Review of bioactive compounds from root barks of *Morus* plants (Sang-Bai-Pi) and their pharmacological effects

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**Abstract:** *Morus*, a plant genus from the family of Moraceae, most plants of which are used as traditional medicines in Asian counties. The root barks of *Morus* plants are normally called as Sang-Bai-Pi (SBP) in Chinese and used for the treatment of inflammatory and respiratory diseases. Decades of research on phytochemistry of SBP have led to the identification of various compounds, such as Diels–Alder-type adducts, flavonoids, benzofurans, stilbenes, polyhydroxylated alkaloids, etc. These compounds have showed a wide range of bioactive features including anti-inflammatory, anti-oxidative, anti-microbic, etc. This review focus on the bioactive compounds and their pharmacological effects of SBP which will help us fully understand the effective substances of SBP, and pave our way to further explore medicinal uses of SBP and comprehensive utilization of *Morus* species.

**Subjects:** Drug Discovery; Natural Products; Pharmacology

**Keywords:** *Morus*; Sang-Bai-Pi; root barks; bioactive compounds; pharmacological effects

1. Introduction

*Morus* Linn, a plant genus from family Moraceae, consists of 10–16 species recognized by botanists including *Morus alba* L., *Morus nigra* L., *Morus cathayana* Hemsl., *Morus wittiorum* Hand.-Mazz., *Morus mongolica* (Bur.) Schneid., *Morus australis* Poir., etc. (Datwyler & Weiblen, 2004). *M. alba*, a perennial herb, is the dominant specie among the genus *Morus*. It is distributed throughout Asia, Africa, Europe and South and North America, and found in wide range of areas (Zafar et al., 2013). The main use of *M. alba* is as the feed for silk worms, and it is also appreciated as medicines, fruits, vegetables,

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**ABOUT THE AUTHORS**

The author’s group mainly focus on the quality control of traditional Chinese medicines (TCM), including standards and process control of TCM industry, preparation technology of the chemical controls of TCM, comprehensive evaluation technology standard for TCM, harmful substances removal technology of TCM, and enhancement of the quality control level and ability in industry.

The author’s key research activities are isolation and identification of new compounds from TCM, preparation of the chemical controls of TCM, and discovery of effective substances from TCM.

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**PUBLIC INTEREST STATEMENT**

Root barks of *Morus* plants are usually called Sang-Bai-Pi (Mori Cortex). It has been recorded in Chinese Pharmacopoeia and widely applied in traditional Chinese medicine since 500 B.C. for the treatment of lung heat, cough, edema, oliguria, etc. Decades of research on phytochemistry of Sang-Bai-Pi (SBP) have led to the identification of various compounds, which showed a wide range of biological properties. The current review is intended to focus on the bioactive compounds of SBP and their pharmacological effects from 1976 to 2015. This paper will help us fully understand the effective substances of SBP, and pave our way to further explore medicinal uses of SBP and comprehensive utilization of *Morus* plants.
animal feed, and landscaping (Kumar & Chauhan, 2008). In Asian countries, *M. alba* plays a key role in agriculture and traditional medicine. Besides its uses in agriculture, different parts of *M. alba* (i.e. fruits, leaves, twigs, and root barks) with abundant resources are commonly used as traditional medicines.

Root barks of *M. alba* (Sang-Bai-Pi or Mori Cortex) have been recorded in Chinese Pharmacopoeia and widely applied in traditional Chinese medicine since 500 BC for the treatment of lung heat, cough, edema, and oliguria (Pharmacopoeia Committee of P. R. China., 2010). In fact, original plants of ancient Chinese Sang-Bai-Pi (SBP) originated from more than one species of *Morus* by textual research. Thus, SBP include the root barks of most *Morus* plants in China (Yang & Wan, 2008). There are several reviews on the chemical and pharmacological advances of species in the genus *Morus* (Zafar et al., 2013). However, no detailed reports have been made on SBP of what bioactive compounds it contained and what are their pharmacological effects. Decades of research on phytochemistry of SBP have led to the identification of various compounds, which showed a wide range of biological properties. These studies prompted us to compile the progress. The current review is intended to focus on the bioactive compounds of SBP and their pharmacological effects from 1976 to 2015. There over 110 compounds, mostly Diels–Alder-type adducts, flavonoids, 2-Arylbenzofurans, and stilbenes, with anti-inflammatory, anti-oxidative, anti-microbial, anti-diabetic, anti-tumor, and other pharmacological effects are summarized in this paper. This will help us fully understand the effective substances of SBP, and pave our way to further explore medicinal uses of SBP and comprehensive utilization of *Morus* plants.

2. Ethnomedicinal and traditional uses

The root barks of *Morus* plants are called SBP in Chinese and Sōhakuhi in Japanese (Figure 1). In China, SBP was first recorded in Shennong’s Herbal—one of the world’s earliest pharmacopoeia. It is suggested that the roots of *Morus* plants are collected between late autumn and early spring. Brown layer is removed from fresh roots by copper knife without discarding the surface juice, then the white root barks are dried or fried with honey to make SBP. It is slightly sweet and contains lots of fiber, and much powder appears when it is torn open. SBP of good quality is usually white, thick, and flexible (Chinese Herbalism Editorial Board, 1999). SBP is used as dietary Chinese herbs (Yanze, Zhimin, & Junzeng, 2015), and in traditional Chinese medicine (TCM), it has been used in doses 9–15 g by decocting method for the treatment of cough, yellow sputum, bronchitis, xerophthalmia, nephritis, pulmonary diseases, incised wound, and so on (Chinese Herbalism Editorial Board, 1999; Li & Xu, 2012; Ma & Cai, 2013; Zhao, Yan, & Xiong, 2003).

![Figure 1. Commercially available Sang-Bai-Pi (without removal of brown layer).](image)
Figure 2. Bioactive Diels–Alder-type adducts from Sang-Bai-Pi.
3. Bioactive compounds

3.1. Diels–Alder-type adducts
Diels–Alder-type adducts, which formed by a Diels–Alder reaction between the \( \alpha, \beta \)-olefinic moiety of a chalcone and an isoprene moiety, are the most representative compounds in the genus *Morus*. Nearly 90 Diels–Alder-type adducts have been isolated from *Morus* plants so far (Yang, Tan, Chen, & Kang, 2014). We summarized and updated the structures of some bioactive Diels–Alder-type adducts [1–38] from SBP are shown in Figure 2.

3.2. Flavonoids
The genus *Morus* is a rich source of flavonoids, and most flavonoids are substituted by prenyl and geranyl groups (Yang et al., 2014). Diverse flavonoids are resulted by different positions of substituents or cyclization. We summarized and updated the structures; some bioactive flavonoids [39–73] from SBP are shown in Figure 3.

3.3. 2-Arylbenzofurans and stilbenes
*Morus* plants are also rich sources of 2-arylbenzofurans and stilbenes, among which, 2-arylbenzofurans are commonly substituted by prenyl and geranyl groups. Diverse 2-arylbenzofurans are
resulted by different positions of substituents or cyclization (Yang et al., 2014). We summarized and updated the structures some bioactive 2-arylbenzofurans [74–101] and stilbenes [102–106] from SBP are shown in Figure 4.

3.4. Polyhydroxylated alkaloids
Polyhydroxylated alkaloids (alkaloidal iminosugars) are considered as analogs of saccharides in which the ring oxygen is replaced by nitrogen, and they are considered to have therapeutic potentials (Watson, Fleet, Asano, Molyneux, & Nash, 2001). The genus Morus has attracted much attention.

Figure 3. Bioactive flavonoids from Sang-Bai-Pi.
for its polyhydroxylated alkaloids, especially the principal α-glycosidase inhibitor—1-deoxyjirimycin (1-DNJ) [111] (Zhang, Li, et al., 2013). SBP contains 1-DNJ with high content and the structure is shown in Figure 5.
3.5. Other bioactive compounds

Triterpenoids [107–109] are seldom found in Morus plants. To the best of our knowledge, not more than 10 triterpenoids have been identified from SBP up to date. Besides the compounds motioned above, there are also other types of bioactive compounds [110, 112–117] isolated from SBP (Figure 5).

4. Pharmacological effects

4.1. Anti-inflammatory effects

Kimura, Okuda, Nomura, Fukai, & Arichi (1986a, 1986b) firstly reported the inhibitory effects of SBP on arachidonate metabolism in rat platelets. Extracts of SBP showed inhibitory effects on cyclooxygenase (COX) isoenzymes (Rollinger et al., 2005). Total flavonoids of SBP (400 mg/kg) could obviously inhibit the xylene-induced ear swelling and the capillary permeability resulted from inflammation by acetic acid (Feng, Xie, Lin, Zhao, & Zhou, 2013). Studies reported that SBP extracts suppressed the production of nitric oxide (NO), prostaglandin E2 (PGE2), and mRNA expression of COX-2 in RAW 264.7 cells (Seo, Lim, Jeong, Ha, & Shin, 2013), and inhibited nuclear factor kappa B (NF-κB) activation (Eo et al., 2014).

A large number of anti-inflammatory compounds were found from SBP. Morusin [46], oxydihydromorusin (morusinol) [48], kuwanon C [39], mulberrofuran A [79], kuwanon G (moracenin B or albanin F) [1], kuwanon H (moracenin A or albanin G) [2], sanggenon D [10], and mulberrofurans G (albanol A) [29], J [31], O [32] were found to affect on arachidonate metabolism in rat platelets (Kimura et al., 1986a, 1986b). Morusin [46], kuwanon C [39], sanggenons B [24], C [7], D [10], E [11], O [8] inhibited COX activity (Cheon et al., 2000; Chi et al., 2001; Rollinger et al., 2005). Oxyresveratrol [102] inhibited the LPS-stimulated increase of inducible nitric oxide synthase (iNOS) expression (Chung et al., 2003). Moracins C [74], D [87], O [89], P [90], R [78], artoindonesianin O [84], alabafuran A [85], mulberrofurans J [31], L [81], Y [83], kuwanons A [53], C [39], E [55], T [40], sanggenon F [65], sanggenol L [69] and morusin [46] showed inhibitory effects on NO production (Qin et al., 2015; Yang, Matsuzaki, Takamatsu, & Kitanaka, 2011). Kuwanon J 2,4,10''-trimethyl ether [19], kuwanon R [20] inhibited NF-κB activity (Phung et al., 2012). Cudraflavone B [51] inhibited Tumor Necrosis Factor (TNF-α) gene expression and secretion by blocking the translocation of NF-κB (Hošek et al. 2011; Kollar et al., 2013). Kuwanon E [55], kuwanon G [1] and norartocarpanone [58] significantly inhibited IL-6 production in lung epithelial cells (A549) and NO production in lung macrophages (MH-S) (Lim, Jin, Woo, Lee, & Kim, 2013). Caffeic acid [116] and p-coumaric acid [117] inhibited the production of PGE2 and mRNA expression of COX-2 in RAW 264.7 cells (Seo et al., 2013). Moracin C [74], mulberrofuran Y [83], mulberrofuran H [30], kuwanons C [39], E [55], oxydihydromorusin [48],
sorokeal [22], and sanggenons E [11], H [66] inhibited the secretion of TNF-α, IL-1β and NF-κB nuclear translocation in LPS-stimulated macrophages (Zelová et al., 2014).

Hot-water extract of SBP inhibited anti-chicken gamma globulin IgE-induced mast cell activation and histamine release which is important to allergic reactions (Chai, Lee, Han, Kim, & Song, 2005). The anti-allergic activities of SBP may be related to the regulation of NF-κB and inhibition of Th2 cytokines IL-5 and IL-13 (Lee, Kim, & Kil, 2013). Hot-water extract also exerted antiasthmatic effects via enhancement of CD4+CD25+Foxp3+ regulatory T cells and inhibition of Th2 cytokines (Kim, Lee, Jeong, et al., 2011). While ethanol extract of SBP inhibited IL-6 production and bronchitis-like symptoms of lipopolysaccharide (LPS)-induced airway inflammation in mice (Lim et al., 2013). Moracin M [77] was found to be an effective phosphodiesterase-4 inhibitor (PDE4) (Chen, Zhao, et al., 2012).

4.2. Antioxidative effects
SBP extract showed strong free radical scavenging effect and inhibitory effect of xanthine oxidase and lipid peroxidation (Choi et al., 2002). Water extract of SBP showed antioxidant effects in assays FeCl₂-ascorbic acid-induced lipid peroxidation in rats (Jin, Sa, Shim, Rhee, & Wang, 2005), and methanolic extract showed antioxidant activity through ameliorating the level of blood glutathione content, superoxide dismutase, and catalase activities (Singab, Ayoub, Ali, & Mostafa, 2010).

Many antioxidant compounds were detected in SBP. Australone B [73] and morusin [46] showed inhibitory effects on superoxide anion formation from rat neutrophils stimulated with phorbol myristate acetate (PMA) (Ko, Wang, Lin, Wang, & Lin, 1999). Moracins C [74], N [76], chalconoracin [35] could scavenge superoxide anion and inhibit lipid peroxidation (Sharma et al., 2001). Oxyresveratrol [102] and 5,7-dihydroxycoumarin 7-Me ether [114] showed superoxide scavenging effects (Oh et al., 2002). Mulberrosides A [103] showed liver protective action against CCL₃-induced hepatotoxicity (Jin, Kim, Heo, Han, & Wang, 2007; Jin et al., 2006). Moracins C [74] and M [77] inhibited malondialdehyde produced during microsomal lipid peroxidation induced by ferric(II) (Tan, Liu, & Chen, 2008). Albano B [34], moracin M [77], 2-methylen-3-methoxy-2,5-dihydrofurano-4-O-β-D-glucopyranoside [110], mulberrosafuran G [29] showed potential activities on 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2’-azinobis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) (Cui, Wang, Liu, & Chen, 2008; Fu, Lei, Cai, Zhou, & Ruan, 2010). Mornigrol D [94] and altabafuran C [38] inhibited release of β-glucuronidase from rat polymorphonuclear leucocytes induced by platelet activating factor (Wang et al., 2010). Oxyresveratrol [102], moracin M [77], morusin [46] showed moderate DPPH radical scavenging activity (Mazimba, Majinda, & Mothanka, 2011). Besides, SBP contained many aromatic compounds (Diels–Alder-type adducts, flavonoids, 2-arylbenzofuran, and stilbenes), which were highly correlated with antioxidant potentials of SBP (Chon et al., 2009; Cui, Li, & Jiang, 2011; Khan et al., 2013).

4.3. Antimicrobial effects
Nomura (Nomura, Fukai, Uno, & Arai, 1978) firstly tested antimicrobial activity of SBP. The methanolic extract of SBP has potent antimicrobial activities (Park, Lee, & Yang, 1990; Rollinger et al., 2006), and extracts of SBP also have inhibitory activity against respiratory viruses (Zhang, Li, Ye, Zhang, & Li, 2005). Bioassay-guided and phytochemical research resulted in the isolation of many antimicrobial and parasitic compounds. Mulberrosafuran A [79] showed antimicrobial activity against Staphylococcus aureus and Fusarium roseum (Nomura et al., 1978). Ethyl β-resorcylate (ethyl 2,4-dihydroxybenzoate) [115] and 5,7-dihydroxychromone [113] exhibited antimicrobial activities against plant pathogenic fungi and bacteria (Uno, Isogai, Suzuki, & Shirata, 1981). 1-DNJ [111] may be effective in the treatment of AIDS infection (Sergio, 1989). Morusin [46], morusin 4'-glucoside [47], and kuwanon H [2] showed positive activities on HIV (Luo, Nemec, & Ning, 1995). Kuwanon G [1] and sanggenon C [7] inhibited the growth of oral pathogenic bacteria such as Streptococcus mutans, Streptococcus sobrinus, Streptococcus sanguis, and Porphyromonas gingivalis (Park, You, Lee, Baek, & Hwang, 2003; Park et al., 1990). Leachianone G [70] showed potent antiviral activity against herpes simplex type 1 virus (HSV-1) (Du et al., 2003). Kuwanon C [39], mulberrosafuran G [29], albanol B [34], morusin [46],
sanggenons B [24], D [10] were effective to pathogenic bacteria and fungi include Candida albicans, Saccharomyces cerevisiae, Salmonella typhimurium, Staphylococcus epidermis, and S. aureus (Sohn, Son, Kwon, Kwon, & Kang, 2004). Both 2',4',5-trihydroxy-3-(γ,γ′,γ′-hydroxymethyl)propyl-2''-2''-dimethylpyrano(5''',6'''':6,7)-flavone [52] and 7-methoxy-5,4'-dihydroxyflavanonol [59] had significant antiviral effects against influenza viruses, respiratory syncytial viruses, and adenoviruses (Zhang et al., 2005). Kuwanon L [13], sanggenons B [24], C [7], D [10], E [11], G [15], O [8] revealed inhibition against Venturia inaequalis (Rollinger et al., 2006). Mulberroside C [95], moracin P [90], moracin O [89], moracin M [77] showed significant inhibitory activities against hepatitis C virus (Lee et al., 2007). Moracins C [74], Q [91], M [77] inhibited the growth of S. aureus, Bacillus subtilis, Micrococcus flavus, S. faecalis, Salmonella enterica, Shigella dysenteriae, Pseudomonas aeruginosa, Salmonella typhi, Citrobacter freundii, Candida albicans, Microsporum audouinii (Kuete et al., 2009). Oxyresveratrol [102], moracin M [77], morusin [46], and kuwanon C [39] showed inhibitory activities against S. aureus, Bacillus subtilis, Micrococcus flavus, S. faecalis, Salmonella enterica, P. aeruginosa (Mazimba et al., 2011). Mulberrofuran G [29] showed moderate inhibitory activity on hepatitis B virus DNA replication (Geng et al., 2012). Kuwanons G [1], O [14] were effective to control Ichthyophthirius multifiliis (Liang et al., 2015).

4.4. Antidiabetic effects

Aqueous extract of SBP significantly lowered the elevated blood glucose level with improvement in the serum lipid profile of streptozotocin (STZ)-induced diabetic rats (Ali, Ali, Mir, & Ali, 2011). Ethanol extract of SBP reduced the amount of the glucose, increased insulin production, protected pancreatic β cells from degeneration, diminished lipid peroxidation, inhibited low density lipoprotein (LDL) atherogenic modification and lipid peroxides formation, and increased the expression of adipogenic maker proteins, such as peroxisome proliferator-activated receptors γ (PPARγ), adipocyte-specific fatty acid binding protein 4 (aP2), and GLUT4 (glucose transporter 4) (El-Beshbishy, Singab, Sinkonen, & Pihlaja, 2006; Oh, Choi, & Yun, 2011; Singab, El-Beshbishy, Yonekawa, Nomura, & Fukai, 2005).

Much of anti-hyperglycemic activities attributed to some functional components such as moran A (Hikino, Mizuna, Oshima, & Konno, 1985), moran 20 K (Kim et al., 1999), morusin [46], cyclomorusin [49], neocyclomorusin [50], kuwanon E [55], moracin M [77], betulinic acid [109] (Singab et al., 2005), steppogenin-4''-O-β-D-glucoside [60], mulberroside A [103] (Heo, Jin, Jung, & Wang, 2007; Zhang, Chen, et al., 2009). Inhibitors for protein tyrosine phosphatase 1B (PTP1B) include sanggenons C [7], G [15], mulberrofuran C [27] (Cui et al., 2006), albanol A [85], mulberrofuran W [82], mulberrofuran D [80], kuwanon J [18], kuwanon R [20], kuwanon V [21] (Hoang et al., 2009), albanol A [85], B [86], mulberrofuran A [79], and moracin I [75], 4''-(6,6-dimethyl-5-hydroxy-2-methylenecyclohexylmethyl)-3',5',6-trihydroxy-2-arylbenzofuran [92], 2''-[(3-methyl-3-(4-methyl-3-penten-1-yl)-2-oixiranyl)methyl]-3',5',6-trihydroxy-2-arylbenzofuran [97] (Zhang, Luo, Wan, Zhou, & Kong, 2014). α-glucosidase inhibitors include 4''-(6,6-dimethyl-5-hydroxy-2-methylenecyclohexylmethyl)-3',5',6-trihydroxy-2-arylbenzofuran [92], 2''-(1,3,3-trimethyl-7-oxabicyclo[2.2.1]hept-2-ylmethyl)-3'-methoxy-5',6-dihydroxy-2-arylbenzofuran [93], 2''-(6-hydroxy-3,7-dimethyl-2,7-octadien-1-yl)-3'-methoxy-5',6-dihydroxy-2-arylbenzofuran [96], 4''-(6-hydroxy-3,7-di-methyl-2,7-octadien-1-yl)-3',5',6-trihydroxy-2-arylbenzofuran [99], 2''-(6,7-dihydroxy-3,7-dimethyl-2-oxo-3-yl)-3',5',6-trihydroxy-2-arylbenzofuran [98], 4''-(6,7-dihydroxy-3,7-dimethyl-2-oxo-3-yl)-3',5',6-trihydroxy-2-arylbenzofuran [100], 2''-(6,7-dihydroxy-3,7-dimethyl-2-oxo-3-yl)-3'-methoxy-5',6-dihydroxy-2-arylbenzofuran [101], albanol B [86], moracin I [75], and 1-DNJ [111] (Zhang, Li, et al., 2013; Zhang et al., 2014).

Anti-hyperlipidemic compounds include mulberrofuran G [29], albanol B [34], 5,7,2''-trihydroxyflavanone-4''-O-β-D-glucoside [57] (El-Beshbishy et al., 2006), kuwanons A [53], C [39], T [40], morusin [46], sanggenon F [65], uvaol [108], betulinic acid [109] (Yang et al., 2011), mulberroside A [103], and oxyresveratrol [102] (Jo, Kim, & Lim, 2014).

4.5. Antitumor effects

Extract of SBP exhibited cytotoxic activity on human leukemia cells (K-562, B380) and mouse melanoma cells (B16) by inhibiting microtubule assembly (Nam et al., 2002), and induced cell growth arrest and apoptosis in human colorectal cancer cells (SW480) by activating ATF3 expression and down-regulated cyclin D1 level (Eo et al., 2014). Besides, SBP may be useful for treating multidrug-resistant cancer cells (Choi et al., 2013).

Compounds from SBP exhibited cytotoxic activities against various cancer cell lines. Cytotoxic compounds include sanggenon M [17], sanggenon C [7] (Shi et al., 2001), 7,2',4',6'-tetrahydroxy-6-geranyllflavonone [112] (Kofujita, Yaguchi, Doi, & Suzuki, 2004), australisines A [4], B [36], C [37], mulberrofuran G [29], mongolicin C [33], chalconoracin [35] (Zhang, Tong, Chen, & Yu, 2007), moracin C [74], morusin [46] (Ferlinahayati et al., 2007; Mei, Li, Zhong, Zuo, & Dai, 2011), steppogenin-7,4'-di-O-β-D-glucoside [62] (Zhang, Wang, et al., 2009), CMA-b1-1 (RG-1 type pectic polysaccharide) (Zhang, Liao, et al., 2013), cyclomorusin [49], cyclomulberin [54] (Dat et al., 2010), soroceal B [23], monglicin, sanggenol L [69], licoflavone C [42], oxydihyromorusin [48], 3'-geranyl-3-prenyl-2',4',5,7-tetrahydroxyflavone [43], etc. (Qin et al., 2015).

Lots of compounds with different antitumor mechanisms have been isolated from SBP. Morusin [46] inhibited induction of ornithine decarboxylase by teleocidin in mouse skin (Yoshizawa et al., 1989). Kuwanons G [1], H [2] were found to be specific antagonists for gastrin-releasing peptide (GRP)-preferring receptor (Mihara et al., 1995). Oxysresveratrol [102] and kuwanon Y [26] were shown to inhibit protein kinase C (PKC) (Hu, Chen, Yao, & Xu, 1996). Cathayanons A [12], B [9] exhibited potent activities on the inhibition of H-L-60 cell adhesion to Bovine Arterial Endothelial cells (BAEC) (Shen & Lin, 2001). Sanggenon C [7] inhibited tumor cellular proteasomal activity and cell viability (Huang et al., 2012). Mulberrofurans G [29], H [30], D [80], W [82], moracins O [89], P [90], Q [91], sanggenon O [8], albafuran A [85], and kuwanon J [18] were found to inhibit Hypoxia-inducible factor-1 (HIF-1) accumulation (Dat et al., 2009). Mulberrofuran G [29] induced apoptotic cell death via both the cell death receptor pathway and the mitochondrial pathway (Kikuchi et al., 2010). Cudraflavone B [51], kuwanon E [55] and 4'-O-methylkuwanon E (kuwanon U) [56] exerted anti-proliferative and anti-inflammatory activities (Kollar et al., 2013).

4.6. Other pharmacological effects

There are also other bioactive compounds from SBP. For example, cyclomorusin [49] (Lin, Shieh, Ko, & Teng, 1993), morusin [46], kuwanon C [39] (Ko, Yu, Ko, Teng, & Lin, 1997), australone B [73] (Ko et al., 1999) have anti-platelet related effects. Morusin [46] has anti-nociceptive effect (De et al., 2000). Mulberroside A [103] showed liver protective and P-Glycoprotein inhibitory effects (Jin et al., 2006; Li et al., 2014). Sanggenons C [7], D [10], G [15] and morusin [46] are positive GABAA receptor modulators (Gupta, Dua, Kazmi, & Anwar, 2014; Kim, Baburin, et al., 2012). Kuwanons C [39], E [55], U [56], 5'-geranyl-4'-methoxy-5,3',7,2'-trihydroxyflavone [44], morusin [46], oxydihyromorusin [48], cyclomorusin [49], and neocyclomorusin [50] exhibited cholinesterase inhibitory effects (Kim, Lee, Kim, et al., 2011). Sanggenol Q [64], kuwanon T [40], sanggenon N [68], mulberrofurans C [27], G [29], cudraflavone B [51], and oxysresveratrol [102] have hepatoprotective effects (Jung et al., 2015; Oh et al., 2002). Moracins C [74], M [77], oxysresveratrol [102] (He et al., 2014), cyclomulberin [54], neocyclomorusin [50], sanggenon I [67], morusin [46], kuwanons E [55], U [56] (Lee et al., 2012),

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Phytochemical investigation revealed that SBP contains several classes of compounds, such as Diels–Alder-type adducts, flavonoids, 2-arylbenzofuran, stilbenes, polyhydroxylated alkaloids, etc. A variety of bioactive compounds were detected, and they showed effects on inflammatory mediators, free radicals, specific pathogenic microbes (influenza and respiratory viruses) and therapeutic targets (PDE4, PTP1B, -glucosidase, PPAR, HIF-1, PKC, GABAA). The main and promising compounds include kuwanons G, H, E, moracin M, morusin, mulberrofuran G, moracenin D, sanggenon T, and kuwanon O, which exhibited tyrosinase inhibitory activities (Zheng, Tan, & Wang, 2012).

5. Conclusion

In TCM, SBP was used to treat inflammatory diseases like incised wound, nephritis, arthritis, swelling, and so on. It is also used to treat respiratory disorders like cough, asthma, yellow sputum, bronchitis, and pulmonary diseases. Pharmacological studies over the past 80 years indicate that SBP have anti-inflammatory, antioxidative, antimicrobial, anti-diabetic, antitumor, and other pharmacological effects. The findings that SBP can in vitro or in vivo inhibit inflammatory mediators and inflammations, at least in part, explains the folk use of SBP in diverse inflammatory diseases. While the antimicrobial effects on influenza and respiratory viruses, in part, proves the use of SBP in respiratory disorders.

Inflammation and oxidations play important roles in several conditions including asthma, allergy, cancer, bacterial and viral infections, diabetes mellitus, cardiovascular diseases, Alzheimer’s disease, rheumatoid arthritis, bronchitis, osteoarthritis, etc. As a result, SBP extracts and its bioactive compounds with anti-inflammatory and antioxidative effects play positive role on these diseases.


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