Springer

Phytosterols in *Salvia* Seeds: Content and Composition and Correlation with Environmental Parameters

Iranian Journal of Science and Technology, Transactions A: Science

October 2019, Volume 43, Issue 5, pp 2129–2140 | Cite as

Research Paper

First Online: 20 June 2019

Part of the following topical collections:

- Biology

Abstract

The purpose of this study was to determine the oil yield, content and composition of phytosterols in the seeds of six wild-grown *Salvia* species from Iran, including *S. ceratophylla* L. (3 populations), *S. nemorosa* L. (6 populations), *S. reuteriana* Boiss. (6 populations), *S. spinosa* L. (5 populations), *S. verticillata* L. (3 populations) and *S. virgata* Jacq. (3 populations). We also evaluated the effects of some environmental parameters on their chemical variations and characterized the investigated populations based on the sterol chemo-types. The results showed that seed oil yields ranged between 16.51 and 42.48%, with an average of 28.93%. The total sterol contents in *Salvia* seeds varied significantly and ranged from 145.13 to 386.75 mg $100\,g_{oil}^{-1}$. β-Sitosterol, campesterol and stigmasterol were the main sterol constituents in all of the *Salvia* seed oils, with the average values of 60.13%, 27.32% and 12.55% of the total sterols, respectively. Among all the tested species, the highest level of total phytosterol and β-sitosterol contents was obtained for the seeds of *S. ceratophylla*. Moreover, the percentages of these compounds varied depending on climatic factors such as precipitation, humidity and temperature. The cluster analysis based on the

β-sitosterol/campesterol ratio contents of the seeds categorized different populations of *Salvia* species into three distinct campesterol, β-sitosterol and β-sitosterol-rich chemo-types.

Keywords

Campesterol Environmental parameters Phytosterols *Salvia* L. Seed oil β-Sitosterol

Notes

Acknowledgements

The authors wish to express their gratitude to the Research Councils of Shahed University for financial support during the course of this research. The authors also thank the Central Research Laboratory of Shahed University for GC analyses.

References

Abbaszadeh S, Radjabian T, Taghizadeh M (2013) Identification and determination of phytosterols in oilseeds of some populations from two Iranian *Echium* species. Iran J Med Aromat Plant 28(4):741–755
Google Scholar (http://scholar.google.com/scholar_lookup?title=Identification%20and%20determination%20of%20phytosterols%20in%20oilseeds%20of%20some%20populations%20from%20two%20Iranian%20Echium%20species&author=S.%20Abbaszadeh&author=T.%20Radjabian&author=M.%20Taghizadeh&journal=Iran%20J%20Med%20Aromat%20Plant&volume=28&issue=4&pages=741-755&publication_year=2013)

Abreu PM, Luis MH (1996) Constituents of *Tephrosia uniflora*. Nat Prod Lett 9(2):81–86
CrossRef (https://doi.org/10.1080/10575639608044930)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Constituents%20of%20Tephrosia%20uniflora&author=PM.%20Abreu&author=MH.%20Luis&journal=Nat%20Prod%20Lett&volume=9&issue=2&pages=81-86&publication_year=1996)

Al-Qudah MA, Al-Jaber HI, Zarga MHA, Orabi STA (2014) Flavonoid and phenolic compounds from *Salvia palaestina* L. growing wild in Jordan and their antioxidant activities. Phytochemistry 99:115–120
CrossRef (https://doi.org/10.1016/j.phytochem.2014.01.001)
Google Scholar (http://scholar.google.com

/scholar_lookup?title=Flavonoid%20and%20phenolic%20compounds%20from%20Salvia%20palaestina%20L.%20growing%20wild%20in%20Jordan%20and%20their%20antioxidant%20activities&author=MA.%20Al-Qudah&author=HI.%20Al-Jaber&author=MHA.%20Zarga&author=STA.%20Orabi&journal=Phytochemistry&volume=99&pages=115-120&publication_year=2014)

Amar S, Becker HC, Möllers C (2008) Genetic variation and genotype × environment interactions of phytosterol content in three doubled haploid populations of winter rapeseed. Crop Sci 48(3):1000–1006
CrossRef (https://doi.org/10.2135/cropsci2007.10.0578)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Genetic%20variation%20and%20genotype%E2%80%89%C3%97%E2%80%89environment%20interactions%20of%20phytosterol%20content%20in%20three%20doubled%20haploid%20populations%20of%20winter%20rapeseed&author=S.%20Amar&author=HC.%20Becker&author=C.%20M%C3%B6llers&journal=Crop%20Sci&volume=48&issue=3&pages=1000-1006&publication_year=2008)

Beleggia R, Platani C, Nigro F, De Vita P, Cattivelli L, Papa R (2013) Effect of genotype, environment and genotype-by-environment interaction on metabolite profiling in durum wheat (*Triticum durum* Desf.) grain. J Cereal Sci 57(2):183–192
CrossRef (https://doi.org/10.1016/j.jcs.2012.09.004)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20genotype%2C%20environment%20and%20genotype-by-environment%20interaction%20on%20metabolite%20profiling%20in%20durum%20wheat%20%28Triticum%20durum%20Desf.%29%20grain&author=R.%20Beleggia&author=C.%20Platani&author=F.%20Nigro&author=P.%20Vita&author=L.%20Cattivelli&author=R.%20Papa&journal=J%20Cereal%20Sci&volume=57&issue=2&pages=183-192&publication_year=2013)

Brufau G, Canela MA, Rafecas M (2008) Phytosterols: physiologic and metabolic aspects related to cholesterol-lowering properties. Nutr Res 28(4):217–225
CrossRef (https://doi.org/10.1016/j.nutres.2008.02.003)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Phytosterols%3A%20physiologic%20and%20metabolic%20aspects%20related%20to%20cholesterol-lowering%20properties&author=G.%20Brufau&author=MA.%20Canela&author=M.%20Rafecas&journal=Nutr%20Res&volume=28&issue=4&pages=217-225&publication_year=2008)

Chawla R, Sivakumar S, Goel N (2016) Phytosterol and its esters as novel food ingredients: a review. Asian J Dairy Food Res 35(3):217–226
CrossRef (https://doi.org/10.18805/ajdfr.v3i1.3576)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Phytosterol%20and%20its%20esters%20as%20novel%20food%20ingredients%3A%20a%20review&author=R.%20Chawla&author=S.%20Sivakumar&author=N.%20Goel&journal=Asian%20J%20Dairy%20Food%20Res&volume=35&issue=3&pages=217-226&publication_year=2016)

Cheikh-Rouhou S, Besbes S, Lognay G, Blecker C, Deroanne C, Attia H (2008) Sterol composition of black cumin (*Nigella sativa* L.) and Aleppo pine (*Pinus halepensis* Mill.) seed oils. J Food Compos Anal 21(2):162–168
CrossRef (https://doi.org/10.1016/j.jfca.2007.09.001)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Sterol%20composition%20of%20black%20cumin%20%28Nigella%20sativa%20L.%29%20and%20Aleppo%20pine%20%28Pinus%20halepensis%20Mill.%29%20seed%20oils&author=S.%20Cheikh-Rouhou&author=S.%20Besbes&author=G.%20Lognay&author=C.%20Blecker&author=C.%20Deroanne&author=H.%20Attia&journal=J%20Food%20Compos%20Anal&

volume=21&issue=2&pages=162-168&publication_year=2008)

Ciftci ON, Przybylski R, Rudzińska M (2012) Lipid components of flax, perilla, and chia seeds. Eur J Lipid Sci Technol 114(7):794–800
CrossRef (https://doi.org/10.1002/ejlt.201100207)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Lipid%20components%20of%20flax%2C%20perilla%2C%20and%20chia%20seeds&author=ON.%20Ciftci&author=R.%20Przybylski&author=M.%20Rudzi%C5%84ska&journal=Eur%20J%20Lipid%20Sci%20Technol&volume=114&issue=7&pages=794-800&publication_year=2012)

Daoued K, Chouaibi M, Gaout N, Haj OB, Hamdi S (2016) Chemical composition and antioxidant activities of cold pressed lentisc (*Pistacia lentiscus* L.) seed oil. Riv Ital Sostanze Gr 93(1):31–38
Google Scholar (http://scholar.google.com/scholar_lookup?title=Chemical%20composition%20and%20antioxidant%20activities%20of%20cold%20pressed%20lentisc%20%28Pistacia%20lentiscus%20L.%29%20seed%20oil&author=K.%20Daoued&author=M.%20Chouaibi&author=N.%20Gaout&author=OB.%20Haj&author=S.%20Hamdi&journal=Riv%20Ital%20Sostanze%20Gr&volume=93&issue=1&pages=31-38&publication_year=2016)

Fernández-Cuesta A, Nabloussi A, Fernández-Martínez JM, Velasco L (2012) Tocopherols and phytosterols in sunflower seeds for the human food market. Grasas Aceites 63(3):321–327
CrossRef (https://doi.org/10.3989/gya.010112)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Tocopherols%20and%20phytosterols%20%0Ain%20sunflower%20seeds%20for%20the%20human%20food%20market&author=A.%20Fern%C3%Alndez-Cuesta&author=A.%20Nabloussi&author=JM.%20Fern%C3%Alndez-Mart%C3%ADnez&author=L.%20Velasco&journal=Grasas%20Aceites&volume=63&issue=3&pages=321-327&publication_year=2012)

Górnaś P, Rudzińska M, Segliņa D (2014) Lipophilic composition of eleven apple seed oils: a promising source of unconventional oil from industry by-products. Ind Crop Prod 60:86–91
CrossRef (https://doi.org/10.1016/j.indcrop.2014.06.003)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Lipophilic%20composition%20of%20eleven%20apple%20seed%20oils%3A%20a%20promising%20source%20of%20unconventional%20oil%20from%20industry%20by-products&author=P.%20G%C3%B3rna%C5%9B&author=M.%20Rudzi%C5%84ska&author=D.%20Segli%C5%86a&journal=Ind%20Crop%20Prod&volume=60&pages=86-91&publication_year=2014)

Górnaś P, Rudzińska M, Raczyk M, Mišina I, Soliven A, Segliņa D (2016a) Composition of bioactive compounds in kernel oils recovered from sour cherry (*Prunus cerasus* L.) by-products: impact of the cultivar on potential applications. Ind Crop Prod 82:44–50
CrossRef (https://doi.org/10.1016/j.indcrop.2015.12.010)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Composition%20of%20bioactive%20compounds%20in%20kernel%20oils%20recovered%20from%20sour%20cherry%20%28Prunus%20cerasus%20L.%29%20by-products%3A%20impact%20of%20the%20cultivar%20on%20potential%20applications&author=P.%20G%C3%B3rna%C5%9B&author=M.%20Rudzi%C5%84ska&author=M.%20Raczyk&author=I.%20Mi%C5%Alina&author=A.%20Soliven&author=D.%20Segli%C5%86a&journal=Ind%20Crop%20Prod&volume=82&pages=44-50&publication_year=2016)

Górnaś P, Rudzińska M, Raczyk M, Mišina I, Soliven A, Lācis G, Segliņa D (2016b) Impact of species and variety on concentrations of minor lipophilic bioactive compounds in oils recovered from plum kernels. J Agric Food Chem 64(4):898–905

CrossRef (https://doi.org/10.1021/acs.jafc.5b05330)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Impact%20of%20species%20and%20variety%20on%20concentrations%20of%20minor%20lipophilic%20bioactive%20compounds%20in%20oils%20recovered%20from%20plum%20kernels&author=P.%20G%C3%B3rna%C5%9B&author=M.%20Rudzi%C5%84ska&author=M.%20Raczyk&author=I.%20Mi%C5%A1ina&author=A.%20Soliven&author=G.%20L%C4%81cis&author=D.%20Segli%C5%86a&journal=J%20Agric%20Food%20Chem&volume=64&issue=4&pages=898-905&publication_year=2016)

Górnaś P, Rudzińska M, Raczyk M, Mišina I, Segliņa D (2016c) Impact of cultivar on profile and concentration of lipophilic bioactive compounds in kernel oils recovered from sweet cherry (*Prunus avium* L.) by-products. Plant Food Hum Nutr 71(2):158–164
CrossRef (https://doi.org/10.1007/s11130-016-0538-5)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Impact%20of%20cultivar%20on%20profile%20and%20concentration%20of%20lipophilic%20bioactive%20compounds%20in%20kernel%20oils%20recovered%20from%20sweet%20cherry%20%28Prunus%20avium%20L.%29%20by-products&author=P.%20G%C3%B3rna%C5%9B&author=M.%20Rudzi%C5%84ska&author=M.%20Raczyk&author=I.%20Mi%C5%A1ina&author=D.%20Segli%C5%86a&journal=Plant%20Food%20Hum%20Nutr&volume=71&issue=2&pages=158-164&publication_year=2016)

Gotor AA, Berger M, Labalette F, Centis S, Dayde J, Calmon A (2015) Comparative analysis of fatty acids, tocopherols and phytosterols content in sunflower cultivars (*Helianthus annuus*) from a three-year multi-local study. Phyton (Buenos Aire). 84:14–25
Google Scholar (http://scholar.google.com/scholar_lookup?title=Comparative%20analysis%20of%20fatty%20acids%2C%20tocopherols%20and%20phytosterols%20content%20in%20sunflower%20cultivars%20%28Helianthus%20annuus%29%20from%20a%20three-year%20multi-local%20study&author=AA.%20Gotor&author=M.%20Berger&author=F.%20Labalette&author=S.%20Centis&author=J.%20Dayde&author=A.%20Calmon&journal=Phyton%20%28Buenos%20Aire%29.&volume=84&pages=14-25&publication_year=2015)

Guye MG (1988) Sterol composition in relation to chill-sensitivity in *Phaseolus* spp. J Exp Bot 39(8):1091–1096
CrossRef (https://doi.org/10.1093/jxb/39.8.1091)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Sterol%20composition%20in%20relation%20to%20chill-sensitivity%20in%20Phaseolus%20spp&author=MG.%20Guye&journal=J%20Exp%20Bot&volume=39&issue=8&pages=1091-1096&publication_year=1988)

Hammer Ø, Harper D, Ryan P (2001) PAST-palaeontological statistics, ver. 3.15. Palaeontol Electron 4(9)
Google Scholar (https://scholar.google.com/scholar?q=Hammer%20%C3%98%2C%20Harper%20D%2C%20Ryan%20P%20%282001%29%20PAST-palaeontological%20statistics%2C%20ver.%203.15.%20Palaeontol%20Electron%204%289%29)

Harrabi S, St-Amand A, Sakouhi F, Sebei K, Kallel H, Mayer PM, Boukhchina S (2008) Phytostanols and phytosterols distributions in corn kernel. Food Chem 111(1):115–120
CrossRef (https://doi.org/10.1016/j.foodchem.2008.03.044)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Phytostanols%20and%20phytosterols%20distributions%20in%20corn%20kernel&author=S.%20Harrabi&author=A.%20St-Amand&author=F.%20Sakouhi&author=K.%20Sebei&author=H.%20Kallel&author=PM.%20Mayer&author=S.%20Boukhchina&journal=Food%20Chem&volume=111&issue=1&pages=115-120&publication_year=2008)

Jiang Y, Wang T (2005) Phytosterols in cereal by-products. J Am Oil Chem Soc 82(6):439–444
CrossRef (https://doi.org/10.1007/s11746-005-1090-5)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Phytosterols%20in%20cereal%20by-products&author=Y.%20Jiang&author=T.%20Wang&journal=J%20Am%20Oil%20Chem%20Soc&volume=82&issue=6&pages=439-444&publication_year=2005)

Jun-Hua H, Yue-Xin Y, Mei-Yuan F (2008) Contents of phytosterols in vegetables and fruits commonly consumed in China. Biomed Environ Sci 21(6):449–453
CrossRef (https://doi.org/10.1016/S0895-3988(09)60001-5)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Contents%20of%20phytosterols%20in%20vegetables%20and%20fruits%20commonly%20consumed%20in%20China&author=H.%20Jun-Hua&author=Y.%20Yue-Xin&author=F.%20Mei-Yuan&journal=Biomed%20Environ%20Sci&volume=21&issue=6&pages=449-453&publication_year=2008)

Kalo P, Kuuranne T (2001) Analysis of free and esterified sterols in fats and oils by flash chromatography, gas chromatography and electrospray tandem mass spectrometry. J Chromatogr A 935(1):237–248
CrossRef (https://doi.org/10.1016/S0021-9673(01)01315-2)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Analysis%20of%20free%20and%20esterified%20sterols%20in%20fats%20and%20oils%20by%20flash%20chromatography%2C%20gas%20chromatography%20and%20electrospray%20tandem%20mass%20spectrometry&author=P.%20Kalo&author=T.%20Kuuranne&journal=J%20Chromatogr%20A&volume=935&issue=1&pages=237-248&publication_year=2001)

Kozłowska M, Gruczyńska E, Ścibisz I, Rudzińska M (2016) Fatty acids and sterols composition, and antioxidant activity of oils extracted from plant seeds. Food Chem 213:450–456
CrossRef (https://doi.org/10.1016/j.foodchem.2016.06.102)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Fatty%20acids%20and%20sterols%20composition%2C%20and%20antioxidant%20activity%20of%20oils%20extracted%20from%20plant%20seeds&author=M.%20Koz%C5%82owska&author=E.%20Gruczy%C5%84ska&author=I.%20%C5%9Acibisz&author=M.%20Rudzi%C5%84ska&journal=Food%20Chem&volume=213&pages=450-456&publication_year=2016)

Kremer D, Bolarić S, Ballian D, Bogunić F, Stešević D, Karlović K, Kosalec I, Vokurka A, Rodríguez JV, Randić M (2015) Morphological, genetic and phytochemical variation of the endemic *Teucrium arduini* L. (Lamiaceae). Phytochemistry 116:111–119
CrossRef (https://doi.org/10.1016/j.phytochem.2015.04.003)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Morphological%2C%20genetic%20and%20phytochemical%20variation%20of%20the%20endemic%20Teucrium%20arduini%20L.%20%28Lamiaceae%29&author=D.%20Kremer&author=S.%20Bolari%C4%87&author=D.%20Ballian&author=F.%20Boguni%C4%87&author=D.%20Ste%C5%Alevi%C4%87&author=K.%20Karlovi%C4%87&author=I.%20Kosalec&author=A.%20Vokurka&author=JV.%20Rodr%C3%ADguez&author=M.%20Randi%C4%87&journal=Phytochemistry&volume=116&pages=111-119&publication_year=2015)

Merah O, Langlade N, Alignan M, Roche J, Pouilly N, Lippi Y, Vear F, Cerny M, Bouniols A, Mouloungui Z (2012) Genetic analysis of phytosterol content in sunflower seeds. Theor Appl Genet 125(8):1589–1601
CrossRef (https://doi.org/10.1007/s00122-012-1937-0)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Genetic%20analysis%20of%20phytosterol%20content%20in%20sunflower%20seeds&

author=O.%20Merah&author=N.%20Langlade&author=M.%20Alignan&author=J.%20Roche&author=N.%20Pouilly&author=Y.%20Lippi&author=F.%20Vear&author=M.%20Cerny&author=A.%20Bouniols&author=Z.%20Mouloungui&journal=Theor%20Appl%20Genet&volume=125&issue=8&pages=1589-1601&publication_year=2012)

Milovanović M, Banjac N, Vucelić-Radović B (2009) Functional food: rare herbs, seeds and vegetable oils as sources of flavors and phytosterols. J Agric Sci 54(1):81–94
Google Scholar (http://scholar.google.com/scholar_lookup?title=Functional%20food%3A%20rare%20herbs%2C%20seeds%20and%20vegetable%20oils%20as%20sources%20of%20flavors%20and%20phytosterols&author=M.%20Milovanovi%C4%87&author=N.%20Banjac&author=B.%20Vuceli%C4%87-Radovi%C4%87&journal=J%20Agric%20Sci&volume=54&issue=1&pages=81-94&publication_year=2009)

Moazaffarian V (2008) A dictionary of Iranian plant names. Farhange Moaser, Tehran
Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20dictionary%20of%20Iranian%20plant%20names&author=V.%20Moazaffarian&publication_year=2008)

Moazzami Farida SH, Radjabian T, Ranjbar M, Salami SA, Rahmani N, Ghorbani A (2016) Fatty acid patterns of seeds of some *Salvia* species from Iran—a chemotaxonomic approach. Chem Biodivers 13(4):451–458
CrossRef (https://doi.org/10.1002/cbdv.201500147)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Fatty%20acid%20patterns%20of%20seeds%20of%20some%20Salvia%20species%20from%20Iran%E2%80%94a%20chemotaxonomic%20approach&author=SH.%20Moazzami%20Farida&author=T.%20Radjabian&author=M.%20Ranjbar&author=SA.%20Salami&author=N.%20Rahmani&author=A.%20Ghorbani&journal=Chem%20Biodivers&volume=13&issue=4&pages=451-458&publication_year=2016)

Moghaddam FM, Farimani MM, Salahvarzi S, Amin G (2007) Chemical constituents of dichloromethane extract of cultivated *Satureja khuzistanica*. Evid Based Alt 4(1):95–98
CrossRef (https://doi.org/10.1093/ecam/nel065)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Chemical%20constituents%20of%20dichloromethane%20extract%20of%20cultivated%20Satureja%20khuzistanica&author=FM.%20Moghaddam&author=MM.%20Farimani&author=S.%20Salahvarzi&author=G.%20Amin&journal=Evid%20Based%20Alt&volume=4&issue=1&pages=95-98&publication_year=2007)

Moharram FA, Marzouk MS, El-Shenawy SM, Gaara AH, El Kady WM (2012) Polyphenolic profile and biological activity of *Salvia splendens* leaves. J Pharm Pharmacol 64(11):1678–1687
CrossRef (https://doi.org/10.1111/j.2042-7158.2012.01544.x)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Polyphenolic%20profile%20and%20biological%20activity%20of%20Salvia%20splendens%20leaves&author=FA.%20Moharram&author=MS.%20Marzouk&author=SM.%20El-Shenawy&author=AH.%20Gaara&author=WM.%20Kady&journal=J%20Pharm%20Pharmacol&volume=64&issue=11&pages=1678-1687&publication_year=2012)

Moradkhani S, Ayatollahi AM, Ghanadian M, Moin MR, Razavizadeh M, Shahlaei M (2012) Phytochemical analysis and metal-chelation activity of *Achillea tenuifolia* Lam. Iran J Pharm Res 11(1):177
Google Scholar (http://scholar.google.com/scholar_lookup?title=Phytochemical%20analysis%20and%20metal-chelation%20activity%20of%20Achillea%20tenuifolia%20Lam&author=S.%20Moradkhani&author=AM.%20Ayatollahi&author=M.%20Ghanadian&author=MR.%20Moin&author=M.%20Razavizadeh&author=M.%20Shahlaei&journal=Iran%20J%20Pharm%20Res&volume=11&issue=1&pages=177&publication_year=2012)

Mounts T, Abidi S, Rennick K (1996) Effect of genetic modification on the content and composition of bioactive constituents

in soybean oil. J Am Oil Chem Soc 73(5):581–586
CrossRef (https://doi.org/10.1007/BF02518111)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20genetic%20modification%20on%20the%20content%20and%20composition%20of%20bioactive%20constituents%20in%20soybean%20oil&author=T.%20Mounts&author=S.%20Abidi&author=K.%20Rennick&journal=J%20Am%20Oil%20Chem%20Soc&volume=73&issue=5&pages=581-586&publication_year=1996)

Ogbe RJ, Ochalefu DO, Mafulul G, Olaniru OB (2015) A review on dietary phytosterols: their occurrence, metabolism and health benefits. Asian J Plant Sci Res 5:10–21
Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20review%20on%20dietary%20phytosterols%3A%20their%20occurrence%2C%20metabolism%20and%20health%20benefits&author=RJ.%20Ogbe&author=DO.%20Ochalefu&author=G.%20Mafulul&author=OB.%20Olaniru&journal=Asian%20J%20Plant%20Sci%20Res&volume=5&pages=10-21&publication_year=2015)

Phillips KM, Ruggio DM, Toivo JI, Swank MA, Simpkins AH (2002) Free and esterified sterol composition of edible oils and fats. J Food Compos Anal 15(2):123–142
CrossRef (https://doi.org/10.1006/jfca.2001.1044)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Free%20and%20esterified%20sterol%20composition%20of%20edible%20oils%20and%20fats&author=KM.%20Phillips&author=DM.%20Ruggio&author=JI.%20Toivo&author=MA.%20Swank&author=AH.%20Simpkins&journal=J%20Food%20Compos%20Anal&volume=15&issue=2&pages=123-142&publication_year=2002)

Russo A, Formisano C, Rigano D, Senatore F, Delfine S, Cardile V, Rosselli S, Bruno M (2013) Chemical composition and anticancer activity of essential oils of mediterranean sage (*Salvia officinalis* L.) grown in different environmental conditions. Food Chem Toxicol 55:42–47
CrossRef (https://doi.org/10.1016/j.fct.2012.12.036)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Chemical%20composition%20and%20anticancer%20activity%20of%20essential%20oils%20of%20mediterranean%20sage%20%28Salvia%20officinalis%20L.%29%20grown%20in%20different%20environmental%20conditions&author=A.%20Russo&author=C.%20Formisano&author=D.%20Rigano&author=F.%20Senatore&author=S.%20Delfine&author=V.%20Cardile&author=S.%20Rosselli&author=M.%20Bruno&journal=Food%20Chem%20Toxicol&volume=55&pages=42-47&publication_year=2013)

Schaller H (2004) New aspects of sterol biosynthesis in growth and development of higher plants. Plant Physiol Biochem 42(6):465–476
CrossRef (https://doi.org/10.1016/j.plaphy.2004.05.012)
Google Scholar (http://scholar.google.com/scholar_lookup?title=New%20aspects%20of%20sterol%20biosynthesis%20in%20growth%20and%20development%20of%20higher%20plants&author=H.%20Schaller&journal=Plant%20Physiol%20Biochem&volume=42&issue=6&pages=465-476&publication_year=2004)

Shahani S, Monsef-Esfahani HR, Saeidnia S, Saniee P, Siavoshi F, Foroumadi A, Samadi N, Gohari AR (2012) Anti-helicobacter pylori activity of the methanolic extract of *Geum iranicum* and its main compounds. Z Naturforsch C 67(3–4):172–180
CrossRef (https://doi.org/10.1515/znc-2012-3-409)

Google Scholar (http://scholar.google.com/scholar_lookup?title=Anti-helicobacter%20pylori%20activity%20of%20the%20methanolic%20extract%20of%20Geum%20iranicum%20and%20its%20main%20compounds&author=S.%20Shahani&author=HR.%20Monsef-Esfahani&author=S.%20Saeidnia&author=P.%20Saniee&author=F.%20Siavoshi&author=A.%20Foroumadi&author=N.%20Samadi&author=AR.%20Gohari&journal=Z%20Naturforsch%20C&volume=67&issue=3%E2%80%934&pages=172-180&publication_year=2012)

Velasco L, Fernández-Cuesta Á, García-Ruiz JR, Fernández-Martínez JM, Domínguez-Giménez J (2013) Genetic variation and genotype × environment interactions for seed phytosterols in sunflower. Crop Sci 53(4):1589–1593
CrossRef (https://doi.org/10.2135/cropsci2012.10.0593)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Genetic%20variation%20and%20genotype%E2%80%89%C3%97%E2%80%89environment%20interactions%20for%20seed%20phytosterols%20in%20sunflower&author=L.%20Velasco&author=%C3%81.%20Fern%C3%AIndez-Cuesta&author=JR.%20Garc%C3%ADa-Ruiz&author=JM.%20Fern%C3%AIndez-Mart%C3%ADnez&author=J.%20Dom%C3%ADnguez-Gim%C3%A9nez&journal=Crop%20Sci&volume=53&issue=4&pages=1589-1593&publication_year=2013)

Vlahakis C, Hazebroek J (2000) Phytosterol accumulation in canola, sunflower, and soybean oils: effects of genetics, planting location, and temperature. J Am Oil Chem Soc 77(1):49–53
CrossRef (https://doi.org/10.1007/s11746-000-0008-6)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Phytosterol%20accumulation%20in%20canola%2C%20sunflower%2C%20and%20soybean%20oils%3A%20effects%20of%20genetics%2C%20planting%20location%2C%20and%20temperature&author=C.%20Vlahakis&author=J.%20Hazebroek&journal=J%20Am%20Oil%20Chem%20%0ASoc&volume=77&issue=1&pages=49-53&publication_year=2000)

Walker JB, Sytsma KJ (2007) Staminal evolution in the genus *Salvia* (Lamiaceae): molecular phylogenetic evidence for multiple origins of the staminal lever. Ann Bot 100(2):375–391
CrossRef (https://doi.org/10.1093/aob/mcl176)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Staminal%20evolution%20in%20the%20genus%20Salvia%20%28Lamiaceae%29%3A%20molecular%20phylogenetic%20evidence%20for%20multiple%20origins%20of%20the%20staminal%20lever&author=JB.%20Walker&author=KJ.%20Sytsma&journal=Ann%20Bot&volume=100&issue=2&pages=375-391&publication_year=2007)

Weng J-K, Philippe RN, Noel JP (2012) The rise of chemodiversity in plants. Science 336(6089):1667–1670
CrossRef (https://doi.org/10.1126/science.1217411)
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20rise%20of%20chemodiversity%20in%20plants&author=J-K.%20Weng&author=RN.%20Philippe&author=JP.%20Noel&journal=Science&volume=336&issue=6089&pages=1667-1670&publication_year=2012)

Whitaker BD (1993) Lipid changes in microsomes and crude plastid fractions during storage of tomato fruits at chilling and nonchilling temperatures. Phytochemistry 32(2):265–271
MathSciNet (http://www.ams.org/mathscinet-getitem?mr=1234859)
CrossRef (https://doi.org/10.1016/S0031-9422(00)94979-3)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Lipid%20changes%20in%20microsomes%20and%20crude%20plastid%20fractions%20during%20storage%20of%20tomato%20fruits%20at%20chilling%20and%20nonchilling%20temperatures&author=BD.%20Whitaker&journal=Phytochemistry&volume=32&issue=2&pages=265-271&publication_year=1993)

Yamaya A, Endo Y, Fujimoto K, Kitamura K (2007) Effects of genetic variability and planting location on the phytosterol

content and composition in soybean seeds. Food Chem 102(4):1071–1075
CrossRef (https://doi.org/10.1016/j.foodchem.2006.07.001)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20genetic%20variability%20and%20planting%20location%20on%20the%20phytosterol%20content%20and%20composition%20in%20soybean%20seeds&author=A.%20Yamaya&author=Y.%20Endo&author=K.%20Fujimoto&author=K.%20Kitamura&journal=Food%20Chem&volume=102&issue=4&pages=1071-1075&publication_year=2007)

Yang J, Zhou F, Xiong L, Mao S, Hu Y, Lu B (2015) Comparison of phenolic compounds, tocopherols, phytosterols and antioxidant potential in Zhejiang pecan [*Carya cathayensis*] at different stir-frying steps. LWT-Food Sci Technol 62(1):541–548
CrossRef (https://doi.org/10.1016/j.lwt.2014.09.049)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Comparison%20of%20phenolic%20compounds%2C%20tocopherols%2C%20phytosterols%20and%20antioxidant%20potential%20in%20Zhejiang%20pecan%20%5BCarya%20cathayensis%5D%20at%20different%20stir-frying%20steps&author=J.%20Yang&author=F.%20Zhou&author=L.%20Xiong&author=S.%20Mao&author=Y.%20Hu&author=B.%20Lu&journal=LWT-Food%20Sci%20Technol&volume=62&issue=1&pages=541-548&publication_year=2015)

Ye J-C, Chang W-C, Hsieh DJ-Y, Hsiao M-W (2010) Extraction and analysis of β-sitosterol in herbal medicines. J Med Plants Res 4(7):522–527
Google Scholar (http://scholar.google.com/scholar_lookup?title=Extraction%20and%20analysis%20of%20%CE%B2-sitosterol%20in%20herbal%20medicines&author=J-C.%20Ye&author=W-C.%20Chang&author=DJ-Y.%20Hsieh&author=M-W.%20Hsiao&journal=J%20Med%20Plants%20Res&volume=4&issue=7&pages=522-527&publication_year=2010)

Copyright information

About this article

Cite this article as:
Moazzami Farida, S.H. & Radjabian, T. Iran J Sci Technol Trans Sci (2019) 43: 2129. https://doi.org/10.1007/s40995-019-00721-5

Received
23 March 2019

Accepted
20 May 2019

First Online
20 June 2019

DOI
https://doi.org/10.1007/s40995-019-00721-5

Publisher Name
Springer International Publishing

Print ISSN
1028-6276

Online ISSN
2364-1819