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The Genus *Chenopodium*: Phytochemistry, Ethnopharmacology and Pharmacology

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ABSTRACT

The review includes 154 references on the genus *Chenopodium* covered up to December 2008 and has been compiled using references mainly from Chemical Abstracts and Pubmed. This article briefly reviews the phytochemistry, ethnopharmacology and pharmacology of *Chenopodium* genus. Three hundred seventy nine compounds isolated from different species are reported. Fenolics, flavonoids, saponins, ecdysteroids and triterpenoids were the major classes of phytoconstituents of this genus. The detailed distribution of these compounds among the different *Chenopodium* species with the related references is given in tables. In addition, this review discusses the traditional medicinal uses of different *Chenopodium* species as well as recent developments done in this aspect.

KEYWORDS: *Chenopodium*, chemical constituents, folk medicine, pharmacology

ABBREVIATIONS

WHO, world health organization; EtOH, ethanol; H_2O, water; MeOH, methanol; GC-MS, gas chromatography-mass spectrometry; ED_{50}, effective dose; BALB/c, an albino, laboratory-bred strain of the house mouse; CCRF-CEM, human acute lymphoblastic leukemia; MDA-MB-231, human breast cancer; HL60, human promyelocytic leukemia; i.p., intra peritoneal; PSA, prostate-specific antigen; DPPH, 2,2-diphenyl-1-picrylhydrazyl; TEAC, trolox equivalent antioxidant capacity; ABTS, 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid); FRAP, ferric reducing antioxidant power; AP, antioxidative power; ESR**,** electron spin resonance; AU, antioxidative units; CpG, cytosine and guanine separated by a phosphate; IgG2a/IgG1, immunoglobulin G2a/immunoglobulin G1; IFN-γ**,** interferon-gamma; IL-10, interleukin 10; $CHCl_3$, chloroform; Et_2O, diethyl ether; H_2SO_4, sulfuric acid; 5-HT, 5-hydroxytryptamine (serotonin); SDS-PAGE ISTA, International Seed Testing Association approved sodium dodecyl sulfate polyacrylamide gel electrophoresis; s.c., subcutaneous; p.o., oral; b. wt, body weigth.

INTRODUCTION

According to the WHO, about three-quarters of the world population relies upon traditional remedies (mainly herbs) for the health care of its people. In fact, plants are the oldest friends of mankind. They not only provided food and shelter but also served the humanity to cure different ailments (1).

The family Chenopodiaceae is a large family comprising about 102 genera and 1400 species (2). The genus *Chenopodium* includes varieties of weedy herbs (more than 200 species) native to Europe, Asia, and both North and South America (3). Many of these possess therapeutic and edible properties. However, at present, the medicinal uses of *Chenopodium* are not widely known.

The review includes 154 references on the genus *Chenopodium* and has been compiled using mainly Chemical Abstracts and Pubmed. The article briefly reviews the phytochemistry, ethnopharmacology and pharmacology. Three hundred seventy nine compounds of diverse chemical nature (fenolics, saponins, ecdysteroids, triterpenoids, etc.) isolated from different species were included. The detailed distribution of these compounds among the different species of *Chenopodium* is shown in the Tables 1 and 2. A wide range of applications in folk medicine as well as pharmacological activities of chenopods (antimicrobial, antiviral, antifungal, anthelmintic, antioxidant, trypanocidal, antineoplastic, immunomodulatory, etc.) appeared in the literature have been discussed as well.

The authors hope to attract the attention of the scientific community on the unexplored potential of the *Chenopodium* species so that potential species can be exploited as therapeutic agents.

PHYTOCHEMISTRY

The widespread uses of *Chenopodium* genus in traditional medicine have resulted in considerable chemical analysis of the plants and their active principles. The phytochemical investigations of genus *Chenopodium* have afforded compounds with vast variety of structural patterns. From the phytochemical point of view, the chenopods were reported to contain: minerals, primary metabolites- carbohydrates, amino acids, nonpolar constituents, proteins, aromatic cytokinins, hormones (Table 1) and secondary metabolites- flavonoids, saponins, terpenes, sterols, alkaloids and vitamins. A detailed distribution of later classes of metabolites in *Chenopodium* species were shown in Table 2.

Secondary metabolites

Organic acids

The content of oxalic acid in *C. album* is with a range of values from 360 to 2000 mg/100g (19). Oxalic, malic and succinic acids were identified in the EtOH and H_2O-EtOH extracts of *C. ambrosioides* (10).

Phenolics

Phenol derivatives-alcohols, aldexydes and glycosides

Table 1: Primary metabolites

Plant	Primary metabolites
C. album	**Pentoses and methylpentoses**-ribosa (4);
	Amino acids- glutamic acid (4), alanine (4), asparagine (4), lysine (4);
	Nonpolar constituents- n-tetradecane (5), n-pentadecane (5), n-hexadecane (5), n-heptadecane (5), 2,6-dimethylheptadecane (5) 2,6,10,14-tetramethyl-heptadecane (5), n-octadecane (5), 2-methyloctadecane (5), palmitic acid (5), methyl palmitate (5), ethyl palmitate (5), stearic acid (5), methyl stearate (5), linoleic acid (5, 6), methyl linoleate (5), methyl linolenate (5), oleic acid (6), n-eicosane (5), n-heneicosane (5), 9Z,12Z-octadecadien-1-ol (5), n-octacosane (5), n-octacosanal (7), octacosanyl acetate (7), n-nonacosane (5, 7), n-pentatriacontane (5), n-tetracontane (5), n-hexadecanal (5), n-octadecanal (5), n-tritetracontane (5);
C. acuminatum	**Amino acids**- aspartic acid (8), glutamic acid (8), glycine (8), phenylalanine (8), serine (8), valine (8), isoleucine (8), threonine (8), tyrosine (8), cystine (8);
C. amaranticolor	**Proteins**- hemagglutinin (9);
C. ambrosioides	**Hexoses**- glucose (10);
	Amino acids- alanine (11), glycine (11), valine (11), leucine (11);
C. murale	**Pentoses и methylpentoses**- rhamnose (12), arabinose (12), xylose (12); **Hexoses**- glucose (12), fructose (12), galactose (12);
	Uronic acids- galacturonic acid (12);
	Disaccharides- saccharose (12), cellobiose (12); **Trisaccharides**- rhafinose (12);
C. quinoa	**Hexoses**-glucose (13)-, fructose (13);
	Disaccharides- saccharose (13);
	Amino acids- aspartic acid (13), glutamic acid (13), alanine (13), asparagine (13), glycine (13), phenylalanine (13), serine (13), valine (13), lysine (13), leucine (13), isoleucine (13), threonine (13), tyrosine (13), cystine (13), methionine (13), glutamine (13), histidine (13), arginine (13), proline (13);
	Proteins- chenopodin (14), albumin (15), globulin (15);
C. rubrum	**Aromatic cytokinins**- 6-[2-(β-D-glucopyranosyloxy)benzylamino]purine (16), 6-[2-(β-D-glucopyranosyloxy)benzylamino]-2-methylthiopurine (16), 6-benzylamino-9-β-D- glucopyranosylpurine (16);
	Hormones- melatonin (17, 18);

Analysis of the aqueous solution of the hydro-alcoholic extract from the twigs of *C. album* after acetone precipitation, led to the isolation of 4-vinyl phenol **1** (20). Resorcinol **2** and 4-methyl resorcinol **3** were tentatively identified as being the principal phenolic compounds of *C. pallidicaule* (21). The analysis of the aqueous solution of the hydro-alcoholic extract from the leaves of *C. album* after acetone precipitation, led to the isolation of **4**, vanillic alcohol **5** and 4-methyl benzaldehyde **6** (20). Vanillic acid **7** was identified in *C. pallidicaule* (canihua) and its amount was higher than that in oats, sorghum, barley, wheat and purple corn, suggesting that canihua is an important source of this phenolic acid (21). Previously, vanillic acid glucosyl ester **8** was found in the seeds of *C. quinoa* (22). Cell-suspension cultures of *C. rubrum* accumulate various soluble secondary phenolic metabolites such as glycosides **9** and **10** (23). A new phenolic glycoside, named chenoalbuside **11** was isolated from the methanol extract of the seeds of *C. album* (24). Cinnamic acid **12**, sinapic acid **14**, ferulic acid **16** and their derivatives **13** and methyl ferulate **17** were isolated from the leaves of *C. album* (20). Ferulic acid **16** was also reported for *C. pallidicaule* (21). The hydroxycinnamic acylglycosides **15** and **18-20** were isolated from the cell-suspension cultures of *C. rubrum* (23). In addition, Strack *et al.* isolated **18** and **20** from the cell-suspension cultures of *C. rubrum* (25). New hydroxycinnamic acid esters **19** and **21** were also isolated from the cell suspension cultures of *C. rubrum* (26). The structures **1-21** are shown in Figure 1.

Table 2: Secondary metabolites

Plant	Compounds	Secondary metabolites (References)
1. *C. album*	Phenols	**1** (20), **4-6** (20), **12-14** (20), **16-17** (20), **11** (24), **22-28** (20), **38** (33), **39** (33-35), **44-45** (33), **47** (34, 36), **55** (35), **57-58** (34), **61** (33), **62** (34, 35), **63** (35, 42), **64** (33), **65** (34), **67** (35), **71** (35), **74** (34)
	Sterols	**88** (45, 47), **90** (45), **91** (45, 47), **95** (45), **97-98** (45, 47), **100** (45), **101** (24, 50-52), **102-103** (51), **107** (24), **111** (24, 50), **113** (50, 52, 57), **114-115** (51)
	Terpens	**123** (59), **125** (59), **131** (59), **155** (59), **171-172** (59), **174** (59), **204** (78), **206** (78), **222-239** (80)
	Saponins	**253-254** (95), **257** (95)
	Amids	**294** (101), **295** (101, 102), **296-299** (101), **301** (103), **302** (101), **304** (100)
	Vitamins	**305** (105), **307** (4, 105-108), **306** (4), **308-309** (4)
2. *C. ambrosioides*	Phenols	**37** (31), **38** (32), **42** (41), **43a-43d** (41), **47** (36), **48-49** (32), **61** (30, 32), **75** (32)
	Sterols	**96-98** (45)
	Terpens	**116** (58, 59), **117-118** (58), **119** (60), **120** (61), **121-122** (58), **123** (58-60, 62, 109-113), **124** (58-61, 63, 68, 72, 109-117), **125** (58, 59, 109, 112, 113), **126** (112, 113), **127** (58), **128** (63), **131** (58-61, 63, 72, 67-69, 110-113, 115-117), **132** (63), **133** (60, 63, 67, 110), **134** (59, 60, 110), **135** (60), **137** (62), **138** (63), **142-143** (58), **144** (65), **147** (65), **148** (60), **149** (59, 61), **150** (63), **151** (67), **153-154** (63), **155** (59, 68, 69), **156-159** (70), **160** (71), **161** (63, 67, 70, 71, 109-121), **162** (67, 110, 111), **163** (59), **164** (58), **165** (117), **166** (59, 117), **167** (58), **168** (67), **169** (59), **170** (67, 72), **171** (59, 61), **174** (61), **175** (65), **176** (67), **180-181** (58), **220-221** (79)
3.*C. bonus-henricus*	Sterols	**101** (53)**, 106** (53), **113** (53)
	Vitamins	**307** (106)
4. *C. botrys*	Phenols	**30** (28), **31-34** (29), **35** (29, 30), **36** (30), **61** (30), **62** (28), **67** (28)
	Terpens	**116** (59), **123-125** (59), **131** (64, 59), **133-134** (59), **136** (59), **139** (64), **155** (59), **162** (64), **171** (59), **173** (59), **177** (73, 74), **178** (74), **179-180** (59), **182** (75), **183** (74), **184** (76), **185** (73), **186** (59), **187** (77), **188** (76), **190** (74), **191** (77), **192** (74), **193** (77), **194** (74), **195** (77), **196** (75), **197-198** (74), **199** (74, 76, 77), **200** (76, 77), **201** (76), **202** (74, 76, 77), **203** (76), **205** (76), **207-218** (76)
	Amides	**303** (104)
5. *C. chilense*	Terpens	**131** (122), **161** (122)
6. *C. ficifolium*	Phenols	**47** (36)
	Sterols	**88-89** (48), **92** (48)
	Terpens	**124-125** (59), **130-131** (59), **133** (59), **140** (59), **155** (59), **163** (59), **169** (59)
	Saponins	**250** (48), **257** (48), **263** (48)
7. *C. foliosum*	Terpens	**123-125** (59), **129** (59), **131** (59), **133-134** (59), **140-141** (59), **155** (59), **171-174** (59), **180** (59)
8. *C. hybridum*	Phenols	**61** (30)
9. *C. hircinum*	Phenols	**40** (42), **63** (42)
10. *C. leptophyllum*	Sterols	**88** (45), **91** (45), **95-96** (45), **98** (45)

11. *C. missouriense*	Terpens	**123-124** (59), **131** (59), **140** (59), **155** (59), **163** (59)
12. *C. multifidum*	Sterols	**93-94** (49), **99** (49)
	Terpens	**131** (66), **145**-**146** (66), **152** (66), **169** (66), **219** (49)
13. *C. murale*	Phenols	**29** (27), **38** (27, 34), **42** (27), **47** (27, 34, 36), **50** (27), **56** (34, 37), **57-58** (34, 37), **59** (34), **60** (27), **61** (27, 30), **62** (34), **63** (34), **80-81** (43), **82** (27)
	Sterols	**89** (43), **92** (43)
	Terpens	**116** (59), **123-125** (59), **131** (59), **136** (59), **149** (59), **155** (59), **171**-**172** (59)
	Alkaloids	**284** (96)
14. *C. opulifolium*	Phenols	**39** (33), **62** (33)
	Terpens	**116** (59), **124-125** (59), **131** (59), **171-174** (59)
15. *C. pallidicaule*	Phenols	**2-3** (21), **7** (21), **16** (21), **38** (21), **46** (38), **61** (21), **63** (38), **66** (38), **68-69** (38), **72** (38), **76-79** (38), **86-87** (21)
	Sterols	**101** (54), **107** (54)
	Saponins	**242** (91)**, 258** (91), **260** (91), **262** (91), **266** (91), **269** (91), **273** (91)
16. *C. polyspermum*	Terpens	**116** (59), **123-125** (59), **130-131** (59), **141** (59), **169** (59)
17. *C. procerum*	Phenols	**83-85** (44)
18. *C. rubrum*	Phenols	**9**-**10** (23), **15** (23), **18** (23, 25), **19** (23, 26), **20** (23, 25), **21** (26)
	Sterols	**88** (46)**, 91** (46)**, 95** (46), **96**-**98** (45)
	Terpens	**123** (59), **124-125** (59), **155** (59), **169** (59), **179**-**180** (59), **186** (59)
	Alkaloids	**285**-**286** (97), **291-292** (23, 97), **293** (23, 97, 99)
	Amides	**300** (23)
19. *C. quinoa*	Phenols	**8** (22), **41** (22), **51-52** (40), **53-54** (22, 39, 40), **61** (30), **70** (22, 40), **72** (40), **73** (22), **75** (30)
	Sterols	**101** (13, 55), **104-106** (55), **107** (55), **108-110** (56), **112** (13)
	Terpens	**124-125** (59), **129** (59), **131** (59), **136** (59), **141** (59), **149** (59), **155** (59), **172-174** (59), **180** (59)
	Saponins	**240** (81-83), **241** (88), **243** (86), **244** (89), **245** (84, 86-89, 92), **246** (84, 92), **247** (82, 92), **248** (82), **249** (85), **250** (81-83), **251-252** (94), **253** (88), **255** (94), **256** (82, 92, 94), **257** (82, 87, 89, 92), **259** (82, 88, 92), **260** (87, 90), **261** (87, 90, 92), **264** (81-83), **265** (88, 89), **267** (84, 88, 89, 92), **268** (84, 87-89, 92, 90), **270** (86, 87, 90), **271** (84, 92), **272** (82, 88, 90, 92), **273** (86, 92), **274** (90), **275** (82, 83), **276** (92), **277** (92), **278** (87, 88, 92), **279** (86), **280** (82, 86, 88, 92), **281** (92, 93), **282-283** (92)
	Amides	**303** (98)
	Alkaloids	**287**-**290** (98)
20. *C. urbicum*	Sterols	**88** (45), **91** (45), **95-98** (45)
	Terpens	**123-125** (59), **129-131** (59), **140-141** (59), **149** (59), **163** (59), **169** (59), **171**-**173** (59), **179**-**180** (59)
21. *C. vulvaria*	Terpens	**124-125** (59), **155** (59), **163** (59), **171**-**172** (59)

Lignans

The analysis of the aqueous solution of the hydro-alcoholic extract from the leaves of *C. album* after acetone precipitation, led to the isolation of 7 lignans: pinoresinol **22**, syringaresinol **23**, lariciresinol **24** its derivative compound **25** and three sesquilignans **26**-**28** (20). Compounds **27** and **28** were new

natural products. The structures **22-28** are shown in Figure 2.

Coumarins

One coumarin scopoletin **29** was isolated from the aerial parts of *C. murale* (27). The structure is shown in Figure 2.

Flavons

Rustembekova *et al.* reported the occurence of the flavon chrysoeriol **30** in the methanolic extract from the aerial parts of *C. botrys*. The compound was not previously found in any representatives of *Chenopodium* (28). From *C. botrys* have been isolated 5 flavons: salvigenin **31**, sinensetin **34**, hispidulin **35** and their derivatives **32** and **33**. None of them have been previously reported for *C. botrys* (29). Bahrman *et al.* investigated 5 species of *Chenopodium*: *C. ambrosioides*, *C. botrys*, *C. hybridum*, *C. murale* and *C. quinoa*. The flavons hispidulin **35** and jaclosidin **36** were found only in *C. botrys* (30). Kamil *et al.* isolated a novel flavon glycoside **37** from the fruits of *C. ambrosioides* (31). The structures **30-37** are shown in Figure 3.

Flavonol and their glycosides

Kaempferol **38**, quercetin **61**, isorhamnetin **75** and herbacetin **82** and their glycosides were the only flavonols isolated from *Chenopodium* species. Quercetin **61** was found in 7, kaempferol **38** in 5, isorhamnetin **75** in 2 and herbacetin **82** in 1 species. Kaempferol **38** was encountered in *C. ambrosioides* (32), in the aerial parts of *C. album* (33) and *C. murale* (27, 34) as well as in *C. pallidicaule* (21). The occurrence of quercetin **61** in the aerial parts and fruits of *C. ambrosioides* (30, 32) as well as in the aerial parts of *C. album* (33), *C. botrys* (30), *C. hybridum* (30), *C. murale* (27, 30), *C. pallidicaule* (21) and *C. quinoa* (30) was reported. Isorhamnetin **75** was found in the fruits of *C. ambrosioides* (32) and *C. quinoa* (30). The aerial part of *C. murale* also produced herbacetin **82** (27). The structures are shown in Figure 3.

The group of kaempferol glycosides **39-60** includes mono, di and triglycosides. These were found in the aerial parts of *C. album* (33-36), *C. ambrosioides* (36), *C. ficifolium* (36), *C. murale* (27, 34, 36, 37), *C. opulifolium* (33) as well as in the seeds of *C. pallidicaule* (38), *C. quinoa* (22, 39, 40), in the fruits (32) and leaves (41) of *C. ambrosioides* and in the leaves of *C. hircinum* (42). Arisawa and co-workers isolated a kaemferol triglycoside named ambroside from the leaves of *C. ambrosioides* and four variants **43a**-**43d** of its structure were suggested (41). The structures **39-60** are shown in Figure 3.

Quercetin glycosides **62**-**74** were found in 7 species of *Chenopodium*. These were isolated from the aerial parts of *C. album* (33-35), *C. botrys* (28), *C. murale* (34) and *C. opulifolium* (33), seeds of *C. pallidicaule* (38) and *C. quinoa* (40) as well as from the leaves of *C. album* and *C. hirsutum* (42). Four flavonol glycosides **76-79** of isorhamnetin **75** were isolated from the seeds of *C. pallidicaule*, of which **79** was a new natural product (38). Phytochemical evaluation of the whole plant of *C. murale* revealed the presence of two flavonols: **80** and **81**. These compounds were known, but isolated for the first time from this plant species (43). The structures **62-81** are shown in Figure 3.

Flavanones and isoflavones

The flavanone dihydrowogonin **83** as well as the isoflavones irilin A **84** and irilin B **85** were isolated from the dichloromethane extract of the aerial parts of *C. procerum* (44). The structures **83-85** are shown in Figure 3.

Catechins

Penarrieta *et al.* reported the presence of catechin **86** in the water-soluble extract from *C. pallidicaule*, while catechin gallate **87** was encountered in the water-insoluble extract from this plant (21). The structures of the reported catechins are shown in Figure 3.

Sterols

Phytosterols

The occurrence of sitosterol **88** was encountered in the leaves and stems of *C. album*, *C. urbicum* and *C. leptophyllum* (45). This compound was also found in cell the cultures of *C. rubrum* (46) and *C. album* (47). Sitosterol **88** and its glucoside **89** were isolated from the aerial parts of *C. ficifolium* (48). The later compound was also found in *C. murale* (43). Sitostanol **90** was isolated from the leaves and stems of *C. album* (45), while campesterol **95** was found in *C. album*, *C. urbicum, C. leptophyllum* (45) and in the cell cultures of *C. rubrum* (46), respectively. Stigmasterol **91** was found to be a constituent of 4 species namely *C. album* (45, 47), *C. leptophyllum* (45), *C. rubrum* (46) and *C. urbicum* (45). The roots of *C. ficifolium* (48) and the aerial parts of *C. murale* (43) contain a stigmasterol glucoside **92**. Stigmasterol derivatives **93** and **94** were found in the aerial parts of *C. multifidum* (49). Phytochemical investigation of the leaves and stems of *C. ambrosioides*, *C. rubrum* and *C. urbicum* revealed the presence of avenasterol **96** and spinasterol **97** (45). These compounds were also found in the leaves and stems of *C. leptophyllum* and *C. album,* respectively (45). A spinasterol derivative **98** was found to be a constituent of *C. ambrosioides*, *C. album*, *C. rubrum*, *C. urbicum* and *C. leptophyllum* (45). Corio-Costet and co-workers established the presence of two phytosterols **97** and **98** in the cell cultures of *C. album* (47). The compound **99** was shown to be the major sterol in *C. multifidum* (49). The structures **88-99** are shown in Figure 4.

Zoosterols

The group of zoosterols includes cholesterol **100**. Cholesterol **100** was identified in the leaves and stems of *C. album* (45). The structure is shown in Figure 4.

Ecdysteroids

20-hydroxyecdysone **101** was found in four species: in the aerial parts (50), seeds (24), leaves (51) and roots (52) of *C. album*, in the roots of *C. bonus-henricus* (53), as well as in the seeds of *C. pallidicaule* (54) and *C. quinoa* (13, 55). The occurrence of its 20,22- and 2,3- monoacetonides compounds **102** and **103**, respectively were reported for the leaves of *C. album* (51). The group of ecdysteroids includes makisterone A **104** and its derivatives **105** and **106**. These were reported in the seeds of *C. quinoa* (55). The presence of compound **106** was also established in the roots of *C. bonus-henricus* (53). Compound **107** is a constituent in the seeds of *C. album* (24), *C. pallidicaule* (54) and *C. quinoa* (55). Three new ecdysteroids **108**-**110** (56) and kancollosterone **112** (13) were isolated from the seeds of *C. quinoa*. Polypodine B **113** was isolated from the roots (52) and the whole plant (50, 57) of *C. album* and from the roots of *C. bonus-henricus* (53). Phytochemical investigation of the leaves of *C. album* revealed the presence of poststerone

114 and a new ecdysteroid **115** (51). *C. album* also contains compound **111** (24, 50). The structures **101-115** are shown in Figure 4.

Terpenoids

Monoterpenoids

Acyclic monoterpenoids - hydrocarbones monoterpenoids and alcohols

Three acyclic hydrocarbone monoterpenoids *β*-myrcene **116**, *cis*-*β*-ocimene **117** and its *trans* isomer **118** were isolated from the essential oil of the leaves of *C. ambrosioides* (58). In addition, *β*-myrcene **116** was found also in other *Chenopodium* species, namely *C. botrys*, *C. murale*, *C. opulifolium* and *C. polyspermum* (59). Two alcohols nerol **119** (60) and geraniol **120** (61) were reported in the oil of *C. ambrosioides*. Citronellyl acetate **121** and compound **122** were isolated from the essential oil of the leaves of *C. ambrosioides* (58). The structures **116-122** are shown in Figure 5.

Monocyclic monoterpenoids - hydrocarbones and aromatic monoterpenoids, alcohols, ketones, acetates, hydroperoxides and peroxides.

This group of monocyclic hydrocarbone monoterpenoids includes – limonene **123**, *a*-terpinene **124** and its *γ*-isomer **125**, *a*-terpinolen **126**, *β*-phellandrene **127** and three related derivatives **128- 130** that were found in different species- *C. album*, *C. ambrosioides*, *C. botrys*, *C. ficifolium*, *C. foliosum*, *C. missouriense*, *C. murale*, *C. opulifolium*, *C. polyspermum*, *C. quinoa*, *C. rubrum*, *C. urbicum* and *C. vulvaria*. Aromatic monoterpenoid *p*-cymene **131** was discovered in 13 species- *C. album*, *C. ambrosioides*, *C. botrys*, *C. chilense*, *C. ficifolium*, *C. foliosum*, *C. missouriense*, *C. multifidum*, *C. murale*, *C. opulifolium*, *C. polyspermum*, *C. quinoa* and *C. urbicum* while its derivative **132** only in one - *C. ambrosioides*. Carvacrol **133** was detected in four: *C. ambrosioides*, *C. botrys* , *C. ficifolium*, *C. foliosum* while thymol **134** was present in three: *C. ambrosioides*, *C. botrys* and *C. foliosum*. Phytochemical investigation of *C. murale* and *C. quinoa* led to the isolation of *trans*-carveol **136** (59). This compound was also reported for *C. botrys* (59). *C. ambrosioides* contains *trans*-pinocarveol **137** (62) and *a*-terpineol **138** (63) while *γ*- terpineol **139** was reported for *C. botrys* (64). The compound **140** was identified in *C. ficifolium*, *C. foliosum*, *C. missouriense*, *C. urbicum* while the compound **141** was found in *C. foliosum*, *C. polyspermum*, *C. quinoa*, *C. urbicum* (59). Four related derivatives were isolated from *C. ambrosioides*- **142, 143** (58), **144** (65), **147** (65) and from *C. multifidum* compounds **145** and **146** (66). Carvone **148** (60) and pinocarvone **149** (59, 61) were isolated from *C. ambrosioides*. Compound **149** was also identified in three species- *C. murale*, *C. quinoa* and *C. urbicum* (59). In addition, the presence of piperitone **150** (63) and its acetates **151** (67), **153**, **154** (63) and **155** (59, 68, 69) were reported for *C. ambrosioides***.** The later compound **155** was also found in *C. album*, *C. botrys*, *C. ficifolium*, *C. foliosum, C. missouriense, C. murale, C. rubrum*, *C. vulvaria* and *C. quinoa* (59). The presence of compound **152** in *C. multifidum* was established (66). Four monoterpene hydroperoxides **156**-**159** (70) and *trans*-pinocarveylhydroperoxide **160** (71) were isolated from the aerial parts of *C. ambrosioides*. The group of monoterpene peroxides includes ascaridole **161**, isoascaridole **162**, dihydroascaridole **163**, piperitone oxide **164**, cariophyllenepoxide **168** and three related derivatives **165**-**167**. The structures **123-168** are shown in Figure 5.

Bicyclic Monoterpenes - carene, pinene and camphane derivatives

C. ambrosioides contains Δ^3-carene **169** (59) and Δ^4-carene **170** (67, 72). The former compound **169** was also found in *C. ficifolium*, *C. polyspermum*, *C. rubrum*, *C. urbicum* (59) and in the oil of *C. multifidum* (66). Two pinen isomers *a*-pinene **171** and *β*-pinene **172** were found in different species of *Chenopodium*: *C. album*, *C. ambrosioides*, *C. botrys*, *C. foliosum*, *C. murale*, *C. opulifolium*, *C. quinoa*, *C. vulvaria* and *C. urbicum*. Both camphene **173** and camphor **174** were detected in *C. foliosum*, *C. opulifolium* and *C. quinoa*. The former **173** was also found in *C. urbicum* and *C. botrys*, while the later **174** in *C. album* (59), *C. botrys* (73) and *C. ambrosioides* (61). The aerial parts of *C. ambrosioides* contained chenopanone **175** (65) while in the essential oil apiole **176** was found (67). The structures **169-176** are shown in Figure 5.

Sesquiterpenoids

Monocyclic sesquiterpenoids

The presence of elemol **177** (73, 74), its acetate **178** (74) was reported for the essential oil of *C. botrys*. *β*-Elemene **179** and *β*-caryophyllene **180** were identified in *C. botrys*, *C. rubrum* and *C. urbicum*. In addition the later **180** was found in *C. quinoa, C. foliosum* (59) and *C. ambrosioides* (58). The later species also contained *γ*-curcumene **181** (58). The structures **177-181** are shown in Figure 6.

Bicyclic sesquiterpenoids

Bicyclic sesquiterpenoids were found in *C. botrys*, *C. rubrum* and *C. album*. Guaiol **182** (75) and its derivatives **183** (74) and **184** (76) were reported in *C. botrys*. The compound **183** was found to be a new sesquiterpen alcohol. The group of *a*-cadinol **185** (73), botrydiol **189** (74, 77) and selinan derivatives *β*-selinene **186** (59), **187** (77) as well as **188** (76) were also found in *C. botrys*. The compound **186** was also encountered in *C. rubrum* (59). Further constituents of the essential oil of *C. botrys* were *a*-eudesmol **190**, *β*-eudesmol **192**, *γ*-eudesmol **194** (74) as well as their acetates **191**, **193**, **195** (77) and compounds **196** (75), **197** and **198** (74). *a*-Chenopodiol **199**, *β*-chenopodiol **202** (74, 76, 77), the (4)-monoacetate **207**, the (6)-monoacetates **200**, **201, 203** as well as chenopodienolone **208** (76) were also identified in this plant. Phytochemical investigation of *C. album* revealed the presence of cryptomeridiol **204** and its 8-*a*-acetoxy derivative **206** (78). Acetate of cryptomeridiol **205** was detected in the essential oil of *C. botrys* (76). Ten sesquiterpenes of eudesmane type were isolated from the aerial parts of *C. botrys*: three triols: chenopotriol **209**, 3-epichenopotriol **211**, isochenopotriol **217**, two tetraols: chenopotetraol **213**, 3-epichenopotetraol **215** and their (3)-monoacetates **210**, **212**, **214**, **216** and **218,** respectively (76). The structures **182-218** are shown in Figure 6.

Triterpenes

A triterpene **219** was isolated from the aerial parts of *C. multifidum* (49). The structure is shown in Figure 7.

Carotenoid Terpenoids

The main carotenoids in *C. ambrosioides* were *a*-carotene **220** and *β*-carotene **221** (79). Two new apocarotenoids **222**, **223**

and 16 previously reported: S-(+)-abscisic alcohol **224**, **225-228**, blumenol A **229**, (+)-dehydrovomifoliol **230**, **231-236**, grasshopper ketone **237** and racemic allenic ketones **238** and **239** were isolated from the weed of *C. album*. Five of the known compounds (**231**, **235, 236, 238** and **239**) were previously reported only as synthetic compounds (80). The structures **220-239** are shown in Figure 7.

Saponins

Sapogenins and their glycosides

The group includes four sapogenins: hederagenin **240**, oleanolic acid **250**, phytolaccagenic acid **264** and serjanic acid **275**. These were found in *C. quinoa* (81) - brans of the grains (82), leaves and seeds (83). Oleanolic acid **250** also was identified in the roots of *C. ficifolium* (48).

Hederagenin glycosides **241-249** and phytolaccagenic acid glycosides **265**-**274** were isolated from the seeds of *C. quinoa* (82, 84-90) and *C. pallidicaule* (91).

Phytochemical investigation of the flowers, fruits, seed coats and seeds of *C. quinoa* revealed the presence of serjanic acid glycosides **276**-**280** (87, 92). The structures **276**, **277** as well as **282** and **283** proved to be the new natural compounds (92), while compound **281** was previously reported (92, 93). A further constituents of *C. quinoa* seeds were the glycosides of oleanolic acid calenduloside E **253** (88), chikusetsusaponin IVa **257** (82, 87, 89, 92), quinoside D **256** (82, 92, 94), quinoside A **249** (85) and glycosides **251**, **252**, **255** (94), **259** (82, 88), **260** (87), **261** (87, 92). Compound **260** was also found in the seeds of *C. pallidicaule* (91). Constituents of the seeds of this species were also the glycosises **258** and **262** (91). The isolation of three glycosides of oleanolic acid calenduloside E **253**, chikusetsusaponin IVa **257** and **254** from the roots of *C. album* were reported (95). A new triterpene saponin **263** together with the known compound **257** was obtained from the roots of *C. ficifolium* (48). The structures **240-283** are shown in Figure 8.

Alkaloids

Piperidine, pyridine and tropane alkaloids are the major alkaloids of *Chenopodium* genus.

Phytochemical investigation of the aerial parts of *C. murale* let to the isolation of piperidine alkaloid piperine **284** for the first time (96). Pyridine derivatives were obtained from *C. rubrum* (97) and *C. quinoa* (98). Vulgaxanthin I **285** and vulgaxanthin II **286** were the constituents of the cells suspension cultures of *C. rubrum* (97), while trigonelline **287**, its two esters **288, 289** and compound **290** were found in the polar extracts of the seeds of *C. quinoa* (98). The cells suspension cultures of *C. rubrum* were the source of aromatic indol derivatives such as betanin **291** (23, 97), amaranthin **292** (23, 97) and celosianin II **293** (23, 97, 99). The structures **284-293** are shown in Figure 9.

Amides and amines

Choline **304** was detected in the water-soluble fraction of the MeOH extract from dry *C. album* herb (100). Seven cinnamic acid amides **294**-**299** and **302** were isolated from *C. album* of which one **297**, was described for the first time (101). Previously, phenolic amide **295** was found in the roots of *C. album* (102). N-feruloylaspartate **300** was encountered in the cell-suspension cultures of *C. rubrum* (23). A novel cinnamic acid amide alkaloid, chenoalbicine **301** was isolated from the roots of *C. album* (103). Betaine **303** was found to be a constituent of the *C. botrys* herb. Rustembekova and co-workers reported 1.52% yield of betain (104). Analysis of the polar extracts from *C. quinoa* seeds also led to the isolation of this compound (98). The structures **294-304** are shown in Figure 10.

Vitamins

Vitamin A **305** was isolated from *C. album* and the content was between 13,000 and 15,000 IU/ 100 mg fresh weight (105). Vitamin C **307** was detected in *C. album* (4, 105-108) and *C. bonus-henricus* (106). *C. album* was found to contain further water-soluble vitamins: folic acid **306**, thiamine **308** and niacin **309** (4). The structures **305-309** are shown in Figure 11.

ETHNOPHARMACOLOGY

The importance *Chenopodium* species was due to their wide variety of medicinal properties. A wide range of application in folk medicine of plants belonging to this genus has been reported. Table 3 summarizes ethnopharmacological data on chenopods found in the literature.

Table 3 : Ethnopharmacological data for some Chenopodium species

Species	Uses
Bassia scoparia (L.) A.J. Scott. (*Chenopodium scoparia* L.)	►The plant possessed antibacterial and antifungal properties. It was used to treat skin infections such as eczema, scabies and diseases of the urinary tract. ►The leaves and fruits possessed cardiotonic and diuretic properties. ►The stems were used in the treatment of dysentery, diarrhea and dyspepsia. ►The seeds possessed antiphlogistic, astringent and diuretic properties. They also contain harmine, which can have adverse effects upon the gastro-intestinal tract and the central nervous system (123).
Chenopodium album L. (*Chenopodium reticulatum Aell.*)	►Traditionally the plant has been used as diuretic, laxative, sedative, hepatoprotective and antiparasitic remedies from centuries (34, 95). ►An infusion from this plant was taken to treat rheumatism (123). ►The leaves possessed anthelmintic, antiphlogistic, antirheumatic, mildly laxative

	and odontalgic properties. In addition, the leaves also were applied as a wash or poultice to bug bites, sunstroke, rheumatic joints and swollen feet, whilst a decoction is used for carious teeth (123). The young leaves were used as a salad for human consumption (95). ►The seeds were chewed in the treatment of urinary problems and were considered useful for relieving the discharge of semen through the urine. ►The juice of the stems was applied to freckles and sunburn. The juice of the root was used in the treatment of bloody dysentery. ►Food that comprises 25.5% of the powdered herb may suppress the oestrus cycle (123).
Chenopodium ambrosioides L. and *Chenopodium ambrosioides var. anthelminticum* (L.) Gray.	►Mexican tea is a Central American herb that has been used for centuries to expel parasitic worms from the body. ►The whole plant possessed analgesic, antiasthmatic, carminative, stomachic and vermifuge properties. ►An infusion can be used as a digestive remedy, being taken to settle a wide range of problems such colic and stomach pains. ►Externally, it has been used as a wash for haemorrhoids, as a poultice to detoxify snake bites and other poisons and was thought to have wound-healing properties. ►An essential oil is very effective against most parasites, including the amoeba that causes dysentery, but was less effective against tapeworm. The essential oil is used externally to treat athlete's foot and insect bites (123). ►The leaves were added in small quantities as a flavoring for various cooked bean dishes because their carminative activity can reduce flatulence (123). ►Ethnobotanical sources mentioned that the most common medicinal use of this plant involves the action against protozoa species of the genera *Trypanosoma* and *Trichomona* (70, 124). ►In Brazil 32% of the rural population used this plant to treat cutaneous ulcers due to *Leishmania braziliensis* (125). ►The plant was used in Traditional medicine for the treatment of enteroparasitosis – *Ascaris lumbricoides*, *Trichuris trichuria* and *Ancilostoma duodenale* (126).
*Chenopodium bonus-henricu*s L.	►The plant possessed emollient, laxative and vermifuge properties. ►This remedy should not be used by people suffering from kidney complaints or rheumatism. ►A poultice of the leaves has been used to cleanse and heal chronic sores, boils and abscesses. ►The seed was a gentle laxative that was suitable for children (123).
Chenopodium botrys L.	►The plant has been used as an anthelmintic as a substitute of *C. ambrosioides* and was useful in the treatment of catarrh (123). ►In Serbian traditional medicine, from the dried aerial parts of *C. botrys* infusions or liquid extracts were prepared that were used as remedies with diuretic, antispasmodic, carminative and antidiarrhoric properties. The herb sometimes was used as a spice (127).
Chenopodium californicum Watson.	►A decoction of the whole plant has been used to treat stomach disorders. ►A decoction of the root has been applied as a poultice on numbed or paralysed limbs (123).
Chenopodium capitatum (L.) Asch.	►The plant has been used as a lotion for treating black eyes and head bruises. ►The juice of the seeds and an infusion of the plant has been used to treat lung congestion (123).
Chenopodium chilense Schrad.	►In Chilean traditional medicine the plant has been used as a remedy for stomach-ache (122).
Chenopodium cristatum F. Muell.	►The plant possessed antiseptic properties (123).

Chenopodium graveolens Willd	►The plant has been steeped in hot water and the steam inhaled as a treatment for headaches (123). ►It has been also applied as an antialergic, sedative and inducing sleep (128).
Chenopodium hybridum L.	►The plant possessed analgesic properties (123).
Chenopodium murale L.	►The plant was used as a potherb instead of spinach. It also possessed anthelmintic and laxative properties (34).
Chenopodium pallidicaule Aellen.	►The leaves were used for the treatment of dysentery while the seeds were used for the care of blennorrhea and urinary ailments (129).
Chenopodium schraderianum Roem.&Schult.	►The plant exerted antiasthmatic effect. It was also used for treatment of migraine and catarrhal conditions (123).
Chenopodium vulvaria L.	►The whole plant possessed antispasmodic and emmenagogue properties. ►An infusion of the dried leaves was used in the treatment of hysteria and nervous troubles connected with women's ailments (123).

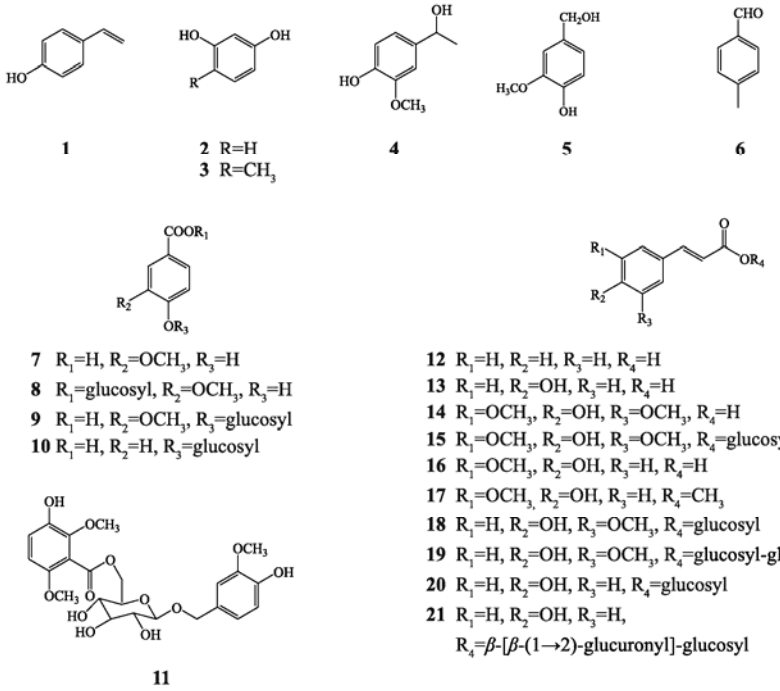

Fig. 1: The structures of phenolics

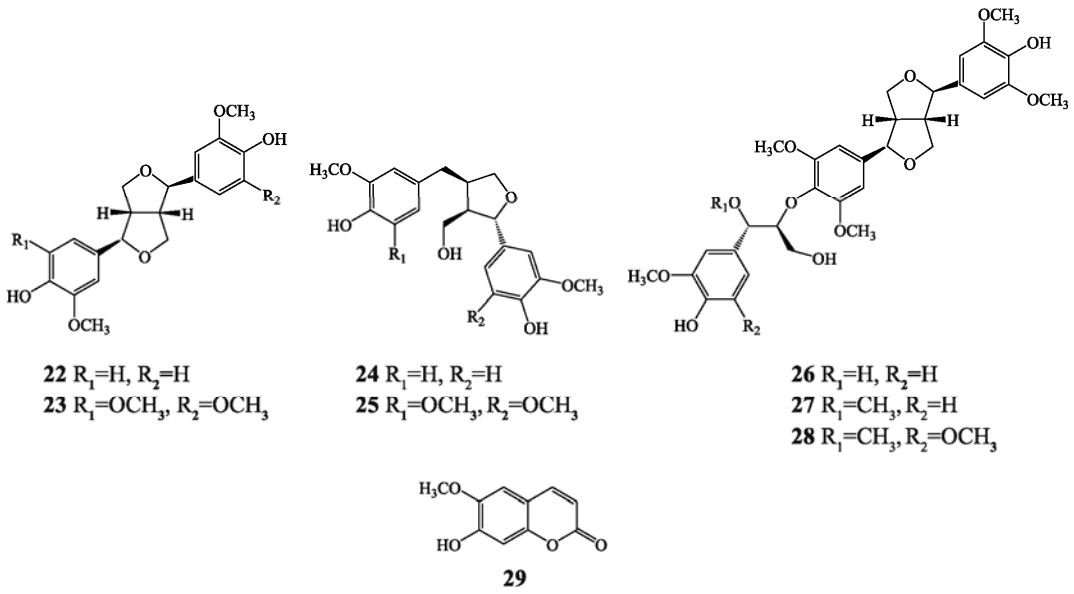

Fig. 2: The structures of lignans and coumarins

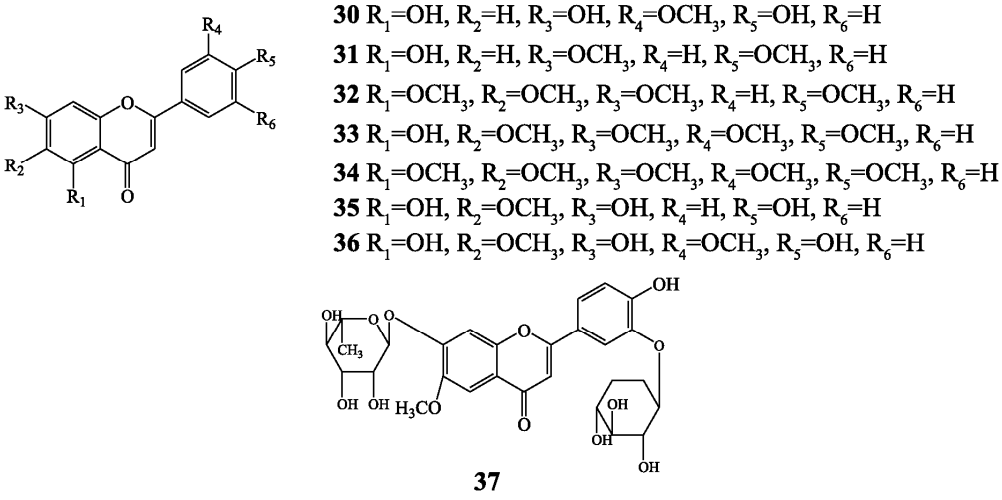

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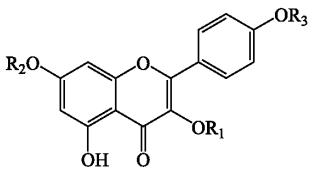
Figure 3 : The structures of flavonoids



38 R_1=H, R_2=H, R_3=H
39 R_1=*β*-D-glucosyl, R_2=H, R_3=H
40 R_1=galactosyl, R_2=H, R_3=H
41 R_1=*β*-D-glucuronopyranosyl, R_2=H, R_3=H
42 R_1=H, R_2=rhamnosyl, R_3=H
43a R_1=glucorhamnosyl, R_2=rhamnosyl, R_3=H
43b R_1=rhamnoglucosyl, R_2=rhamnosyl, R_3=H
43c R_1=rhamnosyl, R_2=rhamnoglucosyl, R_3=H
43d R_1=glucosyl, R_2=dirhamnosyl, R_3=H
44 R_1=*β*-diglucosyl, R_2=H, R_3=H
45R_1=*β*-arabinoglucosyl, R_2=H, R_3=H
46 R_1=robinobiosyl, R_2=H, R_3=H
47 R_1=R_2=rhamnosyl, R_3=H
48 R_1=rhamnosyl, R_2=H, R_3=xylosyl
49 R_1=rhamnosyl, R_2=xylosyl, R_3=H
50 R_1=rhamnosyl, R_2=glucosyl, R_3=H

51 R_1=*β*-D-apiofuranosyl-(1'''-2'')-*β*-D-galactopyranosyl, R_2=H, R_3=H
52 R_1=*α*-L-rhamnopyranosyl-(1'''-2'')-*β*-D-galactopyranosyl, R_2=H, R_3=H
53 R_1=*β*-D-apiofuranosy-(1'''-2'')-α-L-rhamnopyranosyl-(1'''-6'')-*β*-D-galactopyranosyl, R_2=H, R_3=H
54 R_1=2,6-di-*α*-L-rhamnopyranosyl-*β*-D-galactopyranosyl, R_2=H, R_3=H
55 R_1=2'',6''-di-O-R-L-rhamnopyranosyl-*β*-D-glucopyranosyl, R_2=H, R_3=H
56 R_1=*β*-D-glucopyranosyl, R_2=*α*-L-rhamnopyranosyl, R_3=H
57 R_1=4-*β*-D-xylopyranosyl-*α*-L-rhamnopyranosyl, R_2=*α*-L-rhamnopyranosyl, R_3=H
58 R_1=4-*β*-D-apiofuraranosyl-*α*-L-rhamnopyranosyl, R_2=*α*-L-rhamnopyranosyl, R_3=H
59 R_1=2-*β*-D-glucopyranosyl-*α*-L-rhamnopyranosyl, R_2=*α*-L-rhamnopyranosyl, R_3=H
60 R_1=*α*-L-rhamnopyranosyl, R_2=*β*-D-xylopyranosyl-(1→2)-O-*α*-L-rhamnopyranosyl, R_3=H

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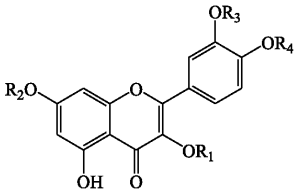
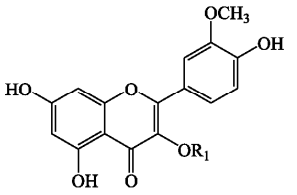
Fig. 3: -continued



61 R_1=H, R_2=H, R_3=H, R_4=H
62 R_1=β-D-glucopyranosyl, R_2=H, R_3=H, R_4=H
63 R_1=rhamnoglucosyl, R_2=H, R_3=H, R_4=H
64 R_1=xyloglucosyl, R_2=H, R_3=H, R_4=H
65 R_1=glucosylglucuronyl, R_2=H, R_3=H, R_4=H
66 R_1=robinobiosyl, R_2=H, R_3=H, R_4=H
67 R_1=β-D-glucopyranosyl-(1'''-6'')-β-D-glucopyranosyl, R_2=H, R_3=H, R_4=H
68 R_1=[β-(1→2)-D-apiosyl-α-(1→6)-L-rhamnosyl]-glucosyl, R_2=H, R_3=H, R_4=H
69 R_1=[α-(1→2)-L-rhamnosyl-α-(1→6)-L-rhamnosyl]-galactosyl, R_2=H, R_3=H, R_4=H
70 R_1=2,6-di-α-L-rhamnopyranosyl-β-D-galactopyranosyl, R_2=H, R_3=H, R_4=H
71 R_1=2'',6''-di-O-R-L-rhamnopyranosyl-β-D-glucopyranosyl, R_2=H, R_3=H, R_4=H
72 R_1=β-D-apiofuranosyl-(1'''→2'')-α-L-rhamnopyranosyl-(1''''-6'')-β-D-galactopyranosyl, R_2=H, R_3=H, R_4=H
73 R_1=β-D-apiofuranosyl-(1'''→2'')-O-α-L-rhamnopyranosyl-(1'''→6'')-β-D-galactopyranosyl, R_2=H, R_3=CH_3, R_4=CH_3
74 R_1=β-D-glucopyranosyl, R_2=β-D-glucopyranosyl, R_3=H, R_4=H



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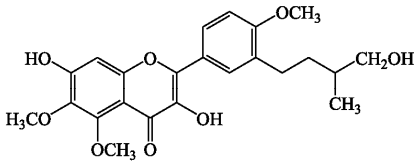
76 R_1=rutinosyl
77 R_1=robinobiosyl
78 R_1=[α-(1→2)-L-rhamnosyl-α-(1→6)-L-rhamnosyl]-galactosyl
79 R_1=β-D-apiofuranosyl-(1→2)-O-α-L-rhamnopyranosyl (1→6)-β-D-glucopyranosyl



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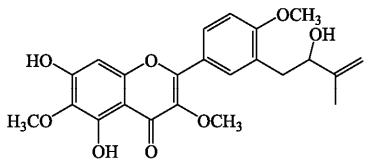

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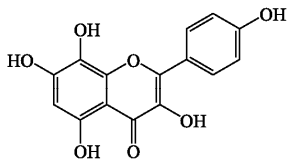

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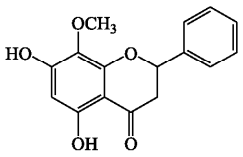

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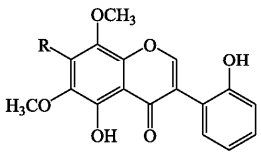
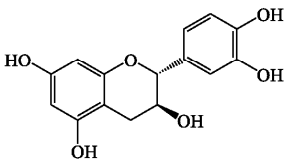


84 R=OCH_3
85 R=OH



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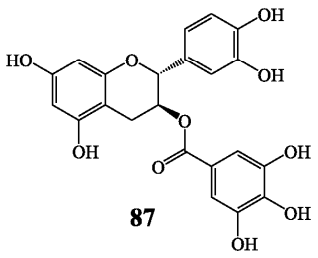
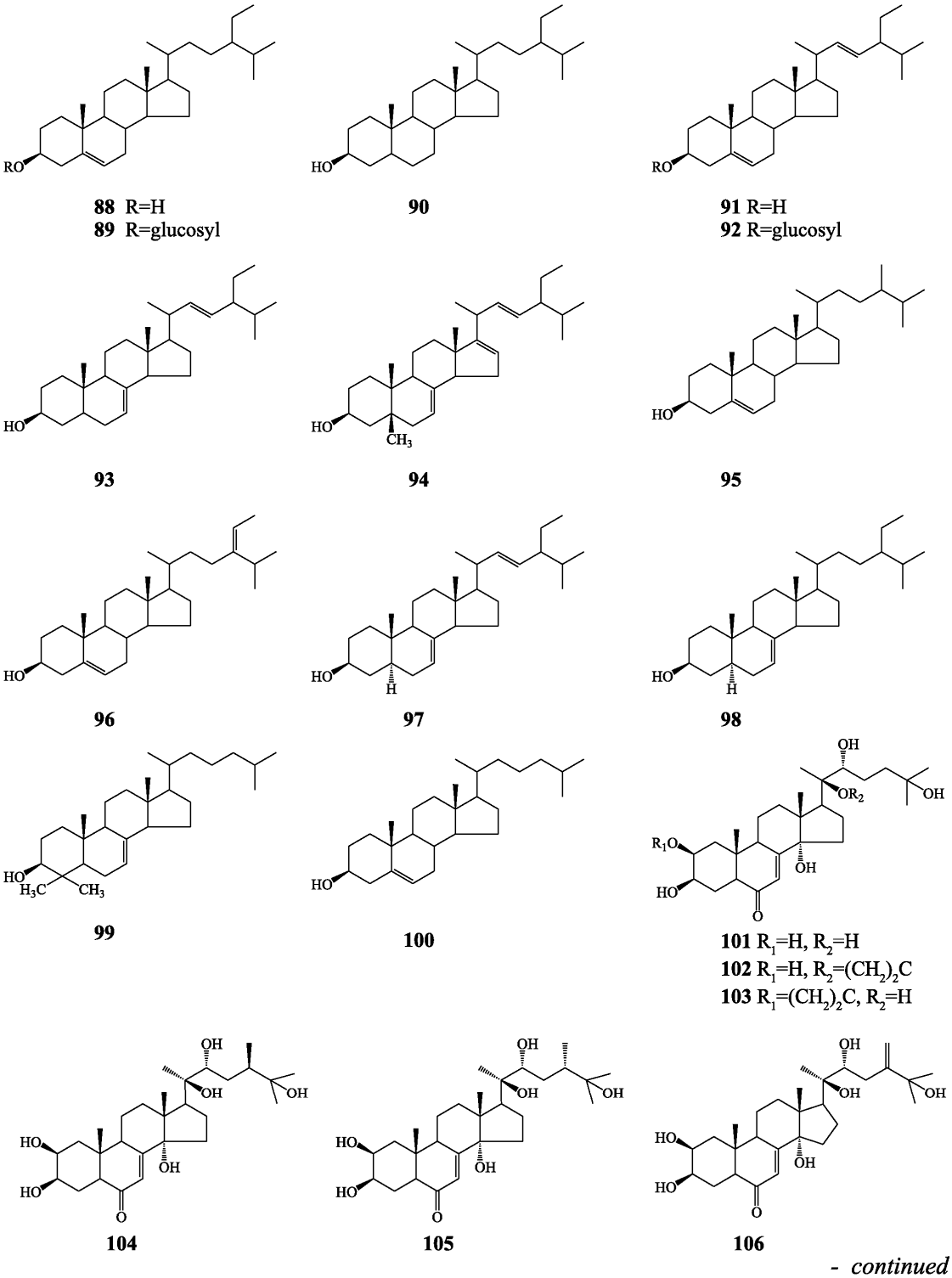


87

Fig. 3: -continued



- *continued*

Fig. 4: The structures of sterols

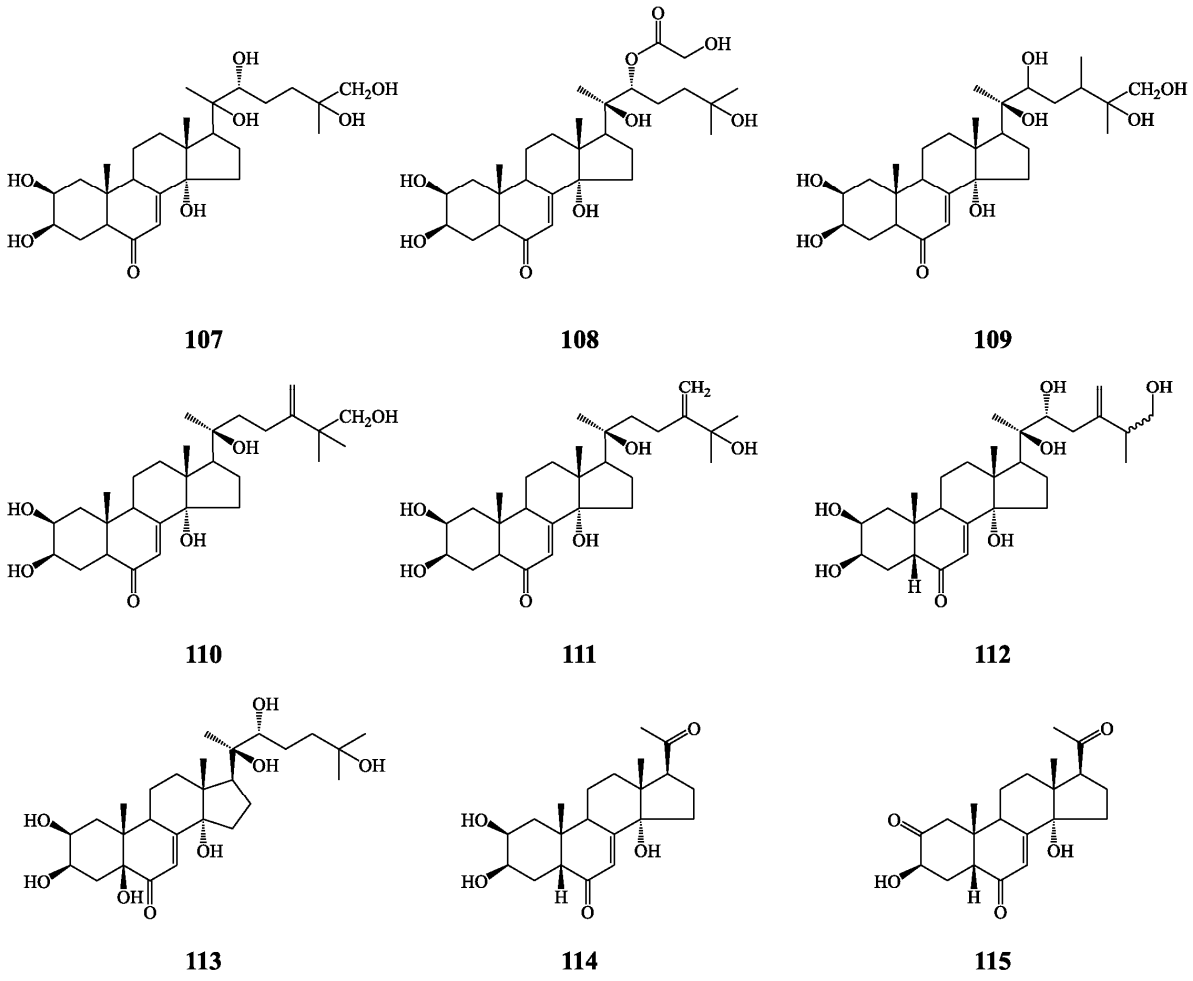


Fig. 4: - continued

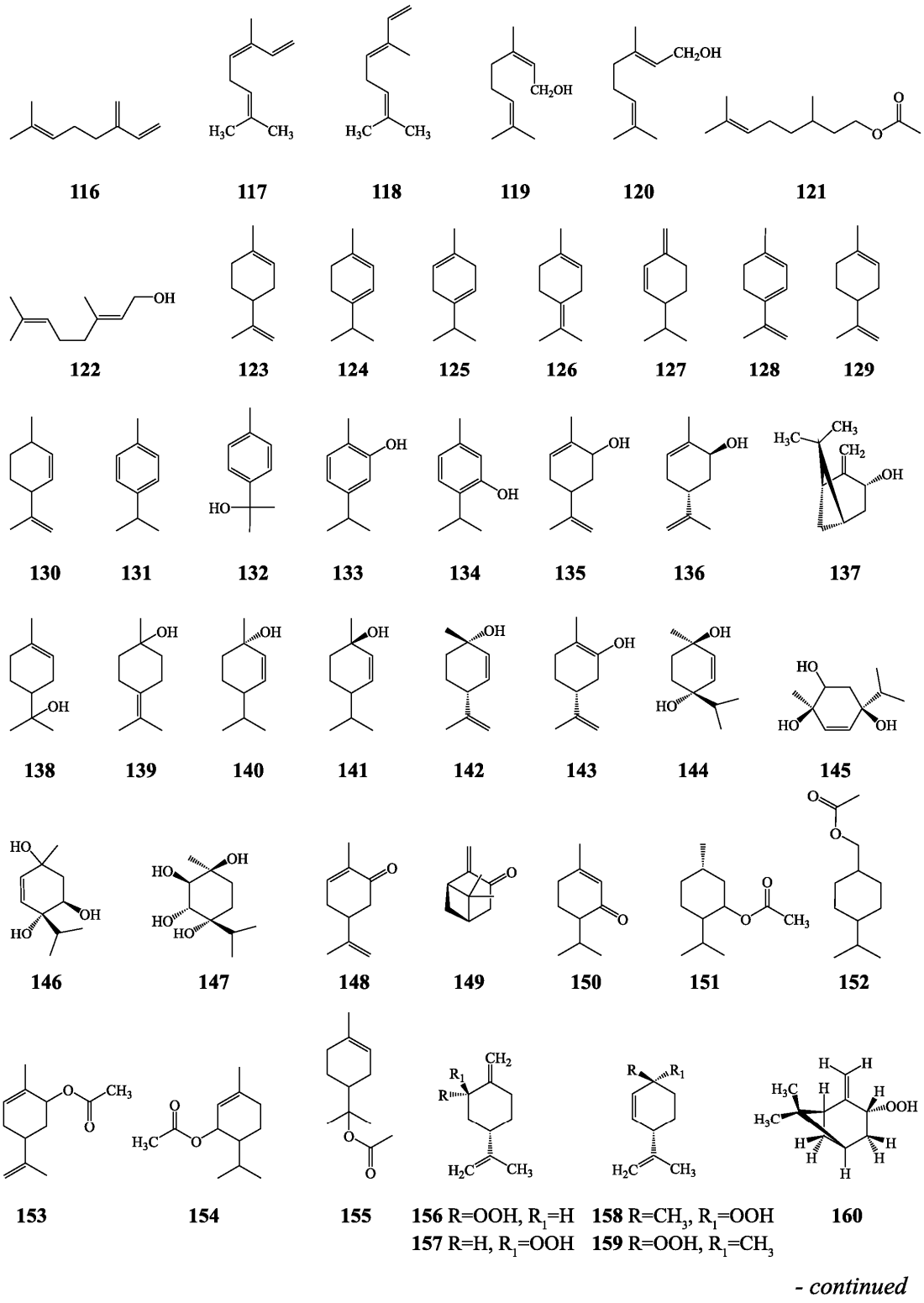


Fig. 5: The structures of monoterpenoids

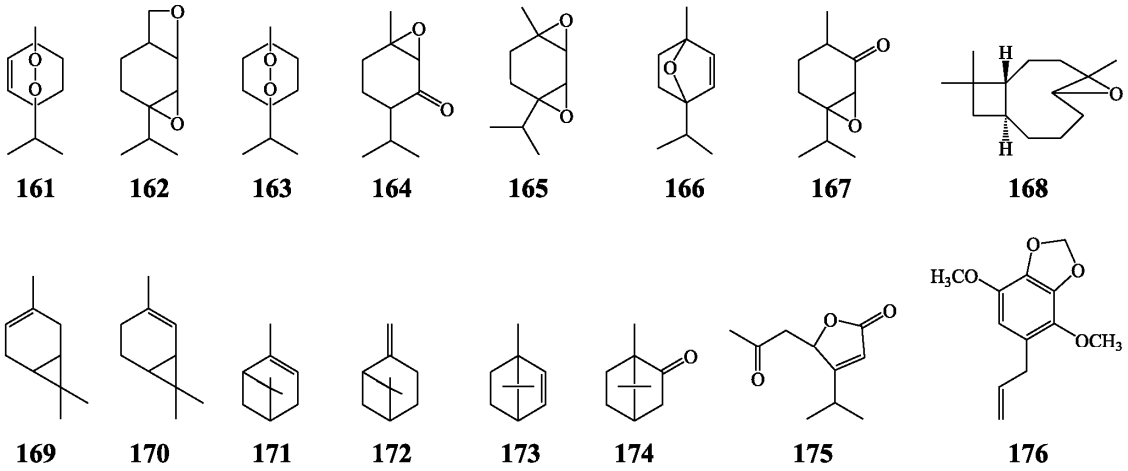
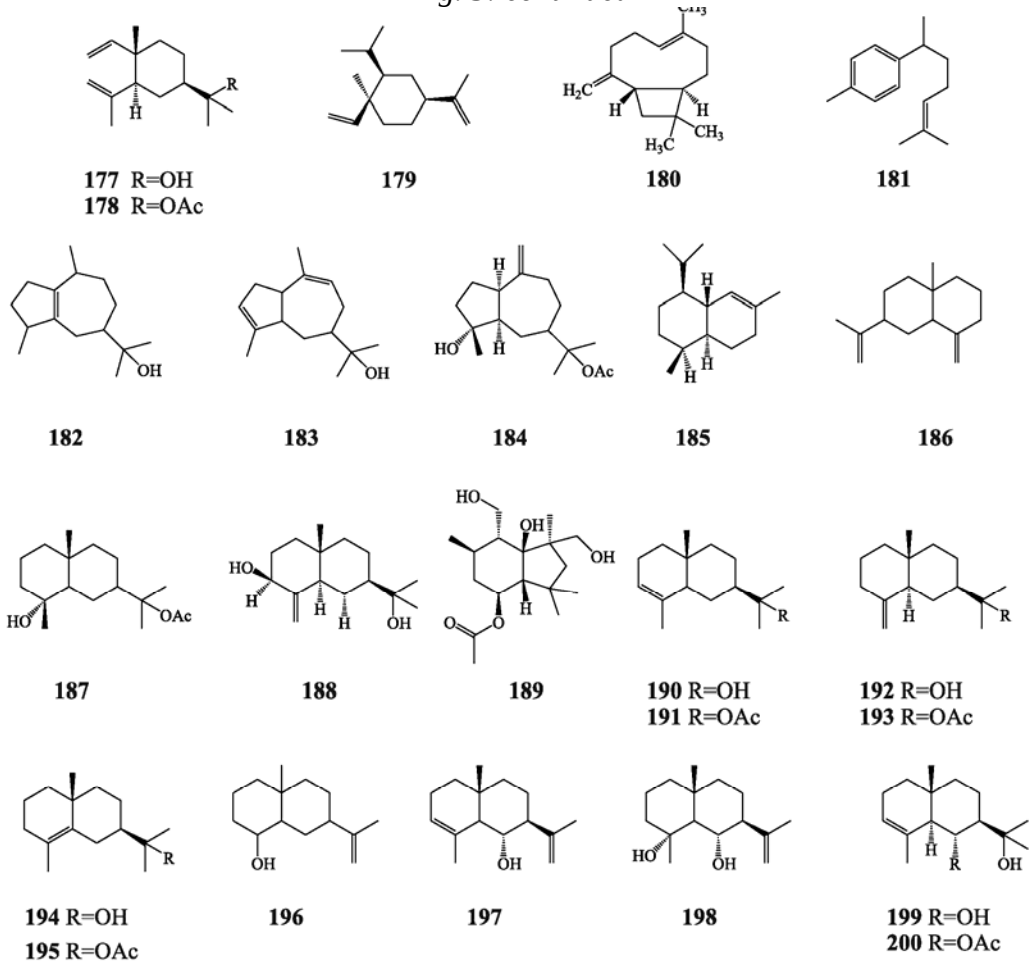


Fig. 5: continued



-Continued

Fig. 6: The structures of sesquiterpenoids

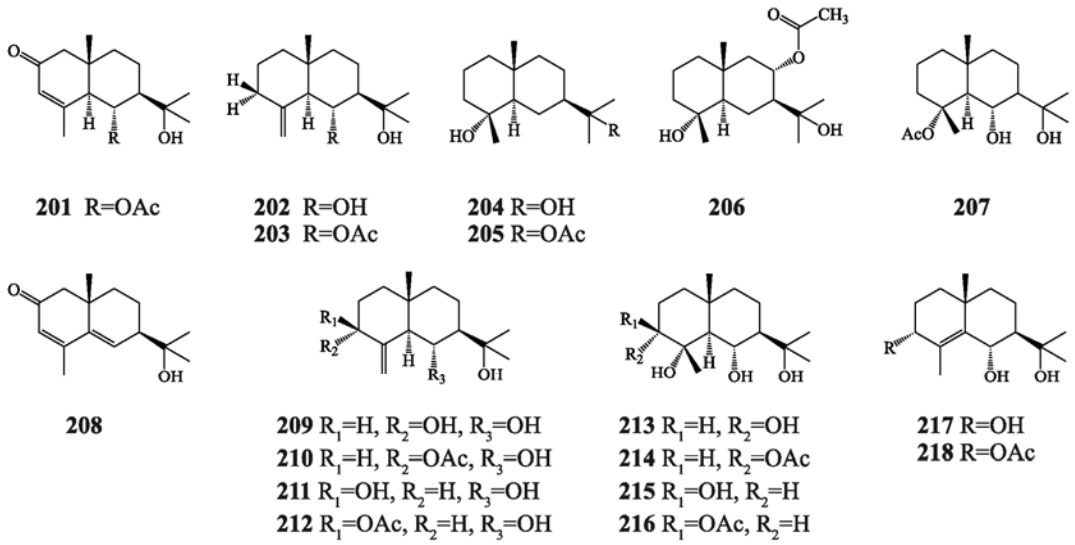
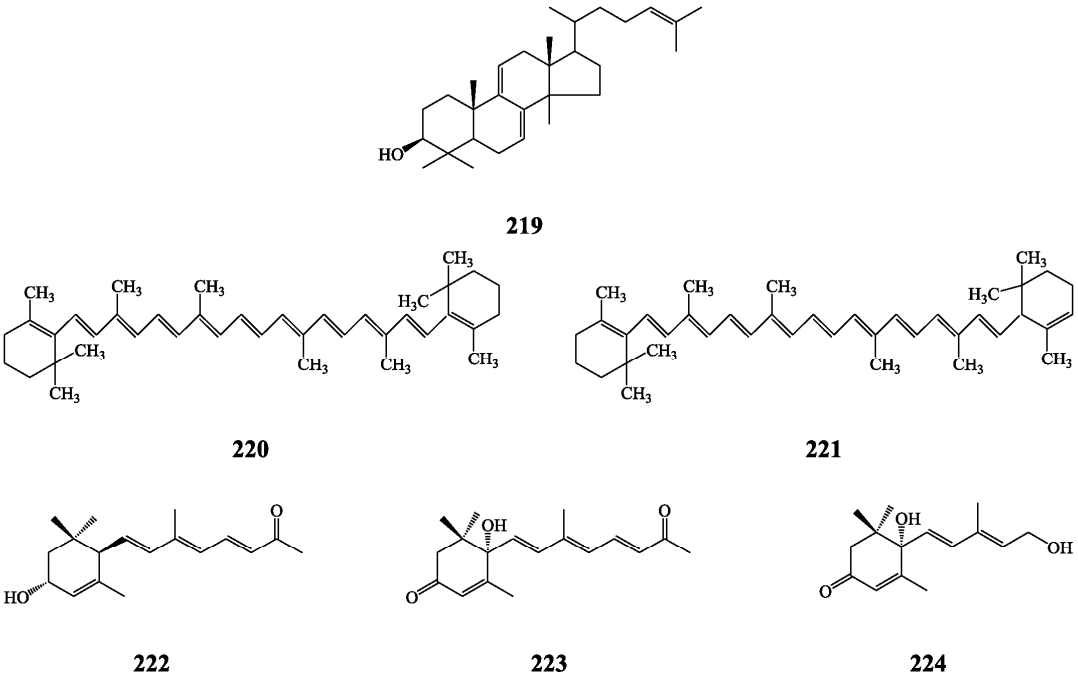


Fig 6 : -Continued



-Continued

Fig. 7: The structures of a triterpene and carotenoids

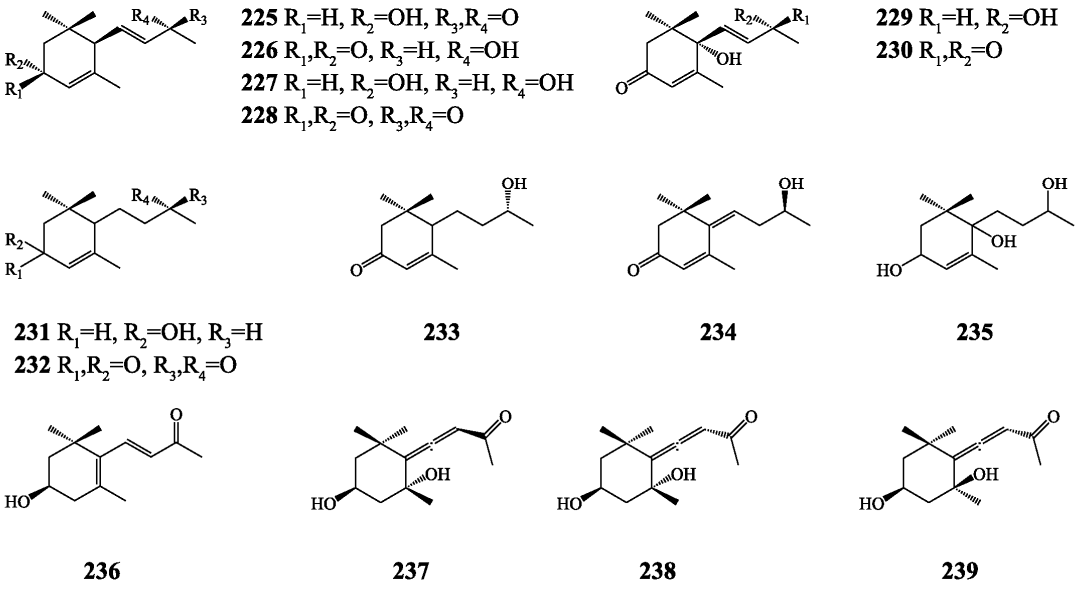
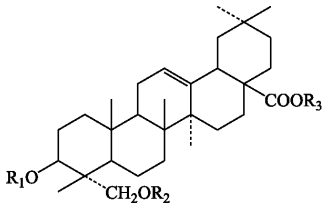
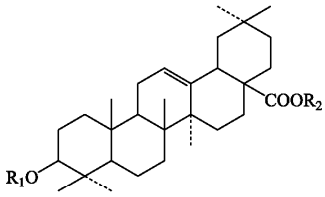


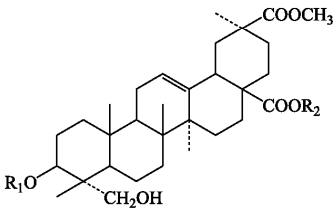
Fig. 7: -Continued



240 R_1=H, R_2=H, R_3=H
241 R_1=*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=H, R_3=H
242 R_1=*α*-L-arabinopyranosyl-(1→3)-*β*-D-glucuronopyranosyl, R_2=H, R_3=β-D-glucopyranosyl
243 R_1=*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl, R_2=H, R_3=*β*-D-glucopyranosyl
244 R_1=*α*-L-arabinopyranosyl, R_2=H, R_3=*β*-D-glucopyranosyl
245 R_1=*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=H, R_3=*β*-D-glucopyranosyl
246 R_1=*β*-D-glucopyranosyl-(1→3)-*β*-D-galactopyranosyl R_2=H, R_3=*β*-D-glucopyranosyl
247 R_1=*β*-glucuronopyranosyl, R_2=H, R_3=*β*-glucopyranosyl
248 R_1=*β*-xylopyranosyl-(1→3)-*β*-D-glucuronopyranosyl , R_2=H, R_3=*β*-glucopyranosyl
249 R_1=*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl, R_3=*β*-D-glucopyranosyl-(1→3)-O-*α*-L-arabinopyranosyl



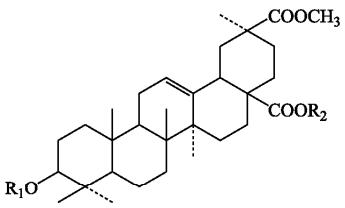
250 R_1=H, R_2=H
251 R_1=*β*-D-glucopyranosyl, R_2=H
252 R_1=*β*-D-xylopyranosyl-(1→3)-*β*-D-glucuronopyranosyl, R_2=H
253 R_1=β-D-glucuronopyranosyl, R_2=H
254 R_1=3'-O-(2"-O-glycolyl)-glyoxylyl-*β*-D-glucuronopyranosyl, R_2=H
255 R_1=*β*-D-xylopyranosyl-(1→3)-*β*-D-glucuronopyranosyl-6-O-methyl-ester, R_2=H
256 R_1=*β*-D-xylopyranosyl-(1→3)-*β*-D-glucuronopyranosyl, R_2=*β*-D-glucopyranosyl
257 R_1=*β*-D-glucuronopyranosyl, R_2=*β*-D-glucopyranosyl
258 R_1=*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl
259 R_1=*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
260 R_1=*α*-L-arabinopyranosyl-(1"→3')-*β*-D-glucuronopyranosyl, R_2=*β*-D-glucopyranosyl
261 R_1=*β*-D-glucopyranosyl-(1"→3')-*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
262 R_1=2'-4'-di-O-(*β*-D-glucopyranosyl)-*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl
263 R_1=*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl-(1→2)-*β*-D-glucuronopyranosyl



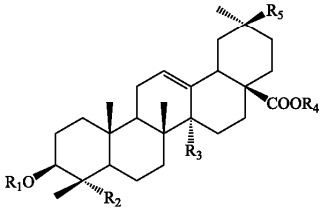
264 R_1=H, R_2=H
265 R_1=*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=H
266 R_1=*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl
267 R_1=*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
268 R_1=*β*-D-glucopyranosyl-(1"→3')-*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
269 R_1=*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl
270 R_1=*α*-L-arabinopyranosyl-(1"→3')-*β*-D-glucuronopyranosyl, R_2=*β*-D-glucopyranosyl
271 R_1=*β*-D-glucopyranosyl-(1→3)-*β*-D-galactopyranosyl, R_2=*β*-D-glucopyranosyl
272 R_1=*β*-D-glucopyranosyl-(1'"→2")-*β*-D-glucopyranosyl-(1"→3')-*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
273 R_1=*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl, R_2=*β*-D-glucopyranosyl
274 R_1=*β*-D-glucopyranosyl-(1'"→3")-*β*-D-xylopyranosyl-(1"→2')-*β*-D-glucopyranosyl, R_2= *β*-D-glucopyranosyl

- continued

Fig. 8: The structures of saponins



275 R_1=H, R_2=H
276 R_1=*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
277 R_1=*β*-D-glucuronopyranosyl, R_2=*β*-D-glucopyranosyl
278 R_1=*β*-D-glucopyranosyl-(1"→3')-*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl
279 R_1=*α*-L-arabinopyranosyl-(1"→3')-*β*-D-glucuronopyranosyl, R_2=*β*-D-glucopyranosyl
280 R_1=*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=*β*-D-glucopyranosyl



281 R_1=*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=CH_2OH, R_3=CH_3, R_4=*β*-D-glucopyranosyl, R_5=CH_2OH
282 R_1=*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=CHO, R_3=CH_3, R_4=*β*-D-glucopyranosyl, R_5=CH_3
283 R_1=*β*-D-glucopyranosyl-(1→3)-*α*-L-arabinopyranosyl, R_2=CH_3, R_3=CHO, R_4=*β*-D-glucopyranosyl, R_5=CH_3

Fig. 8: - continued

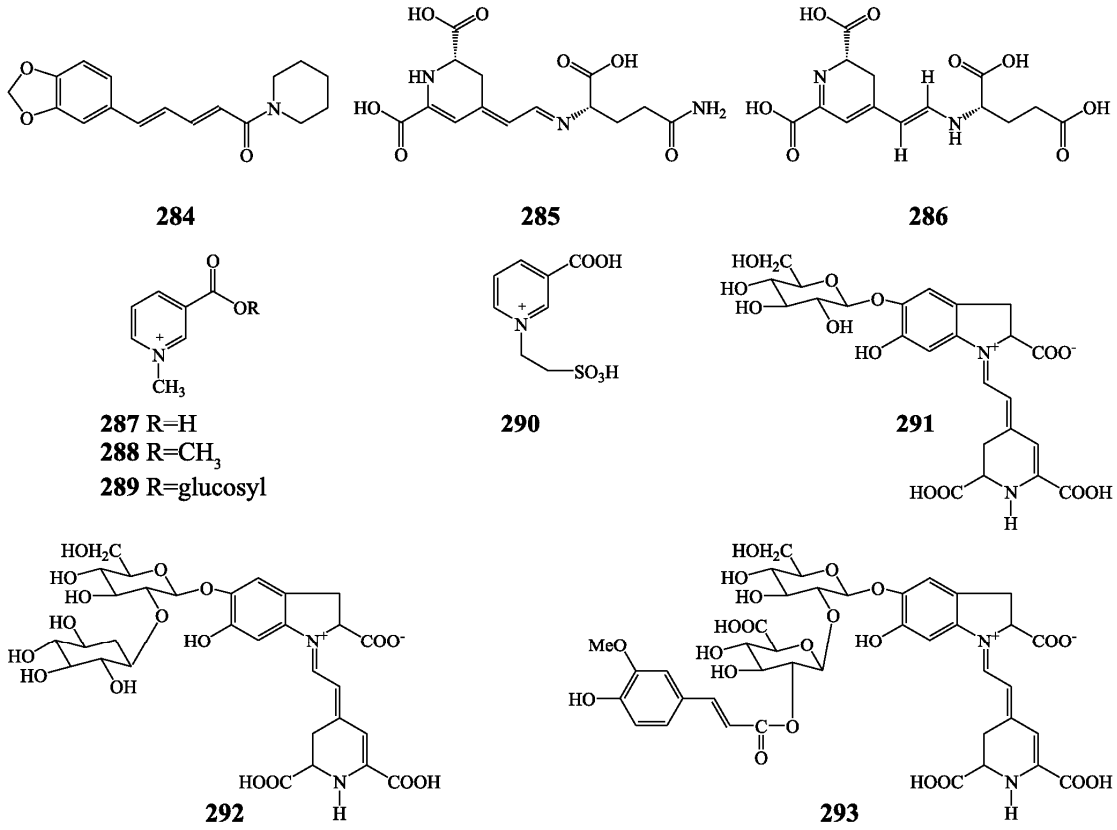


Fig. 9: The structures of alkaloids

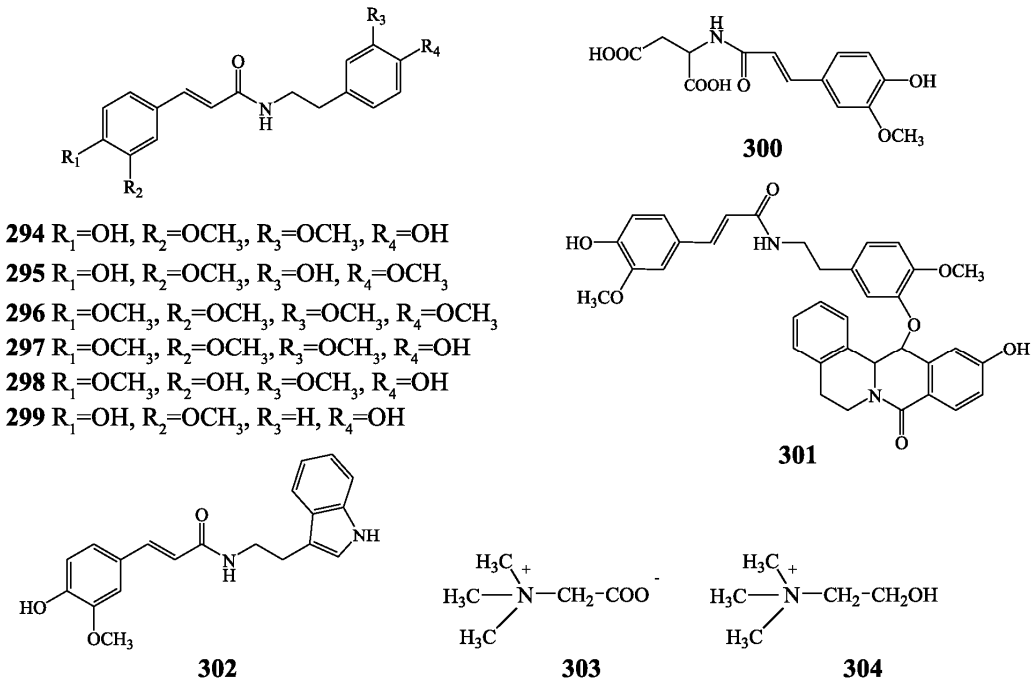


Fig. 10: The structures of amides and amines

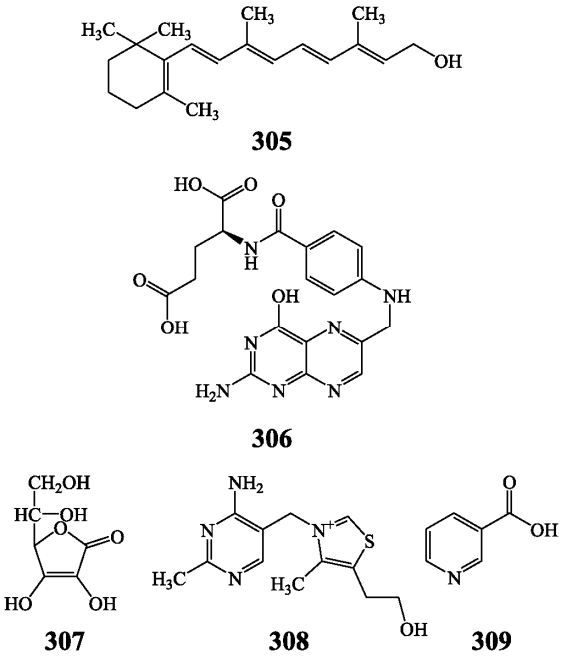


Fig. 11: The structures of vitamins

BIOLOGICAL ACTIVITY

To validate traditional claims associated with the genus many studies have been carried out using various animal models and *in vitro* assays. These studies showed that the diverse *Chenopodium* species have a potential for developing potent remedial agents. Some major activities are described below.

Antiviral activity

Vichkanova and Goryunova showed that saponins from *C. anthelminticum* were the strongest antiviral agents tested against influenza type A infections in mouse tissue (130).

Antimicrobial activity

The essential oil from aerial parts of *C. botrys*, expressed significant bactericidal activity against selected strains of G(+), G(-) bacteria comparable to that of the reference antibiotics amicacin and cephotaxim (131). The essential oil obtained from *C. botrys* showed a strong activity against the tested dermatophytes – *Trichophyton mentagrophytes*, *Epidermo phytonfloccosum* and *Microsporum canis*. These results confirm that the oil possessed bactericidal but not bacteriostatic effects (132). The essential oil from *C. botrys* exhibited significant antibacterial activity against *Salmonella aureus* and *Bacillus cereus*. The residual water solution showed a good activity against *Salmonella haidelberg* and *Bacillus cereus* (75). Ruggeri *et al.* investigated the total hydrocarbon fraction from the aerial parts of *C. multifidum*. The extract was active against G(+) bacteria (49). Chinese drug composition for treatment of peptic ulcer and preparations thereof were formulated. Capsules of the weight 80 mg containing oil from *C. ambrosioides* about 39 mg and an oil from *Adina pilulifera* about 1mg. Among 633 cases the results of clinical symptom and Barium meal check showed that total effective rate was 95.26%. The patients were administered with 3 capsules and one course of treatment is 4 weeks (133). A new capsule formulation of *C. ambrosioides* extract for treating gastritis and peptic ulcer caused by *Helicobacter pylori* (112) and a new method for preparing *C. ambrosioides* extracts were reported (113). Easily obtainable raw material, simple preparation process, remarkable effect as well as less side effects were the major advantages of the invented product (112, 113).

Antifungal activity

The essential oil extracted from the leaves of *C. ambrosioides* inhibited the myceliar growth of *Aspergillus flavus* at 100 μg/ml. In addition, it also exhibited broad fungitoxic spectrum against *Aspergillus niger*, *Aspergillus fumigatus*, *Botryodiplodia theobromae*, *Cladosporium cladosporioides*, *Helminthosporium oryzae*, *Pythium debaryanum* at 100 μg/ml (134). In an alternative investigation, the antifungal activity of essential oil from *C. ambrosioides* L. was evaluated by the poison food assay at concentrations of 0.3%, 0.1%, and 0.05% with eight postharvest deteriorating fungi (*Aspergillus flavus*, *Aspergillus glaucus*, *Aspergillus niger*, *Aspergillus ochraceous*, *Colletotrichum gloesporioides*, *Colletotrichum musae*, *Fusarium oxysporum*, and *Fusarium semitectum*). Autobiographic thin layer chromatography of the essential oil used to separate the principal fungitoxic fraction yielded only one fraction that completely inhibited the growth of all test fungi at a concentration of 0.1%. This fraction was characterized by Kováts retention indices and GC-MS presenting a composition of *p*-cymene **131** (25.4 %), (*Z*)-ascaridole (44.4 %), and (*E*)-ascaridole (30.2 %). The results suggest that the ascaridoles were the principal fungitoxic components of the essential oil (63). The essential oil from the aerial parts of *C. botrys*, expressed significant fungicidal activity against selected strains of *Aspergillus niger* and *Candida albicans* comparable to that of the reference antibiotics nystatine and amphotericin (131).The total saponins from *C. quinoa* were found to inhibit the growth of *Candida albicans* at 50 μg/mL (89).

Antiparasitic activity

A crude aqueous methanolic extract of *C. album* possess anthelmintic activity *in vitro* and *in vivo*. *In vitro* anthelmintic activity was evaluated by administering the crude power and the extract in increasing doses 1.0-3.0 g/kg. *In vivo* maximum reduction in eggs per gram of faeces was recorded as 82.2% at 3.0g/kg on day 5 post-treatment (135). The anthelmintic potential of *C. ambrosioides* in goats has been also reported (136).

Ascaridole **161** along with four monoterpene hydroperoxides **156**-**159** isolated from the aerial parts of *C. ambrosioides* were tested *in vitro* for trypanocidal activity against epimastigotes of *Trypanosoma cruzi* with values of 23, 1.2, 1.6, 3.1, and 0.8 μM, respectively (70). Monzote *et al.* evaluated the leishmanicidal effect of an essential oil from *C. ambrosioides* against *Leishmania amazonensis*. The tested product had a potend inhibitory action against promastigote and amastigote forms, with ED_{50} values of 3.7 and 4.6 μg/ml, respectively. The essential oil showed a moderate toxicity on macrophages from BALB/c mice. An optimal dose of 30 mg/kg/day was effective when administered during 15 days by intraperitoneal route to BALB/c mice infected experimentally (67). Monzote *et al.* investigated different routes of treatment. The intraperitoneal administration of the essential oil at dose of 30 mg/kg prevented lesion development and decrease the parasite burden. Oral administration retarded the infection compared with untreated mice. The intraperitoneal and oral treatment at 30 mg/kg had better antileishmanial effect that treatment with the reference drug amphotericin B at 1 mg/kg (137). It was found that the essential oil of *C. ambrosioides* showed a synergic activity after incubation in conjunction with pentamidine against promastigotes of *Leishmania amazoniensis* (138). Furthermore, the *in vitro* antileishmanial effect of the essential oil from *C. ambrosioides* against *Leishmania donovani* was investigated as well. The essential oil showed significant activity against promastigotes and amastigotes with a EC_{50} of 4.45 and 5.1 μg/ml, respectively. It caused an irreversible inhibition of the growth of promastigotes after a treatment with 100 or 10 μg/ml for 1 or 24 h, respectively (139). Intralesional treatment with a hydroallcoholic crude extract from the leaves of *C. ambrosioides* was more efficient than the oral treatment since the former was able to control the dissemination of infection. This effect can be due to either a direct leishmanicidal effect of the extract or the improvement in the nitric oxid production by extract-stimulated macrophages (140).

Ascaridole **161** was found to be a potent inhibitor *in vitro* of

plasmodial growth of *Plasmodium falciparum*. After 3 days, development was arrested by concentrations of 0.05 μM, and at 0.1 μM no parasites were visible in the culture. The peroxide group is essential for the antimalarial activity of ascaridole **161**, as judged from the fact that cineol, which bears an epoxide group instead of the peroxide group found in ascaridole **161**, was totally inactive at indentical concentrations (119). Giove studied *C. ambrosioides* as an antiparasitic agent in two villages near Tarapoto, San Martin. Extracts from leaves were given to 72 patients (children and adults). Their stools were analized before and 8 days after the intake. The efficacy was 100% for *Ancilostoma* and 50% for *Ascaris* (126).

The oil extracted from *C. ambrosioides* showed a promising activity against *Trichomonas vaginalis* with minimum inhibitory concentrations of 25 mg/mL (124).

Antineoplastic activity

Efferth *et al.*, 2002 found that ascaridole **161** exerts antineoplastic activity against different tumor cell lines in vitro (CCRF-CEM, HL60, MDA-MB-231). Ascitic and solid Ehrlich tumor inhibition by the i.p administration of *C. ambrosioides* hydroalkoholic extract of the leaves was investigated *in vivo*. The treatments increased the survival of tumor-bearing mice. *C. ambrosioides* has a potent anti-tumoral effect which was evident with a small dose and even when the treatment was given two days after the tumor implantation. This effect is probably related with anti-oxidant properties of *C. ambrosioides* (141). Hall patented a method of treating abnormal growths in patients – cancers, tumors, fibroids, cysts and cystadenomas. Dry leaves and stalks of *C. ambrosioides* were administered as a tea beverage and the patients drink the tea daily. The method also reduces high PSA counts (142).

Antioxidant activity

A new phenolic glycoside named chenoalbuside **11** that was isolated from *C. album* was assessed by the DPPH assay, and the RC_{50} value was found to be 1.4×10^{-4}mg/mL (24). Puhaca *et al.* showed that plant extract from *C. ambrosioides* alone and with synergist (lecithin and citric acid) have effects similar to those of common antioxidants and might be applied in stabilization of unsaturated compounds in the food and pharmaceutical industry (143). An antioxidant screening of medicinal herbal teas showed a moderate TEAC activity of the water extract of *C. ambrosioides* (144). The essential oil from *C. ambrosioides* exhibited a potent antioxidant activity when it was tested by ABTS method (134). The water-soluble and water-insoluble extracts from samples of *C. pallidicaule* were tested for the total antioxidant capacity by FRAP and ABTS methods. It was revealed that resorcinols contributed most of the antioxidant capacity of the water-soluble extract. The results show that *C. pallidicaule* is a potential source of natural antioxidant compounds that can be important for human health (21). Six flavonol glycosides isolated from *C. quinoa* seeds **51-54**, **70** and **72** exhibited antioxidant activity in DPPH test. Two quercetine 3-glycosides showed much stronger activity compared to that of kaempferol 3-glycosides. The results confirm that compounds with 3',4'-dihydroxy substituents in the B ring have much stronger antioxidative activities than those without ortho-dihydroxy substitution in the B ring and suggests that quinoa seeds serve as a good source of free radical scavenging agents. (40). Jung *et al.* investigated the antioxidant activity of the seeds and sprouts of *C. quinoa* by using a new rapid AP method. The method was performed by ESR spectroscopy and was based on the well-known DPPH method with the major diference that both the antioxidative capacity and the antioxidative activity were used to characterise an antioxidant. The resulting antioxidative power was expressed in AU, where 1 AU corresponds to the activity of a 1 ppm solution of vitamin C as a benchmark (145). Three new phytoecdysteroids **108**-**110** with DPPH scavenging ability were isolated from the seeds of *C. quinoa* (56).

Toxicity

It was found that the essential oil from *C. ambrosioides* was toxic to mammalian systems (146, 147). The cytogenetic effects of aqueous extracts of *C. multifidum* were determined by addition of the extracts and fractions to human lymphocyte cultures. Toxicity was evaluated by analysis of chromosomal aberrations, sister chromatid exchange, mitotic and replication indexes. These results suggested genotoxic effects of Paico aqueous extracts (147). Gadano *et al.* investigated the genetic damaged induced by decoction and infusion of *C. ambrosioides* which was assayed in different concentrations (1, 10, 100, 1000 μg/ml), by addition of the extract to human lymphocytes cell cultures. The results suggest a possible genotoxic effect (148).

Immunomodulatory effect

Mousavi *et al.* found that co-administration of CpG oligonucleotides and *C. album* extract reverse IgG2a/IgG1 ratios and increase IFN-γ and IL-10 productions in a murine model of asthma. These components could be used with the other allergens in order to induce the prevention of inflammatory conditions (149). Rossi-Bergmann *et al.* have tested the immunomodulatory activity of the crude extact of *C. ambrosioides*. It was found that the extract was strongly stimulatory to murine but not to human lymphocytes and that the stimulatory substance was present in a protein-enriched fraction (150).

Agglutinating and hemolytical activity

A hemagglutinin was isolated from the leaves of *C. amaranticolor*. This compound has an abillity to aglutinate rabbit erytrocytes (9). The hemolitic activities of triterpenoid saponins from *C. quinoa* were investigated. Results of the hemolysis test showed that the only bidesmoside to be active, chikusetsusaponin IVa **257**, showed activity at 260 μg/mL, which can only be described as week. The most active saponin was its monodesmoside form **253**. Hederagenin monodesmosides also showed strong activity (89).

Analgesic, spasmolitic and sedative activity

Compared with the analgesic effect of novaldin (5 mg/kg b. wt.) on rats, the ethanolic extracts from *C. album* and *C. murale* were considered to have a significant analgesic activity. The untreated rats responded to the electric shock at about 73 volts. The extract-treated rats gave a response at about 150 and 140 volts after 3 h (34). The oral administration of ascaridole **161** at a dose of 100 mg/kg showed the

hypothermic effect and an analgesic effect on acetic acid-induced writhing in mice. Ascaridole **161** reduced the locomotor activity which was enhanced by methamphetamine. The administration of 300 mg/kg, however produced convultions and lethal toxicity in mice. These facts indicate that ascaridole isolated from *C. ambrosioides* possibly has sedative and analgesic effect (71). The methanolic extract from the aerial portions of *C. chilense* used in Chilean traditional medicine as a remedy for stomach-ache, has been found to exert the major spasmolytic activity in acetylcholine contracted rat ileum. This extract is practically non-toxic both for rats and brine shrimp *Artemia salina* in acute toxicity test (122). At doses (300-700 mg kg^{-1}), methanol extract of *C. ambrosioides* has an analgesic effect with the hot plate device maintained at 55°C as well as on the early and late phases of formalin-induced paw licking in rats (151).

Effects on cardiovascular and respiratory system

Kaempferitrin **47** as well as the total flavonoid mixture from the aerial parts of *C. murale* were tested on the rabbit cardiovascular system. These showed dose-related hypotension and bradycardia. In addition, kaempferitrin also produced a dose-related hypotension in genetically prone hypertensive rats and did not block α_1 or β_1-adrenoceptors when tested using isolated guinea-pig aoric strip and atria. Alcoholic extracts of *C. album* (I) and *C. murale* (II) have a significant diuretic effect throughout the 24 hours after administration, where the volume of urine increased from 4 mL to 12 and 20 mL, respectively compared to the effect of Moduretic (1.1 mg/100 g b. wt) on urine volume, where the volume increased from 4 to 13 mL. Concerning the concentration of Na^+ and K^+ in urine extract II as a diuretic agent has a less adverse effect on serum potassium ion level than Moduretic. The alcoholic extract of both plants in doses of 80 and 71.3 mg/kg b. wt, respectively did not showed any ulcerogenic effect on the stomach of treated rats and no irritations was detected in the stomach (34). The $CHCl_3$, Et_2O-H_2SO_4 and petroleum ether extracts of *C. botrys* were studied. Alkaloids extracted by Et_2O-H_2SO_4, when applied in doses of 0.005-0.01 g/kg caused temporal excitation of respiration and increase of the arterial pressure by 10-40 mm Hg. Tartrates from the petroleum ether had an analogous effect in doses of 0.002-0.03 g/kg. On the other hand tartrates from the $CHCl_3$ extract caused a marked decrease in the arterial pressure and respiration, when applied in doses of 0.001-0.009 g/kg. Doses of 0.01-0.015g/kg led to acomplete loss of the pressure and caused a block in respiration (152).

Cosmetics and skin disease

The ethanolic extract from the fruits of *C. album*, orally administered at doses of 100-400 mg/kg, dose-dependently inhibited scratching behavior induced by 5-HT (10 µg per mouse, s.c.) or compound 48/80 (50 µg per mouse, s.c.) in mice. The extract significantly attenuated the writhing responses induced by an intraperitoneal injection of formalin in mice. At a dose of 400 mg/kg, it also inhibited the neurogenic pain responese of formalin test. The extract possesses antipruritic and antinociceptive activities and the antinociceptive effects are not secondary to anti-inflammatory effects and can be used to treat cutaneous pruritus (153). The ethanolic extracts of *C. album* and *C. murale* showed anti-inflammatory activity on the rat paw edema and the cotton pellet models. Diclofenac sodium (1mg/kg b. wt.) was used as a reference drug (34). A methanol extract of the dried leaves of *C. ambrosioides* was investigated for anti-inflammatory activity. The extract (300-700 mg kg^{-1}, p.o.) produced a dose related inhibition of carrageenan-induced paw oedema and cotton pellet-induced granuloma in rats (151).

Other effects

Saponins extracted from the seed of *C. quinoa* were studied for their ability to act as mucosal adjuvants upon their intragastric or intranasal administrations together with model antigens in mice. The study indicates the potential of quinoa saponins as adjuvants for mucosally administered vaccines (154). Electrophoretic analysis PAGE of prolamine proteins or SDS-PAGE ISTA, devoloped for gluten proteins, confirmed the results of immunological tests on the suitability of quinoa for the diet in celiac disease (15).

CONCLUSION

This article briefly reviews the phytochemistry, ethnopharmacology and pharmacology of *Chenopodium* species that are a rich source of organic compounds and varying structural patterns. The literature revealed ethnopharmacological reports for 15 species. Twenty one species of *Chenopodium* have been partially investigated for their phytoconstituents. Three hundred seventy nine compounds isolated from different species were reported. Pharmacological reports of 10 species support medicinal potential of some chenopods for developing new drugs.

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