IRSTI 31.23.17

A.M. Yelshibayeva*, R.I. Jalmakhanbetova

L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan
(E-mail: jalmakhanbetova_ri@enu.kz)
**Corresponding author: individ_93@mail.ru*

Prospective sources of natural sesquiterpenoids

Abstract. *Sesquiterpene lactones are the main component of many genera of the Asteraceae (Compositae) family. They include active compounds that are used in traditional medicine to treat a variety of ailments. Several sesquiterpene lactones, such as mipsagargin and artemisinin, are already available for sale and used to fight tumor growth, and malaria, respectively. In this article, we present data on prospective sources of new sesquiterpene lactones from species of the Asteraceae family over the past 10 years. The review contains information on the geographical distribution of genera, instrumental methods of analysis, as well as an explanation of the chemical structure and biological activity of sesquiterpene lactones isolated for the first time.*
Keywords: *isoprenoids, sesquiterpene lactones, Asteraceae.*

DOI: https://doi.org/10.32523/2616-6771-2022-140-3-7-18

Introduction

Higher plants have unique feature such as secondary metabolism. The group of metabolites called "substances of secondary metabolism" covers an almost limitless spectrum of a wide variety of compounds synthesized mainly by plants. These substances perform various functions, and far from all of these functions have been elucidated to date.

Plants characterized by a significant accumulation of certain secondary metabolites are valuable raw materials for many industries.

Isoprenoids are the most important class of secondary metabolites, most of which have high biological activity. Sesquiterpene lactones from the *Asteraceae* family occupy a special place among isoprenoids [1].

There is currently a growing interest in sesquiterpene lactones, mainly because of their importance as chemical markers in biosystematic studies, but also because of their wide spectrum of biological activity. The antioxidant, antimicrobial, molluscicidal, antitumor, antidepressant, antiulcer, anthelmintic, anti-inflammatory, hepatoprotective and hypnotherapeutic biological properties of sesquiterpene lactones have been described. The importance of these compounds as attractants, repellents, and antifeedants in the interaction of plants with insects is mentioned [2, 3].

The chemical structure of these compounds is based on a 15-carbon skeleton containing an α, β-unsaturated-γ-lactone part. The biological activity of sesquiterpene lactones is largely due to the presence in their chemical structure of the α-methylene-γ-lactone group. Both natural and semisynthetic derivatives are considered, focusing on sesquiterpene lactones as candidates for the development of new drugs for the treatment of different disorders [4].

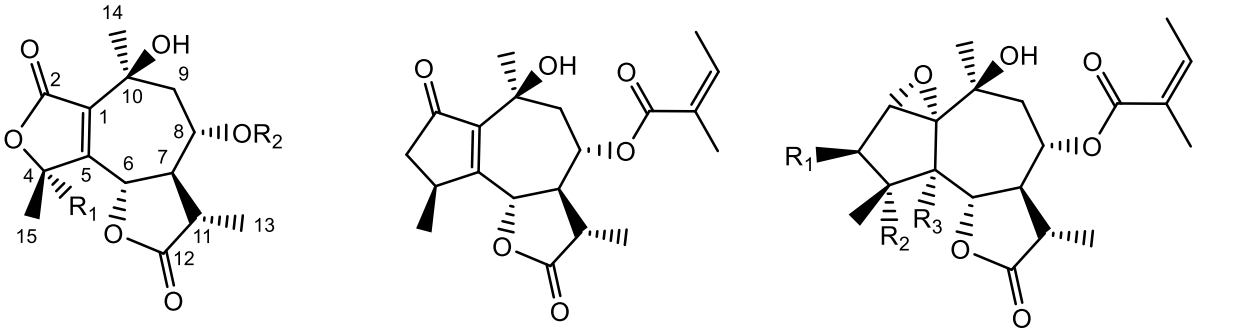
The purpose of this review is to analyze prospective sources of new perspective sesquiterpene lactones over the past 10 years and elucidate their structure and biological activity for further development of useful drugs with a wide range of pharmacological activity.

Results and discussions

The present review contains an investigation of promising sources of sesquiterpene lactones from the *Asteraceae* family.

For 20 years, 133 species of plants from the *Compositae* family were studied. About 6,000 plant species grow on the territory of Kazakhstan, of which more than 600 are endemic, which have not previously been studied by environmental sources. A chemical analysis of these plants was carried out, as a result of which more than 60 sesquiterpene lactones were identified, among which 11 are eudesmanic, 15 compounds are germacrane type. Also, 32 guaianes, 3 pseudoguaianes, and 3 dimeric lactones were obtained. It should be noted that most of the isolated lactones are guaianolides. Among the yields of identified sesquiterpene lactones, 12 are formed, not previously described [5].

Achillea millefolium L., from the *Asteraceae* family, is native to Europe and western Asia and is now widely distributed in Europe, North America, North Africa, Iran, Mongolia, and Siberia [6]. According to Hongliang Li seven undescribed guaianolide sesquiterpene lactones, millefoliumins (1-7), and five known substances were isolated from the whole plant of *Achillea millefolium* L. that grows in Xinjiang, China. They described the isolation, structural elucidation, and biological activities of foregoing compounds (3) Figure 1 shows the planar structure of millefoliumins (1-7), which contain a 3-oxo-guaianolide sesquiterpene lactone with a rare cyclopentenone ester moiety. Analysis of 1D and 2D NMR data suggested high similarities between the structures of (1) and (2) except for the replacement of an angeloyloxy (ang) group in compound (1) by a 3-methylbutyryloxy (isovalerate) group in compound (2).



1 R_1 = OH R_2 = Ang
2 R_1 = OH R_2 = Isovalerate
3 R_1 = OCH_3 R_2 = Ang
4 R_1 = H R_2 = Ang

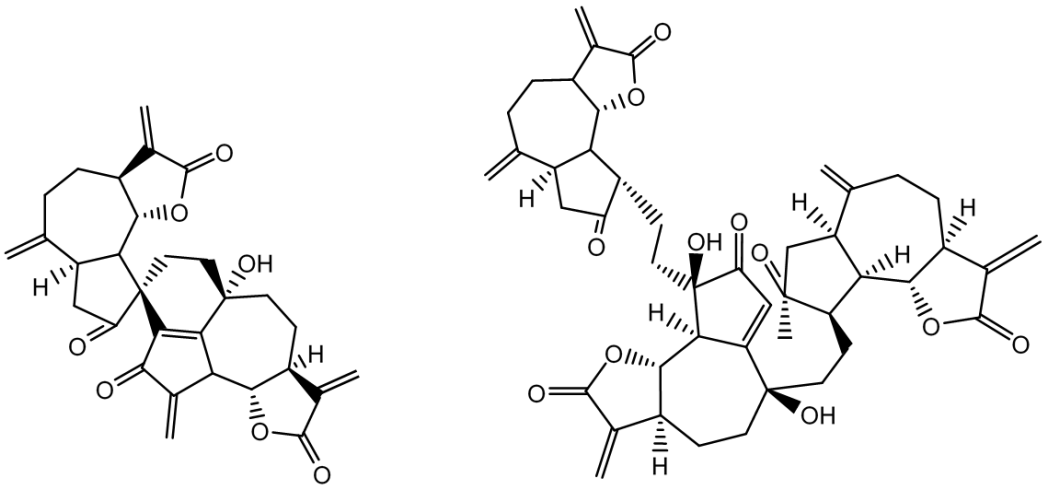
5

6 R_1 = Cl R_2=OH R_3 = H
7 R_1 = H R_2=Cl R_3 = OH

Figure 1. Structures of millefoliumins (1-7)

The researchers note that millefoliumins F (6) and G (7) and austricin may improve melanogenesis by increasing melanin content and tyrosinase activity in melanoma cells. In addition, millefoliumins A (1), C (3), and D (4) and austricin showed anti-inflammatory activity in relation to the production of NO in cells [7].

A group of scientists has investigated EtOAc phase of the ethanol extract of *Ainsliaea yunnanensis* which is distributed in Yunnan, Guizhou, and Sichuan provinces in China [8] and isolated 10 sesquiterpenoids and 16 triterpenoids from which four known compounds showed selective cytotoxic activities and one new compound showed anti-inflammatory activity [9–11]. Furthermore, the remaining fraction of the EtOAc phase showed good anti-microbial, cytotoxic, and anti-inflammatory activities. The experiment was conducted with the remaining active fraction and resulted in the isolation and further structural identification of one new dimeric, gochnatiolid E (8), and trimeric, ainsliatriolide C (9) sesquiterpene lactones.



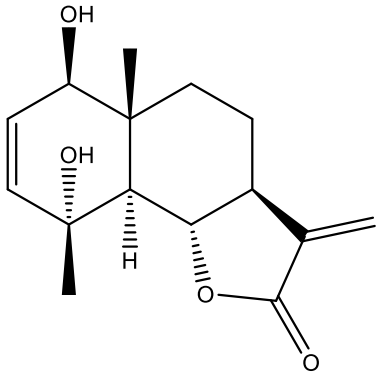
8 **9**

Figure 2. Structures of gochnatiolid E (8) and ainsliatriolide C (9)

The chemical structure of gochnatiolid E (8) and ainsliatriolide C (9) combining with its molecular formula in the ^{1}H and ^{13}C-NMR spectra indicated the presence of two and three guaianolide moieties respectively in Figure 2 [12].

Artemisia is one of the largest and most extensively dispersed genera in the *Asteraceae* family, with approximately 500 species found primarily in temperate regions of Europe, North America, and Asia. *Artemisia* species are tiny shrubs or annual, perennial, or biennial herbs. These species primarily contain coumarins, terpenoids, flavonoids, sterols, caffeoylquinic acids, and acetylenes, according to previous research [13]. Most isolated sesquiterpenes from the class *Artemisia* highlight the α-methylene-γ-lactone moiety, which has regularly spoken to a wide range of bioactivities counting anti-inflammation, antitumor, antimicrobial, and so on [14,15].

A new sesquiterpene lactone, artemarginolide E (10), was isolated from a traditional Chinese medicine taken from *Artemisia argyi*. Its structure was presented in Figure 3 based on the broad investigation of spectroscopic information [16].



10

Figure 3. Structure of artemargyinolide E (10)

Similarly, a team of researchers from the China University of Pharmacy reported the isolation, structural identification, and determination of the inhibitory biological activity of four novel highly oxidized sesquiterpenoids, argioxinolides A-D (11-14), from the leaves of *Artemisia argyi.* The structures in Figure 4 were characterized by extensive spectroscopic methods [17].

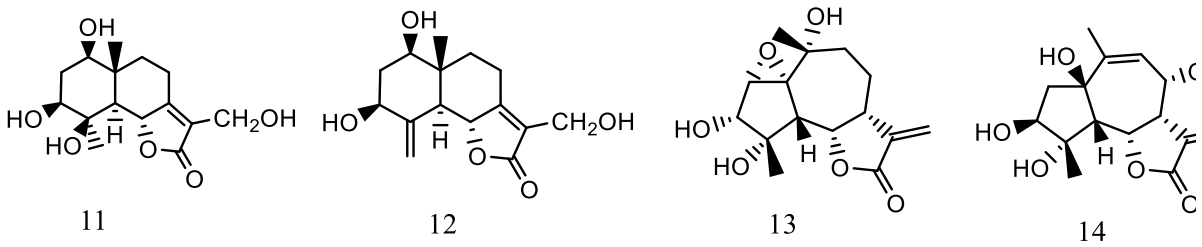


Figure 4. Chemical structures of argioxinolides A-D (11-14)

Genus *Artemisia* L. has been used since ancient times as a folk remedy to relieve coughs, reduce phlegm, improve blood circulation, etc. [18].

As a result of the research of Kazakh scientists under the leadership of Academician S.M. Adekenov, two new eudesmane sesquiterpene lactones (15-16) were isolated from the species *Artemisia halophila* (Figure 5). Their structure has been proven by X-ray structural analysis in addition to spectroscopic methods [19].

Figure 5. Chemical structures of arhalin (15) and 3β-hydroxyarhalin (16)

According to the literature, one new dimeric, artemisiane E (17) and two monomeric, artemdubolide I (18) and noreudesmane (19) sesquiterpene lactones were isolated for the first time from the *Artemisia* genus *Artemisia heptapotamica*, which was collected in Almaty region of Kazakhstan. It is noted that most monomeric sesquiterpenes demonstrated stronger inhibitory activities than the dimerized sesquiterpenoids, but further evidence was not provided for the structure-activity relationship. The chemical structures in Figure 6 were mostly achieved by detailed analysis of MS, ECD spectrum, 1D, and 2D NMR spectroscopic data as well [20].

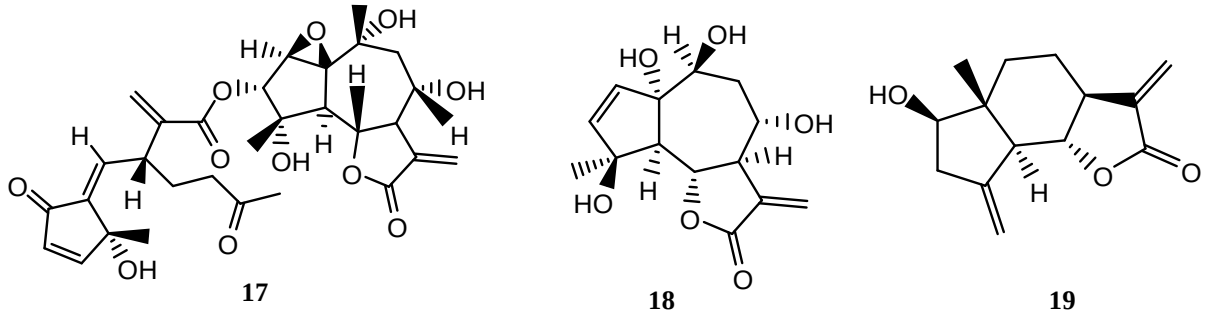


Figure 6. Chemical structures of artemisiane E (17), artemdubolide I (18) and noreudesmane (19)

Similarly, two new guaiane sesquiterpene lactones were isolated from *Artemisia vulgaris* aerial parts. A combination of spectroscopic tests, including 1D and 2D NMR, CD, and HR ESI MS, were used to deduce the structure of sesquiterpene lactones, vulgarolides A (20) and B (21), in Figure 7. The sulforhodamine B colorimetric assay was used to assess theirs in vitro cytotoxic capabilities against five human cancer cell lines [21]. It is known that this herb is widely grown in Vietnam and has been used in folk medicine to treat metrorrhagia, the threat of pregnancy loss, menstrual abdominal pain, and irregular menstruation [22].

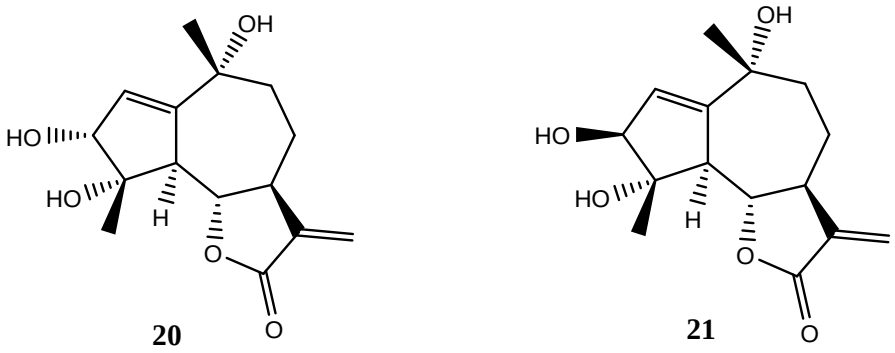


Figure 7. Chemical structures of vulgarolides A (20) and B (21)

As part of an ongoing investigation on *Campuloclinium macrocephalum* extracts and their isolated sesquiterpene lactones exhibit anticancer activities against various cancer cell lines [23–27]. In addition, phytochemical research on *Campuloclinium macrocephalum* showed the identification of three unknown germacranolide sesquiterpene lactones, macrocephalide A-C (22-24), as well as known steroids and triterpenes, and the flavonoids taxifolin and quercetin-3-O—L-rhamnopyranoside-7-O—D-glucopyranoside.

Also, the isolation, structure elucidation in Figure 8, including absolute stereochemistry assignment, and the cytotoxic activities of the undescribed sesquiterpene lactones, macrocephalide A-C (22-24), was described.

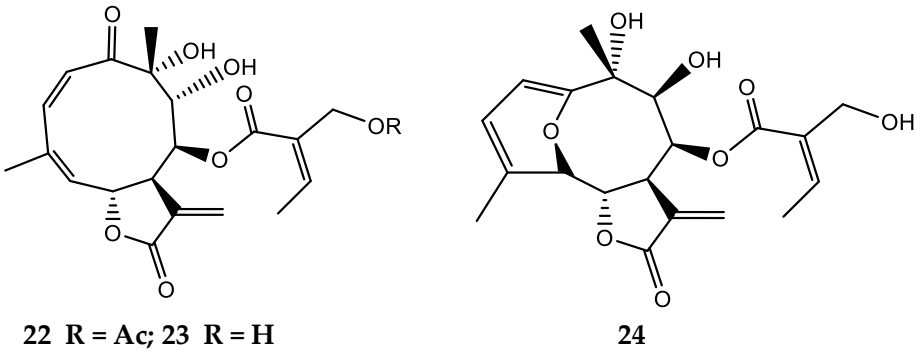


Figure 8. Chemical structures of macrocephalide A (22), macrocephalide B (23), and macrocephalide C (24)

In antiproliferative experiments, macrocephalide A (22) suppressed the growth of melanoma and kidney tumor cells more selectively, while macrocephalide B (233) inhibited the growth of adenocarcinoma ovarian cells more effectively. The findings support the anticancer characteristics of sesquiterpene lactones and may contribute to their ecological roles, such as C (24). Macrocephalum's effect on phytopathogenic fungi was already described [28].

One of the perspective sources of sesquiterpene lactones is *Carpesium abrotanoides* from the *Compositae* family. *Carpesium* is a genus that contains approximately 21 species, the majority of which are found in Asia and Europe. The chemical constituents of *Carpesium abrotanoides* were investigated as part of the study of the bioactive components of medicinal plants. As a result, three new sesquiterpene lactones were discovered: 5-hydroxy-4,15-epoxy-11H-eudesman-12,8-olid (25), carabrol-4-O-palmitate (26), and carabrol-4-O-linoleate (27), in addition to five known sesquiterpene lactones [29–33]. The isolation and structure elucidation in Figure 9 of these new compounds have been proven by extensive spectroscopic analysis.

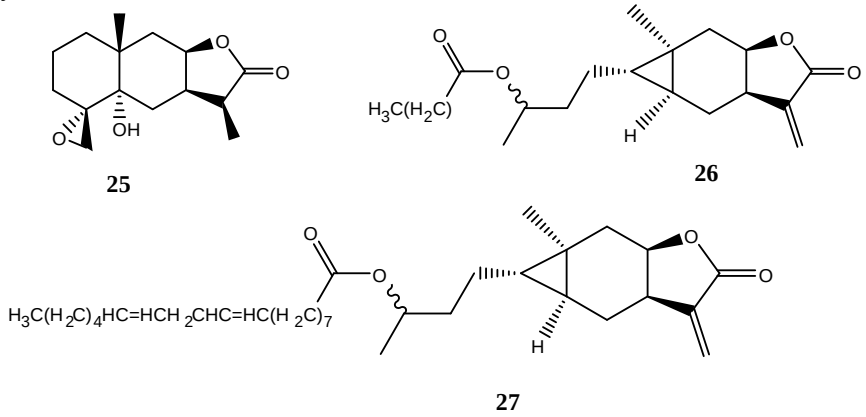
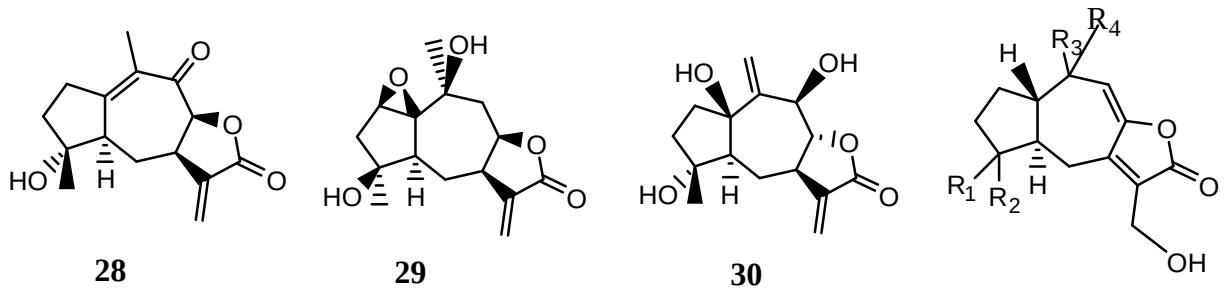


Figure 9. Chemical structures of 5α-hydroxy-4α, 15-epoxy-11αH-eudesman-12,8β-olide (25), carabrol-4-O-palmitate (26), and carabrol-4-O-linoleate (27)

They also tested new sesquiterpene lactones for cytotoxicity against human leukemia and breast cancer cells [34].

Similarly, the traditional Chinese plant *Carpesium abrotanoides* L. was used to isolate five new guaiane-type sesquiterpene lactones from the whole plant. All sesquiterpene lactones have been tested in vitro for their cytotoxic activity against cancer cell lines, of which carogyanolide A-E (28-32) has shown significant cytotoxic activity. Chemical structures of compounds in Figure 10 were determined on the basis of spectroscopy data. Further, their relative configuration was determined from the NOESY spectrum.



	R_1	R_2	R_3	R_4
31	α-OH	β-CH_3	β-OH	α-CH_3
32	β-OH	α-CH_3	α-OH	β-CH_3

Figure 10. Chemical structures of carogyanolide A-E (28-32)

From the point of view of biosynthesis, all isolated compounds are close relatives and are derivatives of +/- germacrene A. The authors of the article indicated the probable pathways for the biosynthesis of new *8, 12*-guaianolides A-E (28-32) [35].

The isolation from *Carpesium abrotanoides* of five new dimers of C17/C15 sesquiterpene lactones, namely, carabrodilactones A–E (33-37) aroused considerable interest among researchers. The structures of compounds were established based on spectroscopy data as shown in Figure 11.

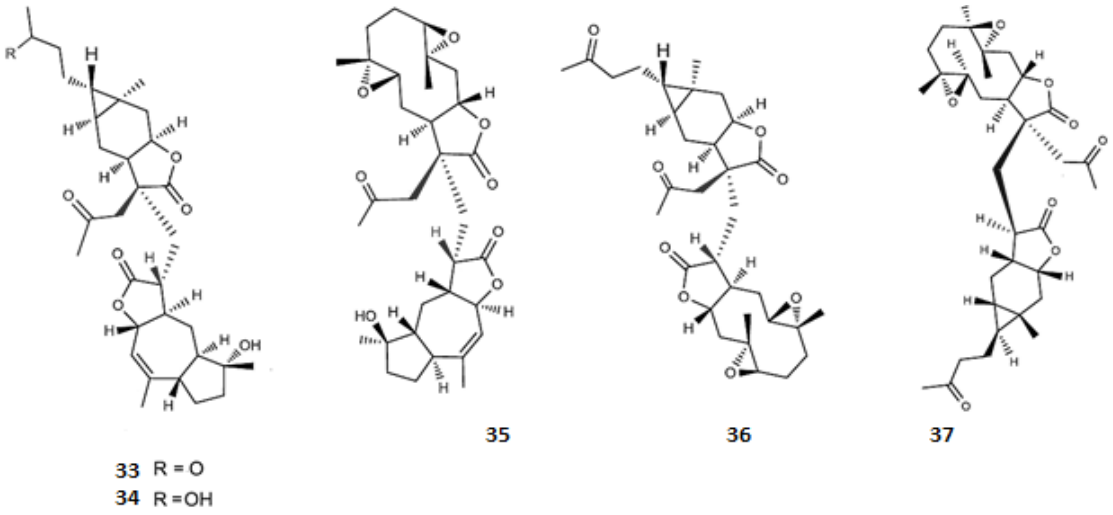


Figure 11. Chemical structures of carabrodilactones A–E (33-37)

They proposed a biogenetic pathway for the synthesis of sesquiterpene lactone dimers through two Michael addition reactions. Most importantly, the absence of exo-ethylene in the C17/C15 sesquiterpene dimers does not affect cytotoxic in the end [36].

As part of the search for new sesquiterpene lactones, a photochemical study was made of sesquiterpene derivatives from Iranian medicinal exhibiting antimicrobial and anticancer properties [37]. Scientists from Iran in the article describe the isolation and elucidation of the structure of two new sesquiterpene lactones, rhisantolide A (38) and rhizantolide B (39), from the aerial parts of *Centaurea rhizantha*, which grows in the northeast of Iran. They also evaluated their antimicrobial and cytotoxic activity against gram-positive and negative bacteria. It is noted that rhisantolide B (39) is a rare guaianolide with a free basic alcohol functionality at C-10, as well as with a 3,10-epoxy functional group.

Their structure was determined using 1D and 2D NMR, as well as HR-ESIMS measurements. According to the detailed spectroscopic analysis, the structure of rhisantolide B (39) is almost identical to rhisantolide A (38) in Figure 12. Exception was in absence of an alcohol group at C-9 and the absence of an exomethylene group which substituted by the primary alcohol function [38].

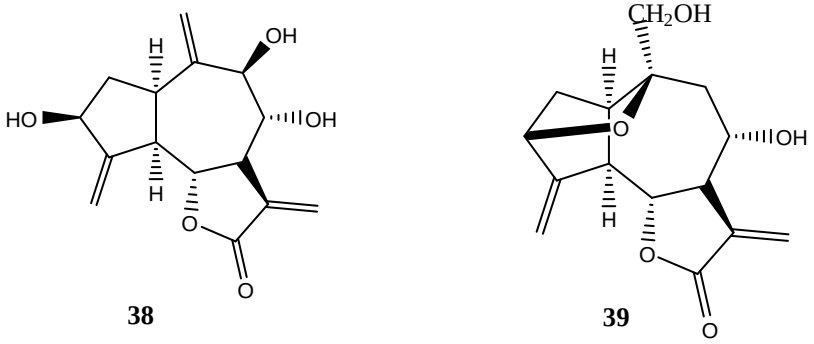
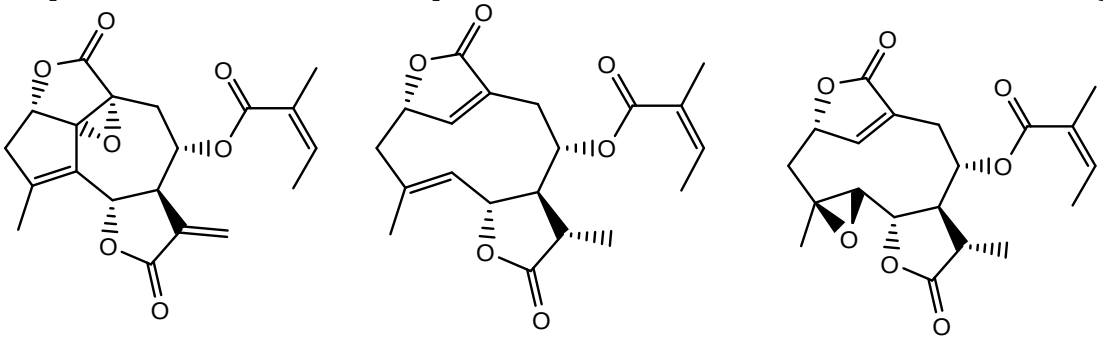


Figure 12. Chemical structures of rhisantolide A (38) and rhizantolide B (39)

Another source of sesquiterpene lactone is *Elephantopus scaber* from the *Asteraceae* family, also known as Didancao in Chinese, which is found throughout Europe, Asia, and Africa [39]. Germacrane-type sesquiterpene lactones, which are the main chemical components of *Elephantopus scaber*, have drawn increased attention from the chemical and biological communities due to their significant anticancer action [40]. Currently, 16 new germacrane-type sesquiterpene lactones, elephantopinolide A-P were isolated by chromatographic purification of *Elephantopus scaber*. Their structures were confirmed by comprehensive spectroscopic analyses, single-crystal X-ray diffraction, and comparison between the experimental and calculated ECD spectra. The study demonstrated that elephantopinolide J could markedly cause G2/M phase arrest, autophagy, and apoptosis in hepatocellular carcinoma cells. Their chemical structure has been confirmed by detailed spectroscopic analysis, X-ray diffraction and ECD spectra [41].

Researchers from the previous study continued their study on the extraction of sesquiterpene lactones from the *Elephantopus scaber*. They have isolated seven undescribed germacranolides, named scabertopinolide A-G from this whole plant. The chemical structures were determined as in the previous investigation. It is worth noting that the cytotoxic activity of scabertopinolide G against the three cancer cells was the highest. Furthermore, flow cytometry data suggests that scabertopinolide G may cause cancer cells to die by inducing apoptosis. The findings suggested that scabertopinolide G might be a viable chemotherapeutic lead chemical worth investigating further for cancer treatment [42].

A group of scientists led by Ding-Chai Lin continued a phytochemical analysis on *Elephantopus scaber* and isolated three novel sesquiterpene lactones, scabertopinolide H-J (40-42). Detailed spectroscopic research and literature comparisons were used to determine their structures in Figure 13.



40 **41** **42**

Figure 13. Chemical structures of scabertopinolide H (40), scabertopinolide I (41), scabertopinolide J (42)

The ^{1}H and ^{13}C NMR data indicated the presence of three olefinic bonds, three methyl, and three carbonyl groups. New sesquiterpene lactones were tested for anti-inflammatory activity and these chemicals were shown to be more effective than the positive control resveratrol [43].

Conclusion

This article demonstrates an investigation of promising sources of sesquiterpene lactones from the *Asteraceae* family, especially: *Achillea millefolium* L., *Ainsliaea yunnanensis, Artemisia argyi, Artemisia halophila, Artemisia heptapotamica, Artemisia vulgaris, Campuloclinium macrocephalum, Carpesium abrotanoides* L., *Centaurea rhizantha, Elephantopus scaber*. The review examines scientific articles published over the past 10 years. The article gives descriptions, biochemical properties, geographic distributions, as well as chemical structures of plants from the *Asteraceae* family, from which new sesquiterpene lactones have been isolated. This review reveals the significant potential of sesquiterpene lactones in promising natural sources from the *Asteraceae* family, which can further be used in traditional antiparasitic medicine, as well as an alternative for cancer treatment and insecticide control in the agro-industry.

References

1. Borisova G.G. et al. Fundamentals of biochemistry of plant secondary metabolite. – Yekaterinburg: Ural university, 2014. – P. 128.

2. Tiwari V.K., Mishra B.B. Opportunity, challenge and scope of natural products in medicinal chemistry. – Kerala: Research Signpost, 2011. – P. 313-334.

3. Helena M., Amorim R., Rui M. Gil da Costa, Carlos Lopes, Margarida M. S. M. Bastos. Sesquiterpene lactones: Adverse health effects and toxicity mechanisms // Critical Reviews in Toxicology. – 2013. – Vol. 43, № 7. – P. 559-579.

4. Sülsen V., Elso O., Borgo J., Laurella L., Catalán C. Recent patents on sesquiterpene lactones with therapeutic application // Studies in Natural Products Chemistry. Elsevier. – 2021. – Vol. 69. – P. 129-194.

5. Adekenov S.M. Sesquiterpene lactones with unusual structure. Their biogenesis and biological activity // Fitoterapia. Elsevier B.V. – 2017. – Vol. 121. – P. 16-30.

6. Ali S.I., Gopalakrishnan B., Venkatesalu V. Pharmacognosy, phytochemistry and pharmacological properties of *Achillea millefolium* L.: A Review // Phytotherapy Research. John Wiley and Sons Ltd. – 2017. – Vol. 31, № 8. – P. 1140-1161.

7. Li H., Li J., Liu M., Xie R., Zang Y., Li J., Aisa H.A. Guaianolide sesquiterpene lactones from *Achillea millefolium* L. Phytochemistry. – 2021. – Vol. 186. – P. 112733. DOI: 10.1016/j.phytochem.2021.112733.

8. Wang R., Sun Z., Wang A.L., Yuan Z.Z., Li J.J., Shang X.Y. GC-MS analysis of low polar components from *Ainsliaea yunnanensis* // Zhong yao cai Journal of Chinese medicinal materials. – 2013. – Vol. 36, № 1. – P. 61-64.

9. Li J.J., Wang A.L., Yuan Z.Z., Wu C.Y., Yang L.H., Shang X.Y. Triterpene compounds of *Ainsliaea yunnanensis* // Zhongguo Zhong yao za zhi China journal of Chinese materia medica. – 2013. – Vol. 38, № 22. – P. 3918-3922.

10. Li J., Zhang B., Liu H., Zhang X., Shang X., Zhao C. Triterpenoids from *Ainsliaea yunnanensis* Franch and Their Biological Activities. //Molecules, – 2016. – Vol. 21. №11. – P. 1481. DOI: 10.3390/molecules21111481.

11. Li J., Li X., Wang X., Zhong X., Ji L., Guo Z., et al. Sesquiterpenoids and their antiinflammatory activity: evaluation of *Ainsliaea yunnanensis*. – 2019. – Vol. 24. № 9. – P. 1701. DOI: 10.3390/molecules24091701.

12. Zhou N., Li J.J., Wu Y., Wang Z.Y., Wang X., Yin Z.P., et al. New polymerized sesquiterpene lactones from *Ainsliaea yunnanensis* and their activity evaluation // Natural Product Research. Taylor and Francis Ltd. –2021. – Vol. 36. – P. 4862-4868. DOI: 10.1080/14786419.2021.1904924.

13. Bora K.S., Sharma A. The genus *Artemisia*: a comprehensive review. // Pharmaceutical biology. – 2011. – Vol. 49, № 1. –P. 101-109.

14. Wang S., Sun J., Zeng K., Chen X., Zhou W., Zhang C., et al. Sesquiterpenes from *Artemisia argyi*: Absolute Configurations and Biological Activities // European Journal of Organic Chemistry. – 2014. – Vol. 5. – P. 973-983.

15. Zhang L., Lv J. Phytochemistry and bioactivities of sesquiterpenoids from the *Artemisia* species // Journal of Chinese Pharmaceutical Sciences. – 2017. – Vol. 26, № 5. – P. 317-334.

16. Zhang L. Bin, Zhu H.H., Guo L.M., Lv J.L. Artemargyinolide E, a new sesquiterpene lactone from *Artemisia argyi* inhibits inflammatory responses via down-regulating NF-κB signaling pathway // Phytochemistry Letters. Elsevier Ltd. – 2020. – Vol. 36. – P. 17-23.

17. Zhao H.R., Liu X.Q., Wu X.T., Kong L.Y., Luo J.G. Four new highly oxidized sesquiterpene lactones from the leaves of *Artemisia argyi* // Phytochemistry Letters. Elsevier Ltd. – 2021. – Vol. 43. – P. 173-178.

18. Abad Martínez M.J., Del Olmo L.M.B., Ticona L.A., Benito P.B. The *Artemisia L.* Genus: A Review of Bioactive Sesquiterpene Lactones // Studies in Natural Products Chemistry. Elsevier. – 2012. – Vol. 37. – P. 43-65.

19. Adekenov S.M., Shaimerdenova Zh.R., Gatilov Yu.V., Atazhanova G.A. Two new sesquiterpene lactones from *Artemisia halophila* // Chemistry of Natural Compounds. – 2017. – Vol. 53, No. 2. – P. 284-289.

20. Abilova Z., Jie Y., Jenis J., Tang C.P., Yang Y.E. Chinese Journal of Natural Medicines Monomeric and dimeric sesquiterpene lactones from *Artemisia heptapotamica*. – 2019. – Vol. 17, № 10. – P. 785-791

21. Hanh T.T.H., Hang L.T.T., Huong P.T.T., Trung N.Q., Cuong T. van, Thanh N. van, et al. Two new guaiane sesquiterpene lactones from the aerial parts of *Artemisia vulgaris* // Journal of Asian Natural Products Research. Taylor and Francis Ltd. – 2018. – Vol. 20, № 8. – P. 752-756.

22. Chi V.V. Dictionary of Vietnamese Medicinal Plants. – 2012. – Vol. 2. – P. 175-176.

23. Huo J., Yang S.P., Ding J., Yue J.M. Cytotoxic sesquiterpene lactones from *Eupatorium lindleyanum* // Journal of Natural Products. – 2004. – Vol. 67, № 9. – P. 1470-1475.

24. Shen Y.C., Lo K.L., Kuo Y.H., Khalil A.T. Cytotoxic sesquiterpene lactones from *Eupatorium kiirunense,* a coastal plant of Taiwan // Journal of Natural Products. – 2005. – Vol. 68, № 5. – P. 745-750.

25. Hensel A., Maas M., Sendker J., Lechtenberg M., Petereit F., Deters A, et al. *Eupatorium perfoliatum L.*: Phytochemistry, traditional use and current applications // Journal of Ethnopharmacology. – 2011. – Vol. 138, № 3. – P. 641-651.

26. Saito Y., Mukai T., Iwamoto Y., Baba M., Takiguchi K., Okamoto Y., et al. Germacranolides and their diversity of *Eupatorium heterophyllum* collected in P. R. China // Chemical and Pharmaceutical Bulletin. – 2014. – Vol. 62, № 11. – P. 1092-1099.

27. Yu X., Zhang Q., Tian L., Guo Z., Liu C., Chen J., et al. Germacrane-type sesquiterpenoids with antiproliferative activities from *Eupatorium chinense* // Journal of Natural Products. – 2018. – Vol. 81, № 1. – P. 85-91.

28. Pereira Cabral M.R., Cecchetto M., Batista J.M., Batista A.N.L., Foglio M.A., Tasca Gois Ruiz A.L., et al. Cytotoxic sesquiterpene lactones from *Campuloclinium macrocephalum* (*Eupatorium macrocephalum*) // Phytochemistry. Elsevier Ltd. – 2020. – Vol. 179. – P. 112469.

29. Liu L.L., Wang R., Yang J.L., Shi Y.P. Diversity of sesquiterpenoids from *Carpesium cernuum* // Helvetica chimica acta. – 2010. – Vol. 93, № 3. – P. 595-601.

30. Shi Y.P., Guo W., Yang C., Jia Z.J. Two new aromatic monoterpene derivatives from *Carpesium lipskyi* // Planta Medica. – 1998. – Vol. 64, № 07. – P. 671-672.

31. Maruyama M., Omura S. Carpesiolin from *Carpesium abrotanoides* // Phytochemistry. – 1977. – Vol. 16. – P. 782-783.

32. Wang F. et al. Sesquiterpene lactones from *Carpesium abrotanoides* // Fitoterapia. – 2009. – Vol. 80, № 1. – P. 21-24.

33. Kim M.-R. et al. Isolation and structures of Guaianolides from *Carpesium m acrocephalum* // Journal of Natural Products. – 2002. – Vol. 65, № 4. – P. 583-584.

34. Hu Q.L. et al. Three new sesquiterpene lactones from *Carpesium abrotanoides* // Phytochemistry Letters. Elsevier Ltd. – 2018. – Vol. 27. – P. 154-159.

35. Wang F., Yang K., Ren F.C., Liu J.K. Caroguaianolide A–E, five new cytotoxic sesquiterpene lactones from *Carpesium abrotanoides* L. // Fitoterapia. Elsevier B.V. – 2018. – Vol. 127. – P. 349-355.

36. Yang Y. Xun, Wang J. Xin, Li H. liang, Mo Q., Huang H. Yan, Tao M., et al. Five new C17/C15 sesquiterpene lactone dimers from *Carpesium abrotanoides* // Fitoterapia. Elsevier B.V. – 2020. – Vol. 145. – P. 104630. DOI: 10.1016/j.fitote.2020.104630.

37. Kasaian J., Iranshahy M., Masullo M., Piacente S., Ebrahimi F., Iranshahi M. Reversal of P-glycoprotein-mediated multidrug resistance in MCF-7/Adr cancer cells by sesquiterpene coumarins // Fitoterapia. – 2015. – Vol. 103. – P. 149-154.

38. Shakeri A., Masullo M., Bottone A., Asili J., Emami S.A., Piacente S., et al. Sesquiterpene lactones from *Centaurea rhizantha* C.A. Meyer // Natural Product Research. Taylor and Francis Ltd. – 2019. – Vol. 33, № 14. – P. 2016-2023.

39. Hiradeve S.M., Rangari V.D. A review on pharmacology and toxicology of *Elephantopus scaber* Linn // Natural Product Research. – 2014. – Vol. 28, № 11. – P. 819-830.

40. Lagoutte R., Serba C., Abegg D., Hoch D.G., Adibekian A., Winssinger N. Divergent synthesis and identification of the cellular targets of deoxyelephantopins // Nature Communications. – 2016. – Vol. 7, № 1. – P. 12470.

41. Bai M., Chen J.J., Xu W., Dong S.H., Liu Q.B., Lin B., et al. Elephantopinolide A-P, germacrane-type sesquiterpene lactones from *Elephantopus scaber* induce apoptosis, autophagy and G2/M phase arrest in hepatocellular carcinoma cells // European Journal of Medicinal Chemistry. Elsevier Masson SAS. – 2020. – Vol. 198. – P. 352-364.

42. Bai M., Chen J.J., Xu W., Dong S.H., Liu Q.B., Yao G.D., et al. Germacranolides from Elephantopus scaber L. and their cytotoxic activities // Phytochemistry. – 2020. – Vol. 178. – P. 112479.

43. Lin D.C., Tang Q., Zhuo X.F., Wang W.Z., Li C.J., Kuang G.K., et al. Three new sesquiterpene lactones from the whole plants of *Elephantopus scaber* // Natural Product Research. Taylor and Francis Ltd. – 2021. – Vol. 36. – P. 3619-3625. DOI: 10.1080/14786419.2021.1873984.

А.М. Елшібаева, Р.И. Жалмаханбетова

Л Н. Гумилев атындағы Еуразия ұлттық университеті, Нұр-Сұлтан, Қазақстан

Табиғи терпеноидтардың келешегі бар көздері

Аңдатпа. Сесквитерпенді лактондар *Asteraceae* (*Compositae*) тұқымдасының көптеген тұқымдарының негізгі құрамдас бөлігі болып табылады. Оларға әртүрлі ауруларды емдеу үшін дәстүрлі медицинада қолданылатын белсенді қосылыстар кіреді. Мипсагаргин және артемизинин сияқты бірнеше сесквитерпенді лактондар қазірдің өзінде сатылымға шығарылған және сәйкесінше ісіктердің өсуімен және безгекпен күресу үшін қолданылады. Берілген мақалада соңғы 10 жылдағы *Asteraceae* тұқымдасының түрлерінен жаңа сесквитерпенді лактондардың перспективалық көздері туралы мәліметтер ұсынылған. Шолуда тұқымдардың географиялық таралуы, талдаудың аспаптық әдістері, сондай-ақ бірінші рет бөлініп алынған сесквитерпенді лактондардың химиялық құрылымы мен биологиялық белсенділігінің түсіндірмесі бар.

Түйін сөздер: изопреноидтар, сесквитерпенді лактондар, *Asteraceae*.

А.М. Елшибаева, Р.И. Джалмаханбетова
Евразийский национальный университет имени Л.Н. Гумилева, Нур-Султан, Казахстан

Перспективные источники природных терпеноидов

Аннотация. Сесквитерпеновые лактоны являются основным компонентом многих родов семейства *Asteraceae* (*Compositae*). В их состав входят активные соединения, которые используются в народной медицине для лечения самых разных болезней. Некоторые сесквитерпеновые лактоны, такие как мипсагаргин и артемизинин, уже доступны для продажи и используются для борьбы с ростом опухоли и малярией соответственно. В данной статье представлены исследования о перспективных источниках новых сесквитерпеновых лактонов из видов семейства *Asteraceae* за последние 10 лет. Обзор содержит сведения о географическом распространении родов, инструментальных методах анализа, а также объяснение химического строения и биологической активности впервые выделенных сесквитерпеновых лактонов.

Ключевые слова: изопреноиды, сесквитерпеновые лактоны, *Asteraceae*.

Information about authors:

Yelshibayeva A.M. – The 1st year doctoral student of the Department of Chemistry, L.N. Gumilyov Eurasian National University, 13 K. Munaitpasov str., Nur-Sultan, Kazakhstan.

Jalmakhanbetova R.I. – Doctor of Chemical Sciences, Associate Professor, Department of Chemistry, L.N. Gumilyov Eurasian National University, 13 K. Munaitpasov str., Nur-Sultan, Kazakhstan.

Елшібаева А.М. – 1-курс докторанты, Л.Н. Гумилев атындағы Еуразия ұлттық университетінің химия кафедрасының докторанты, Қ. Мұңайтпасов көш., 13, Нұр-Сұлтан, Қазақстан.

Жалмаханбетова Р.И. – химия ғылымдарының докторы, қауымдастырылған профессор, Л.Н. Гумилев атындағы Еуразия ұлттық университеті химия кафедрасының доценті, Қ. Мұңайтпасов көш., 13, Нұр-Сұлтан, Қазақстан.