**PHCOG REV.:** Review Article

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; H2O, water; MeOH, methanol; GC-MS, gas chromatography-mass spectrometry; ED50, 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; CHCl3, chloroform; Et2O, diethyl ether; H2SO4, 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 weight.

**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 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 pharmaceutical 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, steroids, 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 H2O-EtOH extracts of *C. ambrosioides* (10).

**Phenolics**

**Phenol derivatives-alcohols, aldehydes and glycosides**
Table 1: Primary metabolites

<table>
<thead>
<tr>
<th>Plant</th>
<th>Primary metabolites</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. album</em></td>
<td>Pentoses and methylpentoses- ribose (4); Amino acids- glutamic acid (4), alanine (4), asparagine (4), lysine (4); Nonpolar constituents- n-tetradecane (5), n-pentadecane (5), n-hexadecane (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-tritriacontane (5);</td>
</tr>
<tr>
<td><em>C. acuminatum</em></td>
<td>Amino acids- aspartic acid (8), glutamic acid (8), glycine (8), phenylalanine (8), serine (8), valine (8), isoleucine (8), threonine (8), tyrosine (8), cystine (8);</td>
</tr>
<tr>
<td><em>C. amaranticolor</em></td>
<td>Proteins- hemagglutinin (9);</td>
</tr>
<tr>
<td><em>C. ambrosioides</em></td>
<td>Hexoses- glucose (10); Amino acids- alanine (11), glycine (11), valine (11), leucine (11);</td>
</tr>
<tr>
<td><em>C. murale</em></td>
<td>Pentoses n 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- rafinose (12);</td>
</tr>
<tr>
<td><em>C. quinoa</em></td>
<td>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);</td>
</tr>
<tr>
<td><em>C. rubrum</em></td>
<td>Aromatic cytokinins- 6-[2-β-D-glucopyranosyl]benzylamino]purine (16), 6-[2-β-D-glucopyranosyl]benzylamino]-2-methylthiopurine (16), 6-benzylamino-9-β-D-glucopyranosylpurine (16); Hormones- melatonin (17, 18);</td>
</tr>
</tbody>
</table>

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 4 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 hydroxyxycinnamic 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 hydroxyxycinnamic 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

<table>
<thead>
<tr>
<th>Plant</th>
<th>Compounds</th>
<th>Secondary metabolites (References)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. C. album</td>
<td>Phenols</td>
<td>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)</td>
</tr>
<tr>
<td></td>
<td>Sterols</td>
<td>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)</td>
</tr>
<tr>
<td></td>
<td>Terpenes</td>
<td>123 (59), 125 (59), 131 (59), 155 (59), 171-172 (59), 174 (59), 204 (78), 206 (78), 222-239 (80)</td>
</tr>
<tr>
<td></td>
<td>Saponins</td>
<td>253-254 (95), 257 (95)</td>
</tr>
<tr>
<td></td>
<td>Amids</td>
<td>294 (101), 295 (101, 102), 296-299 (101), 301 (103), 302 (101), 304 (100)</td>
</tr>
<tr>
<td></td>
<td>Vitamins</td>
<td>305 (105), 307 (4, 105-108), 306 (4), 308-309 (4)</td>
</tr>
<tr>
<td>2. C. ambrosioides</td>
<td>Phenols</td>
<td>37 (31), 38 (32), 42 (41), 43a-43d (41), 47 (36), 48-49 (32), 61 (30, 32), 75 (32)</td>
</tr>
<tr>
<td></td>
<td>Sterols</td>
<td>96-98 (45)</td>
</tr>
<tr>
<td></td>
<td>Terpenes</td>
<td>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)</td>
</tr>
<tr>
<td></td>
<td>Vitamins</td>
<td>307 (106)</td>
</tr>
<tr>
<td>3. C. bonus-hentricus</td>
<td>Sterols</td>
<td>101 (53), 106 (53), 113 (53)</td>
</tr>
<tr>
<td>4. C. botrys</td>
<td>Phenols</td>
<td>30 (28), 31-34 (29), 35 (29, 30), 36 (30), 61 (30), 62 (28), 67 (28)</td>
</tr>
<tr>
<td></td>
<td>Terpenes</td>
<td>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)</td>
</tr>
<tr>
<td>5. C. chilense</td>
<td>Terpenes</td>
<td>131 (122), 161 (122)</td>
</tr>
<tr>
<td>6. C. ficifolium</td>
<td>Phenols</td>
<td>47 (36)</td>
</tr>
<tr>
<td></td>
<td>Sterols</td>
<td>88-89 (48), 92 (48)</td>
</tr>
<tr>
<td></td>
<td>Terpenes</td>
<td>124-125 (59), 130-131 (59), 133 (59), 140 (59), 155 (59), 163 (59), 169 (59)</td>
</tr>
<tr>
<td></td>
<td>Saponins</td>
<td>250 (48), 257 (48), 263 (48)</td>
</tr>
<tr>
<td>7. C. foliosum</td>
<td>Terpenes</td>
<td>123-125 (59), 129 (59), 131 (59), 133-134 (59), 140-141 (59), 155 (59), 171-174 (59), 180 (59)</td>
</tr>
<tr>
<td>8. C. hybrideum</td>
<td>Phenols</td>
<td>61 (30)</td>
</tr>
<tr>
<td>9. C. hircinum</td>
<td>Phenols</td>
<td>40 (42), 63 (42)</td>
</tr>
<tr>
<td>10. C. leptophyllum</td>
<td>Sterols</td>
<td>88 (45), 91 (45), 95-96 (45), 98 (45)</td>
</tr>
</tbody>
</table>
11. *C. missouriense*  
Terpenes 123-124 (59), 131 (59), 140 (59), 155 (59), 163 (59)  
12. *C. multifidum*  
Sterols 93-94 (49), 99 (49)  
Terpenes 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)  
Terpenes 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)  
Terpenes 116 (59), 124-125 (59), 131 (59), 171-174 (59)  
15. *C. pallidaicaule*  
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. polyspernum*  
Terpenes 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)  
Terpenes 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)  
Terpenes 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), 293 (87, 99, 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)  
Terpenes 123-125 (59), 129-131 (59), 140-141 (59), 149 (59), 163 (59), 169 (59), 171-173 (59), 179-180 (59)  
21. *C. vulvaria*  
Terpenes 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, lariresinol 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.

**Flavonols**

Rustembekova *et al.* reported the occurrence 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). Bahraman *et al.* investigated 5 species of *Chenopodium*: *C. ambrosioides*, *C. botrys*, *C. hybridum*, *C. murale* and *C. quinoa*. The flavons hispidulin 35 and jacisoladin 36 were found only in *C. botrys* (30). Kamil *et al.* isolated a novel flavon glycoside 37 from the leaves 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 flavons 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. I sorhamnetin 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. pal tidicaule* (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. bicirium* (42). Arisawa and co-workers isolated a kaempferol triglycoside named ambroseide 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. pal tidicaule* (33), seeds of *C. pallidicaule* (38) and *C. quinoa* (40) as well as from the leaves of *C. album* and *C. bicirium* (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 dihydrowogedin 83 as well as the isoflavones irin A 84 and irin 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**

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.

**Phytosterols**

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 kancolsterolone 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 poststerol....
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 and monoterpenoids**

Three acyclic hydrocarbon 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. mural, C. opulifolium and C. polygynum (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 hydrocarbon monoterpenoids includes - limonene 123, a-terpine ne 124 and its γ-isomer 125, a-terpinol enol 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. missouriensis, C. mural, C. opulifolium, C. polygynum, 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. chilen, C. ficifolium, C. foliosum, C. missouriensis, C. multifidum, C. mural, C. opulifolium, C. polygynum, 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. mural 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 α-terpineol 138 (63) while γ-terpineol 139 was reported for C. botrys (64). The compound 140 was identified in C. ficifolium, C. foliosum, C. missouriensis, C. urbicum while the compound 141 was found in C. foliosum, C. polygynum, C. quinoa, C. urbicum (59). Four related derivatives were isolated from C. amorroides 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. amorroides. Compound 149 was also identified in three species: C. mural, 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. amorroides. The later compound 155 was also found in C. album, C. botrys, C. ficifolium, C. foliosum, C. missouriensis, C. mural, C. rubrum, C. vulvaria and C. quinoa (59). The presence of compound 152 in C. multifidum was established (66). Four monoterpeno hydroperoxides 156-159 (70) and trans-pinocarvylhydroperoxide 160 (71) were isolated from the aerial parts of C. ambrosioides. The group of monoterpeno peroxides includes ascaridole 161, isoascaridole 162, dihydroascaridole 163, piperitone oxide 164, carophyllene oxide 165 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 Δ⁵-carene 169 (59) and Δ⁴-carene 170 (67, 72). The former compound 169 was also found in C. ficifolium, C. polygynum, C. rubrum, C. urbicum (59) and in the oil of C. multifidum (66). Two pinene isomers a-pinene 171 and β-pinene 172 were found in different species of Chenopodium: C. album, C. ambrosioides, C. botrys, C. foliosum, C. mural, 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 α-cadinol 185 (73), botrydiol 189 (74, 77) and selinane derivatives 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 α-eudesmol 190, β-eudesmol 192, γ-eudesmol 194 (74) as well as their acetals 191, 193, 195 (77) and compounds 196 (75), 197 and 198 (74), α-Chenopodiol 199, β-chenopodiol 202 (74, 76, 77), the (4)-monoacetate 207, the (6)- monoacetates 200, 201, 203 as well as chenopodiolone 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: chenopotenol 213, 3-epichenopotenol 215 and their (3)-monoacetates 210, 212, 214, 216 and 218, respectively (76). The structures 182-218 are shown in Figure 6.

**Triterpenes**

A triterpen 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 α-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**

**Saponins and their glycosides**

The group includes four sapogenins: hederagenin 240, oleanolic acid 250, phytolaccaagenic acid 264 and seranic 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 seranic 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 oleanic 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 glycosides 258 and 262 (91). The isolation of three glycosides of oleanic 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. murali led to the isolation of piperidine alkaloid pipering 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 293 was found in the roots of C. album (102). N-feruloylspartate 300 was encountered in the cell-suspension cultures of C. rubrum (23). A novel cinnamic acid amide alkaloid, chenoalbine 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 betaine (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.

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### Table 3: Ethnopharmacological data for some Chenopodium species

<table>
<thead>
<tr>
<th>Species</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bassia scoparia (L.) A.J. Scott. (Chenopodium scoparia L.)</td>
<td>►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).</td>
</tr>
<tr>
<td>Chenopodium album L. (Chenopodium reticulatum Aell.)</td>
<td>►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...</td>
</tr>
</tbody>
</table>
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 *Trichomonas* (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-henricus 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 blennorrhrea 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

30 R₁=OH, R₂=H, R₃=OH, R₄=OCH₃, R₅=OH, R₆=H
31 R₁=OH, R₂=H, R₃=OCH₃, R₄=H, R₅=OCH₃, R₆=H
32 R₁=OCH₃, R₂=OCH₃, R₃=OCH₃, R₄=H, R₅=OCH₃, R₆=H
33 R₁=OH, R₂=OCH₃, R₃=OCH₃, R₄=OCH₃, R₅=OCH₃, R₆=H
34 R₁=OCH₃, R₂=OCH₃, R₃=OCH₃, R₄=OCH₃, R₅=OCH₃, R₆=H
35 R₁=OH, R₂=OCH₃, R₃=OH, R₄=H, R₅=OH, R₆=H
36 R₁=OH, R₂=OCH₃, R₃=OH, R₄=OCH₃, R₅=OH, R₆=H

Figure 3: The structures of flavonoids

-continued
Fig. 3: -continued
Fig. 3: -continued
Fig. 4: The structures of sterols

- continued
Fig. 4: - continued
Fig. 5: The structures of monoterpenoids
Fig. 5: continued

Fig. 6: The structures of sesquiterpenoids

-Continued
Fig. 6: -Continued

Fig. 7: The structures of a triterpene and carotenoids
Fig. 7: -Continued
Fig. 8: The structures of saponins
Fig. 8: - continued

275 $R_1=H$, $R_2=H$
276 $R_1=\alpha$-L-arabinopyranosyl, $R_2=\beta$-D-glucopyranosyl
277 $R_1=\beta$-D-glucuronopyranosyl, $R_2=\beta$-D-glucopyranosyl
278 $R_1=\beta$-D-glucopyranosyl-(1\textsuperscript{"{a}}$\rightarrow$3)$^\prime$-\alpha$-L$-arabinopyranosyl,
  $R_2=\beta$-D-glucopyranosyl
279 $R_1=\alpha$-L-arabinopyranosyl-(1\textsuperscript{"{a}}$\rightarrow$3)-\beta$-D-glucuronopyranosyl,
  $R_2=\beta$-D-glucopyranosyl
280 $R_1=\beta$-D-glucopyranosyl-(1\textsuperscript{→}2)-\beta$-D-glucopyranosyl-
  (1\textsuperscript{→}3)-\alpha$-L$-arabinopyranosyl, $R_2=\beta$-D-glucopyranosyl

281 $R_1=\beta$-D-glucopyranosyl-(1\textsuperscript{→}3)-\alpha$-L$-arabinopyranosyl, $R_2=\text{CH}_3\text{OH},$
  $R_3=\text{CH}_3$, $R_4=\beta$-D-glucopyranosyl, $R_5=\text{CH}_2\text{OH}$
282 $R_1=\beta$-D-glucopyranosyl-(1\textsuperscript{→}3)-\alpha$-L$-arabinopyranosyl, $R_2=\text{CHO},$
  $R_3=\text{CH}_3$, $R_4=\beta$-D-glucopyranosyl, $R_5=\text{CH}_3$
283 $R_1=\beta$-D-glucopyranosyl-(1\textsuperscript{→}3)-\alpha$-L$-arabinopyranosyl, $R_2=\text{CH}_3,$
  $R_3=\text{CHO}$, $R_4=\beta$-D-glucopyranosyl, $R_5=\text{CH}_3$

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(+) and 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, Epidermophyton floccosum 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 enteritis and Bacillus cereus. The residual water solution showed a good activity against Salmonella bairdellberg 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 mycelial 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 food poison assay at concentrations of 0.3%, 0.1%, and 0.05% with eight postharvest deteriorating fungi (Aspergillus flavus, Aspergillus glaucus, Aspergillus niger, Aspergillus ochraceus, Colletotrichum gloeosporioides, 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 fungitoxic 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. albus 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 monoterpane 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 potent inhibitory action against promastigote and amastigote forms, with ED50 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 amazonensis (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 EC50 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). Intraleisional treatment with a hydroalcoholic 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). Giwev 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 analyzed 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**

Effrther et al., 2002 found that ascaridole 161 exerts antineoplastic activity against different tumor cell lines in vitro (CCRF-CEM, HL.60, 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 RC₅₀ value was found to be 1.4x10⁻⁴mg/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 difference 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 phytocytosteroids 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, 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 extract 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 ability to agglutinate rabbit erythrocytes (9). The hemolytic activities of triterpenoid saponins from *C. quinoa* were investigated. Results of the hemolysis test showed that the only bidesmoside to be active, chikusetsusanin IVa 257, showed activity at 260 μg/mL, which can only be described as weak. 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. miracle* 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
hypothemic 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 convulsions 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 spasmylocytic activity in acetylcholine contracted rat ileum. This extract is practically non-toxic both for rats and in mice. At a dose of 400 mg/kg, it also inhibited the responses induced by an intraperitoneal injection of formalin.

Medicine as a remedy for stomach-ache, has been found to the aerial portions of

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 α1 or β1-adrenoceptors when tested using isolated guinea-pig aortic 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 administration, where the volume of urine increased from 4 mL to 12 and 20 mL, respectively compared to the effect of Moduretic. The alcoholic extract of both plants in doses of 0.01-0.015 g/kg led to a complete loss of the pressure and convulsions and lethal toxicity in mice. These facts indicate the potential of quinoa saponins as adjuvants for mucosally administered vaccines (154). Electrophoretic analysis PAGE of prolamine proteins or SDS-PAGE ISTA, developed 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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REFERENCES


