The Potential of Using Bee Pollen in Cosmetics: a Review

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Abstract: During ancient times in China, bee pollen was used for skin whitening and beauty. Around 70% of substances in bee pollen are biologically active, such as proteins, carbohydrates, lipids and fatty acids, phenolic compounds, vitamins and bioelements. This review describes the cosmeceutical properties of bee pollen and the mechanism of its active components action, its beneficial influence on human skin. As a natural bee product, bee pollen may effectively enhance protective mechanisms against skin aging, skin dryness, ultraviolet B radiation, oxidative damage, inflammatory and melanogenesis, which are involved in a wide range of negative effects on human skin, thus they have attracted attention for health and cosmetic applications.

Key words: bee pollen, active ingredients, cosmetics

1 Introduction

Bee pollen is the pollen cluster that the honeybee brings back when collecting honey. The pollen formed after storage and fermentation in the hive. It was formed by mixture of flower pollen from different species agglutinated by nectar and honeybee enzymes (e.g. amylase, catalase) secreted by salivary glands and pollen-loads¹. It plays an important role in the treatment of diseases in ancient Chinese medicine. For thousands of years, the health and medicinal properties of bee pollen have been used up to now². It demonstrates a series of actions such as antioxidant, anti-inflammatory, anti-carcinogenic, anti-bacterial, anti-fungicidal, hepatoprotective, and anti-atherosclerotic activities capable of modifying or regulating immune functions (Table 1).

During ancient times in China, bee pollen was used for skin whitening and beauty. There are many chemical constituents in bee pollen, which has great potential for development in the cosmetics field. Such as, proteins, amino acids, carbohydrates, lipids, fatty lipids, phenolic compounds, vitamins and bioelements. Amino acids consist of methionine, lysine, threonine, histidine, leucine, isoleucine, valine, phenylalanine, and tryptophan. Carbohydrates consist of fructose, glucose, sucrose, fibre. Fatty acids consist of linoleic, γ-linoleic, and archaic. Phenolic compounds include flavonoids, leukotrienes, catechins, and phenolic. Vitamins such as provitamin A (β-carotene), vitamin E (tocopherol), niacin, thiamine, biotin and folic acid, enzymes or co-enzymes. And bioelements include Ca, Mg, Fe, Zn, Cu, with a high K/Na ratio (Table 2). A number of these secondary metabolites derived from plant are known for their benefits to the skin. The metabolites are used in skin protection such as skin whitening, moisturization, free-radical scavenging, anti-inflammatory, antiaging effects. These effects have provided beneficial support for the development of bee pollen in the field of cosmetics.

2 Phytochemicals to cosmetics

2.1 Proteins of bee pollen in cosmetics

2.1.1 Cosmetic and skin care protein derivatives

Many biological reactions of proteins play a vital role in the body. Environmental pollution, ultraviolet (UV) radiation, microorganisms and viruses, these exogenous or environmental-derived free radicals may cause premature aging and aging of the skin. The current study found that wrinkles, senile plaques, and dry skin may be related to im-
balances in the body of the protein \(^2\). Surfactants are an important component of cosmetics and they are an integral part. However, prolonged skin contact with surfactants can cause side effects. The main mechanism of action is that the surfactant molecules denature the stratum corneum of the skin and cause skin damage. Based on this, the addition of protein derivatives to cosmetics to complex with surfactants (Fig. 2) may have a role in preventing the surfactant from entering the dense mesh of keratin fibers \(^3,4\).

Most of the skin care products use a substance rich in protein, which can promote the ability of water to combine with the cuticle skin and its appendages, and play a role in skin whitening \(^5\). In recent years, it has been found that protein derivatives can also be used in various skin care...

### Table 1

<table>
<thead>
<tr>
<th>Therapeutic properties</th>
<th>Plausible biological mechanisms(^{ref.})</th>
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| Anti-inflammatory       | 1. Activation of numerous cells (macrophages, T cells, B cells, NK cells, hepatocytes, mast cells, basophils, neutrophils, eosinophils) \(\downarrow\) \(^1,4\)  
2. Arachidonic acid metabolism \(\downarrow\), the level of proinflammatory prostaglandins \(\downarrow\) \(^5,6\)  
3. Protein phosphorylation \(\downarrow\), modify cell signaling pathways \(^7\)  
4. Proinflammatory NF-\(\kappa\)B pathway \(\downarrow\) \(^5\)  
5. Cyclooxygenase and lipoxygenase \(\downarrow\) \(^8\)  
6. Enzymes (Turning arachidonic acid into toxic compounds) \(\downarrow\) \(^8\) |
| Anti-oxidative          | 1. ROS \(\downarrow\) \(^6,10\)  
2. Inactivation of electrophiles, free radicals \(\downarrow\) \(^6\) |
| Anti-carcinogenic       | 1. ROS \(\downarrow\) \(^4\)  
2. Inactivation of oxygen reactive species \(^11\)  
3. Apoptosis \(\uparrow\) \(^12\)  
4. TNF-\(\alpha\) \(\uparrow\) \(^12\) |
| Anti-bacterial, Anti-fungal | 1. Cytoplasm membrane degradation \(^13\)  
1. Ig M and IgG \(\uparrow\) \(^14\)  
2. Activation of mast cells \(\downarrow\), histamine \(\downarrow\) \(^15\)  
3. Ig E binding to FceRI \(\downarrow\) \(^15\)  
4. Histamine secretion \(\downarrow\) \(^15\)  
1. Total lipids \(\downarrow\), Triacylglycerol \(\downarrow\) \(^16,17\)  
2. Platelet aggregation \(\downarrow\) \(^18\)  
3. Fibrinolytic activity \(\uparrow\) \(^18\)  
4. Cholesterol \(\downarrow\) \(^19\) |
| Hypolipidemic           | 1. Plasma total lipids \(\downarrow\) \(^20\), Triacylglycerols \(\downarrow\) \(^21\)  
2. Lipid correlated hormones (e.g. insulin, testosterone, thyroxine) \(\downarrow\) \(^22\) |
| Detoxifying             | 1. Pathological levels of enzymes Enzymes (e.g. alanine and aspartate transaminase, acid phosphatase, and bilirubin) \(\downarrow\) \(^23\)  
2. Bilirubin \(\downarrow\) \(^20\)  
1. Vitamin C and magnesium \(\uparrow\) \(^23-25\) |
| Dietary supplement      | 2. Hemoglobin content and red blood cells \(\uparrow\) \(^23-25\)  
3. Protein metabolism regulation and enhancement \(^22\) |

### Table 2

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Content</th>
<th>Main components(^{ref.})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>30.8%</td>
<td>Reducing sugars (e.g. fructose, glucose) (^26)</td>
</tr>
<tr>
<td>Proteins</td>
<td>22.7%</td>
<td>Essential amino acids, nucleic acids (e.g. ribonucleic) (^27-29)</td>
</tr>
<tr>
<td>Lipids</td>
<td>5.1%</td>
<td>Essential fatty acids, Phospholipids, Phytosterols (e.g. P-sitosterol) (^30)</td>
</tr>
<tr>
<td>Polyphenolics</td>
<td>1.6%</td>
<td>Flavonoids, leukotrienes, catechins, and phenolic acids (^31)</td>
</tr>
<tr>
<td>Vitamins</td>
<td>0.7%</td>
<td>Provitamin A, Vitamin B(_1), B(_2), B(_6), and C, Vitamin E and D and acids (^27,28,32,33)</td>
</tr>
<tr>
<td>Bioelements</td>
<td>1.6%</td>
<td>Macronutrients (Ca, P, Mg, Na, K) and Micronutrients (Fe, Cu, Zn, Mn, Si, Se) (^27,28,32,33)</td>
</tr>
</tbody>
</table>
and cosmetic formulations. Studies have found that soluble protein derivative ingredients are suitable for almost all types of cosmetic forms (emulsions, lotions, and gels, etc.). Other studies have shown that protein derivatives used for cosmetic purposes are obtained from simple proteins that can be easily obtained from lower organisms (algae, fungi), eliminating many complicated procedures. As mentioned in the review, the use of protein in bee pollen has great potential for development in cosmetics.

2.1.2 Amino acids in cosmetics

Protein hydrolyzed small molecule substances are used by most cosmetics. Natural proteins produce 20 basic proteins after hydrolysis, and their spatial structure and sequence determine their biological properties. Numerous studies have found that protein diets rich in amino acids that are well-balanced can help maintain beautiful skin. UV irradiation is the main culprit implicated in premature skin aging, which is referred to as photoaging. They are capable of inducing aging-related changes even in the dermis, partly due to their greater average depth of skin penetration. A large number of studies have shown that intracellular MAAs can provide effective protection for radiation-sensitive organisms. Some MAAs may protect the cell not only against UV radiation by absorbing the high-energy photons and dissipating the energy as heat but also by scavenging reactive oxygen species such as singlet oxygen, superoxide anions, hydroperoxyl radicals, and hydroxyl radicals. Chiaki Oyamada et al. examined the protective effects of the three MAAs on human fibroblast cells from UV irradiation. Currently detectable (MAA) in amino acids have been shown to have a role in preventing UV radiation-induced apoptosis. Amino acids can prevent the accumulation of melanin and can effectively prevent ultraviolet rays from damaging the skin and achieve skin care (Fig. 3).

On the other hand, the stratum corneum on the surface of the skin maintains moisture in the skin. Among them, the natural moisturizing factor (NMF) is an important ingredient for keeping moisture. NMF is mainly composed of fi-
brin-derived free amino acids, which also provides a basis for the application of this protein derivative in skin care. In addition, L-serine is the most abundant (~36%) followed by glycine (22%) and L-alanine (13%). Histidine, ornithine, citrulline and arginine all account for 6–8% of free amino acids within NMF. The data in Fig. 4 show some correlation ($R^2 = 0.82$) between increasing bond energies and increasing DRH, suggesting that when amino acids can form strong intermolecular bonds, it is less likely to form intermolecular hydrogen bonds with water.

Recently, amino acids have attracted more attention in the cosmetics market. The estimated market of amino acids for use in cosmetics is 14,000 tons per year. As described above, amino acid derivatives are used for foaming cleansing agents. From the cosmetic ingredients instructions, arginine was found to be the most used in cosmetics and personal care products, with more than 500 cases being used; more than 400 were used for leave-in preparations. The second most used amount of glycine is a total of 360 kinds of which 252 of them are used for the prepara-
Bee Pollen in Cosmetic


2.2 Carbohydrates of bee pollen in cosmetics

Carbohydrates (e.g., alginates, carrageenans, ulvans, fucoidans, laminarans, agar) of bee pollen are mainly used as thickeners, emulsion stabilizers, protective colloids, gelling, moisturizing and chelating agents. They possess anti-oxidative, anti-cellulite, anti-viral, anti-inflammatory and anti-aging properties. It can be applied to prevent skin aging and cutaneous disorders (Fig. 5).

2.2.1 Carbohydrates against skin aging

Degeneration of skin tissue can lead to skin aging. Through morphometric examination of skin biopsies it is found that the total skin thickness will be lost by about 7% every 10 years. Fodil-Bourahla proved that L-fucose can effectively promote the increase of skin thickness and densify collagen. Other findings indicate that 3H-L-fucose penetrates into the dermis and can produce more pronounced results. L-fucose and fucose-rich oligosaccharides and polysaccharides (FROP-s) can affect collagen biosynthesis and accumulation in fibroblasts.

2.2.2 Carbohydrates against ultraviolet B radiation

UVA and UVB reach the skin surface and are partially reflected by the epidermis’s stratum corneum and absorbed by epidermal melanin. However, a large amount of radiation is not reflected inside the skin and induces damage to DNA and other skin cells, which greatly increases the incidence of skin cancer. Studies have found that the use of Cordyceps sinensis polysaccharides can prevent UVB-induced cyclobutane-pyrimidine dimer (CPD) formation. After 24 hours of pretreatment with Cordyceps polysaccharide, the CPD content of irradiated cells was also significantly reduced.

2.2.3 Carbohydrates against oxidative damage

Skin is one of the most frequently exposed tissues to oxidative stress from exogenous and endogenous sources. Reactive oxygen species (ROS) are the cause of various skin diseases, such as skin cancer, skin autoimmune diseases, xeroderma pigmentosus and skin aging. Currently, studies have found that polysaccharides have the effect of scavenging free radicals and are increasingly used as antioxidants to prevent oxidative damage in food and living organisms. Experiments have found that polysaccharides in black fungus can significantly reduce the skin malondialdehyde (MDA), lipofuscin (LF) content and enhance the activity of superoxide dismutase (SOD).

2.2.4 Carbohydrates against skin dryness

Moisturizing of the skin is recognized as the first anti-aging skin care. Cosmetics and skin care products have a certain moisturizing effect. With aging and prolonged exposure of the skin, tissues with moisturizing effects in the skin can be damaged. Natural polysaccharides, mainly from natural or biotechnological origin, were proposed as external moisturizing agents. These natural polysaccharides,
known to capture humidity on the skin’s surface after integration in topical formulations, are very useful to increase skin hydration in dry environments such as winter or air-conditioned rooms. Hyaluronic acid (HA), a common mucopolysaccharide is an important functional ingredient in cosmetics and in clinical medicine because of its excellent moisture-retention ability\(^{30}\). Li et al. reported good moisture retention activity of the polysaccharide from Nostoc commune\(^{51}\). Xylose, a sugar and a component of natural glycosaminoglycans, has also been shown to be a keratinocyte HA synthesis stimulating agent and skin hydrating agent\(^{52}\).

### 2.3 Lipids of bee pollen in cosmetics

Recent studies suggest that supplementing intercellular lipids of the stratum corneum can enhance the functioning of the skin. In the epidermis, lipids of bee pollen are crucial ingredients that allow us to form the permeability barrier that prevents the movement of water and electrolytes through the stratum corneum that is essential for life. Extracutaneous lipids also make a significant contribution to the formation and maintenance of a normal permeability barrier. And topical treatment with lipids can improve permeability barrier function and treat cutaneous disease.

#### 2.3.1 Glycolipids by bee pollen

Studies have shown that supplementing the intercellular lipids of the stratum corneum can improve the protective function of the skin. In the epidermis, lipids are key substances that make the skin a permeable barrier that blocks the penetration of water and electrolytes through the stratum corneum, which is an important part of skin metabolism. Subcutaneous lipids also make a significant contribution to the formation and maintenance of normal permeability barriers. And topical treatment with lipids can improve permeability barrier function and treat skin diseases\(^{53, 54}\).

#### 2.3.2 Effect of Lipopeptides

Lipopeptides are biosurfactants extensively used in cosmetics. Due to its unique surface activity, it has been made into various forms of cosmetics. It was found to be an amphiphilic cyclic polypeptide consisting of 7-10 amino acids (Fig. 6). In addition to their anti-wrinkle, moisturizing and

Fig. 6  Primary structure of Lipopeptides, surfactin (A), iturin (B) and fengycin (C)\(^{55, 56}\).
cleansing properties, their broad spectrum of anti-bacterial and fungal activity has also been demonstrated, and as a result, lipopeptides in this bee pollen have also been more developed potential.  

2.3.3 Polyunsaturated fatty acids (PUFA)

The importance of polyunsaturated fatty acids (PUFAs) in human skin health is increasingly favored by people, and the protective effect of PUFAs on the skin has received much attention. Studies have shown that n-3 PUFA can reduce the sensitivity of human skin to radiation. According to reports, fish oil is a natural rich source of EPA and DHA, which can reduce UVR-induced erythema in human skin. As shown in Fig. 7. Polyunsaturated fatty acids can regulate lipid metabolism and inflammation by binding to nuclear transcription factors such as NFB, AP-1 and sterol regulatory element binding protein (SREBP) and receptors including peroxisome proliferator-activated receptor (PPAR). Related Genes, Liver X and Retinoid X Receptors.

2.4 Vitamins of bee pollen in cosmetics

Vitamins are increasingly used in cosmetics. It is believed that the extra use of vitamins from bee pollen in cosmetics can better protect and possibly correct damage by neutralizing free radicals. In addition, some vitamins may be beneficial to the skin because other effects such as inhibiting pigmentation and bruising, stimulate collagen production, improve keratinization or anti-inflammatory effects.

2.4.1 The value of vitamin A from bee pollen in cosmetics

In recent years, vitamin A and its derivatives and β-carotene (provitamin A) have been widely used in cosmetics. The main feature of vitamin A and its derivatives in cosmetics is the ability to normalize keratinization. Vitamin A (retinol and retinyl ester) has a strong absorption peak in ultraviolet (UV) radiation between 300 and 350 nm with a maximum of 325 nm, which is the visible wavelength range. In addition to being a precursor of the biologically active form of epidermal vitamin A with photocarcinogenic properties, epidermal retinyl esters also help protect DNA from UV-induced changes in the sequence.

2.4.2 The value of vitamin C from bee pollen in cosmetics

The main cause of skin aging is light and the environment consumes a large amount of vitamin C in the body. Even if the minimum UV exposure is 1.6, the minimum erythema dose (MED) will significantly reduce vitamin C levels. Therefore, increasing the content of vitamin C in the skin is an important factor in delaying skin aging, and secondly, it may also be very beneficial as a topical administration of medicinal cosmetics.

2.4.3 The value of vitamin E from bee pollen in cosmetics

In the skin, vitamin E is especially abundant in the stratum corneum, delivered there by sebum. Topical vitamin E has been used effectively to treat melasma and pigmented contact dermatitis, as demonstrated in one multiclinical doubleblind study. Clinically, topical vitamin E does decrease wrinkles and solar lentigines of photoaging. Microscopic examination showed correction of the UV-induced epidermal hypertrophy, thickened stratum corneum, increased "sunburn cells" in the basal layer, and disruption of dermal collagen. Further electron microscopic analysis confirmed correction of collagen and elastin fiber damage.
and demonstrated repair of UV-induced disruption of the basement membrane anchoring fibrils\(^6\)\(^{60}\).

2.4.4 Vitamin B\(_3\) by bee pollen

Vitamin B\(_3\), also known as nicotinamide, is a niacin derivative obtained from the diet. Bee pollen contains a lot of vitamin B\(_3\). The coenzyme nicotinamide adenine dinucleotide (NAD\(^+\)), NAD phosphate (NADP\(^-\)), is a component of nicotinamide and its reduced forms are NADH and NADPH. Nicotinamide is one of the widely used vitamins in pharmaceutical cosmetics. Most of the existing studies have anti-inflammatory and anti-acne effects\(^{61}\). A small amount of nicotinamide improves the skin’s appearance of sphingolipids, free fatty acids, and also has a certain correlation in reducing transepidermal water loss\(^{63}\).

2.5 Polyphenolics from bee pollen in cosmetics

Polyphenols are a large class of phytochemicals found in many edible and medicinal plants. The chemical structure of polyphenolic compounds causes their reducing properties, which allow them to act as antioxidants and free radical scavengers. So they are of great interest to manufacturers of cosmetic and cosmeceutical products\(^{66}\). Studies have found that pure natural polyphenols (such as green tea polyphenols (GTP), mainly derived from milk chrysin silymarin and grape seed (GSP) procyanidins) can effectively control UV radiation-induced inflammation, oxidative stress, DNA damage and immune response (Table 3).

<table>
<thead>
<tr>
<th>Polyphenolics</th>
<th>Major source</th>
<th>Molecular structures</th>
<th>Molecular targets/mechanism</th>
</tr>
</thead>
</table>
| Catechins (EGCG)    |              | ![Catechins](image)  | 1. \(\text{H}_2\text{O}_2\), NO, iNOS, LPO, MPO ↓  
2. Inflammation, COX-2, PGs, IL, NF-\(\kappa\)B, IKK\(\alpha\), AP-1, MAPK proteins ↓  
3. Antioxidant defense enzymes ↑  
4. DNA damage ↓  
5. DNA repair mechanism |
| Genistein           |              | ![Genistein](image)  | 1. Inflammation, IL, TCA cycle, Protein Synthesis ↓  
2. MDA ↓  
3. T-SOD, GSH-PX, NO ↑ |
| Proanthocyanidins   |              | ![Proanthocyanidins](image) | 1. Inflammation ↓  
2. \(\text{H}_2\text{O}_2\), iNOS, LPO, MPO, NF-\(\kappa\)B, IKK\(\alpha\), AP-1, MAPK proteins ↓  
3. Antioxidant defense enzymes ↑ |
| Resveratrol         |              | ![Resveratrol](image) | 1. Inflammation, \(\text{H}_2\text{O}_2\), LPO, COX-2, PGs, NF-\(\kappa\)B, IKK\(\alpha\), MAPK proteins ↓ |
| Silymarin/silibinin |              | ![Silymarin/silibinin](image) | 1. \(\text{H}_2\text{O}_2\), LPO, NO, iNOS, MPO ↓  
2. Inflammation, COX-2, PGs, PCNA, NF-\(\kappa\)B, IKK\(\alpha\), AP-1, MAPK proteins ↓ |

2.5.1 Photoprotective properties of polyphenols by bee pollen

The photoprotective properties of polyphenols can be measured, when treated skin area is irradiated with UV light and the resulting erythema is appraised. Polyphenol extracts from pistachio nut significantly reduced UVB-induced skin erythema by topical application in human volunteers\(^{67}\). Polyphenols have a role in the prevention of UV irradiation. It has been found that water-extracting polyphenols in green tea leaves can effectively prevent the occurrence of UV-induced tumors\(^{68}\). The application of chemopreventive constituent in green tea, (−)-epigallocatechin-3-gallate (EGCG) may prove helpful in ameliorating the harmful effects caused by UVB exposure through decreased ROS production (Fig. 8).

2.5.2 Anti-inflammatory effects of polyphenols

UV-induced cyclooxygenase-2 (COX-2) expression and the increase in prostaglandin (PG) metabolites in the skin are characteristic responses of keratinocytes to acute or chronic skin sensitization. It has been reported that treatment with green tea polyphenols can inhibit the UV radiation-induced expression of COX-2 and its PG metabolites\(^{69}\). Topical application of EGCG can inhibit the production of UV-induced PG metabolites. PGE metabolites include PGE\(_2\), PGE\(_3\) and PGE\(_4\), which play an important role in inflammatory diseases and proliferative skin diseases. A possible pathway for polyphenols to interfere with inflammatory responses is their ability to inhibit the activation of transcription factors NF-\(\kappa\)B and AP-1, which regulate the secretion of pro-inflammatory cytokines (TNF-\(\alpha\), IL-1, IL-6, IL-8) (Fig. 9).
2.5.3 Skin-lightening effects of polyphenols from bee pollen

Most women want to maintain by improving skin color and reducing the appearance of pigmentation spots (“age” or “sun” spots). Traditional pigmentation agents, such as hydroquinone, work well for a long time. However, natural resources and extracts represent a library of ingredients that can be used for topical treatment to improve hyperpigmentation and the overall appearance of the skin. Many types of polyphenol plant extracts have been observed to inhibit melanogenesis. Ellagic acid extracted from pomegranate peel showed inhibitory activity against mushroom tyrosinase in vitro. Oral administration of crude polyphenol concentrate extracts from etholob effectively reduced pigmented skin in guinea pigs.

This effect may be mainly by inhibiting tyrosinase activity in melanocytes to inhibit melanin synthesis. Kuwanon O and Sanggenon T are two potential skin whitening ingredients in *M. astralis* root extracts. They were found to have decolorization in mouse b16 and melan-a cell lines. Although polyphenols are widely regarded as an effective whitening substance, verification of clinical trials is still needed.

3 Discussion

There is a long history of the recorded use of bee pollen by humans. Around 70% of substances in bee pollen are biologically active, such as proteins, carbohydrates, lipids and fatty acids, phenolic compounds, vitamins and bioelements. As a natural bee product, bee pollen may effectively enhance protective mechanisms against skin aging, skin dryness, ultraviolet B radiation, oxidative damage, inflammatory and melanogenesis, which are involved in a wide range of negative effects on human skin, thus they have attracted attention for health and cosmetic applications. By learning about the cosmeceutical properties of bee pollen and the mechanism of its active components action, its beneficial influence on human skin can be embraced.
Conflict of interest

The authors declare no conflicts of interest.

Reference


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