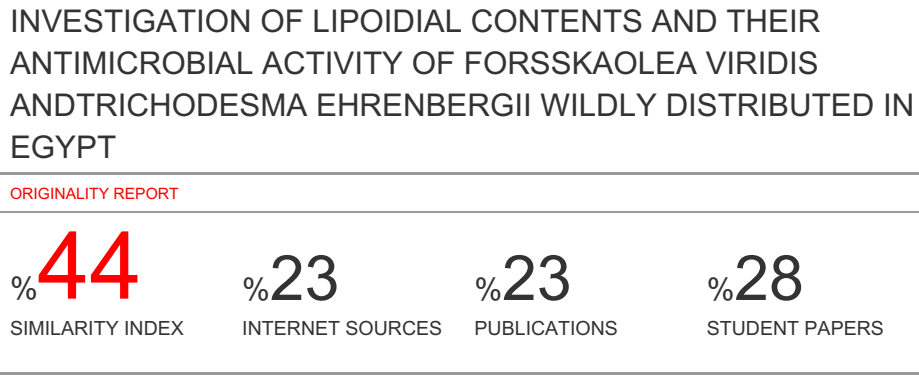
**Reviewer’s Comments**

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**INVESTIGATION OF LIPOIDIAL CONTENTS AND THEIR ANTIMICROBIAL ACTIVITY OF *FORSSKAOLEA VIRIDIS* AND*TRICHODESMA EHRENBERGII* WILDLY DISTRIBUTED IN EGYPT**

**Abstract:**

**Objective:** The objective of this study was to assess the antimicrobial activity and investigation of lipoidial contents of*F. viridis*and *T.ehrenbergii*wildly distributed in Gebel Elba, Southeast of Egypt for the first time.

**Methods:**The phytochemical investigation of the ether extracts of *F. viridis*and *T.ehrenbergii* carried out by saponification of two lipoidial extracts and using gas chromatography (GC) with reference standards.The antimicrobial activity of the ether extract was performed as *in vitro* studies by diffusion agar technique for selected +ve and –ve gram bacterial and fungal strains with reference used drug as a control.

**Results:**The findings of this study revealed that the two lipoidial extracts have sufficient steroidal and fatty acid methyl ester compounds where *F. viridis* contain (22) hydrocarbons, (6) sterols and (14) fatty acid methyl esters while, *T.ehrenbergii*contain (20) hydrocarbons, (5) sterols and (17) fatty acids where *β*-amyrin &stigmasterolandpalmitic &Tricyclicacid were the major concentration of steroid and fatty acid methyl ester contents of *F. viridis*and *T.ehrenbergii* respectively.The lipoidial extract of *F. viridis* and *T.ehrenbergii*showed potent antimicrobial activity against all tested strains as compared to reference used drug.

**Conclusion:** It can be elicited that the ethereal extracts of two plants have moderate antimicrobial activity against selected strains and need further studies to study the possibility of using the plant extracts as some strains of anti-bacterial and fungi-fighting drugs.

**Keywords:** Lipoidial extract, antimicrobial, *F. viridis* and *T. ehrenbergii*

**INTRODUCTION**:

Medicinal plants have been identified and used throughout human history. Plants make many chemical compounds that are for biological functions, including defense against insects, fungi and herbivorous mammals. The use of plants as medicine predates written human history. Many of the herbs and spices used by humans to season food also yield useful medicinal compounds. The use of herbs and spices in cuisine developed in part as a response to the threat of food-borne pathogens**1**. *Forsskaolea*is a small genus in the Urticaceae family, represented by 6 species, distributed inover the world**2,3**.*Trichodesma ehernbergii*is a small genus in Boraginaceae family where, is an annual erect herb, 15-45 cm high, densely short hairy **4**.

The survey on the previous studies on the *F. viridis* and *T.ehrenbergii*plants showed no chemical and biological studies performed on it so, we aimed to investigate the active chemical constituents in addition to their biological activity 5,6,7,8. In this study we concerned to focus our study on the lipoidial extract of the two plant extracts and its antimicrobial activity to obtain about complete chemical and biological profile of two important plant species of two different families from same location Gebel Elba, Haliab, Southeast of Egypt.

**MATERIALS AND METHODS**

**Plant Material**

Aerial parts of *F.viridis*  and *T. ehrenbergii* were collected from their wild habitat in wadikanthesrob, sarmati, Gebel Elba region, southeast corner of Egypt. The plant specimens were identified, authenticated and deposited in the herbarium of Desert Research Center (CAIH).

**Preparation of lipoidial matter**

The air-dried powder of *F. viridis* and *T. ehrenbergii*aerial parts (250 g) were exhaustively extracted separately by petroleum ether: di ethyl ether (1:1) using soxhlet continuous extraction until exhaustion. The solvent was evaporated at 40◦C under reduced pressure to give 24 g and 26 g residue of lipoidial matter **6,9**.

**Preparation of the Unsaponifiable Matter**

3 g of lipoidial matter of two plants were saponified by refluxing with 50 ml of 10% alcoholic potassium hydroxide solution for 6 hr followed by evaporating the alcohol, diluting with distilled water and extracting with ether exhaustively. The collected ethereal extract was washed with distilled water till being free from alkalinity, dried over anhydrous sodium sulphate, and then evaporated to give 1.5 g unsaponifiable matter (USM) residue **6,9**.

**Preparation of saponifiable matter (fatty acids)**

The remaining saponifiable alkaline aqueous layer left after extraction of unsaponifiable matter with ether was acidified with hydrochloric acid (2 N) to liberate the free fatty acids, followed by extraction several times with ether. The ether extracts were washed three times with distilled water until neutralization, dried over anhydrous sodium sulfate. The residual were kept for studying the fatty acid contents **10**.

**Preparation of fatty acid methyl esters**

The preparation of methyl esters of free fatty acids (0.6 g) was carried out by refluxing with 100 ml of absolute methanol and 5 ml sulphuric acid for 2 hr, The major part of alcohol was distilled off and the residue was solubilized with distilled water and then extracted several times with ether. The combined ether extracts were washed with distilled water, till the wash was free from any acidity then drying the ethereal layer concentrated and the residue was dried over anhydrous sodium sulfate followed by evaporation of ether to give residue of the fatty acid methyl esters (FAME) and kept for GC analysis **10**.

**GC analysis of the lipoidial matter conditions:**

The saponifiable and unsaponifiable matter of aerial parts of the plant was carried by method described in**11**. Using Hewlett Packard hp 6890 Series Agilent Gas Chromatograph. Authentic samples according to the apparatus library from C10 to C32. With Capillary column hp-5 (5% diphenyl-95% dimethyl polysiloxane, 150 mm x 4mm), 2 ml/min of chart speed 80 / 280 ºC for initial/Final time for 25 minutes.

**Antimicrobial Activity**

Antimicrobial activity was determined by diffusion agar technique in Regional Center for Mycology and Biotechnology Al-Azhar university, Cairo, Egypt (RCMB) according to CLSI **11,12**. Strains were obtained from the bacteria stock present at RCMB. Petri plates containing 20 ml of Nutrient (for bacteria) or Malt extract (for fungi), Agar medium were seeded with 1-3 day cultures of microbial inoculums (standardized inoculums 1-2 X 107cfu/ml 0.5Mcfarland standard). Wells (6 mm in diameter) were cut off into agar and 100μl of plant extracts were tested in a concentration of 5mg/ml and incubated at 37°C for 24 h (bacterial strains) and at 25°C for 7 days (fungal strains). The assessment of antimicrobial activity was based on measurement of the diameter of the inhibition zone formed around the well. Positive control used for fungi was ketoconazole with MIC 100 mg/ml, while positive control used for bacteria strains was gentamycin with MIC 4 mg/ml.

**RESULTS AND DISSCUSSIONS**

**Investigation of Saponifiable Matter Using GC**

The data recorded in table (1) revealed that, there were 22 hydrocarbons beside 6 sterols and 20 hydrocarbons beside five sterols compoundswere detected where,the highest concentration of the sterols was *β*-amyrin followed by *β*-sitosterol and stigmasterol followed by cholesterol of*F. viridis* and *T. ehernbergii*ethereal extractrespectively,the high concentration of the phytosterols in the lipoidial extracts may be due to their lipid metabolism inside the cell membrane of the plant through converting the lipoidial matters to compounds which have chemical structures of sterols, where they acts a vital role in cell membrane structure and utilities as a precursor to fat-soluble vitamins (A, D, E, K) and steroid hormones **13.** The highest percent of *β*-amyrin and stigmasterol reflected to the medicinal importance of the two plantsrespectively, where studies showed activity of*β*-amyrin and stigmasterol as anti-inflammatory, antimicrobial, human bladder cancer, breastand skin epidermoid anticancer **14** and as antiulcer **15**. prospective antihyperglycemic and hypolipidemic effects of *β*-amyrin and stigmasterol suggested that, it could be a probable compound for drug development effective in diabetes and atherosclerosis **16** While, The relatively high percent of *β*-sitosterol and cholesterol in the lipoidial extract of *F. viridis* plays a vital role in pharmaceutical drugs used for enhancing sexual activity, treating benign prostatic hyperplasia, relieving symptoms of menopause, lowering of high bad blood cholesterol level by reducing the amount of cholesterol absorbed by the body. Also, used for boosting the immune system and for preventing colon cancer, synthesis of cortisone as well as for gallstones **17,18 .**

**Investigation of Saponifiable Matter Using GC:**

The fatty acids methyl esters results represented in table (2) indicated that, there were 14 fatty acid methyl ester, 10 saturated beside 4 unsaturated and 16 fatty acid methyl ester, 13 saturated beside 4 unsaturated ofboth plants*F. viridis* and *T. ehernbergii*saponifiable extractsrespectively, the investigation of saponifiable contents showed that the palmitic and oleic acid were major concentrations of saturated and unsaturated fatty acids methyl ethers of*F.viridis* respectively,and the tridecylic and γ-Linoleic revealed the major percent for saturated and unsaturated fatty acid of *T. ehrenbergii* respectively.The essential fatty acids have great value where, they give the body healthy value as contrary to what was previously believed where, converted in the body by enzymes into long chain polyunsaturated fatty acids (LCPUFAs). Where *γ*-linolenic acid  (*ω*-6) which needed for the maintenance of hormonal balance and healthy skin structure. The existence  of essential unsaturated fatty acids in both plants; oleic acid (*ω*-9), linoelaidicacid (*ω*-6 trans fatty acid), *α*- linolenic (*ω*-3) and *γ*- linolenic acid (*ω*-6) refers to the importance of all *ω*-3, ω-6 and *ω*-9 fatty acids as dietary fats where, each one of them has a number of health benefits for your body by right balance between them, where the imbalance may contribute to a number of chronic diseases. Oleic acid (*ω*-9) fats are non-essential fats, since they can be produced by the body. The high relatively percent of oleic acid (ω-9) can qualify the plant in utilization for reducing plasma triglycerides by 19% and very-low-density-lipoprotein cholesterol by 22% in patients with diabetes **19**, improved insulin sensitivity and decreased inflammation **20**. The relatively high percent of *α*- linolenic (*ω*-3) and *γ*- linolenic acid (*ω*-6) reflected to the importance of the plant for reducing triglycerides, blood pressure and the formation of arterial plaques, decreasing liver fat, promoting bone health, preventing asthma and reducing a number of symptoms of rheumatoid arthritis **21**.On the other hand,  the two plants contains high percent of saturated  fatty  acid, palmitic acid which has a critical role in cellular membrane functionality by affecting their flexibility and permeability and it forms reversible links to cell membrane proteins, thus being involved in regulating the traffic of molecules in and out of cells and inter cells communication**22**. Palmitic acid is then the precursor of palmitoyl ethanol amide (PEA) compound which produced by our body with neuroprotective, anti-inflammatory and analgesic activities**23.**

**Table 1: Hydrocarbons and Sterols Determined of *F. viridis* and *T. ehrenbergii* using GC**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No. C atom** | **RT** | **Name** | **M. F.** | ***F. viridis*** | ***T. ehrenbergii*** |
| **Area (%)** | **Area (%)** |
| **Hydrocarbons** | | | | | |
| C13 | 9.791 | n-Tridecane | C13H28 | 0.421 | 0.596 |
| C14 | 10.755 | n-Tetradecane | C14H30 | 0.793 | 2.357 |
| C15 | 12.060 | n-Pentadecane | C15H32 | 1.665 | 12.220 |
| C15:1 | 12.879 | n- Pentadecene-1 | C15H30 | 1.048 | 6.439 |
| C16 | 13.457 | n-Hexadecane | C16H34 | 7.370 | 14.974 |
| C17 | 13.884 | n-Heptadecane | C17H36 | 4.146 | 5.519 |
| C17:1 | 14.386 | n-Heptadecene-1 | C17H36 | 4.513 | 14.920 |
| C18 | 14.869 | n-Octadecane | C17H34 | 15.309 | 3.351 |
| C18:1 | 15.767 | n- Octadecene-1 | C18H38 | 4.580 | 3.003 |
| C19 | 16.129 | n-Nonadecane | C19H40 | 12.599 | 0.596 |
| C19:1 | 16.524 | n- nonadecene-1 | C19H38 | -- | 0.829 |
| C20 | 17.015 | n-Eicosane | C20H42 | 2.811 | 0.409 |
| C21 | 17.832 | n- Heneicosane | C21H44 | 2.959 | -- |
| C22 | 17.975 | n-Docosane | C22H46 | 0.956 | 0.506 |
| C23 | 18.953 | n-Tricosane | C23H48 | 0.707 | 0.456 |
| C24 | 21.090 | n-Tetracosane | C24H50 | 0.541 | 0.344 |
| C24-1 | 21.738 | n-Tetracosene-1 | C24H48 | 0.562 | -- |
| C25 | 22.086 | n-Pentacosane | C25H52 | 0.627 | 0.563 |
| C26 | 23.068 | n-Hexacosane | C26H54 | 1.741 | -- |
| C27 | 23.616 | n-Heptacosane | C27H56 | 1.354 | 0.563 |
| C28 | 24.913 | n- Octacosane | C28H58 | 4.642 | 0.174 |
| C28:1 | 25.464 | n- Octacosene-1 | C28H56 | -- | 0.303 |
| C29 | 26.729 | n- Nonacosane | C29H60 | 2.275 | 1.004 |
| C30 | 29.063 | n-Triacontane | C30H62 | 4.714 | 1.359 |
| **Sterols** | | | |  |  |
| C:27 | 30.239 | Cholesterol | C27H46O | 2. 750 | 6.450 |
| C:28 | 32.055 | Campesterol | C28H48O | 3.211 | 2.797 |
| C:29 | 34.228 | Stigmasterol | C29H48O | 2.612 | 13.575 |
| C:29 | 35.138 | β -Sitosterol | C29H50O | 3.956 | 4.890 |
| C:30 | 37.168 | *γ*- Amyrin | C30H50O | 3.652 | 1.894 |
| C:30 | 38.734 | *β*- Amyrin | C30H50O | 4.978 | ---- |

RT= Retention time M.F.= Molecular formula**Table 2: Saponifible Matter (Fatty acids) of *F. viridis* and *T. ehrenbergii* using GC**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No. of C atom** | **Systemic name** | **Trivial name** | **RT** | **Area (%)** | |
| ***F.viridis*** | ***T. ehrenbergii*** |
| C:10 | Decanoic acid | Capric acid | 8.562 | 4.403 | --- |
| C:11 | Undecanoic acid | Undecylic | 8.673 | 7.680 | 3.723 |
| C:12 | Dodecanoic acid | Lauric | 9.398 | 2.351 | 15.102 |
| C:13 | Tridecanoic acid | Tridecylic | 11.018 | **---** | 22.140 |
| C:14 | Tetradecanoic acid | Myristic | 12.657 | 2.400 | 6.084 |
| C:15 | Pentadecanoic acid | Pentadecylic | 14.094 | ---- | 1.062 |
| C:16 | Hexadecanoic acid | Palmitic | 15.605 | 29.482 | 16.225 |
| C:17 | Heptadecanoic acid | Margaric | 17.522 | 2.060 | 2.540 |
| C18 | Octadecanoic acid | Stearic | 18.685 | 7.190 | 4.639 |
| C18:1 | Cis-9-Octadecanoic acid | Oleic | 19.258 | 21.073 | 2.589 |
| C18:2 | Cis, cis-9, 12-  Octadecanoic acid | *α*-Linoleic | 20.440 | 5.211 | 3.160 |
| C18:2 | Trans, trans -9, 12-  Octadecanoic acid | Linoelaidic | 21.697 | 6.350 | --- |
| C18:3 | All Cis-9, 12, 15-Octadecatrienoic acid | γ-Linoleic | 22.523 | 6.701 | 3.177 |
| C19 | Cis-10-Nonadecylic acid | Nonadecanoic |  | 4.146 | ---- |
| C20 | Eicosanoic acid | Arachidic | 23.346 | 0.512 | 0.842 |
| C22 | Docosanoic | Behenic | 24.316 | ---- | 4.163 |
| C24 | Tetracoanoic acid | Lignocoric | 26.985 | 0.355 | 4.885 |
| C26 | Hexacosanoic acid | Ceric acid | 28.293 | ---- | 0.655 |
| C27 | Heptacosanoic acid | Carboceric | 29.605 | --- | 8.485 |

**Antimicrobial activity**

The antimicrobial activity of the lipoidial extract of *F.viridis* and *T. ehrenbergii*showed potent antibacterial activity against gram (+) ve (*Methicillin-Resistant Staphylococcus aureus*)with activity73%and 86% respectively, moderate activity against *Streptococcus mutants* and *Micrococcus* sp.) with activity 57.3, 57.3 and 59, 50%, respectively as compared with gentamicin as reference used drug. Also, it showed weak activity against all tested gram (-) ve bacteria and no activity against the tested filamentous fungi while, it showed moderate activity against yeasts fungi (*Cryptococcus neoformans*) with activity 64and 56 % respectively, as compared to ketoconazole as used reference drug. The moderate activity of the lipoidial extract may be due to its phytosterols contents which characterized with antimicrobial activity and fat-soluble vitamins which have ability to inhibit the activity of micro-organisms and acts in cell membrane and DNA of microbial strains [24]. From the previous obtained data the *F.viridis* show little improvement more than *T. ehrenbergii* as antimicrobial activity this is may be due to little changes in steroidal contents between them where the presence of *β*- Amyrin in *F.viridis* and absence in *T*. *ehrenbergii*, Also the high percent of stigmasterol in *T. ehernbergii*may be act more activity against *Penicilliumexpansum*more than *F.viridis*. so we can say as general the two plants extract have moderate activity against some of tested strains as showen in table 3.

**Table 3: Antimicrobial Activity of lipoidial extract of *F. viridis*and  *T.ehrenbergii*.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Tested Organism** | **Inhibition Zone Diameter (mm)** | | |
| **Gram (+ve) Bacteria** | **Control** | ***F.viridis*** | ***T. ehrenbergii*** |
| **Gentamycin (MIC) 4 mg/ml (reference- drug)** | | | |
| *Micrococcus* sp. (RCMB 028)s | 22 | 13 | 11 |
| *Streptococcus mutants* (RCMB 017) (ATCC 25175) | 21 | 12 | 12 |
| Methicillin-Resistant *Staphylococcus aureus* | 15 | 11 | 13 |
| **Gram (-ve) Bacteria** | | | |
| *Salmonella typhrimurium*(RCMB 006) (ATCC 14028) | 17 | 10 | 10 |
| *Escherichia coli* (RCMB 010052) (ATCC 25955) | 30 | 13 | 11 |
| *Klebsiella pneumonia* (RCMB 003) (ATCC 13883) | 21 | 12 | 9 |
| **Filamentous Fungi** | | | |
| **Ketoconazole(MIC) 100 mg/ml (reference- drug)** | | | |
| *Aspergillusfumigatus* (RCMB 002008) | 17 | 2 | 7 |
| *Penicilliumexpansum*(RCMB 001001) | 17 | NA | 8 |
| **Yeasts** | | | |
| *Candida albicans*(RCMB 005003) (ATCC 10231) | 20 | 1 | NA |
| *Cryptococcus neoformans*(RCMB 0049001) | 25 | 16 | 14 |

MIC = Minimum inhibitory concentration,NA= No activity, The sample was tested at 5 mg/ml concentration

**CONCLUSION:**

The investigation of lipoidial contents of *F. viridis*and *T.ehrenbergii*using (GC) revealed that, of *F. viridis* contain 22 hydrocarbons, 6 sterols and 14 fatty acid methyl ester while*T.ehrenbergii* contain 21 hydrocarbons, 5 sterols and 16 fatty acid methyl esters. The *in vitro*antimicrobial studies showed that moderate antimicrobial activity of two plants against most ~~gram~~ (-ve and + ve) bacteria while, weak and no activity of fungal strains ~~while, the~~ *F.viridis* showed little improvement than *T.ehrenbergii*.

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**CONFLICT OF INTEREST** No conflict of interest associated with this work.

**AUTHOR'S CONTRIBUTION** All authors have worked equally for this work.

**REFRENCES**:

1. Tapsell LC, Hemphill I,Cobiac L. In "Health benefits of herbs and spices: the past, the present, the future". Med J Aust 2006; 185.
2. Kitikar KR, Basu BD. An ICS Indian Medical Plants,Bishen Singh &Mahendrapal Singh, New Delhi, Secondedition, III 1975; 2291: 2298.
3. AlfarhanAH, Al-Turki TA, Basahy AY. Flora of Jizan Region. Vol. 1, King Abdulaziz City for Science and Technology (KACST) 2005.
4. Alfarhan AH, Al-Turky TA,Basahy AY. In "Flora of JizanRegion". Final Report Supported by King AbdulazizCity for Science and Technology2005; 1: 545.
5. Ahmed FA, El-Mesallamy AMD, and El-Bassossy TAI. Phytochemical analysis and biological evaluation of Forsskaolea viridis aerial parts. ActaPoloniaePharmaceutica - Drug Research 2019; 76(5): 815-823.
6. Ahmed FA, El-Bassossy TAI. Active constituents and biological activity of methanolic extract of Forsskaolea viridis aerial parts. AJPCR2020; 13 (3): 40-46.
7. Ahmed FA., El-Mesallamy AMD, El-Bassossy TAI.. Hepatoprotective and antitumor activity of phenolic content of *Trichodesma ehrenbergii Schewienf. ex Boiss aerial parts. Wjpmr* 2016; 2(4): 119-125.
8. El-Mesllamy AMD, Ahmed FA,ELHawe MH and Ibrahim TA. Chemical investigation and evaluation of antimicrobial activity of  *Trichodesma ehrenbergii* Shweienf. ex Boiss. growing at Gebel Elba region. *IAJPS* 2015; 2(5): 947- 953.
9. Johnson AR, Davenport JB. Biochemistry and Methodology of Lipids. New York: John Wiley and Sons, Inc., 1971; 31-33.
10. El-Said FM, Amer MM. Oils, Fats, Waxes and Surfactants. Cairo, Anglo-Egyptian Bookshop 1965; 130-131.
11. Vogel AJ. A Text Book of Practical Organic Chemistry, 3rd ed. English Language Book Society and Longman Group Ltd., London 1975; 969-971.
12. CLSI, Performance Standards for Antimicrobial Disk Susceptibility Tests, Approved Standard, 7th ed., CLSI document M02-A11. Clinical and Laboratory Standards Institute, 950 West Valley Road, Suite 2500, Wayne, Pennsylvania 19087, USA, 2012.
13. Kametani T, Furuyama H. Synthesis of vitamin D3 and related compounds. Med Res Rev 1987; 7 (2): 147-71.
14. Wei H, Xinchi Y, Paula V. Sterol synthesis in diverse bacteria. Frontiers in Microbiology 2016; 7: 990-109.
15. Csapi B, Zsuzsanna H, Zupkó I, Berényi A, Forgo P, Szabó P,Hohmann J. Bioactivity-guided isolation of antiproliferative compounds from Centaureaarenaria. Phytotherapia Research 2010; 24: 1664-69.
16. Acevedo RH, Terrazas T, González ME., Guzmán Y, Hernández M. Anti-ulcer activity of Cyrtocarpaprocera analogous to that of Amphipterygiumadstringens, both assayed on the experimental gastric injury in rats. Journal of Ethnopharmacology 2011; 134: 67-73.
17. Santos FA., Frota TJ, Arruda RB, Melo ST, daSilva CA, Britoand CG, Chaves HM. and Rao SV. Antihyperglycemic and hypolipidemic effects of α, β-amyrin, a triterpenoid mixture from Protiumheptaphyllum in mice. Lipids in Health and Disease 2012; 11: 98-106.
18. Soy Infocenter. In "History of Soybean and Soyfoods in Mexico and Central America". Extensively Annotated Bibliography and Sourcebook 2009; 1877.
19. Rakel DMD. In “ Integrative Medicine”, (4th ed.). Elsevier, 2018; 1096-1123.
20. Garg A. High-monounsaturated-fat diets for patients with diabetes mellitus: a meta-analysis. Am JClinNutr 1998; 67(3): 577S-582S.
21. Finucane OM, Lyons CL, Murphy AM, and Reynolds CM. Monounsaturated fatty acid-enriched high-fat diets impede adipose NLRP3 inflammasome-mediated IL-1β secretion and insulin resistance despite obesity. Diabetes 2015; 64(6): 2116-28.
22. Simopoulos AP. The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed Pharmacother 2002; 56(8): 365-379.
23. Hesselink JM,Hekker TA. Therapeutic utility of palmitoylethanolamide in the treatment of neuropathic pain associated with various pathological conditions: a case series. J. Pain Res 2012; 5: 437–442.
24. Hesselink JM, Hekker TA. Therapeutic utility of palmitoylethanolamide in the treatment of neuropathic pain associated with various pathological conditions: a case series. J. Pain Res 2012; 5: 437–442.