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Review of *Polygonatum sibiricum*: A new natural cosmetic ingredient

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With the developments of science and technology, social development and people's pursuit of quality life, natural and safe skin care products occupied half of the cosmetics industry. In recent years, as synthetic drugs were found that which had toxic and some side effects, people have a tendency to return to nature. Thus, traditional Chinese medicinal plants were applied to natural cosmetics with good efficacy, little side effects and no allergy which had more advantages than synthetic products. The cosmetic products with pure natural ingredients were more and more favored by consumers. Therefore, the article mainly pays attention to the relationship between the active ingredients of *Polygonatum sibiricum* (PS) and their cosmetic effects, mainly included anti-aging activity, anti-bacteria effect, skin whitening and moisturizing effects. The article will provide more possibilities for research of natural ingredients cosmetics.

1. Introduction

According to statistics, more than 75 percent of cosmetics market contained natural plant extractions in the US (Shi 2012). In Germany, natural products account for two-thirds of total beauty spending. In Asia, the demands for natural skin care products has grown by more than 15 percent a year. Through the advertising industry, we could know that many brands at home and abroad launched cosmetics with natural ingredients, such as the edible skin care products launched by suitably Bencao and the French Lancome brand red cloisonne roots series (Zhang et al. 2012). From these data, we concluded that in the present cosmetic market, natural herbal extracts should have promising research prospects. Although the bioactive components of natural plants are complex in structure, their three-dimensional configurations are stable. After the extraction of natural materials from herbs, they could still maintain stable chemical structures and development direction of cosmetics industry (Zhang et al. 2006).

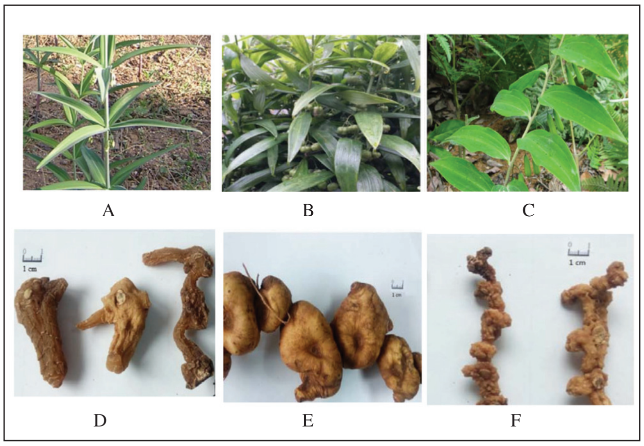

Fig. 1: A: Overground part from *Polygonatum sibiricum* Red.; B: Overground part from *Polygonatum kinginanum* Coll. et Hemsl; C: Overground part from *Polygonatum cyrtonema* Hua.; D: Rhizoma from *Polygonatum sibiricum* Red.; E: Rhizoma from *Polygonatum kinginanum* Coll.et Hemsl; F: Rhizoma from *Polygonatum sibiricum* Red.

Polygonatum sibiricum (PS) is the dry rhizoma from *Polygonatum kinginanum* Coll. et Hemsl, *Polygonatum sibiricum* Red. and *Polygonatum cyrtonema* Hua (Ping et al. 2018)(Fig. 1) which is a traditional Chinese medicine and could be used for medical, edible, ornamental and health protection, PS has high economic value and social benefit (Liu et al. 2017). Based on advanced research we conclude that PS also has various biological and pharmacological activities as shown in Table 1.

As natural materials are applied more and more widely in cosmetics, PS as a plant with extensive curative effect should have great potential in cosmetics as well, such as whitening, anti-wrinkle and moisturizing effects (Liu et al. 2017). Thus, this review summarizes the relationship between its applications in cosmetics and active components of PS.

2. Chemical ingredients of PS

Polygonatum sibiricum polysaccharides (PSP) are the main active components in PS (Zhang et al. 2006). *Polygonatum sibiricum* saponins (PSS) are characterized by a skeleton derived of oxidosqualene, consisting of a sugar moiety linked to a triterpenoid (30 carbon atoms) or a steroidal (27 carbon atoms) aglycone. There is a number of steroidal saponins and fewer triterpenoids (Zhao et al. 2018). *Polygonatum sibiricum* flavonoids (PSF) are other components of PS having 15C atoms and are composed of C6-C3-C6 tricyclic elementary units (Liu et al. 2017). *Polygonatum sibirium* lectins (PSL) are carbohydrate-binding proteins (Zhang et al. 2010; Wang et al. 2013).

The main active components extracted from PS are shown in Table 2.

3. PSP in cosmetics

According to previous research, PS could moisturize and whiten the skin, has anti-bacterial effects, thus having great potential as cosmetic ingredient (Liu et al. 2017; Peng 2017). Wei et al. (2009a, 2010b) confirmed that PS could act against free radicals, increase the collagen fibers in the skin of mice and make them compact. Thus, PS could protect, reduce or repair skin damage, decrease the content of lipofuscin in the skin, and significantly retard skin aging of mice (Peng 2017).

Table 1: Pharmacological effects of PS and plausible biological mechanisms

Pharmacological effects	Plausible biological mechanisms
Immunomodulatory effects	1. Different levels of organs, cells and molecules. Thymus and spleen index, IgA, IgG, IgM, IL-6, IL-2, cAMP, cAMP/cGMP (Ren et al. 2005; Yang et al. 2009; Wu et al. 2014), IL-8, IL-10↑, NO, COX-2, iNOS, NF-êB, TNF-α↓ (Xian et al. 2012; Liu et al. 2018; Zhao et al. 2018) 2. Phagocytosis, hemolysin, hemolysin plaque, Bcl-2, Bcl-2/Bax, lymphocytes↑, Bax (Yang et al. 2009; Khan et al. 2013), GLUT2↓ (Xie 2018)
Anti-oxidant activity	1. Collagenous fiber, telomerase↑ (Li et al. 2005; Yang et al. 2005;) 2. Osteocalcin, IL-1, IL-6↓ (Zeng et al. 2012) 3. CAT, glutathione↑, TBARS, hydrogen peroxide↓ (Jeon et al. 2004) 4. MDA↓, Na$^+$, K$^+$-ATP and Ca^{2+}-ATP atpase↑ (Jiang et al. 2017) 5. T-AOC, SOD, GSH-Px↓(Ma et al. 2010; Qi et al. 2010) 6. LPO, LF, MAO-B↓ (Wang et al. 2011; Lu et al. 2013)
Anti-fatigue performance	1. Swimming time↑(Chen et al.1990), ALT, AST, LDH, CK, MDA, H_2O_2, BUN↓, Mn-SOD, GSH-Px, Na$^+$-ATP, Ca^{2+}-ATP, CAT, Glu, liver and muscle glycogen, hepatic glycogen, myoglycogen and hepatoglycogen↑ (Mao et al.2007; Lu et al. 2014) 2. Blood lactate, serum urea nitrogen↓ (Cui et al. 2018)
Anti-tumor effect	Inhibit H22 solid tumor, S180 ascites tumor, MCF-27, Herps, EAC-109, HGC-27, HCT-8, Hela, MDA-MB-435, HL-60, H14 (Zhu et al.1994; Xu et al.1996; Zhang et al. 2007; Ye et al. 2008; Yau et al. 2015)
Treatment of diabetes	1. Pancreatic cells, the level of insulin↑(Li et al. 2005; Gong et al. 2009), accelerated the transfer the serum glucose to target tissue cells (Dong et al. 2012; Wang et al. 2002; Lu et al. 2015) 2. ALX-induced diabetic mice: MDA, T-SOD, GSH-Px, CAT, GLUT4, blood glucose level↓, thymus index, spleen index, liver index, liver tissue↑ (Kim et al.2009; Cui et al. 2018) 3. STZ-induced diabetic mice: FGB, GSP, TC, TG, NO, Caspase-3, iNOSmRNA, islet cell apoptotic, water drinking, food intake, urinary volume↓ (Cui et al. 2018)
Cardiovascular protection	1. Blood fat and atherosclerosis↓ (Zhang et al. 2006) 2. Regulating NF-κB mediated inflammation (Zhu 2010) 3. Inhibit Na$^+$, K$^+$-ATP (Hirai et al. 1977)
Effects on the central nervous system	1. MAO, BDNF and TrkB↓ (Zhang and Qin 2008; Wei et al. 2012) 2. NE, DA, 5-HT, PPAR-γ↑ (Li et al. 2006) 3. Bax/Bcl-2 ration, protein level of p-Akt, P13K↑(Zhang et al.2015), mitochondrial dyfunction and cytochrome release, Caspase-3 activation↓ (Cui et al. 2018)
Antimicrobial activities	1. *Escherichia coli*, *Staphylococcus aureus*, *Rhodotorula* (Yu et al. 2008), *Salmonella typhi*, w*hite Staphylococcus aureus*, *Colletotrichum gloeosporioides*, *Pear anthracnose*, *Grape gray mold*, *Botryosphaeria dothidea* (Zheng et al. 2010), *Bacillus subtilis*, *Staphylococcus epidermidis* (Khan et al. 2015), *Paratyphoid bacillus*, *Micrococcus luteus*, *Streptomyces microflavus*, *Saccharomyces cerevisiae* (Cui et al. 2018) 2.Anti-HIV (Ding et al.2010), HSV-1 (Chen and Sun 2010), HSV-2 (Gu et al. 2003), HIV/AIDS, HIVI/II (Zheng et al. 2010)
Treatment of osteoporosis	1. ALP, OC, PINP, BMP-2, SPARC↑ (Zong et al. 2015) 2. RUNX2, BGP, OCN, BMSCs↑ (Cui et al. 2018)
Anti-atherosclerotic ability	1. TC, LDL-C, Lp(a), intimal foam cell, ECs injury↓ (Cui et al. 2018), HDL-C↑(Chen and Sun 2010) 2. Hypolipidemic activities (Cui et al. 2018)
Liver protection	Weight, SOD, CAT, GSH-Px, GR↑, AST, ALT, ALP, MDA↓ (Liu et al. 2017; Cui et al. 2018)
Skin care	1. Anti-aging and anti-wrinkle activities (Liu et al. 2017; Yang et al. 2005) 2. Skin whitening effect (Peng 2017) 3. Anti-bacterial effect (Cui et al. 2018) 4. Moisturizing effect (Peng 2017)

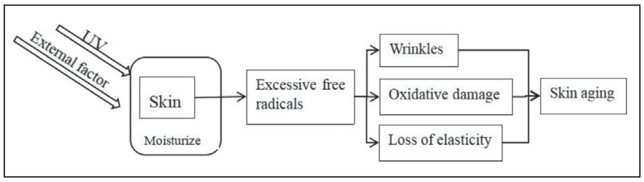

Fig. 2: Free radical theories of skin aging.

3.1. *Anti-aging activity*

Skin is an important organ covering the surface of human body (Xie et al. 2011). There are many mechanisms of skin aging, more than 30 theories had appeared successively. The more representative ones are free radical theory, photoaging theory, mitochondria theory, immune function degradation theory, metabolic disorders theory, cell apoptosis theory, matrix metalloproteinase aging theory (Lai and He 2009; Lopez-Otin et al. 2013; Heng et al. 2017). Many of these theories reveal the demand of medical treatment, so we concentrate on scavenging free radical ability and moisturizing the skin (Fig. 2, Lai and He 2009).

In the natural aging process, the decrease of free radicals scavenging abilities and the influence of external environment (UV, radiation, depression, excessive pressure, mental tension, etc.) leads to excessive production of free radicals, modified cell membrane modified metamorphism, errors in the genetic information, protein loss, damaged physiological function, and, eventually, aging (Lai and He 2009; Xie et al. 2011).

A large number of experiments proved that moisturing the skin could greatly alleviate skin aging problems. At present, almost all cosmetics which relieved aging are containing moisturizing ingredients (Lai and He 2009). Some Chinese herbal medicine ingredients could resist lipid peroxidation and eliminate free radicals, exerting also anti-aging activities (Xie et al. 2011; Cao et al. 2003). Polysaccharides could capture and quench the oxygen-activated free radicals in epidermal cells, and could protect the cell biofilm from the damage of free radicals in advance. Therefore, polysaccharides have strong anti-oxidation and anti-aging effects (Lee et al. 2003; Guo et al. 2008). Natural and safe plant polysaccharides have extensive and efficient biological activities and are among the important natural additives in skin whitening and anti-aging cosmetic products (Liu et al. 2017).

3.1.1. *Scavenging ability of DPPH free radical*

The DPPH spectrophotometric method is widely used to study free radical scavenging and to screen natural antioxidants. The IC50

Table 2: Main active ingredients of PS and their compositions

Chemical ingredients	Compositions
PSP	Mannose (62.3~76.3%), glucose (15.2~20.3%), galactose(4.35~15.3%), andarabinose (4.00~7.65%) (Wang 2012; Wu et al. 2015; Yelithao et al. 2016), fructose, rhamnose, xylose, galacturonic acid (Liu et al. 2017)
PSS	1. Steroidal saponins: mainly diosgenin, digitoxin, smilagenin and suger bases as follows, glucose, galactose, rhamnose, arabinose, xylose and fucose, totally more than 100 kinds (Hirai et al. 1977; Dong et al. 2005; Yang et al. 2007; Xu et al. 2006; Wang et al. 2015; Jiang et al. 2017) 2. Triterpenoid saponins: ursane pentacyclic triterpenoid, oleanolic acid pentacyclic triterpenoid, dammarane tetracyclic triterpenoid (Jiang et al. 2017)
PSF	1. Isoflavones, flavanones, chalcones, homoisoflavones (Liu et al. 2017) 2. High isoflavones, flavonone (Jiang et al. 2017)
Amino acid	3. lysine, glutamic acid, leucine, isoleucine, glycine, leucine, tyrosine, proline, aspartic acid, homoserine, diaminobutyric acid (Wang et al.2015; Jiang et al. 2017), threonine, alanine (Dong et al. 2005)
Alkaloids	Polygonatine A, polygonatine B, kinganone, N-trans-p-coumaroyloctopamin- e, adenosine and 3-butylmethyl-5,6,7,8-tetrahydro-8-indolazineketone (Jiang et al. 2017), 3-hydroxymethyl-5,6,7,8-tetrahydroindolizin-8-one, 3-ethoxyme thyl-5,6,7,8-tetrahydroindolizin-8-one (Sun and Li 2005)
Lignans	Dextroeugenin, detroeugenin-O-β-D-pyranglucoside, dextropinol-O-β-D -pyranglucose-(6→1)-β-D-pyranglucoside (Jiang et al. 2017), syringaresinol, liriodendrin (Dong et al. 2005)
Sterols	(22S)-Cholest-5-ene-1,3,16,22-tetrol-1-O-α-L-rhamnopyranosyl-16-O-β-D-glucopyranoside, palmiticacid-3β-sitosterol, daucosterol, 3β-sitosterol (Jiang et al. 2017).
Volatile oil	Acid (26.32%), olefins (25.83%), aldehydes (5.83%), alcohols (1.09%), esters (0.66%) (Jiang et al. 2017; Wang et al. 2011)
Macro and trace elements	Major elements: K, Mg, Cu, P(Wang et al. 2001) Trace elements: Fe, Zn, Sr (Wang et al.2015; Jiang et al. 2017), Ca, Mg, Al (Dong et al. 2005) Ba, Ge, Mn, Bi (Wang et al. 2011)

value is commonly used as indicator of oxidants which could scavenge DPPH free radicals (Yue et al. 2005).

Crude extracts with DPPH free-radical scavenging activity mainly contained PSP. The activity of DPPH inhibition was dose-dependent and the IC50 was 9 μg/mL. So, it is suggested that the a substantial antioxidant activity is associated with PSP (Horng et al. 2014). Among four types of PSP, two had antioxidant effects (Li et al. 2018). Their scavenging abilities are shown in Table 3.

Table 3: Scavenging activities of DPPH and hydroxyl radicals

Type	DPPH radical scavenging activity (%)	Hydroxyl radical scavenging (%)
1	75.648	78.585
2	28.005	21.113

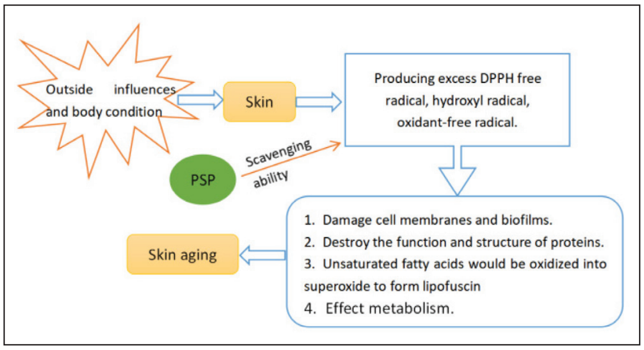

Fig. 3: Mechanism of PSP scavenging free radicals.

3.1.2. Scavenging ability of hydroxyl and oxidant-free radical

The scavenging ability to hydroxyl free radical, superoxide anion free radical and the total antioxidant activity of PSP have been studied by Fenton method, pyrogallol autoxidation method and phosphomolybdenum complex method. The results showed that PSP had good antioxidant activity, the scavenging ability of hydroxyl radical, while superoxide anion free radical and total antioxidant ability increased with concentration. The scavenging rates on hydroxyl radical and superoxide anion free radical could reach 92.1 % and 80 %, respectively (Sebti and Coma 2002; Xia et al. 2006; Liang et al. 2013). Other studies also confirmed that PSP have the ability of scavenging hydroxyl and oxidant-free radicals (Cao et al. 2003; Zhao et al. 2006).

Overall, PSP have good anti-oxidant potential and could play a huge role in anti-aging cosmetics. The mechanism of PSP scavenging free radicals is shown in Fig. 3 (Yang et al. 2005; Zhao et al. 2018).

3.1.3. Moisturizing effect

Plant polysaccharides are bioactive ingredients with good water absorption and high moisture retention. On the one hand, polysaccharides contain a large number of hydrophilic groups, which could moisturize by hydrogen bonding with water. On the other hand, polysaccharides are forming membranes which could cover the skin surface to reduce moisture volatilization and had a shrinking effect. Therefore, polysaccharide bioactive ingredients have strong moisturizing activity (Sebti and Coma 2002; Peng 2017). It was shown that PSP have the effect of instant moisturizing, with skin moisture content reaching 62.261 U after 0.5 h, with effects decreasing over time (Peng 2017; Wang et al. 2018).

Table 4: Anti-bacterial effects of PSP

The types of bacteria		Inhibition rings(mm)	MIC(mg/mL)
Gram-positive organisms	*Bacillus subtilis*	18.9	0.98
	Staphylococcus aureus	15.8	1.31
Gram-negative bacteria	*Escherichia coli*	10.9	1.23
	Salmonella typhimurium	8.4	Not mentioned

3.2. Anti-bacterial effects

Many bacteria are living on our skin surface, partly leading to diseases and decreased skin protection, resulting in skin aging, acne and other problems caused, for example, by *Propionibacterium acnes* and *Staphylococcus aureus* (Chen et al. 2006). There were many cosmetics containing anti-bacterial elements in order to enhance the skin protective effect.

Many studies confirmed that PSP had anti-bacterial effects on Gram-positive organisms and Gram-negative bacteria as shown in Table 4 (Cao et al. 2017; Jiang et al. 2017; Li et al. 2018). So PSP could inhibit white *Staphylococcus aureus*, *Paratyphoid bacillus*, *Micrococcus luteus* (Li et al. 2018), *Streptomyces microflavus* and *Saccharomyces cerevisiae* (Zheng et al. 2010). Some studies demonstrated that PSP could also inhibit fungi (*Viola trichoriae* and *Erythroderma capitis*) (Jiang et al. 2017). PSP could be used to treat various ringworm diseases caused by skin fungi (Xia et al. 2006; Su et al. 2007; Chen and Sun 2010). Based on previous studies, PSP could also control ear swelling caused by xylene (Wang et al. 2017). In conclusion, PSP could inhibit common and morbigenous bacteria on the skin surface. PSP could restrain bacteria to protect our skin which was added as active components in cosmetics.

3.3. *Skin whitening effect*

Tyrosinase was the key rate-limiting enzyme on melanin synthesis (Fig. 4) (Tu et al. 2003; Xie et al.2011). Polysaccharides are known as effective ingredients in natural sunscreen (Lai et al. 2009). It was also reported that PS could be used in skin care cosmetics because of their moisturizing, whitening and wrinkle removal activities. Studies have shown that the main active ingredients were PSP, PSF, and PSS (Peng 2017).

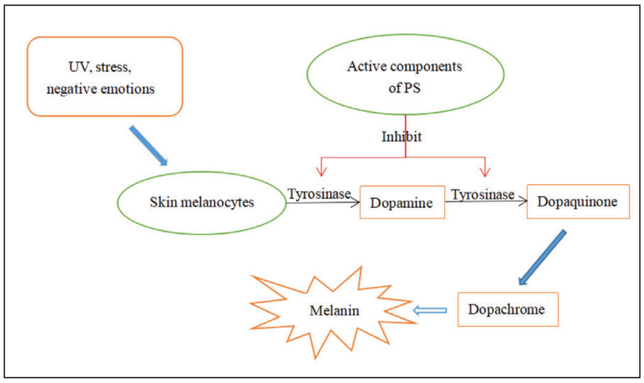

Fig. 4: Mechanism of inhibiting the production of melanin.

Thus, PSP could protect our skin through anti-aging, anti-bacterial, moisturizing and skin whitening activities. In the light of the above, we come to the conclusion that PSP were the strong active ingredients in PS, which have great potential in natural anti-aging and whitening cosmetics.

4. PSS to cosmetics

4.1. *Anti-aging activity*

PSS carry a large number of alcohol-hydroxyl structures, being able to effectively bind with oxygen-activated free radicals as hydrogen donors to achieve antioxidant effects (Zhao et al. 2001; Yang et al. 2016). Studies showed that the half inhibitory concentration (IC50) of free radical scavenging activity of diosgenin was 65.80 µg ml^{-1} (Khan et al. 2016). Extracts containing about 77.5 % PSS had scavenging abilities of DPPH and superoxide anion free radicals, showing a dose dependence increase (Hu et al.2013).

4.2. *Anti-bacterial effect*

PSS had weak inhibitory activities against *Bacillus megaterium*, *Bacillus cereus* and *Proteus vulgaris*, as well as against *Exserohilum turcicum*, *Verticillium dahiae*, *Botryosphaeria ribis* and the inhibition rate as high as 69.0 %, 71.6 %, 84.1 %, respectively (Gong et al. 2003; Wang et al. 2007).

5. PSF to cosmetics

Flavonoids have several the functions in cosmetics, such as whitening, anti-allergy, sun protection and antibacterial effects (Wang et al.2014).

5.1. *Anti-aging activity*

Flavonoid ingredients widely exist in PS, the active components not only could effectively eliminate the active free radicals to delay the aging of the skin, they could also promote cell metabolism to accelerate the replacement of cells. In addition, PSF could protect skin from UV damage, moisturize and reduce spots (Peng et al. 2017).
PSF carry a large number of alcohol-hydroxyl structures, which could effectively bind with oxygen-activated free radicals as hydrogen donor to achieve antioxidant effects (Zhao et al. 2001; Yang et al. 2016). Antioxidant activities of PSF were measured by DPPH method and reducing power assays. The results showed that PSF exert high scavenging activities against the DPPH radical and reducing power (Peng 2017). Others experiments confirmed that the EC_{50} of PSF antioxidant capacity measured by ABTS was 12.4 g·mL^{-1}, the EC_{50} of antioxidant activity was 2.27 g·mL^{-1} (Chen et al. 2008; Khan et al. 2012; Tao et al. 2018; Zhang et al. 2018). The clearance rate of PSF to DPPH free radicals could reach 91.29 %, far higher than the same concentration of rutin (Chen et al. 2013). The scavenging rates of DPPH and hydroxyl free radicals were the same as those of Vitamin C when the concentration was 120 µg·mL^{-1} of PSF (Qian et al. 2017). Another study confirmed that PSF had scavenging capacities of superoxide anion free radical (Ma 2012). Otherwise, PSF not only had antioxidant activity, but also had good photothermal, acid and alkali stability (Wang et al. 2014). A study confirmed that C-methylated homoisoflavanones are possessing the ability to decrease oxidative stress (Wang et al. 2013).

5.2. *Anti-bacterial effect*

PSF inhibit many kinds of bacteria, like *Escherichia coli*, *Salmonella typhi*, *Shigella* and *Staphylococcus* (Table 5, Khan et al. 2012; Tao et al. 2018).
In conclusion, PSF are another main group of active ingredients in cosmetics, which have of anti-aging activity, anti-bacterial effects, while showing photothermal, acid and alkali stability.

6. Phenols of PS to cosmetics

6.1. *Anti-aging activity*

There is growing interest in exploration, optimization and enumeration of the antioxidant constituents of herbal medicinal plants because of their potential health benefits (Bahramikia et al. 2009). Some studies confirmed that phenol compounds, tannins and flavonoids have obvious antioxidant activities from the scavenging of DPPH and ABTS free radicals assay, when the Vitamin C was used as a standard drug for comparison (Kumar Singh 2018). Qiu et al. used a new parameter to evaluate its activity of scavenging DPPH free radical and the results showed that the phenols of PS had

Table 5: Antibacterial effects of PSF in cosmetics

PSF effects in cosmetics				
Anti-aging activity	EC_{50} by ABTS	Clearance rate to DPPH free radicals		
	12.4 g·mL^{-1}	91.29 %		
Antibacterial effects (MIC)	*Escherichia coli*	*Salmonella typhi*	*Shigella*	*Staphylococcus*
	1.5 µg·mL^{-1}	31.5 µg·mL^{-1}	31.5 µg·mL^{-1}	751.5 µg·mL^{-1}

Table 6: Antibacterial effects of phenols from PS (µg·mL^{-1})

The effects in cosmetics				
Anti-aging activity (IC_{50})	DPPH	ABTS	The total antioxidant capacity	
	5.21	4.89	27.48	
Anti-bacterial effect (MIC)	*Escherichia coli*	*Salmonella typhi*	*Shigella*	*Staphylococcus*
	40.00	6.00	40.00	80.00

Table 7: Relationship between applications in cosmetics and the main active ingredients of PS

Active ingredients	Effects	Major mechanism
PSP	Anti-aging activity	DPPH free radical, Hydroxyl and oxidant-free radical, Moisturizing, Removed wrinkles, Total antioxidant capacity
	Anti-bacterial effect	*Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhimurium*
	Skin whitening	Inhibit tyrosinase
PSS	Anti-aging activity	DPPH free radical, superoxide anion free radical
	Anti-bacterial effect	*Exserohilum turcicum*, *Verticillium dahiae*, *Botryosphaeria ribis*
PSF	Anti-aging activity	Oxygen-activated free radicals, DPPH and hydroxyl free radicals, reducing power, ABTS
	Anti-bacterial effect	*Escherichia coli*, *Salmonella typhi*, *Shigella*, *Staphylococcus*
Phenols	Anti-aging activity	DPPH and ABTS free radicals, superoxide anion and hydroxyl free radicals, the total antioxidant capacity
	Anti-bacterial effect	*Escherichia coli*, *Salmonella typhi*, *Shigella* and *Staphylococcus*, *Bacillus subtilis*
Other components	Anti-aging activity	Moisturizing, Reduce wrinkles, oxidant-free radical,
	Anti-bacterial effect	*Escherichia coli*, *Staphylococcus aureus* and *Red yeast*
	Odorous	Deodorant

obviuos ability of scavenging DPPH free radical (Yue et al. 2005). Through the experiments of scavenging DPPH, superoxide anion and hydroxyl free radicals, these studies confirmed that phenols had strong antioxidant activity with Vitamin C as a contrast. Wu et al. extracted polyphenol compounds by flash extraction and studied the total antioxidant capacity, DPPH scavenging capacity and ABTS scavenging capacity. The IC_{50} were 27.48, 5.21 and 4.89 $\mu g \cdot mL^{-1}$ respectively (Wu et al. 2007; Zhang et al. 2017). Phenols of PS are a kind of natural antioxidant with great potential in cosmetics (Zhang et al. 2017).

6.2. *Anti-bacterial effect*

PS had antibacterial effects on *Escherichia coli*, *Salmonella typhi*, *Shigella* and *Staphylococcus* (Table 6, Khan et al. 2012; Tao et al. 2018. It was also shown that phenols of PS could inhibit *Escherichia coli* and *Bacillus subtilis* with MIC and MBC of 50 mg mL^{-1} and 100 mg mL^{-1}, respectively (Chen et al. 2018).

7. Other components of PS to cosmetics

There were many other components of PS, such as amino acids, lignin, volatile oil, major and trace elements with important effects in cosmetics.

7.1. *Amino acids*

Amino acids could be used to slow the aging of the skin, reduced wrinkles and also could act as a moisturizer (Yuan 1988). The content of glutamate in PS was particularly high, and it was shown that amino acids could possibly delay aging processes (Wang et al. 2001; Cao et al. 2003, Peng 2017).

7.2. *Lignin*

Phenolic hydroxyl groups could effectively eliminate the effect of oxygen active free radical, so that it should have anti-aging activity (Zhang et al. 2006). Lignin could effectively eliminate oxygen-active free radicals, so it had significant antioxidant activity because of the abundant phenol hydroxyl similarly (Peng 2017).

7.3. *Volatile oil*

Volatile (aromatic) oils are odorous ingredients in plants and natural spices. Some volatile oils exert sterilization, disinfection, deodorant and other properties (Chen et al. 2018). Many studies confirmed that the volatile oil from PS has strong inhibition ability to *Escherichia coli*, *Staphylococcus aureus* and Red yeast (Van Damme et al. 1996; Yu et al. 2008; Ye et al. 2009).

7.4. *Macro and trace elements*

Wang et al. found that major and trace elements of PS were associated with anti-aging, while a higher content of Mn, Sr, Ge is related to anti-aging effects (Table 7, Cao et al. 2003; Wang et al. 2012).

8. Discussion

From the above, we could draw the conclusion, that PS and its active ingredients could have great potential in cosmetics, showing anti-aging, anti-bacterial, skin whitening, moistening effect and so on. With the natural active and plant cosmetics becoming more and more popular, the development of PS cosmetics will become more and more promising.

The application of natural cosmetics originated from ancient China. In recent years, the growth of natural plants cosmetics has consistently surpassed synthetic cosmetics. China is the country with the fastest growth of natural plant cosmetics and the cosmetics market of China is dominated by Chinese herbal medicine cosmetics. The use of PS in China has a long history, with extensively studied pharmacological activities. However, few studies investigated applications of PS in cosmetics. Under the trend that cosmetics tend to return to natural plants and natural ingredients, the active ingredients of PS should have great applications prospect in natural cosmetics. Probably, and in view of green civilization and green ecology, returning to the nature, natural active cosmetics may create a new chapter in the cause of human beauty.

Abbreviations

ALP: Alkaline phosphatase; ALP: Alkaline phosphatase; ALT: Alanine aminotransferase; ALT: Alanine transferase; ALX: Alloxan; AST: Aspartate transaminase; ATP: Adenosine triphosphate; Bax: Bcl2-associated X protein; Bcl-2: B cell lymphoma/lewkmia-2; BDNF: Brain derived neurotrophic factor; BGP: Bone Gla-protein; BMP-2: Bone morphogenetic protein-2; BMSCs: Bone marrow mesenchymal stem cells; BUN: Blood urea nitrogen; cAMP: Cyclic adenosine monophosphate; cGMP: Cyclic guanosine monophosphate; CAT: Catalase; CK: Creatine kinase; COX-2: Cyclooxygenase-2; DA: Dopamine; DPPH: Diphenyl picryl hydrazine; EAC-109: Human esophageal cancer cells; EC50: 50% effective concentration; ECs: Endothelial cells; FGB: Fasting blood glucose; Glu: Glutamic acid; GLUT-2: Glucose transporter-2; GLUT4: Glucose transport protein-4; GR: Glutathione reductase; GSH-Px: Glutathione peroxidase; GSP: Glycosylated serum protein; H14: Human lung cancer cells;

HCT-8: Human colorectal cancer cells; HDL-C: Low-density lipoprotein; HGC-27: Human gastric cancer cells; HL-60: Human leukemia cells; HT:5-hydroxytryptamine; IC50: 50 % inhibitory concentration; IgA: Immunoglobulin A; IgG: Immunoglobulin G; IgM: Immunoglobulin M; IL: Interleukin; iNOS: Inducible nitric oxide synthase; LDH: Lactate dehydrogenase; LDL-C: Low-density lipoprotein; LF: Lipofuscin; Lp(a): Lipoprotein; LPO: Lipid peroxidation; MAO: Monoamine oxidase; MAO-B: B-type monoamine oxidase; MCF-27: Human breast cancer cells; MDA: Malondialdehyde; MDA-MB-435: Human breast cancer cells; MIC: Minimal inhibition concentration; Mn-SOD: Manganese superoxide dismutase; NE: Norepinephrine; NF-êB: NF-kappaB inhibitor alpha; NO: Nitric oxide; OC: Osteocalcin; OCN: The major sign of the start of mineralization; p-Akt: Phosphorylated Akt; PINP: N-terminal propeptide of type I procollagen; PPAR-γ: Peroxisome proliferator-activated receptor-γ; RUNX2: Runt-related transcription factor; SOD: Superoxide Dismutase; SOD: Total superoxide dismutase; SPARC:ecreted protein, acidic and rich in cysteine; STZ: Streptozocin; T-AOC: Total antioxigenic capacity; TBARS: Thiobarbituric acid reactive substance; TC: Total cholesterol; TG: Triglyceride; TNF-α: Tumor necrosis factor-α; TrkB: Tyrosine kinase B; VC: Ascorbic acid

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