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ECDYSTEROIDS AND THEIR BIOLOGICAL ACTIVITY

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REFERENCES

1. Goodwin T. W., Horn D. H. S., Karlson P., Koolman J., Nakanishi K., Robbins W. E., Siddall J. B., Takemoto T. 1978. Ecdysteroids: a new generic term. Nature. 272 (5649): 122.

2. Rees H. H. 1995. Ecdysteroid biosynthesis and inactivation in relation to function. Eur. J. Entomol. 92 (1): 9—39.

3. Lafont R. 1997. Ecdysteroids and related molecules in animals and plants. Arch. Insect. Biochem. Vol. 35 (1—2): 3—20.

4. Akhrem A. A., Levina I. S., Titov Yu. A. 1973. Ekdizony — steroidnye gormony nasekomykh. 232 p. (In Russian)

5. Akhrem A. A., Kovganko N. V. 1989. Ekdisteroidy: khimiya i biologicheskaya aktivnost. 327 p. (In Russian)

6. Nakanishi K. 1971. The ecdysones. Pure Appl. Chem. 25 (1): 167—195.

7. Butenandt A., Karlson P. 1954. Über die Isoilerung eines Metamorphose-Hormones der Insekten in kristallisierten Form. Z. Naturforsch. B. 9b (6): 389—391.

8. Huber R., Hoppe W. 1965. Zur Chemie des Ecdysons. VII. Die Kristall- und Molekül-strukturanalyse des Insektenverpuppunghormons Ecdyson mit der automatisierten Falt-molekülmethode. Chem. Ber. 98 (7): 2403—2424.

9. Nakanishi K., Koreeda M., Sasaki S., Chang M. L., Hsu H. Y. 1966. Insect hormones. The structure of ponasterone A, an insect-moulting hormone from the leaves of *Podocarpus nakaii* Hay. J. Chem. Soc., Chem. Commun. 24: 915—917.

10. Galbraith M. N., Horn D. H. S. 1966. An insect-moulting hormone from a plant. J. Chem. Soc., Chem. Commun. 24: 905—906.

11. Takemoto T., Ogawa S., Nishimoto N. 1967. Isolation of moulting hormones of insects from *Achyranthis radix*. Yakugaku Zasshi. 87 (3): 325—327.

12. Jizba J., Herout V., Šorm F. 1967. Isolation of ecdysterone (crustecdysone) from *Polypodium vulgare* L. rhizomes. Tetrahedron. 8 (18): 1689—1691.

13. Ohsawa T., Yukawa M., Takao C., Muruyama M., Bando H. 1992. Studies on constituents of fruit body of *Polyporus umbellatus* and their cytotoxic activity. Chem. Pharm. Bull. 40 (1): 143—147.

14. Vokáč K., Buděšinský M., Harmatha J., Piš J. 1998. New ergostane type ecdysteroids from fungi. Ecdysteroid constituents of mushroom *Paxillus atrotomentosus*. Tetrahedron. 54 (8): 1657—1666.

15. Vokáč K., Buděšinský M., Harmatha J., Kohoutová J. 1998. Ecdysteroid constituents of the mushroom *Tapinella panuoides*. Phytochemistry. 49 (7): 2109—2114.

16. Ishida H., Inaoka Y., Shibatani J., Fukushima M., Tsuji K. 1999. Studies of the active substances in herbs used for hair treatment. II. Isolation of hair regrowth substances, acetosyringone and polyporusterone A and B, from *Polyporus umbellatus* Fries. Biol. Pharm. Bull. 22 (11): 1189—1192.

17. Sun Y., Yasukawa K. 2008. New anti-inflammatory ergostane-type ecdysteroids from the sclerotium of *Polyporus umbellatus*. Bioorg. Med. Chem. Lett. 18 (11): 3417—3420.

18. Lafont R. 1998. Phytoecdysteroids in the World flora: diversity, distribution, biosynthesis and evolution. Fiziologiya rasteniy. 45 (3): 326—346. (In Russian)

19. Kozlova T., Thummel C. S. 2000. Steroid regulation of postembryonic development and reproduction in Drosophila. Trends Endocrin. Metabol. 11 (7): 276—280.

20. Smith S. 1998. Small brain neuropeptides. Trends Endocrin. Metabol. 9 (7): 301—302.

21. Tomashko K. H., Gukler R. 1996. Ecological significance of ecdysteroids in sea arthropod. Mezhdunarodnoe soveschanie po fitoekdisteroidam. Syktyvkar. P. 43—44. (In Russian)

22. Phytoecdysteroids. 2003. Ed. by V. V. Volodin. St.-Petersburg. 293 p. (In Russian)

23. Lafont R., Dinan L. 2003. Practical uses for ecdysteroids in mammals including humans: an update. J. Insect Sci. 3 (7): 1—30.

24. Timofeev N. P. 2009. Ecological relations of agricultural populations of ecdysteroid-containing plants *Rhaponticum carthamoides* (Willd.) Iljin and *Serratula coronata* L. to herbivorous insects. Rep. 1. Sibirskiy ekologicheskiy zhurnal. 5: 765—780. (In Russian)

25. Dinan L. 1998. Astrategy towards the elucidation of the contribution made by phytoecdysteroids to the deterrence of invertebrate predators on plants. Rus. J. Plant Physiol. 45 (3): 347—359.

26. Suhr S. T., Gil E. B., Senut M.-C., Gage F. H. 1998. High level transactivation by a modified *Bombyx ecdysone* receptor in mammalian cells without exogenous retinoid X receptor. Proc. Nat. Acad. Sci. USA. 95 (14): 7999—8004.

27. Wang S. F., Ayer S., Segraves W. A., Williams D. R., Raikhel A. S. 2000. Molecular determinants of differential ligand sensitivities of insect ecdysteroid receptors. Mol. Cell. Biol. 20 (11): 3870—3879.

28. Saez E., Nelson M. C., Eshelman B., Banayo E., Koder A., Cho G. J., Evans R. M. 2000. Identification of ligands and coligands for the ecdysone-regulated gene switch. Proc. Natl. Acad. Sci. USA. 97 (26): 14 512—14 517.

29. Vögtli M., Elke C., Imhof M. O., Lezzi M. 1998. High level transactivation by the ecdysone receptor complex at the core recognition motif. Nucleic Acids Res. 26 (10): 2407—2414.

30. Patrick C. W., Zheng B., Wu X., Gurtner G., Barlow M., Koutz C., Chang D., Schmidt M., Evans G. R. 2001. Muristerone A-induced nerve growth factor release from genetically engineered human dermal fibroblasts for peripheral nerve tissue engineering. Tissue Eng. Pt B. 7 (3): 303—311.

31. Aarnisalo P., Kim C.-H., Lee J. W., Perlmann T. 2002. Defining requirements for heterodimerization between the retinoid X receptor and the orphan nuclear receptor Nurr1. J. Biol. Chem. 277 (38): 35 118—35 123.

32. Constantino S., Santos R., Gisselbrecht S., Gouilleux F. 2001. The ecdysone inducible gene expression system: unexpected effects of muristerone A and ponasterone A on cytokine signaling in mammalian cells. Eur. Cytokine Netw. 12 (2): 365—367.

33. Wolter S., Mushinski J. F., Saboori A. M., Resch K., Kracht M. 2002. Inducible expression of a constitutively active mutant of mitogen-activated protein kinase kinase 7 specifically activates c-JUN NH2-terminal protein kinase, alters expression of at least nine genes, and inhibits cell proliferation. J. Biol. Chem. 277 (5): 3576—3584.

34. Timofeev N. P. 2001. Leuzea and preparations on its basis. Innovatsionnye tekhnologii i produkty. Sb. trudov. Novosibirsk. Vol. 4. P. 16—25. (In Russian)

35. Falkenstein E., Tillmann H.C., Christ M., Feuring M., Wehling M. 2000. Multiple actions of steroid hormones — a focus on rapid, nongenomic effects. Pharmacol. Rev. 52 (4): 513—556.

36. Mak P., Karathanasis S. K. Mechanism based screen for retinoid X receptor agonists and antagonists. US Patent 5,700,682. December 23, 1997.

37. Evans R. M., Saez E. 2001. Formulations useful for modulating expression of exogenous genes in mammalian systems, and products related thereto. US Patent 6,333,318. December 25, 2001.

38. Rossant J., McMahon A. 1999. «Cre»-ating mouse mutants — a meeting review on conditional mouse genetics. Genes Develop. 13 (2): 142—145.

39. Timofeev N. P. 2003. Industrial ecdysteroid sources. Part I. Ponasterone and muristerone. In: Netraditsionnye prirodnyi resursy, innovatsionnye tekhnologii i produkty. Sb. nauch. trudov. Moskow. N 9. P. 64—86. (In Russian)

40. Volodin V., Chadin I., Whiting P., Dinan L. 2002. Screening plants of European North-East Russia for ecdysteroids. Biochem. Syst. Ecol. 30 (6): 525—578.

41. Canonica L., Danieli B., Weisz-Vincze G., Ferrari G. 1972. Structure of muristerone A, a new phytoecdysone. J. Chem. Soc., Chem. Commun. 30: 1060—1061.

42. Landon T. M., Sage B. A., Seeler B. J., O'Connor J. D. 1988. Characterization and partial purification of the Drosophila Kc cell ecdysteroid receptor. J. Biol. Chem. 263 (10): 4693—4697.

43. Voigt B., Whiting P., Dinan L. 2001. The ecdysteroid agonist/antagonist and brassinosteroid-like activities of synthetic brassinosteroid/ecdysteroid hybrid molecules. Cell. Mol. Life Sci. 58 (8): 1133—1140.

44. Dinan L. 2003. Ecdysteroid structure-activity relationships. Studies Nat. Prod. Chem. 29 (J): 3—71.

45. Syrov V. N. 1994. Phytoecdysteroids: biological effects in the body of higher animals, and prospects for use in medicine. Eksperimentalnaya i klinicheskaya farmakologiya. 57 (5): 61—66. (In Russian)

46. Sláma K., Koudela K., Tenora J., Mathovб A. 1996. Insect hormones in vertebrates: anabolic effects of 20-hydroxyecdysone in Japanese quail. Experientia. 52 (7): 702—706.

47. Bathori M., Toth N., Hunyadi A., Marki A., Zador E. 2008. Phytoecdysteroids and anabolic-androgenic steroids-structure and effects on humans. Curr. Med. Chem. 15 (1): 75—91.

48. Tóth N., Szabó A., Kacsala P., Héger J., Zádor E. 2008. 20-Hydroxyecdysone increases fiber size in a muscle-specific fashion in rat. Phytomedicine. 15 (9): 691—698.

49. Syrov V. N., Saatov Z., Sagdullaev Sh. Sh., Mamatkhanov A. U. 2001. Study of the structure — anabolic activity relationship for the phytoecdysteroids extracted from some plants of Central Asia. Khimiko-farmatsevticheskiy zhurnal. 35 (12): 23—27. (In Russian)

50. Syrov V. N., Kurmukov A. G. 1976. Anabolic activity of phytoecdysone — ecdysterone isolated from *Rhaponticum carthamoides* (Willd.) Iljin. Farmakologiya i toksikologiya. 6: 690—693. (In Russian)

51. Syrov V. N., Nasyrova S. S., Khushbaktova Z. A. 1997. The results of experimental study of phytoecdysteroids as erythropoiesis stimulators in laboratory animals. Eksperimentalnya i klinicheskaya farmakologiya. 60 (3): 41—44. (In Russian)

52. Chaudhary K. D., Lupien P. J., Hinse C. 1969. Effect of ecdysone on glutamic decarboxylase in rat brain. Experientia. Vol. 25, N 3. P. 250—251.

53. Catalan R. E., Aragones M. D., Godoy J. E., Martinez A. M. 1984. Ecdysterone induces acetylcholinesterase in mammalian brain. Comp. Biochem. Physiol. Pt C: Comp. Pharmacol. 78 (1): 193—195.

54. Timofeev N. P., Ivanovskiy A. A. 1996. Anabolic effect of small doses of *Rhaponticum carthamoides* preparations. Mezhdunarodnoe soveshchanie po fitoekdisteroidam. Syiktyivkar. P. 133. (In Russian)

55. Todorov I. N., Mitrohin Yu. I., Efremova O. I., Sidorenko L. I. 2000. Effect of extract from *Leuzea carthamoides* on RNA and protein biosynthesis in mice. Khimiko-farmatsevticheskiy zhurnal. 34 (9): 24—26. (In Russian)

56. Zaynullin V. G., Mishurov V. P., Punegov V. V., Starobor N. A., Bashlyikova L. A., Babkina N. Yu. 2003. Biological efficiency of two fodder additives contained ecdysteroids of *Serratula coronata* L. Rastitelnye resursy. 39 (2): 95—103. (In Russian)

57. Volodin V. V., Pchelenko L. D., Volodina S. O., Kudryasheva A. G., Shevchenko O. G., Zagorskaya N. V. 2006. Pharmacological estimate of new containing ecdysteroid substance «Serpisten». Raststitelnye resursy. 42 (3): 113—128. (In Russian)

58. Syrov V. N. 2000. Comparative study of anabolic activity of phytoecdysteroids and steranabols in experiment. Khimiko-farmatsevticheskiy zhurnal. 34 (4): 31—34. (In Russian)

59. Sláma K., Lafont R. 1995. Insect hormones — ecdysteroids: their presence and actions in vertebrates. Eur. J. Entomol. 92 (1): 355—377.

60. Aranda A., Pascual A. 2001. Nuclear hormone receptors and gene expression. Physiol. Rev. 81 (3): 1269—1304.

61. Ravi M., Hopfinger A. J., Hormann R. E., Dinan L. 2001. 4D-QSAR analysis of a set of ecdysteroids and a comparison to CoMFA modeling. J. Chem. Inf. Comput. Sci. 41 (6): 1587—1604.

62. Gorelick-Feldman J., Maclean D., Ilic N., Poulev A., Lila M. A., Cheng D., Raskin I. 2008. Phytoecdysteroids increase protein synthesis in skeletal muscle cells. J. Agric. Food Chem. 56 (10): 3532—3537.

63. Azizov A. P., Seyfulla R. D., Ankudinova I. A., Kondrateva I. I., Borisova I. G. 1998. Effect of the antioxidants of elton and leveton on the physical capacity of athletes. Eksperimentalnaya i klinicheskaya farmakologiya. 61 (1): 60—63. (In Russian)

64. Seyfulla R. D. 1998. The pharmacological correction of factors limiting human work capacity. Eksperimentalnya i klinicheskaya farmakologiya. 61 (1): 3—12. (In Russian)

65. Gorchakova N. A., Gudivok Ya. S., Gunina L. M., Devyatkina T. A., Ilin V. N., Kanyuka A. I., Kozlovskiy V. A., Kosuba R. B., Marushko Yu. V., Oleynik S. A., Ordzhonikidze Z. G., Pimonenko N. Yu., Rozhkova E. A., Skalnyy A. V., Seyfulla R. D., Platonov V. N., Chekman I. S., Seredenin S. B. 2010. Farmakologiya sporta [Pharmacology of sport]. Kiev. 604 p. (In Russian)

66. Syrov V. N., Tashmukhamedova M. A., Khushbaktova Z. A., Mirtalipov D. T., Mamatkhanov A. U. 1992. Effect of phytoecdysteroids and nerobol on parameters of carbohydrate and lipid metabolism and phospholipid spectrum of liver mitochondrial membrane in experimental diabetes mellitus of rats. Ukrainskiy biokhimicheskiy zhurnal. 64: 61—67. (In Russian)

67. Vasilev A. S. 2012. Farmakologicheskie effekty ekstraktov ekdisteroidsoderzhashchikh rasteniy v usloviyakh modeley sindroma povyshennoy vyazkosti krovi: Avtoref. diss. ... dokt. biol. nauk [The pharmacological effects of extracts from ecdysteroid-containing plants in terms of models of the high blood viscosity syndrome: Author's abstract of Doct. Sci. (Biology) Dissertation]. Tomsk. 48 p. (In Russian)

68. Kutepova T. A., Syrov V. N., Khushbaktova Z. A., Saatov Z. 2001. Hypoglycemic activity of sum of phytoecdysteroids from *Ajuga turkestanica*. Khimiko-farmatsevticheskiy zhurnal. 35 (11): 24—25. (In Russian)

69. Kizelsztein P., Govorko D., Komarnytsky S., Evans A., Wang Z., Cefalu W. T., Raskin I. 2009. 20-Hydroxyecdysone decreases weight and hyperglycemia in a diet-induced obesity mice model. Am. J. Physiol. Endocrinol. Metab. 296 (3): 433—439.

70. Kosovskiy M. I., Syrov V. N., Mikharmedov M. M., Katkova S. P., Khushbaktova Z. A. 1989. The effect of nerobol and ecdysterone on processes related to insulin regulatory function in normal and in experimental insulin resistance. Problemy endokrinologii. 5: 77—81. (In Russian)

71. Tashmukhamedova M. A., Abzalova M. H., Syrov V. N., Sultanov M. B. 1983. On hypoglycemic properties of cyasteron. Doklady AN UzSSR. 2: 33—34. (In Russian)

72. Chen Q., Xia Y., Qiu Z. 2006. Effect of ecdysterone on glucose metabolism *in vitro*. Life Sci. 78 (10): 1108—1113.

73. Tashmukhamedova M. A., Almatov K. T., Syrov V. N., Sultanov M. B., Abidov A. A. 1986. Effect of ecdysterone, turkesterone and nerobol on the functions of rat liver mitochondria in experimental diabetes. Voprosy meditsinskoy himii. 5: 24—28. (In Russian)

74. Syrov V. N., Ayzikov M. I., Kurmukov A. G. 1975. Effect of ecdysterone on the content of protein, glycogen, and fat in white rat liver, heart and muscle. Doklady AN UzSSR. 8: 37—38. (In Russian)

75. Syrov V. N., Khushbaktova Z. A., Khalitov T. R., Vaisbrot W., Tadzhiev B. A. 1988. Effect of ecdysterone and saparal on functional biochemical and morphological characteristics related to muscle capacity. Uzbekskii biologicheskii zhurnal. 3: 61—65. (In Russian)

76. Sagach V. F., Korkach Yu. P., Kotsyuruba A. V., Prysiazhna O. D. 2008. The inhibition of oxidative and nitrosative stresses by ecdysterone as the mechanisms of its cardio- and vasoprotective action in experimental diabetes type I. Fiziologicheskiy zhurnal. 54 (5): 46—54. (In Ukrainan)

77. Korkach Yu. P., Dudchenko N. O., Kotsyuruba A. V., Prysiazhna O. D., Sagach V. F. 2008. Role of non-haem iron in protecting effect of ecdysterone on development of streptozocin-induced hyperglycaemia in rats. Ukrainskiy biokhimicheskiy zhurnal. 80 (1): 46—51. (In Ukrainan)

78. Korkach Yu. P., Kotsyuruba A. V., Prysiazhna O. D., Mogilnitskaya L. D., Sagach V. F. 2007. NO-dependent mechanisms of ecdysterone protective action on the heart and vessels in streptozotocin-induced diabetes mellitus in rats. Fiziologicheskiy zhurnal. 53 (3): 3—8. (In Ukrainan)

79. Mironova V. N., Kholodova Yu. D., Skachkova T. F., Bondar O. P., Datsenko Z. M., Govseeva I. N. 1982. Hypocholesterolemic effects of phytoecdysones in rat experimental hypercholesterolemia. Voprosy meditsinskoy himii. 3: 101—105. (In Russian)

80. Matsuda H., Kawaba T., Yamamoto Y., Ogawa S. 1974. Effects of ecdysterone on experimental atherosclerosis in rabbits. Nippon Yakurigaku Zasshi. 70 (3): 325—339.

81. Esenbaeva V. Z. 1989. Effect of ecdysterone on the lipid composition of heart and skeletal muscle in rats. Doklady AN UzSSR. 2: 53—54. (In Russian)

82. Ji Y. H., Moog C., Schmitt G., Luu B. 1990. Polyoxygenated sterols and triterpenes: chemical structures and biological activities. J. Steroid Biochem. 35 (6): 741—744.

83. Esenbaeva V. Z. 1991. Deystvie ekdisterona na metabolizm fosfolipidov v serdechnoy i skeletnoy myshtsakh: Avtoref. dis. ... kand. biol. nauk [Action of ecdysterone on the phospholipid metabolism in the cardiaction and skeletal muscles: Author's abstract of PhD (Biology) Dissertation]. Tashkent. 24 p. (In Russian)

84. Plotnikov M. B., Aliev O. I., Vasilev A. S., Andreeva V. Yu., Krasnov E. A., Kalinkina G. I. 2008. Effect of *Rhaponticum carthamoides* extract on structural and metabolic parameters of erythrocytes in rats with cerebral ischemia. Byulleten eksperimentalnoy biologii i meditsiny. 7: 50—53. (In Russian)

85. Seyfulla R. D., Vaysberg M. A., Syrov V. N. 1986. Effect of ratibol on the blood coagulation system. Farmakologiya i toksikologiya. 49 (4): 40—42. (In Russian)

86. Kolkhir V. K., Sokolov S. J. 1986. Anticoagulant properties of *Leuzea carthamoides*. New drugs from plants of Siberia and the Far East (Abstr. Proc. Conf.). Tomsk. P. 81. (In Russian)

87. Azizov A. P. 1997. The effect of eleutherococcus, elton, leuzea, and levton on the blood coagulation system in physical exertion of athletes. Eksperimentalnaya i klinicheskaya farmakologiya. 60 (5): 58—60. (In Russian)

88. Plotnikova T. M., Aliev O. I., Fedina O. A., Vasilev A. S. 2001. Antiplatelet effects *Lychnis chalcedonica* L. extract in rats with different models of the pathology of the cardiovascular system. Aktualnye problemy eksperimentalnoy i klinicheskoy farmakologii. Tomsk. P. 116—118. (In Russian)

89. Saratikov A. S. 1966. Some results of the research and study of central nervous system stimulants herbal. Stimulyatory tsentralnoy nervnoy sistemy. Tomsk. P. 3—23. (In Russian)

90. Tuzov S. F. 1968. Comparative characteristic of some certain central nervous system stimulants on muscular human performance. Stimulyatoryi tsentralnoy nervnoy sistemy. Tomsk. P. 156—161 (In Russian)

91. Salnik B. Yu., Saratikov A. S. 1969. The influence of some CNS stimulants for energy supply of muscle activity. Farmakologiya dvigatelnoy aktivnosti. Moscow. P. 51—58. (In Russian)

92. Syrov V. N., Shahmurova G. A., Khushbaktova Z. A. 2008. Effects of phytoecdysteroids and bemithyl on functional, metabolic, and immunobiological parameters of working capacity in experimental animals. Eksperimentalnya i klinicheskaya farmakologiya. 71 (5): 40—43. (In Russian)

93. Salnik B. Yu. 1966. Deystvie ekstraktov eleuterokokka i levzei na uglevodno-fosfornyy i okislitelnyy obmen pri dozirovannoy myshechnoy nagruzke [The effect of extracts from Eleutherococcus and Rhaponticum on carbohydrate-phosphate and oxidative metabolism in dosed muscular load]. Stimulyatory tsentralnoy nervnoy sistemy (zhenshen, zolotoy koren, levzeya, eleuterokokk, piridrol). Tomsk. P. 44—50. (In Russian)

94. Salnik B. Yu. 1970. Vliyanie nekotorykh stimulyatorov tsentralnoy nervnoy sistemy na energeticheskoe obespechenie myshechnoy deyatelnosti razlichnoy dlitelnosti: Avtoref. diss. ... dokt. med. nauk [The influence of some central nervous system stimulants for energy supply of muscle activity of different duration: Author's abstract of Doct. Sci. (Medicine) Dissertation]. Tomsk. 48 p. (In Russian)

95. Dambueva E. A., Salnik B. Yu. 1966. Vliyanie ekstraktov eleuterokokka i levzei na nekotorye pokazateli lipidnogo obmena pri dozirovannoy fizicheskoy nagruzke [The effect of extracts of Eleutherococcus and Rhaponticum on some parameters of lipid metabolism in dosed muscular load]. Stimulyatory tsentralnoy nervnoy sistemy (zhenshen, zolotoy koren, levzeya, eleuterokokk, piridrol). Tomsk. P. 51—54. (In Russian)

96. Chermnykh N. S., Shimanovskiy N. L., Shutko G. V., Syrov V. N. 1988. Effect of methandrostenolone and ecdysterone on the physical endurance of animals and on protein metabolism in the skeletal muscles. Farmakologiya i toksikologiya. 6: 57—60. (In Russian)

97. Plotnikov M. B., Aliev O. I., Vasiliev A. S., Plotnikova A. M., Maslov M. Yu. 2006. Hemorheological and protective in exhausting load properties of extract from *Rhaponticum carthamoides*. 2nd EuroSummer School on Biorheology and Symposium on Micro Mechanobiology of Cell, Tissues and Systems. Varna. P. 64—65.

98. Vasilev A. S., Plotnikova A. M., Aliev O. I., Kalinkina G. I., Angaskieva A. S., Plotnikov M. B. 2007. Hemorheological and actoprotective activity of Serratula coronata extract in exhausting physical exercise in rats. Byulleten eksperimentalnoy biologii i meditsiny. Suppl. 1. P. 19—22. (In Russian)

99. Vasilev A. S., Plotnikov M. B., Aliev O. I., Plotnikova A. M., Kalinkina G. I., Angaskieva A. S. 2008. Hemorheological activity of the extract of the aerial parts of *Serratula coronata* (Asteractae). Rastitelnye resursy. 44 (1): 104—109. (In Russian)

100. Vasilev A. S., Aliev O. I., Plotnikov M. B., Plotnikova A. M., Krasnov E. A. 2008. The hemorheological and actoprotective activity of *Rhaponticum carthamoides* (Asteraceae) extract in rats with exhausting exercise stress. Rastitelnye resursy. 44 (4): 123—130. (In Russian)

101. Plotnikov M. B., Aliev O. I., Vasilev A. S., Maslov M. Yu., Dmitruk S. E., Krasnov E. A. 1999. Effect of extract from leuzea on rheological properties of blood. Byulleten eksperimentalnoy biologii i meditsiny. Suppl. 1. P. 58—60. (In Russian)

102. Fomovskaya G. N.,Berdyshev A. G.,Holodova Yu. D. 1992. Immunomodulatory effect of ecdysteroid. Ukrainskiy biokhimicheskiy zhurnal. 64 (2): 56—61. (In Russian)

103. Miliauskas G., van Beek T. A., de Waard P., Venskutonis R. P., Sudhölter E. J. 2005. Identification of radical scavenging compounds in *Rhaponticum carthamoides* by means of LC-DAD-SPE-NMR. J. Nat. Prod. 68 (2): 168—172.

104. Koleckar V., Opletal L., Brojerova E., Rehakova Z., Cervenka F., Kubikova K., Kuca K., Jun D., Polasek M., Kunes J., Jahodar L. 2008. Evaluation of natural antioxidants of *Leuzea carthamoides* as a result of a screening study of plant extracts from the European Asteraceae and Cichoriaceae. J. Enzyme Inhib. Med. Chem. 23 (2): 218—224.

105. Hamden K., Ayadi F., Jamoussi K., Masmoudi H., Elfeki A. 2008. The rapeutic effect of phytoecdysteroids rich extract from *Ajuga iva* on alloxan induced diabetic rats liver, kidney and pancreas. Biofactors. 33 (3): 165—175.

106. Shevchenko O. G., Zagorskaya N. G., Kudyasheva A. G., Shishkina L. N. 2007. Antiradiation properties of ecdysteroid-containing drugs. Radiatsionnaya biologiya. Radioekologiya. 47 (4): 501—508. (In Russian)

107. Plotnikov M. B., Zibareva L. N., Vasilev A. S., Aliev O. I., Maslov M. Yu. 2000. Hemorheological activity of ecdysterone and different fractions from above-ground parts of *Lychnis chalcedonica* L. *in vitro*. Rastitelnye resursy. 36 (3): 91—94. (In Russian)

108. Timofeev N. P., Lapin A. A. 2008. Vysokaya antiokislitelnaya aktivnost preparatov *Rhaponticum carthamoides* kak funktsiya zaschity zhiznenno vazhnykh organov ot faktorov abioticheskogo stressa [High antioxidant activity of Rhaponticum carthamoides drugs as a function of protecting the vital organs from factors abiotic stress. Sbornik materialov V Vserossiyskoy nauchnoy konferentsii «Khimiya i tekhnologiya rastitelnykh veschestv». Syktyvkar; Ufa. P. 280. (In Russian)

109. Maslov L. N., Guzarova N. V. 2007. Cardioprotective and antiarrhythmic properties of preparations from *Leuzea carthamoides*, *Aralia mandshurica* and *Eleutherococcus senticosus*. Eksperimentalnaya i klinicheskaya farmakologiya. 70 (6): 48—54. (In Russian)

110. Plotnikov M. B., Aliev O. I., Vasilev A. S., Maslov M. Yu., Chernyishova G. A., Krasnov E. A., Zibareva L. N. 1999. The haemorheological activity of extracts from *Lychnis chalcedonica* L. and *Rhaponticum carthamoides* (Willd). Iljin in rats with acute myocardial infarction. Rastitelnye resursy. 35 (1): 103—107.

(In Russian)

111. Plotnikov M. B., Aliev O. I., Vasilev A. S., Anishchenko A. M. 2010. Hemorheological drugs as a means for increasing the efficacy of physical exercise in normal conditions and under ischemic heart disease. In: Treadmill exercise and its effects on cardiovascular fitness, depression and muscle aerobic function. N. Y. P. 35—70.

112. Ermishina O. A., Kurmukov A. G., Salikhova R. E., Ayzikov M. I. 1982. Effect of ecdysterone on the level of enzyme in experimental myocardial infarction. Meditsinskiy zhurnal Uzbekistana. 11: 90—91. (In Russian)

113. Khushbaktova Z. A., Syrov V. N., Umarova F. T., Mirsalikhova N. T., Sultanov M. B. 1987. Changes in activity of Na, K-ATP-ase of miocardium under action of preparations of plant origin by experimental atherosclerosis. Doklady AN UzSSR. (1): 51—53. (In Russian)

114. Kurmukov A. G., Ermishina O. A. 1986. Otsenka razmera i taktika lecheniya infarkta miokarda [Evaluation of the infarct size and treatment tactic of myocardial infarction]. Tomsk. 168 p. (In Russian)

115. Plotnikov M. B., Aliev O. I., Vasilev A. S., Maslov M. Yu., Dmitruk S. E., Krasnov E. A. 2001. Effect of *Rhaponticum carthamoides* extract on hemorheological properties of blood in rats with arterial hypertension. Eksperimentalnaya i klinicheskaya farmakologiya. 64 (6): 45—47. (In Russian)

116. Tang W. H., Chen Z., Liu Z., Zhang J. H., Xi G., Feng H. 2008. The effect of ecdysterone on cerebral vasospasm following experimental subarachnoid hemorrhage *in vitro* and *in vivo*. Neurol. Res. 30 (6): 571—580.

117. Yang S. F., Yang Z. Q., Zhou Q. X., Wu Q., Huang X. N., Shi J. S. 2004. Effect of ecdysterone on the expression of c-fos in the brain of rats induced by microinjection β-AP25-35 into the hippocampus. Yao Xue Xue Bao. 39 (4): 241—214.

118. Tsujiyama S., Ujihara H., Ishihara K., Sasa M. 1995. Potentiation of GABA-induced inhibition by 20-hydroxyecdysone, a neurosteroid, in cultured rat cortical neurons. Jpn. J. Pharmacol. 68 (1): 133—136.

119. Okada M., Ishihara K., Sasa M., Izumi R., Yajin K., Harada Y. 1998. Enhancement of GABA-mediated inhibition of rat medial vestibular nucleus neurons by the neurosteroid 20-hydroxyecdysone. Acta Otolaryngol. 118 (1): 11—16.

120. Mosharrof A. H. 1987. Effect of extract from Rhaponticum carthamoides (Willd.) Iljin (Leuzea) on learning and memory in rats. Acta Physiol. Pharmacol. Bulgar. 3: 37—42.

121. Ipatov A. N. 1995. Use of decoction with Leuzea carthamoides rhizomes for depressive alcoholism. Zhurnal nevropatologii i psikhiatrii im. S. S. Korsakova. 4: 78—79. (In Russian)

122. Hanaya R., Sasa M., Ishihara K., Akimitsu T., Iida K., Amano T., Serikawa T., Arita K., Kurisu K. 1997. Antiepileptic effects of 20-hydroxyecdysone on convulsive seizures in spontaneously epileptic rats / Jpn. J. Pharmacol. 74 (4): 331—335.

123. Plotnikov M. B., Logvinov S. V., Pugachenko N. V., Maslov M. Yu., Aliev O. I., Vasilev A. S., Suslov N. I., Potapov A. V. 2005. Cerebroprotector activity of *Rhaponticum carthamoides* extract in rats with brain ischemia. Eksperimentalnaya i klinicheskaya farmakologiya. 68 (4): 19—23. (In Russian)

124. Plotnikov M. B., Aliev O. I., Vasilev A. S., Maslov M. Yu., Suslov N. I., Zibareva L. N. 2005. Hemorheological and cerebroprotective activity of *Lychnis chalcedonica* L. extract in rats with cerebral ischemia. Byulleten eksperimentalnoy biologii i meditsiny. 139 (1): 68—71. (In Russian)

125. Syrov V. N., Khushbaktova Z. A., Nabiev A. N. 1992. Experimental study of hepatoprotective properties phytoecdysteroids and nerobol with lesions of the liver with carbon tetrachloride. Eksperimentalnaya i klinicheskaya farmakologiya. 55 (3): 61—65. (In Russian)

126. Syrov V. N., Nabiev A. N., Sultanov M. B. 1986. The effect of phytoecdysteroids on the bile secretion function of the liver in normal rats and in animals with experimental hepatitis. Farmakologiya i toksikologiya. 3: 100—103. (In Russian)

127. Shirshova T. I., Politova N. K., Burtseva S. A., Beshley I. V., Volodin V. V. 2006. Antimicrobial activity of natural ecdysteroids from *Serratula coronata* L. and their acyl derivatives. Khimiko-farmatsevticheskiy zhurnal. 40 (5): 34—36. (In Russian)

128. Syrov V. N., Khushbaktova Z. A. 2001. Experimental study of pharmacotherapeutic effect of phytoecdisteroids and nerobol in toxic liver damage. Eksperimentalnaya i klinicheskaya farmakologiya. 64 (4): 66—58. (In Russian)

129. Gao L., Cai G., Shi X. 2008. β-Ecdysterone induces osteogenic differentiation in mouse mesenchymal stem cells and relieves osteoporosis. Biol. Pharm. Bull. 31 (12): 2245—2249.

130. Kholodova Yu. D., Tugay V. A., Zimina V. P. 1997. Effect of vitamin D3 and 20-hydroxyecdysone on the content of ATP, creatine phosphate, carnosine, and Ca2+ in skeletal muscles. Ukrainskiy biokhimicheskiy zhurnal. 69 (3): 3—9. (In Russian)

131. Akhmed I. 1993. Fitoekdisteroidy serpuhi nevooruzhennoy (Serratula inermis) i ikh vliyanie na biosintez nukleotidov i nukleinovykh kislot v tkanyakh tsyiplyat s razlichnoy obespechennostyu vitaminom D3: Avtoref. diss. ... kand. biol. nauk [The phytoecdysteroids of Serratula inermis and their influence on the biosynthesis of nucleotides and nucleic acids in tissues of chickens with different availability of vitamin D3: Author's abstract of PhD (Biology) Dissertation]. Kiev. 27 p. (In Russian)

132. Nsimba R. Y., Kikuzaki H., Konishi Y. 2008. Ecdysteroids act as inhibitors of calf skin collagenase and oxidative stress. J. Biochem. Mol. Toxicol. 22 (4): 240—250.

133. Kucharova S., Farkas R. 2002.Hormone nuclear receptors and their ligands: role in programmed cell death (review). Endocr. Regul. 36 (1): 37—60.

134. Wu X., Wang W. J. 2003. Protective effect of ecdysterone against sodium arsenite-induced endothelial cell apoptosis. Di Yi Jun Yi Da Xue Xue Bao. 23 (11): 1219—1221.

135. Cai Y. J., Dai J. Q., Fang J. G., Ma L. P., Hou L. F., Yang L., Liu Z. L. 2002. Antioxidative and free radical scavenging effects of ecdysteroids from *Serratula strangulata*. Can. J. Physiol. Pharmacol. 80 (12): 1187—1194.

136. Darmogray V. N., Petrov V. K., Gordleev V. A., Ukhov Yu. I. 2001. Preventive and therapeutic effect of phytoecdysteroids in induced anemia and leucopenia. VIII Ros. nats. kongr. «Chelovek i lekarstvo». Moscow. P. 315—316. (In Russian)

137. Trenin D. S., Volodin V. V. 1999. 20-Hydroxyecdysone as a human lymphocyte and neutrophil modulator: In vitro evaluation. Arch. Insect. Biochem. Physiol. 41 (3): 156—161.

138. Azizov A. P., Seyfulla R. D., Chubarova A. V. 1997. Effect of leuzea tincture and leveton on humoral immunity of athletes. Eksperimentalnaya i klinicheskaya farmakologiya. 60 (6): 47—48. (In Russian)

139. Harmantha J., Vokáč K., Kmoničková E., Zidek Z. 2008. Lack of interference of common phytoecdysteroids with production of nitric oxide by immune-activated mammalian macrophages. Steroids. 73: 466—471.

140. Sakhibov A. D., Syrov V. N., Usmanova A. S., Abakumova O. Yu. 1989. Experimental analysis of the immunotropic action of phytoecdysteroids. Doklady AN Uzbekskoy SSR. P. 55—57. (In Russian)

141. Kuzmitskiy B. B., Golubeva M. B., Konoplya N. A., Kovganko N. V., Ahrem A. A. 1990. New prospects in searching for immunomodulators among steroid structure compounds. Farmakologiya i toksikologiya. 53 (3): 20—22. (In Russian)

142. Sergeev P. V., Semeykin A. V., Dukhanin A. S., Soloveva E. V. 1991. Effects of anabolic steroids on the proliferative activity of thymocytes. Byulleten eksperimentalnoy biologii i meditsiny. 112 (10): 393—395. (In Russian)

143. Takei M., Endo K., Nishimoto N., Shiobara Y., Inoue S., Matsuo S. 1991. Effect of ecdysterone on histamine release from rat peritoneal mast cells. J. Pharm. Sci. 80 (4): 309—310.

144. Semeykin A. V., Stanevskaya T. Yu., Chermnyikh N. S., Sergeev P. V. 1991. The mechanism of the thymolytic action of anabolic steroids. Farmakologiya i toksikologiya. 54 (4): 37—38. (In Russian)

145. Bocharova O. A. 1999. Adaptogens as agents of preventive oncology. Vestnik Rossiyskoy akademii meditsinskikh nauk. 5: 49—53. (In Russian)

146. Konovalova N. P., Mitrokhin Yu. I., Volkova L. M., Sidorenko L. I., Todorov I. N. 2002. Ecdysterone modulates antitumor activity of cytostatics and biosynthesis of macromolecules in tumor-bearing animals. Izvestiya RAN. Ser. biol. 6: 650—658. (In Russian)

147. Chabannyy V. N., Levitskiy E. L., Gubskiy Yu. I., Kholodova Yu. D., Vistunova I. E., Vudmaska M. I. 1994. Genoprotective effect of ecdysteroid-based preparations in case of poisoning of rats by tetrachloromethane and chlorophos. Ukrainskiy biokhimicheskiy zhurnal. 66 (5): 67—77. (In Russian)

148. Kotsyuruba A. V., Akhmed I., Tarakanov S. S., Kholodova Yu. D. 1992. Effect of ecdysterone on the metabolism of purine and pyrimidine nucleotides in chicken tissues. Ukrainskiy biokhimicheskiy zhurnal. 5: 52—60. (In Russian)

149. Ogawa S., Nishimoto N., Matsuda H. 1974. Pharmacology of ecdysones in vertebrates. In: Invertebrate endocrinology and hormonal heterophylly. Berlin. P. 341—344.