Biological Activities of Paper Mulberry

Subjects: Biochemistry & Molecular Biology
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Paper mulberry (*Broussonetia papyrifera*) is one of the most common skin-lightening agents in the beauty industry due to its strong anti-tyrosinase activity. It consists of various components, including flavonoids, tannins, alkaloids, phenols, saponins, coumarins, glycosides, and polysaccharides, which possess a wide range of pharmacological properties. Apart from its anti-tyrosinase activity, paper mulberry and its compounds exhibited anti-inflammatory, antioxidant, antimicrobial, antiviral, anticancer, antidiabetic, anticholinesterase, antigout, antinociceptive, and hepatoprotective effects. Phenols and flavonoids were demonstrated to be the main contributors to the biological activities of paper mulberry. Paper mulberry is widely applied in cosmetics for skin lightening and skin moisturizing purposes and shows potential for application in hair care products due to the hair nourishing effects. The safety of paper mulberry for topical application was proven in clinical studies.

Keywords: paper mulberry ; Broussonetia papyrifera ; skin-lightening ; tyrosinase ; pharmacological activities

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1. Chemical Composition of Paper Mulberry

Paper mulberry consists of various chemical constituents, with the main bioactive compounds including flavonoids, tannins, alkaloids, phenols, saponins, coumarins, glycosides, and polysaccharides [1][2][3][4][5][6]. These compounds are derived from different parts of the paper mulberry, such as the bark, roots, twigs, leaves, flowers, and fruits. **Table 1** summarizes the major bioactive components found in paper mulberry.

Table 1. Chemical composition of paper mulberry.

Part	Compound	Reference
Root	(−)-(2S)-kazinol I	[7]
	(2R)-7,3′,4′-trihydroxy-6-prenylflavanone	[7]
	3,3′,4′,5,7-pentahydroxyflavone	[8]
	3,4-dihydroxyisolonchocarpin	[9][10][11]
	3′-(3-methylbut-2-enyl)-3′,4′,7-trihydroxyflavane	[8][9][11][12][13][14]
	4-hydroxyisolonchocarpin	[9][10][11][13]
	7,8-dihydroxy-6-(3-methylbut-2-en-1-yl)-2H-chromen-2-one	[15]
	8-(1,1-dimethylallyl)-5′-(3-methylbut-2-enyl)-3′,4′,5,7-tetrahydroxyflanvonol	[7][8][11][12][16]
	Brossoflurenone A	[16]
	Brossoflurenone B	[16]
	Betulin	[17]
	Betulinic acid	[17]
	Broussoaurone A	[18]
	Broussochalcone A	[7][8][9][10][11][13][14][19]
	Broussochalcone B	[9][10][11][12][13]
	Broussochalcone C	[7]
	Broussocoumarin A	[15]
	Broussoflavan A	[7][9][11][13][14][18]
	Broussoflavanonol A	[7]
	Broussoflavonol B	[7][11][15][16]
	Broussoflavonol C	[7]
	Broussoflavonol F	[15][18]
	Broussoflavonol G	[18]

Part	Compound	Reference
	Broussoflavonol H	[15]
	Broussoflavonol I	[15]
	Broussoflavonol J	[15]
	Broussoflavonol K	[15]
	Broussonin A	[7]
	Broussonin B	[7]
	Broussonol D	[7]
	Broussonol G	[7]
	Daphnegiravan H	[7]
	Glycyrrhiza flavonol A	[15]
	Isolicoflavonol	[15]
	Kazinol A	[7][9][11][12][13]
	Kazinol B	[7][9][11][13][19]
	Kazinol E	[9][11]
	Kazinol F	[7][13][14]
	Kazinol J	[7][13][14]
	Kazinol V	[7]
	Kazinol W	[7]
	Oleanolic acid	[17]
	Papyriflavonol A	[11][12][14][15][16][19][20]
	Ursolic acid	[17]

Part	Compound	Reference
Bark	3,4,5-trimethoxyphenyl-1-O-β-D-xylopyranosyl-β-D-glucopyranoside	[21]
	4,5-dicaffeoylquinic acid	[21]
	5,7,3′,4′-tetrahydroxy-3-methoxy-8,5′-diprenylflavone	[22]
	5,7,3′,4′-tetrahydroxy-3-methoxy-8-geranylflavone	[22]
	7,4′-dihydroxy-3′-prenylflavan	[23]
	Broussochalcone A	[22]
	Broussochalcone B	[23]
	Broussoflavonol B	[22][23]
	Broussonin A	[23]
	Broussonin B	[23]
	Caffeic acid	[24]
	Cathayanon H	[23]
	Chlorogenic acid	[21]
	cis-form-5-coffee acylchlorogenic acid	[21]
	Coumaric acid	[24]
	Cryptochlorogenic acid	[21]
	Epicatechin	[24]
	Glyasperin A	[23]
	Isoliquiritigenin	[23]
	Isoquercetin	[21]
	Kaempferol	[24]
	Marmesin	[23]
	Papyriflavonol A	[22]

Part	Compound	Reference
	Quercetin	[24][25]
	Uralenol	[22]
	Vomifoliol	[23]

Part	Compound	Reference
Branch/twig	(S)-8-methoxymarmesin	[26]
	3,5,7,4′-tetrahydroxy-3′-(2-hydroxy-3-methylbut-3-enyl) flavone	[25]
	5,7,3′,4′-tetrahydroxy-3-methoxy-8,5′-diprenylflavone	[26]
	5,7,3′,4′-tetrahydroxy-3-methoxyflavone	[25]
	5,7,3′,5′-tetrahydroxyflavanone	[25]
	Brossoflurenone C	[26]
	Broussin	[26]
	Broussoflavonol A	[26]
	Broussoflavonol B	[26]
	Broussoflavonol F	[25]
	Fipsotwin	[26]
	Isolicoflavonol	[25]
	Isoliquiritigenin	[25]
	Kazinol B	[26]
	Kazinol N	[26]
	Kazinol M	[26]
	Kazinol Q	[26]
	Luteolin	[25]
	Marmesin	[26]
	Papyriflavonol A	[25]
	Quercetin	[25]
	threo-dadahol A	[26]
	threo-dadahol B	[26]

Part	Compound	Reference
	Uralenol	[25]

Part	Compound	Reference
Fruit	2-(4-hydroxyphenyl) propane-1,3-diol-1-O-β-D-glucopyranoside	[27]
	3,4-dihydroxybenzoic acid	[27]
	3-[2-(4- hydroxyphenyl)-3-hydroxymethyl-2,3-dihydro-1-benzofuran-5-yl]propan-1-ol	[28]
	4-hydroxybenzaldehyde	[27]
	7-hydroxycoumarin	[29]
	8,11-Octadecadienoic acid	[30]
	8-Octadecenoic acid	[30]
	Arbutine	[27]
	Betulin	[17]
	Betulinic acid	[17]
	Broussonpapyrine	[31][32]
	Chelerythrine	[31]
	Chushizisin A	[28]
	Chushizisin B	[28]
	Chushizisin C	[28]
	Chushizisin D	[28]
	Chushizisin E	[28]
	Chushizisin F	[28]
	Chushizisin G	[28]
	Chushizisin H	[28]
	Chushizisin I	[28]
	cis-coniferin	[27]
	cis-syringin	[27]

Part	Compound	Reference
	Coniferyl alcohol	[27]
	Curculigoside C	[27]
	Curculigoside I	[27]
	Dihydroconiferyl alcohol	[27]
	Dihydrosanguinarine	[31]
	Epicatechin	[29]
	erythro-1-(4-hydroxy-3-methoxyphenyl)-2-{4-[(E)-3-hydroxy-1-propenyl]-2-methoxyphenoxy}-1,3-propanediol	[28]
	erythro-1-(4-hydroxyphenyl) glycerol	[27]
	Ferulic acid	[27]
	Linolenic acid	[30]
	Liriodenine	[31][32]
	Nitidine	[31][32]
	N-Norchelerythrine	[31]
	Oleanolic acid	[17]
	Oleic acid	[30]
	Oxyavicine	[31][32]
	Palmitic acid	[30]
	p-coumaraldehyde	[27]
	Polysaccharides	[33]
	Protocatechuic acid	[29]
	Stearic acid	[30]
	threo-1-(4-hydroxy-3-methoxyphenyl)-2-{4-[(E)-3-hydroxy-1-propenyl]-2-methoxyphenoxy}-1,3-propanediol	[28]

Part	Compound	Reference
	threo-1-(4-hydroxyphenyl) glycerol	[27]
	Ursolic acid	[17]
	Caryophyllene	[34]
Seed	Heptadecene-8-carbonic acid	[34]
	Hexadecanoic acid	[34]

Part	Compound	Reference
Leaf	(+)-pinoresinol-4′-O-β-D-glucopyranosyl-4″-O-β-D-apiofuranoside	[35]
	3,5,4′-trihydroxy-bibenzyl-3-O-β-D-glucoside	[35]
	4-Caffeoylquinic acid	[36]
	4-Feruloylquinic acid	[36]
	5-Caffeoylquinic acid	[36]
	Apigenin	[37][38]
	Apigenin-6-C-β-D-glucopyranside	[35]
	Apigenin-7-glucoside	[36]
	Apigenin-7-O-glucuronide	[36]
	Apigenin-7-O-β -D-glucoside	[38]
	Broussonetone A	[37]
	Broussonetone B	[37]
	Broussonetone C	[37]
	Broussoside A	[38]
	Broussoside B	[38]
	Broussoside C	[38]
	Broussoside D	[38]
	Broussoside E	[38]
	Chrysoriol-7-O-β-D-glucoside	[38]
	Cosmosiin	[35]
	Coumaric acid	[38]
	Dihydrosyringin	[38]
	Flacourtin	[38]

Part	Compound	Reference
	Gentisoyl hexoside	[36]
	Isoorientin	[38]
	Isovitexin	[36][38]
	Liriodendrin	[35]
	Luteolin	[38]
	Luteolin-7-O-glucuronide	[36]
	Luteolin-7-O-β-D-glucopyranoside	[35]
	Luteoloside	[38]
	Orientin	[36][38]
	Pinoresinol-4′-O-β-D-glucopyranoside	[38]
	Poliothyrsoside	[38]
	Polysaccharides	[5]
	Syringaresinol-4′-O-β-D-glucoside	[38]
	Vitexin	[36][37][38]
Whole plant	(2S)-2′,4′-dihydroxy-2″-(1-hydroxy-1-methylethyl) dihydrofuro [2,3-h] flavanone	[39]
	(2S)-abyssinone II	[39]
	3′-[γ-hydroxymethyl-(E)-γ-methylallyl]-2,4,2′,4′-tetrahydroxychalcone 11′-O-coumarate	[39]
	5,7,2′,4′-tetrahydroxy-3-geranylflavone	[39]
	Demethylmoracin I	[39]
	Isogemichalcone C	[39]
	Isolicoflavonol	[39]

2. Biological Activities of Paper Mulberry and Its Components

Previous studies have demonstrated that paper mulberry and its components possess a wide range of biological activities, such as antityrosinase, anti-inflammatory, antioxidant, and antimicrobial effects, as listed below (**Table 2**).

Table 2. Biological activities of paper mulberry.

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
Antityrosinase	Leaf	n/a	In vitro	IC50 = 17.68 ± 5.3 μg/mL	Inhibit mushroom tyrosinase	[40]
	Leaf	n/a	In vitro	66.67~666.67 μg/mL	Inhibit mushroom tyrosinase	[41]
	Leaf	Broussonetones A-C	In vitro	IC50 = 0.317 ~ 0.323 mM	Inhibit mushroom tyrosinase	[37]
	Twig	Broussoflavonol F, 3,5,7,4′-tetrahydroxy-3′-(2-hydroxy-3-methylbut-3-enyl)flavone, uralenol, quercetin	In vitro	IC50 = 49.5~96.6 μM	Inhibit mushroom tyrosinase	[25]
	Root	Broussoflavonol B/F/H-K, papyriflavonol A, isolicofavonol, glycyrrhiza flavonol	In vitro	IC50 = 9.29~31.74 μM	Inhibit mushroom tyrosinase	[15]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
	Bark	n/a	RAW264.7 cells	10~200 μg/mL	Inhibit NO and iNOS production	[42]
	Bark	n/a	RAW264.7 cells	10~80 μg/mL	Inhibit production of NO, iNOS, TNF-α, and IL-1β	[43]
	Fruit	8,11-octadecadienic acid, palmitic acid, linolenic acid, 8-octadecenoic acid, stearic acid, oleic acid	RAW264.7 cells	6~100 μg/mL	Reduce NO production	[30]
	Root	Broussoflavonol B, kazinol J	Mice, 3T3-L1 adipocytes	40 mg/kg, 3~40 μg/mL	Decrease TNF-α-induced inflammation by inhibiting the NF-κB pathway via AMPK activation	[44]
	Root	(2R)-7,3′,4′-trihydroxy-6-prenylflavanone, broussochalcone C, broussoflavanonol A/B, kazinol V/W	RAW264.7 cells	2.5~40 μM	Inhibit production of NO, iNOS, COX-2, TNF-α, and IL-6	[7]
Anti-inflammatory	Root	Broussochalcone A	RAW264.7 cells	1~20 μM	Inhibit production of NO, iNOS, TNF-α, and IL-1β	[45]
	Branch, twig	Kazinol M, broussoflavonol A/B	THP-1 cells	1 μM	Reduce production of IL-1β and TNF-α by suppressing NF-κB/AP-1 activation	[26]
	Root	Broussoflavonol H	Jurkat cells	IC50 = 9.95 μM	Decrease IL-2 production	[15]
	Root, fruit	Betulin, betulinic acid	Rat	0.6, 1, 2 g/kg	Reduce edema	[17]
	Root	Broussochalcone A, papyriflavonol A	Rat, MH-S cells	200 mg/kg, 5~50 μg/mL	Combined with *Lonicera japonica* to inhibit the production of NO, TNF-α, and IL-6 in macrophages, reduce pleural cavity inflammation and bronchitis	[46]
	n/a	Papyriflavonol A	Rat	12.5~50 mg/kg	Inhibit IgE-induced passive cutaneous anaphylaxis	[47]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
Antioxidant	Leaf	4-Caffeoylquinic acid, 5-Caffeoylquinic acid, apigenin-7-O-glucuronide, isovitexin, luteolin-7-O-glucuronide, orientin, vitexin	1~10 mM	In vitro	Radical-scavenging activities in DPPH and ABTS assays	[36]
	Leaf	Luteolin, luteoloside, orientin, isoorientin	10 μg/mL	In vitro	Radical-scavenging activities in DPPH and ABTS assays	[38]
	Leaf	Broussonetones A−C, apigenin, vitexin	IC50 = 43.89~107.7 μM	In vitro	Antioxidant effects in SOD-like effect assays	[37]
	Root	n/a	0.1~2.5 mg/mL	SH-SY5Y cells	Decrease extracellular peroxide levels, improve activities of SOD, CAT, glutathione peroxidase, and glutathione reductase	[48]
	Bark, wood	Epicatechin, caffeic acid, coumaric acid, quercetin, kaempferol	10~50 mg/mL	In vitro	Superoxide anion radical and hydroxyl radical scavenging activities	[24]
	Flower	n/a	0.5~5 mg/mL	In vitro	Scavenging activity of DPPH radical	[4]
	Fruit	2-(4-hydroxyphenyl)propane-1,3-diol-1-O-β-D-glucopyranoside, 4-hydroxybenzaldehyde, 3,4-dihydroxybenzoic acid, arbutine, dihydroconiferyl alcohol, coniferyl alcohol, ferulic acid, p-coumaraldehyde, cis-syringin, cis-coniferin, erythro1-(4-hydroxyphenyl)glycerol, threo-1-(4-hydroxyphenyl)glycerol, curculigoside C/I	0.16~100 mM	SH-SY5Y cells	Scavenging activity of DPPH radical and neuroprotective effects against H_2O_2-induced SY5Y cell injury	[27]
	Branch, twig	Kazinol M, broussoflavonol A/B	THP-1 cells	1 μM	Reduce CAA values	[26]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
	Root	Broussochalcone A	RAW264.7 cells	1~20 μM	Inhibit production of NO, iNOS, TNF-α, and IL-1β	[45]
	Root	Broussoflavan A, broussoflavonol F/G, broussoaurone A	In vitro	IC50 = 1.0~2.7 μM	Inhibit oxidative stress caused by Fe^{2+} in rat brain homogenate	[18]
	Fruit	Chushizisins A−I, threo-1-(4-hydroxy-3-methoxyphenyl)-2-{4-[(E)-3-hydroxy-1-propenyl]-2-methoxyphenoxy}-1,3-propanediol, erythro-1-(4-hydroxy-3-methoxyphenyl)-2-{4-[(E)-3-hydroxy-1-propenyl]-2-methoxyphenoxy}-1,3-propanediol	PC12 cells	0.16~100 μM	Scavenging activity of DPPH radical and antioxidant effects against H_2O_2-induced impairment in PC12 cells	[28]
	Whole plant	Lignins	In vitro	10~100 mg/L	Scavenging activity of DPPH radical	[49]
	Aerial part	n/a	Beef cattle	5~15% in food	Increase SOD concentration, total antioxidant capacity	[50]
	Aerial part	n/a	Dairy cow	5~15% in food	Increase the concentration of CAT, SOD, and TAC and decrease the serum concentration of 8-OHdG	[51]
	Leaf	n/a	Piglet	150, 300 g/t	Increase concentration of CAT, SOD, glutathione peroxidase	[52]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
Anti-microbial	Leaf	n/a	In vitro	MIC = 1~7.5 mg/mL	Inhibit growth of bacteria (*Enterococcus faecalis*, *Vibrio cholera*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Klibsella pneumonia*) and fungi (*Aspergilus niger*, *A. flavus*)	[53]
	Seed	Hexadecanoic acid, heptadecene-8-carbonic acid, caryophyllene	In vitro	0.125~1%	Antibacterial activity against *Staphylococcus aureus*, *Proteus vulgaris*, *B. cereus*, *Enterobacter aerogenes*	[34]
	Aerial part	Daphnegiravan F, 5,7,3′,4′-tetrahydroxy-3-methoxy-8,5′-diprenylflavone	In vitro	MIC = 3.9~250 ppm	Anti-oral microbial effect against Gram-positive strains (*Actinomyces naeslundii*, *A. viscosus*, *Streptococcus mutans*, *S. sanguinis*, *S. sorbrinus*) and Gram-negative strains (*Aggregatibacter actinomycetemcomitans*, *Fusobacterium nucleatum*, *Porphyromonas gingivalis*)	[54]
	Root	Papyriflavonol A, kazinol B, broussochalcone A	In vitro	MIC = 12.5~45 μg/mL	Antifungal effect against *Candida albicans* and *Saccharomyces cerevisiae*, antibacterial activity against *Escherichia coli*, *Salmonella typhimurium*, *S. epidermis*, *S. aureus*	[19]
	Root	Papyriflavonol A	In vitro	MIC = 10~25 μg/mL	Antifungal effect against *C. albicans* and *S. cerevisiae*	[20]
	Fruit	Polysaccharides	In vitro	0.4~2.0 mg/mL	Antibacterial activity against *E. coli*, *P. aeruginosa*, *B. subtilis*, *S. aureus*	[33]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
	Root	Broussochalcone A/B, broussoflavan A, 3′-(3-methylbut-2-enyl)-3′,4′,7-trihydroxyflavane, 3,4-dihydroxyisolonchocarpin, 8-(1,1-dimethylallyl)-5′-(3-methylbut-2-enyl)-3′,4′,5,7-tetrahydroxyflanvonol, daphnegiravan I, kazinol A/B/E, 4-hydroxyisolonchocarpin, papyriflavonol A, broussoflavonol B	In vitro	IC50 = 0.7~54 μM	Inhibit bacterial neuraminidase	[11]
Antiviral	Root	Broussochalcone A/B, 4-hydroxyisolonchocarpin, papyriflavonol A (4), 3′-(3-methylbut-2-enyl)-3′,4,7-trihydroxyflavane, kazinol A/B/F/J, broussoflavan A	In vitro	IC50 = 9.2~66.2 μM	Inhibit papain-like protease	[13]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
Anticancer	Bark	n/a	HT-29 cells	50~200 μg/mL	Induce apoptosis-related DNA fragmentation, increase the expression of p53, caspase 3, Bax, inhibit cell proliferation	[42]
	Bark	Papyriflavonol A, broussoflavonol B, broussochalcone A, uralenol, 5,7,3′,4′-tetrahydroxy-3-methoxy-8,5′-diprenylflavone	MCF-7 cells	5~25 μM	Anti-proliferation effects on estrogen receptor-positive breast cancer MCF-7 cells	[22]
	Bark, leaf, fruit	n/a	MCF-7, HeLa, HepG2 cells	31.25~1000 μg/mL	Cytotoxic activity against cancer cells	[55]
	Root	Broussoflavonol F/H/I/K, isolicofavonol, glycyrrhiza flavonol A, papyriflavonol A	NCI-H1975, HepG2, MCF-7 cells	IC50 = 0.9~2.0 μM	Growth inhibition activity against three cancer cell lines	[15]
	Root	Kazinol A	T24, T24R2 cells		Inhibit cell growth through G0/1 arrest mediated by a decrease in cyclin D1 and an increase in p21	[12]
	n/a	Broussochalcone A	HEK293, HCT116, SW480, SNU475 cells	5~20 μM	Induce apoptosis in colon and liver cancer cells	[56]
	n/a	Broussochalcone A	HepG2 cells	5 μM	Cytotoxic effects against human hepatoma HepG2 cells with activation of apoptosis-related proteins	[57]
	Fruit	N-norchelerythrine, dihydrosanguinarine, oxyavicine, broussonpapyrine, nitidine, chelerythrine, liriodenine	BEL-7402, Hela cells	IC50 = 5.97~47.41 μg/mL	Inhibit cancer cell growth	[31]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
Antidiabetic	Root	Broussoflavonol B, kazinol J	Mice	40 mg/kg	Improve glucose tolerance	[44]
	Root	8-(1,1-dimethylallyl)-5′-(3-methylbut-2-enyl)-3′,4′,5,7-tetrahydroxyflanvonol, uralenol, 3,3′,4′,5,7-pentahydroxyflavone, broussochalcone A	In vitro	IC50 = 4.3~36.8 μM	Inhibit the activity of PTP1B	[8]
	Root	Broussochalcone A/B, 3,4-Dihydroxyisolonchocarpin, 4-Hydroxyisolonchocarpin, 3′-(3-Methylbut-2-enyl)-3′,4′,7-trihydroxyflavane, kazinol A/B/E, 8-(1,1-Dimethylallyl)-5′-(3-methylbut-2-enyl)-3′,4′,5,7-tetrahydroxyflanvonol, papyriflavonol A, brossoflurenone A	In vitro	IC50 = 2.1~75.7 μM	Inhibit the activity of α-glucosidase	[10]
Anticholinesterase	Root	8-(1,1-Dimethylallyl)-5′-(3-methylbut-2-enyl)-3′,4′,5,7-tetrahydroxyflanvonol, papyriflavonol A, broussoflavonol B, brossoflurenone A/B	In vitro	IC50 = 0.5~24.7 μM	Inhibit human acetylcholinesterase and butyrylcholinesterase	[16]
Antigout	Root	3,4-dihydroxyisolonchocarpin, broussochalcone A	*In vitro*	IC50 = 0.6~1.8 μM	Inhibit the activity of xanthine oxidase	[9]
Antinociceptive	Root, fruit	Betulin, betulinic acid	Rat	1, 2 g/kg	Inhibit writhing responses	[17]

Biological Activity	Part	Compound	Model	Dose	Detailed Effects	Reference
Hepatoprotective	Leaf	Polysaccharides	Mice	100~400 mg/kg	Improve acetaminophen-induced liver damage, reduce liver apoptosis, enhance the detoxification ability of the liver to acetaminophen	[5]
	Root	Broussoflavonol B, kazinol J	Mice	40 mg/kg	Suppress hepatic steatosis by decreasing lipogenic gene expression and increasing AMPK phosphorylation	[44]

3. Application of Paper Mulberry in Cosmetics

3.1. Skin Lightening and Moisturizing

Paper mulberry is commonly used as a skin-lightening agent in cosmetics. Paper mulberry might prevent skin hyperpigmentation by inhibiting the activity of tyrosinase and melanin formation [58]. Extracts from paper mulberry are included in many skin-whitening compositions for external application [59][60]. Paper mulberry combined with *Styela clava* extract is blended into a facial mask sheet for the whitening purpose [61]. A mask pack containing paper mulberry showed moisturizing effects on the skin [62]. Paper mulberry combined with white ginseng was incorporated in a cosmetic composition for skin moisturizing and smoothing [63].

3.2. Hair Protection and Hair Growth

A previous study showed that the application of formulations containing paper mulberry root extract exerted hair-protective effects by improving the tensile strength, optical absorption, and luster of damaged hair [64]. Another study on 11 healthy subjects indicated that using a leaf extract of paper mulberry for 12 weeks showed beneficial effects on hair growth, indicated by increased total hair count as compared with the start date of the trial. The underlying mechanism might be through regulating the WNT-β-catenin and STAT6 pathways to promote the proliferation of dermal papilla cells [65]. These data suggest the potential application of paper mulberry in hair-care products in cosmetics.

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