



Phytochemical constituents of *Broussonetia papyrifera* (L.) L'He'r. ex Vent: An overview†

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Phytochemistry is an important field of plant biology with a number of applied research applications. Whole metabolome based phytochemical analysis of plants is a technique that requires profiling of known compounds from the plant. In this paper, we present a detailed review of known phytochemistry of paper mulberry tree after a thorough survey of available literature as well as different databases (KnapSack, Plant metabolome database (PMDB), PubChem, ChemSpider) in favor of whole metabolome based phytochemical analysis. A detailed account of known phytochemistry of *Broussonetia papyrifera* sheds light on the multipurpose economic importance (medicinal, high quality fiber, severe pollen allergy, phytotoxic, invasive) of plant.

Keywords: Phytochemistry, plant metabolome analysis, secondary metabolites, Broussonins, Kazinol.

Introduction

The genus *Broussonetia* was named after P.N.V. Broussonet, a French naturalist, who took a male tree (of *B. papyrifera*) from a garden in Scotland, UK and introduced it to Paris, France, where a female tree was growing, thus enabling fruit to be described¹. The genus contains 8 species, 7 native to Asia and one to Madagascar. There are 16 or 17 recognized varieties of the East Asian species *B. papyrifera*, including five wild varieties. The specific name *papyrifera* means paper-bearing. The paper made from wild varieties is inferior to that from non-wild varieties².

Distribution

B. papyrifera is native to East Asia and is extensively cultivated within its natural range for its bark. Native to China, Taiwan and Japan and possibly native to the Pacific islands of Hawaii and Samoa. *B. papyrifera* has become naturalized throughout Asia, from India and Pakistan to Thailand, Malaysia and the Pacific Islands, and also in North America. In Pakistan, paper mulberry was intentionally introduced to make the Islamabad (Capital) and Rawalpindi area green. It

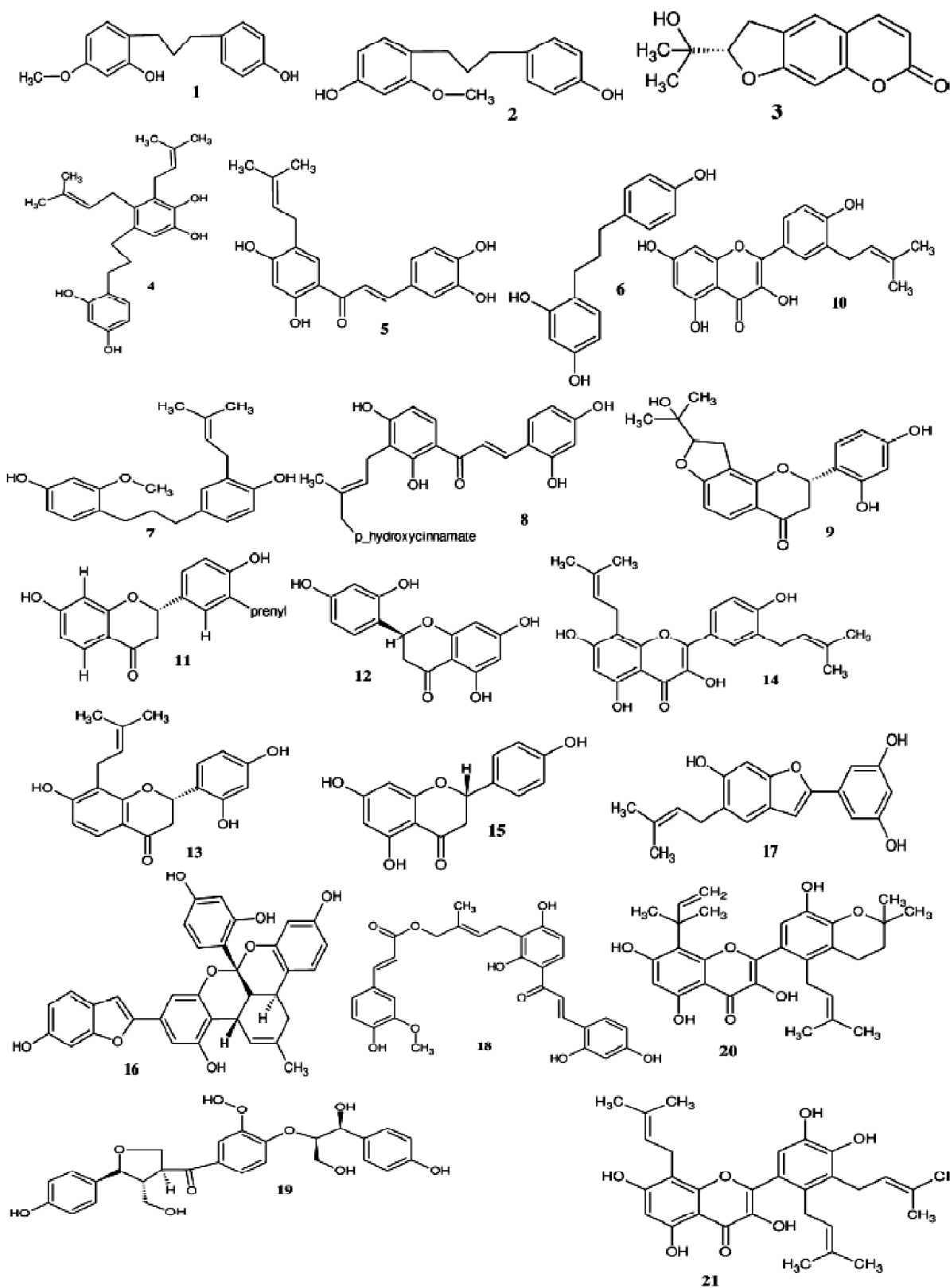
is now commonly found in India and Pakistan from sea level to 1000 m altitude in many localities³.

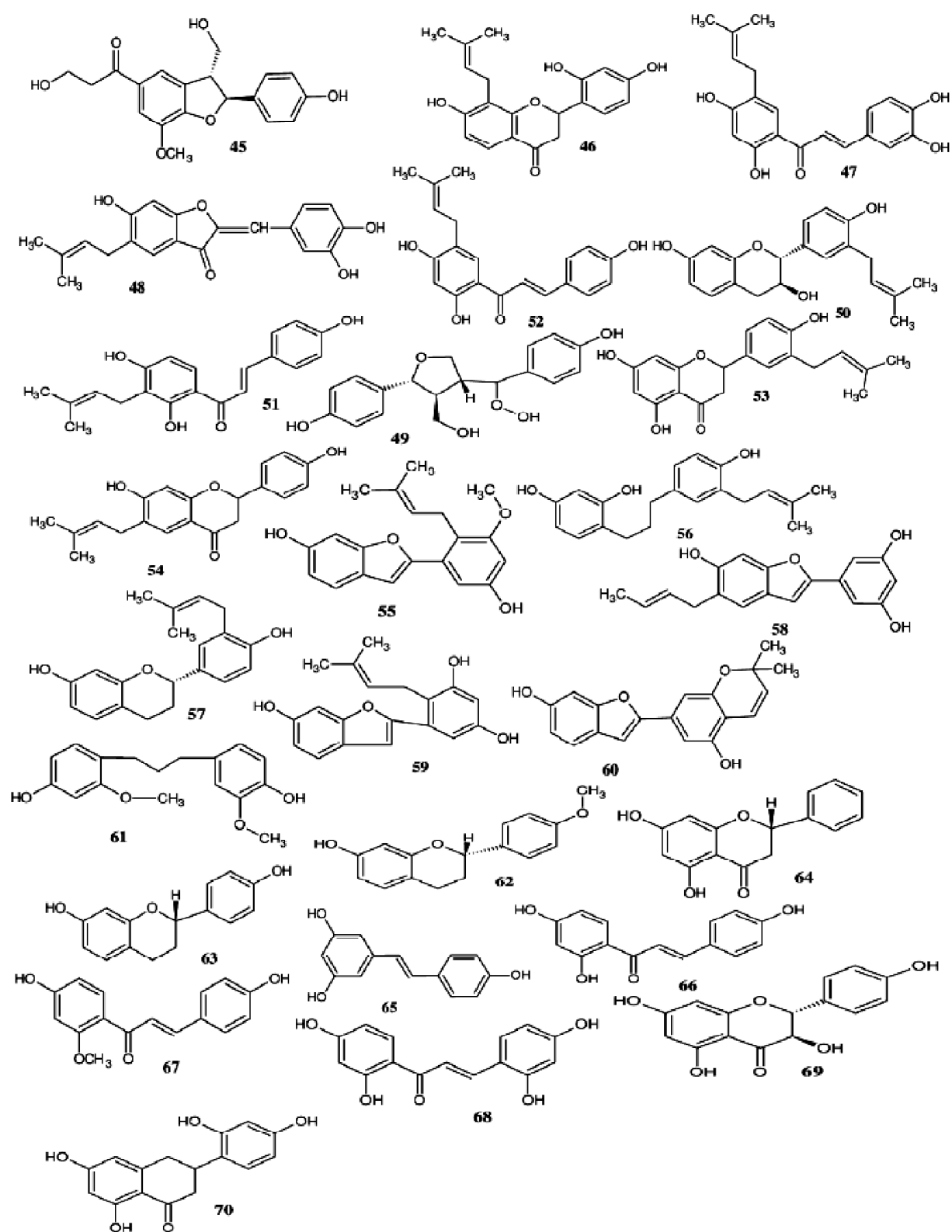
Phytochemistry

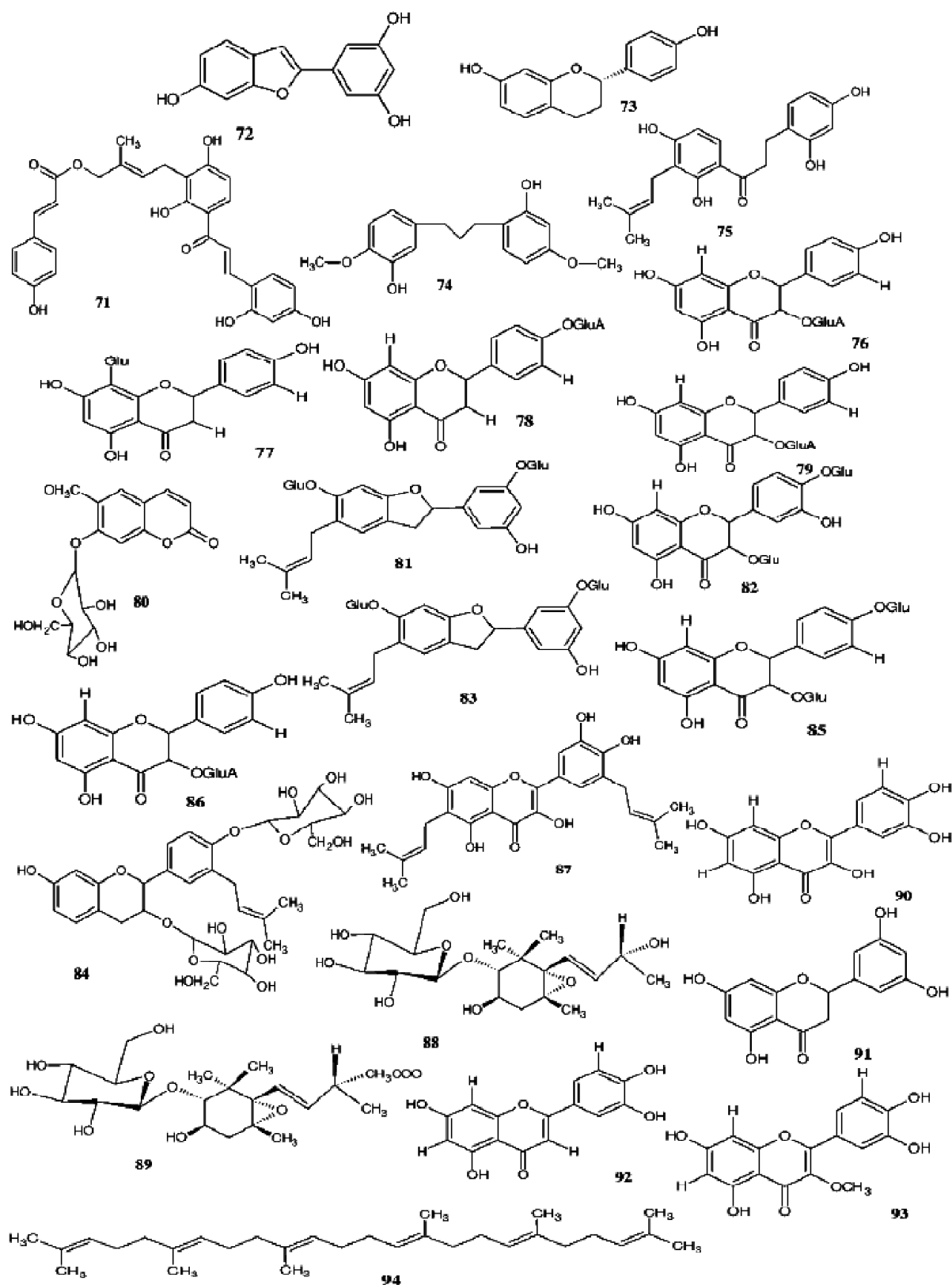
Phytochemicals characterized in *Broussonetia papyrifera* tree are (Fig. 1): broussonin A; C₁₆H₁₈O₃ (**1**)⁴⁻⁶, broussonin B; C₁₆H₁₈O₃ (**2**)^{4,5}, (+)-marmesin; C₁₄H₁₄O₄ (**3**)^{4,7}, kazinol F; C₂₅H₃₂O₄ (**4**)⁸, brousochalcone A; C₂₀H₂₀O₅ (**5**)⁹⁻¹², 1-(2,4-dihydroxyphenyl)-3-(4-hydroxyphenyl)-propane; C₁₅H₁₆O₃ (**6**)⁶, 1-(4-hydroxy-2-methoxyphenyl)-3-(4-hydroxy-3-prenylphenyl)-propane; C₂₁H₂₆O₃ (**7**)⁶, 3'-γ-hydroxy-methyl-(E)-γ-methylallyl-2,4,2',4'-tetrahydroxychalcone-11'-O-coumarate; C₂₉H₂₆O₈ (**8**)^{6,13}, (2S)-2',4'-dihydroxy-2''-(1-hydroxy-1-methylethyl)dihydrofuro-2,3-h flavanone; C₂₀H₂₀O₆ (**9**)⁶, isolicoflavonol; C₂₀H₁₈O₆ (**10**)^{6,14}, (2S)-abyssinone II; C₂₀H₂₀O₅ (**11**)⁶, (2S)-5,7,2',4'-tetrahydroxyflavanone; C₁₅H₁₂O₆ (**12**)⁶, (2S)-euchrenone a7; C₂₀H₂₀O₅ (**13**)⁶, brousoflavonol F; C₂₅H₂₆O₆ (**14**)^{6,14-16}, (2S)-naringenin (Syn. Naringetol); C₁₅H₁₂O₅ (**15**)⁶, albanolA (Syn. Mulberrofuran G); C₃₄H₂₆O₈ (**16**)⁶, moracin N; C₁₉H₁₈O₄ (**17**)⁶, isogemichalcone C; C₃₀H₂₈O₉ (**18**)⁶, chushizisin H;

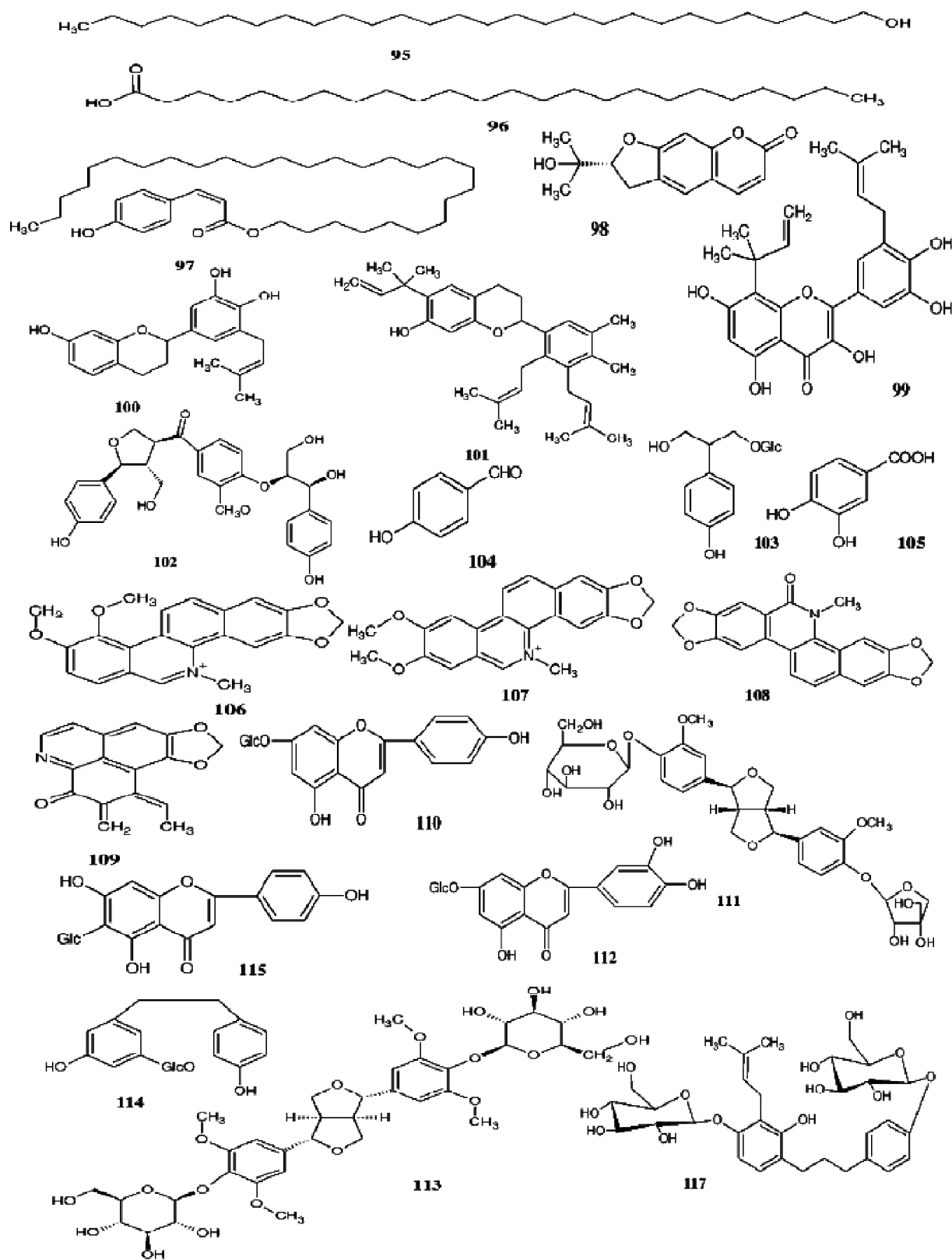
†Review.

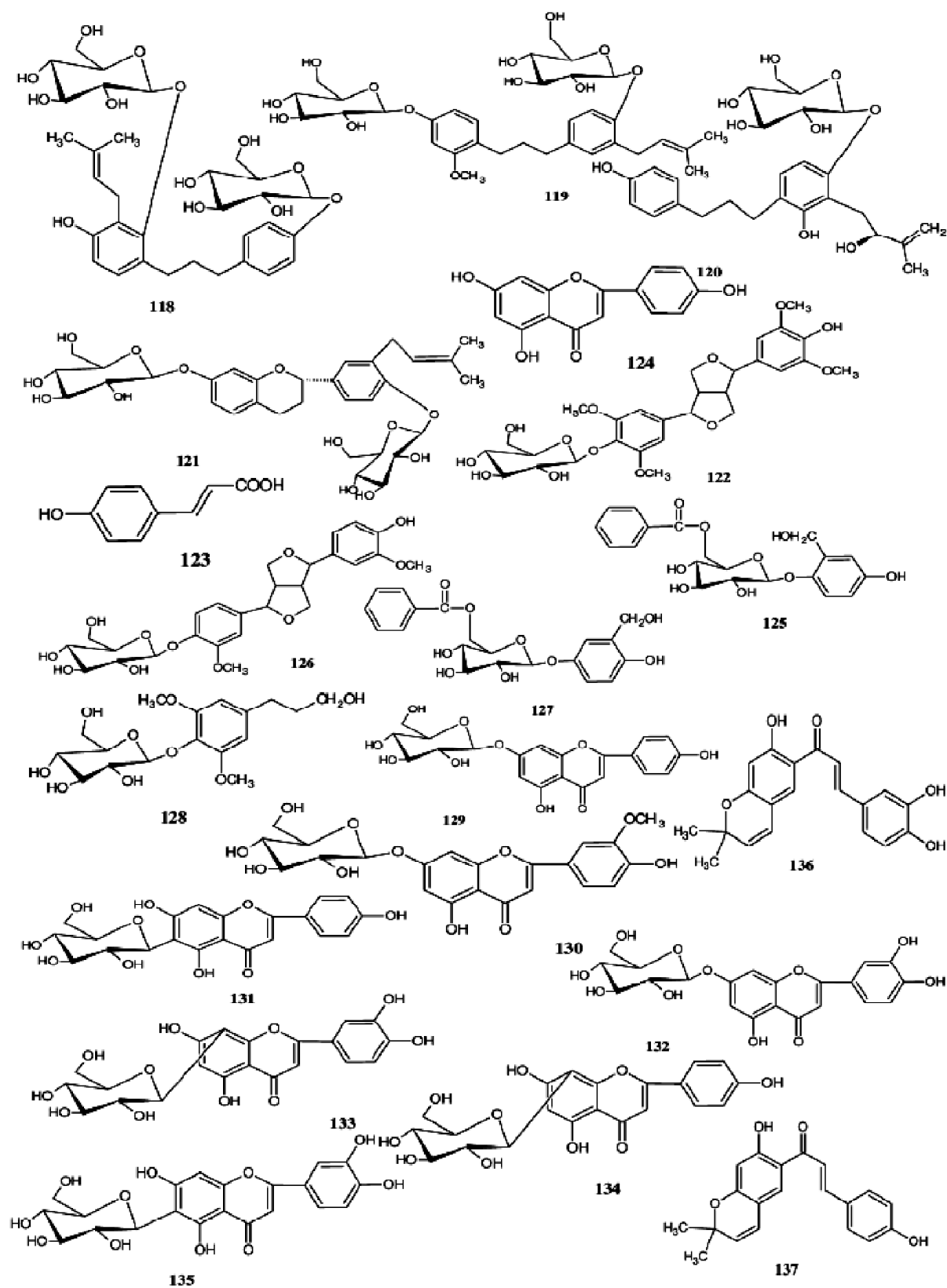
$C_{28}H_{30}O_9$ (**19**)^{17,18}, brousoflavonol E; $C_{30}H_{34}O_7$ (**20**)¹⁹, brousoflavonol G; $C_{30}H_{34}O_7$ (**21**)¹⁶, brousoflavonol C; $C_{30}H_{34}O_7$ (**22**)^{19,20}, brousoflavonol D; $C_{30}H_{32}O_7$ (**23**)²⁰, chushizisin I; $C_{28}H_{28}O_7$ (**24**)¹⁷, 5,7,3',4'-tetrahydroxy-3-methoxy-6-geranylflavone; $C_{26}H_{28}O_7$ (**25**)⁶, brousoflavonol B; $C_{26}H_{28}O_7$ (**26**)^{21,22}, brousoflavonol A; $C_{26}H_{26}O_7$ (**27**)²¹, 5,7,3',4'-tetrahydroxy-6-geranylflavonol; $C_{25}H_{26}O_7$ (**28**)^{6,13}, 4'-O-methylavidioside; $C_{22}H_{26}O_9$ (**29**)²³, brousoflavan A; $C_{25}H_{30}O_6$ (**30**)^{16,24}, (2*R*,3*R*)-lespedezaflavanone C; $C_{25}H_{28}O_6$ (**31**)⁶, brousoflavonol F; $C_{25}H_{26}O_6$ (**32**)²⁵, 5,7,2',4'-tetrahydroxy-3-geranylflavone; $C_{25}H_{26}O_6$ (**33**)^{6,13}, kazinol A; $C_{25}H_{30}O_4$ (**34**)^{12,26}, kazinol B; $C_{25}H_{28}O_4$ (**35**)^{12,26}, gancaonin P; $C_{20}H_{18}O_7$ (**36**)⁶, uralenol; $C_{20}H_{18}O_7$ (**37**)^{22,27}, (2*S*)-2',4'-dihydroxy-2''-(1-hydroxy-1-methylethyl)dihydrofuro-2,3-h flavanone; $C_{20}H_{20}O_6$ (**38**)⁶, isolicoflavonol; $C_{20}H_{18}O_6$ (**39**)⁶, chushizisin C; $C_{19}H_{24}O_6$ (**40**)^{17,18}, chushizisin D; $C_{19}H_{24}O_6$ (**41**)^{17,18}, chushizisin E; $C_{19}H_{22}O_5$ (**42**)^{17,18}, chushizisin B; $C_{19}H_{22}O_6$ (**43**)^{17,18}, chushizisin A; $C_{19}H_{22}O_6$ (**44**)^{17,18}, chushizisin F; $C_{19}H_{20}O_6$ (**45**)^{17,18}, (2*S*)-euchrenone a7; $C_{20}H_{20}O_5$ (**46**)⁶, brousochalcone A; $C_{20}H_{20}O_5$ (**47**)^{9,10,27}, brousoaurone A; $C_{20}H_{18}O_5$ (**48**)^{16,24}, chushizisin G; $C_{19}H_{22}O_5$ (**49**)^{17,18}, broussinol; $C_{20}H_{22}O_4$ (**50**)⁴, isobavachalcone; $C_{20}H_{20}O_4$ (**51**)⁶, brousochalcone B; $C_{20}H_{20}O_4$ (**52**)^{12,21}, (2*S*)-abyssinone II; $C_{20}H_{20}O_5$ (**53**)⁶, bavachin; $C_{20}H_{20}O_4$ (**54**)⁶, moracin I; $C_{20}H_{20}O_4$ (**55**)⁶, broussonin C; $C_{20}H_{24}O_3$ (**56**)⁵, (2*S*)-7,4'-dihydroxy-3'-prenylflavan; $C_{20}H_{22}O_3$ (**57**)⁶, moracin N; $C_{19}H_{18}O_4$ (**58**)⁶, demethylmoracin I; $C_{19}H_{18}O_4$ (**59**)^{6,13}, moracin D; $C_{19}H_{16}O_4$ (**60**)⁶, broussonin F; $C_{17}H_{20}O_4$ (**61**)⁶, broussin; $C_{16}H_{16}O_3$ (**62**)²⁸, 7,4'-dihydroxyflavan; $C_{15}H_{14}O_3$ (**63**)²⁸, pinocembrin; $C_{15}H_{12}O_4$ (**64**)²⁹, resveratrol; $C_{14}H_{12}O_3$ (**65**)³⁰, isoliquiritigenin; $C_{15}H_{12}O_4$ (**66**)¹¹, isoliquiritigenin 2'-methy ether; $C_{16}H_{14}O_4$ (**67**)²⁸, 2,4,2',4'-tetrahydroxychalcone; $C_{15}H_{12}O_5$ (**68**)⁶, (+)-dihydrokaempferol (Syn. (+)-aromadendrin); $C_{15}H_{12}O_6$ (**69**)⁶, norartocarpanone (Syn. Steppogenin); $C_{15}H_{12}O_6$ (**70**)⁶, dimethoxy isogemichalcone C; $C_{29}H_{26}O_8$ (**71**)⁶, moracin M; $C_{14}H_{10}O_4$ (**72**)⁶, (2*S*)-7,4'-dihydroxyflavan; $C_{15}H_{14}O_3$ (**73**)⁶, broussonin E; $C_{17}H_{20}O_4$ (**74**)⁶, 1,2,4-dihydroxy-3-(3-methylbut-2-en-1-yl)phenyl-3-(2,4-dihydroxyphenyl)-propan-1-one; $C_{20}H_{22}O_5$ (**75**)³¹, $C_{21}H_{20}O_{11}$ (**76**)³¹, 2-{5,7-dihydroxy-2-(4-hydroxyphenyl)-4-oxo-3,4-dihydro-2*H*-chromen-8-ylamino}pentanedioic acid; $C_{21}H_{20}O_{10}$ (**77**)³¹, $C_{21}H_{18}O_{11}$ (**78**)³¹, $C_{21}H_{20}O_{12}$ (**79**)³¹, $C_{16}H_{18}O_9$ (**80**)³¹, $C_{25}H_{30}O_9$ (**81**)³¹, $C_{27}H_{30}O_{17}$ (**82**)³¹, $C_{31}H_{38}O_{14}$ (**83**)³¹, $C_{32}H_{42}O_{14}$ (**84**)³¹, $C_{27}H_{30}O_{16}$ (**85**)³¹, $C_{21}H_{18}O_{12}$ (**86**)³¹, papyriflavonol A (Syn. Broussonol E); $C_{25}H_{26}O_7$ (**87**)^{11,12,22,32,33}, (2*R*,3*R*,5*R*,6*S*,9*R*)-3-hydroxy-5,6-epoxy-b-ionol-2-O-β-D-glucopyranoside; $C_{19}H_{32}O_9$ (**88**)³⁴, (2*R*,3*R*,5*R*,6*S*,9*R*)-3-hydroxyl-5,6-epoxy-acety-b-ionol-2-O-β-D-glucopyranoside; $C_{21}H_{34}O_{10}$ (**89**)³⁴, quercetin (Syn. 3,3',4',5,7-pentahydroxyflavone); $C_{15}H_{10}O_7$ (**90**)^{11,27}, 5,7,3',5'-tetrahydroxyflavanone; $C_{15}H_{12}O_6$ (**91**)¹⁴, luteolin; $C_{15}H_{10}O_6$ (**92**)^{14,35}, 5,7,3',4'-tetrahydroxy-3-methoxyflavone; $C_{16}H_{12}O_7$ (**93**)¹⁴, squalene; $C_{30}H_{50}$ (**94**)¹⁵, octacosan-1-ol; $C_{28}H_{58}O$ (**95**)¹⁵, lignoceric acid; $C_{24}H_{48}O_2$ (**96**)¹⁵, 4'-hydroxycis-cinnamic acid octacosyl ester; $C_{37}H_{64}O_3$ (**97**)¹⁵, (-)-marmesin; $C_{14}H_{14}O_4$ (**98**)¹⁵, 8-(1,1-dimethylallyl)-5'-(3-methylbut-2-enyl)-3',4',5,7-tetrahydroxyflavanonol; $C_{25}H_{26}O_7$ (**99**)^{12,27}, 3'-(3-methylbut-2-enyl)-3',4',7-trihydroxyflavane; $C_{20}H_{22}O_4$ (**100**)²⁷, kazinol E; $C_{30}H_{38}O_4$ (**101**)^{12,18}, sesquieolignan; $C_{28}H_{30}O_9$ (**102**)³⁶, 2-(4-hydroxyphenyl)propane-1,3-diol-1-O-β-D-glucopyranoside; $C_{15}H_{22}O_8$ (**103**)³⁶, 4-hydroxybenzaldehyde; $C_7H_6O_2$ (**104**)³⁶, protocatechuic acid; $C_7H_6O_4$ (**105**)³⁶, broussonpapyrine; $C_{21}H_{18}O_4$ (**106**)^{37,38}, nitidine; $C_{21}H_{18}O_4$ (**107**)^{37,38}, oxyavicine; $C_{20}H_{13}NO_5$ (**108**)^{37,38}, liriodenine; $C_{17}H_9O_3$ (**109**)^{37,38}, cosmosiin; $C_{21}H_{20}O_{10}$ (**110**)³⁹, (+)-pinoresinol-4'-O-β-D-glucopyranosyl-4''-O-β-D-apiofuranoside; $C_{31}H_{40}O_{15}$ (**111**)³⁹, luteolin-7-O-β-D-glucopyranoside; $C_{21}H_{21}O_{11}$ (**112**)³⁹, liriodendrin; $C_{34}H_{46}O_{18}$ (**113**)³⁹, 3,5,4'-trihydroxy-bibenzyl-3-O-β-D-glucoside; $C_{20}H_{25}O_9$ (**114**)³⁹, apigenin-6-C-β-D-glycopyranside; $C_{21}H_{21}O_{11}$ (**115**)³⁹, 8,11-octadecadienic acid; (**116**)⁴⁰, broussoside A; $C_{32}H_{44}O_{13}$ (**117**)³⁵, broussoside B; $C_{32}H_{44}O_{13}$ (**118**)³⁵, broussoside C; $C_{33}H_{46}O_{13}$ (**119**)³⁵, broussoside D; $C_{26}H_{34}O_9$ (**120**)³⁵, broussoside E; $C_{32}H_{42}O_{13}$ (**121**)³⁵, syringaresinol-4'-O-β-D-glucoside; $C_{28}H_{36}O_{13}$ (**122**)³⁵, *p*-coumaric acid; $C_9H_8O_3$ (**123**)³⁵, apigenin; $C_{15}H_{10}O_5$ (**124**)³⁵, poliothyrsoside; $C_{20}H_{22}O_9$ (**125**)³⁵, pinoresinol-4'-O-β-D-glucopyranoside; $C_{26}H_{32}O_{11}$ (**126**)³⁵, flacourtin; $C_{20}H_{22}O_9$ (**127**)³⁵, dihydrosyringin; $C_{17}H_{26}O_9$ (**128**)³⁵, apigenin-7-O-β-D-glucoside; $C_{21}H_{20}O_{10}$ (**129**)³⁵, chrysoeriol-7-O-β-D-glucoside; $C_{22}H_{22}O_{11}$ (**130**)³⁵, isovitexin; $C_{21}H_{20}O_{10}$ (**131**)³⁵, luteoloside; $C_{21}H_{20}O_{11}$ (**132**)³⁵, orientin; $C_{21}H_{20}O_{11}$ (**133**)³⁵, vitexin; $C_{21}H_{20}O_{10}$ (**134**)³⁵, isoorientin; $C_{21}H_{20}O_{11}$ (**135**)³⁵, 3,4-dihydroxyisolonchocarpin; $C_{20}H_{18}O_5$ (**136**)¹², 4-hydroxyisolonchocarpin; $C_{20}H_{18}O_4$ (**137**)¹², 3'-(3-methylbut-2-enyl)-3',4',7-trihydroxyflavane; $C_{20}H_{22}O_4$ (**138**)¹², 8-(1,1-dimethylallyl)-5'-(3-methylbut-2-enyl)-3',4',5,7-tetrahydroxyflavanonol; $C_{25}H_{26}O_7$ (**139**)¹², brousofluorenone A; $C_{30}H_{30}O_7$ (**140**)^{12,18}, brouso-

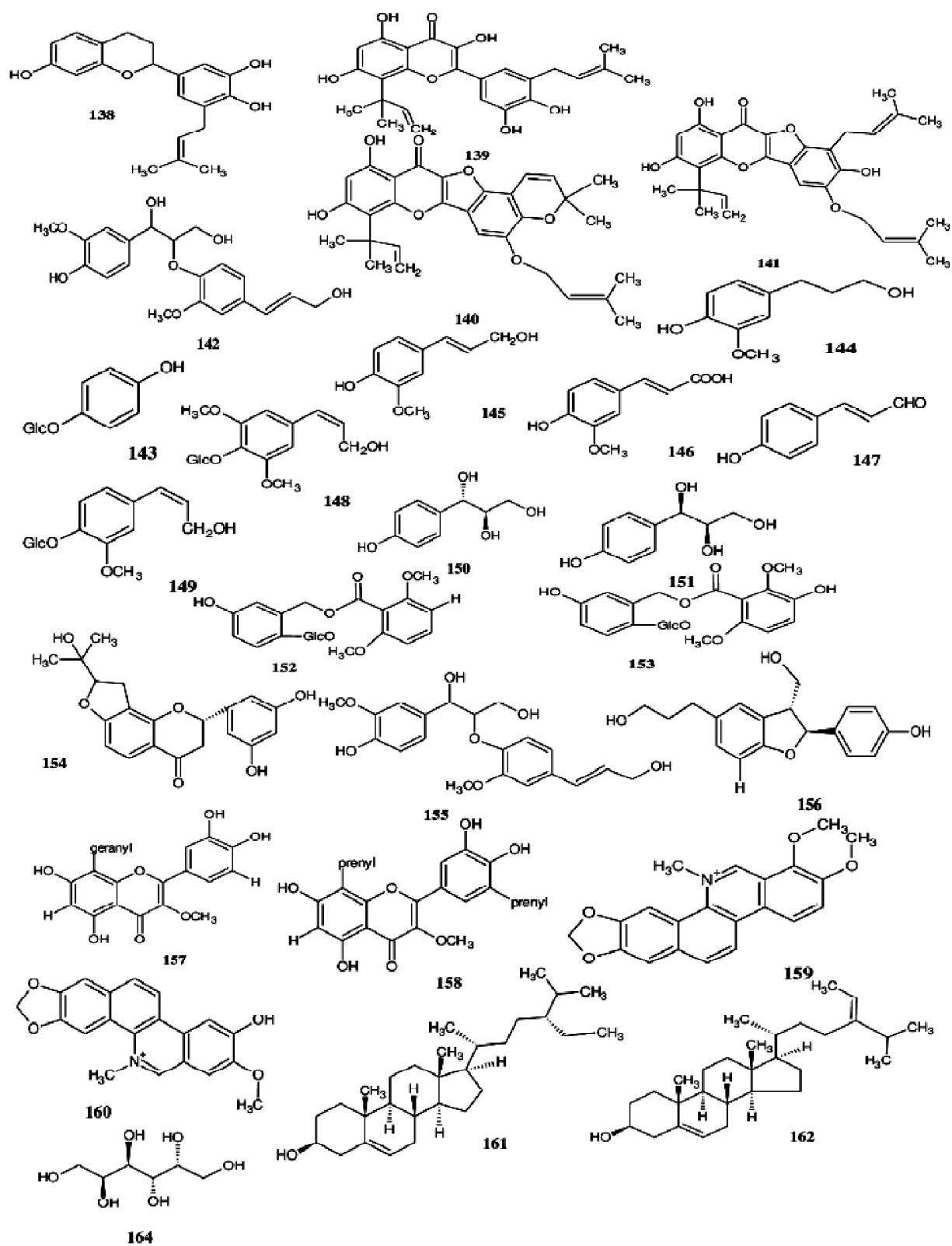


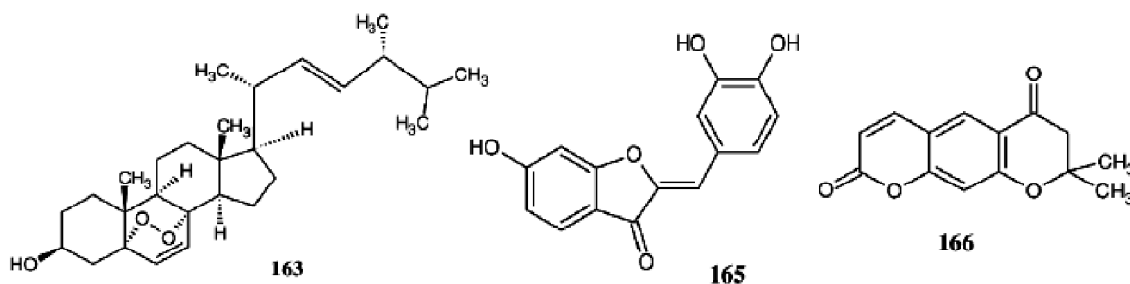










Fig. 1. Phytochemistry of *Broussonetia papyrifera* (L.) L'He'r. ex Vent.

fluorenone B; $C_{30}H_{32}O_7$ (**141**)^{12,18}, threo-1-(4-hydroxy-3-methoxyphenyl)-2-{4-(*E*)-3-hydroxy-1-propenyl-2-methoxyphenoxy}-1,3-propanediol; $C_{20}H_{24}O_7$ (**142**)¹⁷, arbutine; $C_{12}H_{16}O_7$ (**143**)³⁶, dihydro-coniferyl alcohol; $C_{10}H_{14}O_3$ (**144**)³⁶, coniferyl alcohol; $C_{10}H_{12}O_3$ (**145**)³⁶, ferulic acid; $C_{10}H_{10}O_4$ (**146**)³⁶, *p*-coumaraldehyde; $C_9H_8O_2$ (**147**)³⁶, *cis*-syringin; $C_{17}H_{24}O_9$ (**148**)³⁶, *cis*-coniferin; $C_{16}H_{22}O_8$ (**149**)³⁶, erythro-1-(4-hydroxyphenyl)glycerol; $C_9H_{12}O_4$ (**150**)³⁶, threo-1-(4-hydroxyphenyl)glycerol; $C_9H_{12}O_4$ (**151**)³⁶, curculigoside I (**152**)³⁶, curculigoside C (**153**)³⁶, (2*S*)-2',4'-dihydroxy-2''-(1-hydroxy-1-methylethyl)-dihydrofurano-2,3-h-flavanone; $C_{20}H_{24}O_6$ (**154**)¹³, erythro-1-(4-hydroxy-3-methoxyphenyl)-2-{4-(*E*)-3-hydroxy-1-propenyl-2-methoxyphenoxy}-1,3-propanediol; $C_{20}H_{24}O_7$ (**155**)¹⁷, 3-2-(4-hydroxyphenyl)-3-hydroxymethyl-2,3-dihydro-1-benzofuran-5-ylpropan-1-ol; $C_{18}H_{20}O_4$ (**156**)¹⁷, 5,7,3',4'-tetrahydroxy-3-methoxy-8-geranylfavone; $C_{26}H_{28}O_7$ (**157**)²², 5,7,3',4'-tetrahydroxy-3-methoxy-8,5'-diprenylfavone; $C_{26}H_{28}O_7$ (**158**)²², chelerythrine; $C_{21}H_{18}NO_4$ (**159**)⁴¹, isoterihanine; $C_{20}H_{16}NO_4$ (**160**)⁴¹, β -sitosterol; $C_{29}H_{50}O$ (**161**)^{41,42}, fucosterol; $C_{29}H_{48}O$ (**162**)⁴¹, ergosterol peroxide; $C_{28}H_{44}O_3$ (**163**)⁴³, D-galactitol; $C_6H_{14}O_6$ (**164**)⁴³, sulfuretin; $C_{15}H_{10}O_5$ (**165**)⁴³, graveolone; $C_{14}H_{12}O_4$ (**166**)⁴³.

References

- R. N. Parker, "A forest flora for the Punjab with Hazara and Delhi", Government Printing Press, Lahore, Pakistan, 1956.
- G. Watt, "Dictionary of the economic products of India", Vol. I, Periodical Experts, Dehra Dun, India, 1972.
- H. Qureshi, M. Arshad and Y. Bibi, *J. Biodiv. Environ. Sci.*, 2014, **5**, 508.
- M. Takasugi, M. Anetai, T. Masamune, A. Shirata and K. Takahashi, *Chem. Lett.*, 1980, **4**, 339.
- P. A. De Almeida, S. V. Fraiz (Jr.) and R. Braz-Filho *J. Brazil Chem. Soc.*, 1999, **10**, 347.
- D. Lee, K. P. L. Bhat, H. H. S. Fong, N. R. Farnsworth, J. M. Pezzuto and A. D. Kinghorn, *J. Nat. Pro.*, 2001, **64**, 1286.
- Z. Yin, J. Chao, L. Zhang, W. Ye, W. Shen and S. Zhao, *Nat. Pro. Res. Develop.*, 2006, **18**, 420.
- D. I. Jang, B. G. Lee, C. O. Jeon, N. S. Jo, J. H. Park, S. Y. Cho, H. Kee and J. S. Ko, *Cosmetics and Toiletries.*, 1997, **112**, 80.
- J. P. Wang, L. T. Tsao, S. L. Raung and C. N. Lin, *Euro. J. Pharm.*, 1997, **12**, 201.
- Z. Cheng, C. Lin, T. Hwang and C. Teng, *Biochem. Pharmacol.*, 2001, **61**, 939.
- Z. Zheng, K. Cheng, J. Chao, J. Wu and M. Wang, *Food Chem.*, 2008, **106**, 529.
- H. W. Ryu, B. W. Lee, M. J. Curtis-long, S. Jung, Y. B. Ryu, W. S. Lee and K. H. Park, *J. Agric. Food Chem.*, 2001, **58**, 202.
- B. Botta, A. Vitali, P. Menendez, D. Misiti and G. D. Monache, *Curr. Med. Chem.*, 2005, **12**, 713.
- Z. Zheng, K. Cheng, J. Chao, J. Wu and M. Wang, *Food Chem.*, 2008, **106**, 529.
- S. Fang, B. Shieh, R. Wu and C. Lin, *Phytochemistry*, 1995, **38**, 535.
- H. Ko, S. Yu, F. Ko, C. Teng and C. Lin, *J. Nat. Pro.*, 1997, **60**, 1008.
- R. Mei, Y. Wang, G. Du, G. Liu, L. Zhang and Y. Cheng, *J. Nat. Pro.*, 2009, **72**, 621.
- G. Wang, B. Huang and L. Qin, *Phytotherapy Res.*, 2012, **26**, 1.
- T. Fukai, J. Ikuta and T. Nomura, *Chem. Pharm. Bull.*, 1986, **34**, 1987.
- T. Fukai and T. Nomura, *Heterocycles*, 1989, **29**, 2379.
- J. Matsumoto, T. Fujimoto, C. Takino, M. Saitoh, Y. Hano, T. Fukai and T. Nomura, *Chem. Pharm. Bull.*, 1985, **33**, 3250.

Qureshi *et al.*: Phytochemical constituents of *Broussonetia papyrifera* (L.) L'He'r. ex Vent: An overview

22. F. Guo, L. Feng, C. Huang, H. Ding, X. Zhang, Z. Wang and Y. Li, *Phytochem. Lett.*, 2013, **6**, 331.
23. A. C. Dweck, http://www.rarefruit.org/PDF_files/Broussonetia_papyrifera.pdf, 2005.
24. S. C. Fang, B. J. Shieh and C. N. Lin, *Phytochemistry*, 1994, **37**, 851.
25. S. Fang, B. Shieh, R. Wu and C. Lin, *Phytochemistry*, 1995, **38**, 535.
26. J. Ikuta, Y. Hano and T. Nomura, *Heterocycles*, 1985, **23**, 2835.
27. R. M. Chen, L. H. Hu, T. Y. An, J. Li and Q. Shen, *Bioorg. Med. Chem. Lett.*, 2002, **12**, 3387.
28. J. B. Harborne and H. Baxter, "The handbook of natural flavonoids, Band 1+2", Wiley-VCH-Verlag, Weinheim, 1800s, 1999.
29. L. Wang, H. J. Son, M. L. Xu, J. H. Hu and M. H. Wang, *J. Korean Soc. Appl. Bio. Chem.*, 2010, **53**, 297.
30. J. Sun, S. Liu, C. Zhang, L. Yu, J. Bi, F. Zhu and Q. Yang, *PLoS ONE*, 2012, **7**, e32021. doi:10.1371/journal.pone.0032021.
31. L. Luo, L. Shen, F. Sun, Y. Dai, H. Zheng, Z. Ma, Y. Xue and Z. Guo, *Analytical Methods*, 2012, **4**, 230.
32. K. H. Son, S. J. Kwon, H. W. Chang, H. P. Kim and S. S. Kang, *Fitoterapia*, 2001, **72**, 456.
33. H. Y. Sohn, K. H. Son, C. S. Kwon, G. S. Kwon and S. S. Kang, *Phytomedicine*, 2004, **11**, 666.
34. W. S. Feng, H. W. Li, X. K. Zheng and S. Q. Chen, *Chinese Chem. Lett.*, 2007, **18**, 1518.
35. C. Yang, F. Li, B. Du, B. Chen, F. Wang and M. Wang, *PLoS ONE*, 2014, **9**, e94198.
36. H. Zhao, L. Huang, L. Qin and B. Huang, *J. Med. Plants Res.*, 2011, **5**, 6407.
37. S. Pang, G. Wang, B. Huang, Q. Zhang and L. Qin, *Chem. Nat. Comp.*, 2005, **43**, 100.
38. S. Q. Pang, G. Q. Wang, B. K. Huang and L. P. Qin, *Zhong Yao Cai*, 2009, **32**, 1229.
39. X. Ran, X. Wang, P. Liu, Y. Chi, B. Wang, D. Dou, T. Kang and W. Xiong, *Chinese J. Nat. Med.*, 2013, **11**, 269.
40. X. Zhou, R. Mei, L. Zhang, Q. Lu, J. Zhao, A. Adebayo and Y. Cheng, *J. Asian Nat. Pro. Res.*, 2010, **12**, 399.
41. Takasugi, S. Q. Pang, G. Q. Wang, B. K. Huang and L. P. Qin, *Zhong Yao Cai*, 2009, **32**, 1229.
42. H. Zhong, X. Zhang and M. Wang, *Nat. Pro. Res. Devel.*, 2011, **23**, 661.
43. J. F. Chao, Z. Q. Yin, W. C. Ye and S. X. Zhao, *Zhongguo Zhong Yao Za Zhi*, 2006, **31**, 1078.

