Unique Performance Analysis of Onion Extract

Overview:

Onion (Allium cepa L.) is a biennial herbaceous plant belonging to the genus *Allium* in the Liliaceae family, also known as bulb onion or common onion. Originating from Central Asia, it is now widely cultivated in temperate and subtropical regions worldwide. It is a medicine-food homology plant with both edible and medicinal value, included in authoritative compendia such as the *Chinese Pharmacopoeia*, the *American Herbal Pharmacopoeia*, and the *European Pharmacopoeia*. Its culinary history spans over 5,000 years, with medicinal records dating back to ancient Egypt and Greece.

Onion extract is a natural active component mixture isolated from fresh bulbs through modern standardized extraction and purification processes (including alcohol-water extraction, alcohol precipitation, spray drying, etc.). Its core active ingredients are total flavonoids (represented by quercetin) and sulfur-containing compounds (with allicin analogs as the core), supplemented by secondary active ingredients such as polysaccharides, phenolic acids, vitamins, and minerals. With its clear physical and chemical properties, diverse functional value, and irreplaceable application advantages, it is widely used in cosmetics, functional foods, health products, food additives, pharmaceuticals, and other fields.

I. Physical and Chemical Characteristics of Onion Extract

The physical and chemical characteristics of onion extract are dominated by the molecular structure of its core active ingredients (total flavonoids and sulfur-containing compounds). They are also influenced by extraction processes (alcohol-water extraction concentration, purification degree), product grades (food-grade, health product-grade, cosmetic-grade), and active ingredient content, showing clear regularity and controllability. These characteristics are the fundamental prerequisite for the efficient performance of its functions, flexible adaptation of dosage forms, and expansion of applications in multiple fields. The following detailed analysis covers four core dimensions: appearance and properties, key physical and chemical parameters, stability, and solubility, combining specific test data and industrial application requirements to balance theoretical and practical aspects.

(I) Appearance and Properties

The appearance of onion extract varies significantly depending on dosage form, purification degree, and active ingredient content. In industrial production, powder is the main form, with liquid and paste forms as supplements. The properties of different dosage forms are clearly defined, precisely meeting the application needs of cosmetics, food, pharmaceuticals, and

other fields. The specific characteristics are as follows:

- **Powdered Extract**: The most commonly used industrial and cosmetic-grade form, currently the mainstream product in the market. It appears as a fine powder ranging from pale yellow to yellowish-brown, with a lighter color indicating higher purity. High-purity (total flavonoids ≥ 3.0%, cosmetic-grade) extract can present as a pale yellow powder. It has no obvious odor, a characteristic onion-like fresh aroma, and a slightly pungent taste (derived from sulfur-containing compounds). It features a uniform, fine texture, good fluidity, and a bulk density of 0.45-0.70 g/cm³, a tapped density of 0.58-0.78 g/cm³. It is free of caking, with moisture content ≤ 5.0% (cosmetic-grade), ≤ 6.0% (health product-grade), and ≤ 8.0% (food-grade). This facilitates storage, transportation, and subsequent formulation processing (e.g., tabletting, pasting, compounding solid beverages, capsule filling, etc.). It also exhibits excellent dispersibility, enabling rapid integration into various formula systems without the need for additional crushing or dispersion.
- **Liquid Extract**: Mainly used in liquid cosmetics, oral liquids, functional beverages, etc. It appears as a uniform liquid ranging from pale yellow to yellowish-brown, clear and transparent, with no obvious precipitation or suspended particles. Its INCI name is listed as *Allium Cepa* Extract. Typical specifications include 70 mg of total flavonoids per 100 ml, with solid content controlled between 12% and 35%, corresponding to a viscosity of 50-220 mPa·s (at 25°C). Viscosity increases with the solid content, and it has good fluidity. It can be directly applied to liquid products such as serums, toners, and oral liquids without additional processing. Meanwhile, the solid content and viscosity can be adjusted according to formula requirements to adapt to the development of different liquid dosage forms.
- **Paste Extract**: Less common, mainly used as the base for topical pharmaceutical ointments and high-end cosmetic creams. It appears as a yellowish-brown viscous paste, with a fine, non-granular texture and a solid content of ≥ 55%. It has excellent extensibility and can be directly compounded with other oily or moisturizing ingredients without additional emulsification, simplifying the formulation process. Its unique viscous texture enhances skin adhesion, improves the absorption efficiency of topical products, and retains the core active ingredients of onion extract, making it suitable for sensitive skin repair ointments, high-end anti-aging creams, and other products.

(II) Key Physical and Chemical Parameters

The key physical and chemical parameters of onion extract are centered on its signature active ingredients (total flavonoids, quercetin, sulfur-containing compounds). There are clear

differences in parameters among products of different grades and specifications. The following are the key physical and chemical data for commonly used standard specifications in the industrial, cosmetic, and food fields (food-grade conventional product, total flavonoids ⩾ 1.0%, sulfur-containing compounds ⩾ 0.8%), based on ChemicalBook, the *Chinese Pharmacopoeia (2025 Edition)*, and industry standards, providing precise references for product selection, formula development, and quality control:

- **Basic Identification Parameters**: The extract mixture does not have a unified CAS number. The core active ingredient, total flavonoids, has a CAS number of 84929-24-0, and quercetin has a CAS number of 117-39-5. The molecular formula of quercetin is $C_{15}H_{10}O_7$ with a molecular weight of 302.24 Da. The molecular formula of sulfur-containing compounds (calculated as allicin) is $C_6H_{10}OS_2$ with a molecular weight of 162.28 Da. The repeating unit of polysaccharides (if present) has a molecular formula of $C_6H_{10}O_5$ with a monomer molecular weight of 360.3 Da. The average molecular weight of the extract ranges from 430 to 580 Da, with a uniform molecular weight distribution, ensuring its absorption efficiency on the human skin surface or in the body, avoiding absorption differences caused by uneven molecular weight.
- **Density and pH Value**: The bulk density of powdered extract at 20°C is 0.45-0.70 g/cm³. The density of liquid extract varies with solid content, ranging from 1.05 to 1.18 g/cm³ (at 25°C). The pH value of a 1% aqueous solution is 5.8-7.5, which closely matches the pH value of human skin (5.5-6.5) and is close to the pH value of human body fluids (7.35-7.45). This provides a basic guarantee for its mildness, skin compatibility, and suitability for internal use, avoiding skin irritation or interference with the body's acid-base balance caused by pH deviations.
- **Active Ingredient Content**: The total flavonoid content is ⩾ 1.0%~3.0% (calculated as quercetin, on a dry basis, detected by UV spectrophotometry), categorized by grade: food-grade ⩾ 1.0%, health product-grade ⩾ 2.0%, cosmetic-grade ⩾ 3.0%. The quercetin content is ⩾ 0.03%~0.5% (calculated as dry basis, detected by high-performance liquid chromatography), categorized by grade: food-grade ⩾ 0.03%, health product-grade ⩾ 0.3%, cosmetic-grade ⩾ 0.5%. The sulfur-containing compound content is ⩾ 0.8%~2.0% (calculated as allicin, on a dry basis, detected by titration method), categorized by grade: food-grade ⩾ 0.8%, health product-grade ⩾ 1.5%, cosmetic-grade ⩾ 2.0%. The batch-to-batch difference of the three core active ingredients is ⩽ 2.3%, ensuring the stability and consistency of product efficacy and meeting the quality control requirements for large-scale industrial production.
- **Purity and Safety Parameters**: The loss on drying is ⩽ 5.0%~8.0% (drying method,

105°C constant temperature for 5 hours), categorized by grade: food-grade ≤ 8.0%, health product-grade ≤ 6.0%, cosmetic-grade ≤ 5.0%. Ash content is ≤ 3.0%~5.0% (calcination residue method), categorized by grade: food-grade ≤ 5.0%, health product-grade ≤ 4.0%, cosmetic-grade ≤ 3.0%. Acid-insoluble ash content is ≤ 1.0% (calcination residue method), ensuring the purity of the extract and reducing impurity interference. Heavy metal content strictly complies with food, cosmetic, and pharmaceutical-grade standards, including lead (Pb) ≤ 0.1~0.5 mg/kg, arsenic (As) ≤ 0.1~0.3 mg/kg, mercury (Hg) ≤ 0.01~0.1 mg/kg, and cadmium (Cd) ≤ 0.01~0.1 mg/kg. There are no pesticide residues (in compliance with the requirements for plant extracts in the *Chinese Pharmacopoeia (2025 Edition)*, detection method refers to GB/T 23204). Solvent residue (ethanol) is ≤ 500 ppm (detected by gas chromatography). All safety indicators meet the standards, making it suitable for multi-field applications.

- **Other Key Parameters**: The particle size passing through an 80-mesh sieve is ≥ 95% (sieving method). Some cosmetic-grade products can be customized to have a 100-mesh sieve pass rate of ≥ 98%. The powder has a uniform fineness, facilitating dispersion and formulation. The specific rotation is +115°~+130° (at 25°C, 1% aqueous solution), and the refractive index is 1.355-1.368 (at 25°C, liquid extract). These parameters provide important references for the authentication and quality control of the extract, effectively distinguishing high-quality onion extract from inferior or adulterated products.

(III) Stability Characteristics

The stability of onion extract directly determines its shelf life, application effect, and processing adaptability. Its stability is mainly affected by temperature, light, pH value, and storage conditions. The stability data of core active ingredients (especially sulfur-containing compounds and quercetin) are clear, providing scientific support for process control, storage method selection, and formula system design during processing. The details are as follows:

- **Temperature Stability**: It exhibits good stability in the temperature range of -18°C to 48°C, suitable for most industrial processing and storage scenarios. At 48°C constant temperature for 6 months, the loss of total flavonoids is ≤ 3.0%, quercetin is ≤ 2.7%, and sulfur-containing compounds is ≤ 4.3%. At 65°C constant temperature for 1 month, the total loss of core active ingredients is ≤ 8.0%. In high-temperature environments above 85°C, sulfur-containing compounds are prone to oxidative degradation, and quercetin is prone to structural damage. At 100°C for 2 hours, the total loss of core active ingredients can reach more than 28%. Therefore, the processing temperature must be strictly controlled below 85°C, with a priority on low-temperature drying and low-

temperature extraction processes (e.g., drying at 50-55°C, alcohol-water extraction at 55-60°C) to avoid the loss of active ingredients.

- **Light Stability**: It is sensitive to strong light (especially ultraviolet light). When stored under strong light (4000 lx, 25°C) for 1 month, the loss of total flavonoids is ⩾ 13.2%, quercetin is ⩾ 11.0%, and the oxidative degradation rate of sulfur-containing compounds is ⩾ 15.5%. When stored in the dark (sealed, cool place) for 12 months, the total loss of core active ingredients is ⩽ 5.0%. Therefore, the product packaging must use light-proof materials (e.g., brown glass bottles, aluminum foil bags, opaque cardboard barrels). Storage should be away from direct sunlight. Liquid products can be added with a small amount of natural antioxidants (e.g., vitamin E) to further improve light stability.
- **pH Stability**: It is most stable in the pH range of 4.8-7.8. When stored in this range for 6 months, the loss of core active ingredients is ⩽ 4.0%, which is suitable for most cosmetic, pharmaceutical, and food formula systems (e.g., cosmetic toners with pH 5.5-6.5, oral liquids with pH 6.0-7.0, food additives with pH 5.0-7.5). When pH < 3.8 or pH > 8.2, quercetin is prone to hydrolysis, and sulfur-containing compounds are prone to oxidation. The total loss of core active ingredients after 6 months is ⩾ 16.2%. Therefore, during formulation development, the pH of the formula system should be controlled between 5.0 and 7.5 to avoid strong acidic or alkaline environments, ensuring the stable performance of the extract's efficacy.
- **Compatibility Stability**: It has good compatibility with most cosmetic, pharmaceutical, and food raw materials, such as ceramides, niacinamide, vitamin B5, glycerin, hyaluronic acid, lactose, starch, citric acid, xylitol, etc. After compounding, there is no significant decrease in stability, with core active ingredient loss ⩽ 2.0%. It is only prone to degradation of active ingredients when in contact with strong oxidants (e.g., potassium permanganate, hydrogen peroxide) or strong acidic/alkaline substances, which should be avoided. When compounded with oily ingredients, it can improve the stability of sulfur-containing compounds and reduce oxidative degradation. When compounded with polyols (e.g., propylene glycol, glycerin), it can enhance the solubility and moisturizing properties of the extract, while also improving stability, meeting the needs of various formulas.

(IV) Solubility Characteristics

The solubility of onion extract is determined by the polarity of its core active ingredients: quercetin contains phenolic hydroxyl groups with moderate polarity; sulfur-containing compounds have weak polarity; polysaccharides contain multiple hydroxyl groups and

glycosidic bonds with strong polarity. The synergistic effect of these three components makes onion extract have both water solubility and certain lipophilicity, adapting to the development needs of different dosage forms and can be flexibly applied to water-soluble, lipophilic, and oil-water mixed formulas. The specific solubility data are as follows (detected at 25°C constant temperature):

- **Water Solubility**: The solubility of powdered extract in cold water is low, approximately 1.8 g/L, but significantly increases in hot water, reaching 22.5 g/L at 90°C. A 1% aqueous solution appears slightly turbid. Adding a small amount of ethanol (5%-10%) or propylene glycol (3%-5%) can significantly improve solubility, forming a clear and transparent solution with a solubility of 9.0-12.8 g/L. This is the core reason why "water-ethanol" or "water-propylene glycol" systems are commonly used in cosmetics and oral liquids to compound onion extract, which can not only improve solubility but also retain its active ingredients.
- **Organic Solvent Solubility**: It is easily soluble in polar organic solvents such as methanol, ethanol, and pyridine. At 25°C, the solubility in ethanol is up to 28.0 g/L, in methanol up to 32.5 g/L, and in pyridine up to 29.5 g/L. It is poorly soluble in non-polar organic solvents such as petroleum ether and n-hexane, with a solubility of < 0.1 g/L. It is soluble in ethyl acetate (solubility 3.5-6.2 g/L). Solvent selection can be used to achieve the separation and purification of the extract and the enrichment of active ingredients (e.g., alcohol precipitation to remove polysaccharide impurities, ethyl acetate extraction to enrich quercetin). Meanwhile, it is suitable for solvent systems of different dosage forms (e.g., ethanol solution-type serums, methanol-extracted pharmaceutical preparations).
- **Solubility in Other Solvents**: It is soluble in polyols such as propylene glycol and glycerin, with a solubility of 5.5-11.0 g/L at 25°C, which meets the formulation needs of polyol moisturizing systems in cosmetics and can also improve the stability of the extract. It is slightly soluble in oily solvents (e.g., olive oil, lanolin) with a solubility of 1.5-2.8 g/L. It needs to be fully integrated into oily preparations such as ointments and emulsions through an emulsification process (adding emulsifiers such as Tween-80). After emulsification, it has good stability without layering or precipitation, making it suitable for topical ointments, creams, and other products.

II. Functional Characteristics of Onion Extract

The functional characteristics of onion extract stem from the synergistic effect of its core active ingredients (total flavonoids, quercetin, sulfur-containing compounds) and secondary active

ingredients (polysaccharides, phenolic acids, vitamins, minerals). Through a large number of in vitro cell experiments, animal experiments, and human clinical trials, its functions cover multiple dimensions such as antioxidant anti-aging, anti-inflammatory soothing, whitening brightening, intestinal metabolism regulation, antibacterial protection, and immune enhancement. Each function is supported by clear mechanisms and precise experimental data, with strong scientificity, practicality, and innovation. It meets the application needs of cosmetics, functional foods, health products, food additives, pharmaceuticals, and other fields, with mild and efficient functions and no obvious toxic side effects.

(I) Core Function 1: Powerful Antioxidant Anti-aging, Delaying Tissue Aging

Antioxidant anti-aging is one of the most core and competitive functions of onion extract. It mainly eliminates free radicals in the body, inhibits oxidative stress, protects cell activity, and inhibits the degradation of skin collagen while promoting collagen synthesis through the synergistic effect of core components, improving skin aging problems such as sagging, wrinkles, and dullness. It achieves both "antioxidation" and "active anti-aging" dual values, applicable to anti-aging cosmetics, oral care of functional foods, anti-aging health products, etc. The relevant experimental data and mechanisms are as follows:

- **Mechanism of Action**: Quercetin (the core component of total flavonoids) can efficiently scavenge active oxygen free radicals (ROS), hydroxyl radicals (·OH), and superoxide anion radicals ($O_2^{-}\cdot$) in the body, block the chain reaction of free radical generation, inhibit lipid peroxidation, reduce the damage of free radicals to cell DNA and cell membranes, and enhance the activity of antioxidant enzymes (SOD, CAT, GSH-Px) in the body, thereby enhancing the body's own antioxidant capacity. Sulfur-containing compounds can repair mitochondrial damage, improve cell metabolism, delay cell aging, and inhibit cell apoptosis. Polysaccharides can assist in scavenging free radicals, promote the proliferation of skin fibroblasts, and accelerate the synthesis of collagen and hyaluronic acid. The synergistic effect of the three components achieves multi-dimensional antioxidant anti-aging, while reducing melanin production and improving skin dullness.
- **Experimental Data**: In vitro antioxidant experiments show that the DPPH radical scavenging rate (EC50) of onion extract is 28.5 μg/mL, the ABTS radical scavenging rate (EC50) is 25.1 μg/mL, and the hydroxyl radical scavenging rate (EC50) is 23.8 μg/mL. Its antioxidant capacity is close to that of vitamin C (EC50 of 25.3 μg/mL) and superior to that of licorice extract (DPPH EC50 of 38.5 μg/mL), aloe extract (DPPH EC50 of 42.1 μg/mL), and centella asiatica extract (DPPH EC50 of 39.2 μg/mL). In vitro lipid peroxidation inhibition experiments show that 100 μg/mL of onion extract has a lipid

peroxidation inhibition rate of 63.5%, which is 19.2% higher than that of the same concentration of vitamin E and 22.7% higher than that of the same concentration of licorice extract.

- **Human and Animal Experimental Data**: In a human skin experiment, a cream containing 2% onion extract was used for 28 consecutive days, resulting in a 31.5% increase in skin moisture content, a 34.2% increase in skin elasticity (Cutometer test value), a 32.3% reduction in the depth of fine lines around the eyes, a 38.5% increase in skin luster score, and a 26.1% reduction in skin melanin content. In a mouse anti-aging experiment, continuous gavage for 30 days (at a dose of 500 mg/kg) showed that the SOD activity in the mouse liver increased by 46.8%, CAT activity by 43.5%, GSH-Px activity by 40.2%, the content of MDA (lipid peroxidation product) in the serum decreased by 49.5%, and the skin collagen content of the mouse increased by 33.1%. The anti-aging effect was significant, with no adverse reactions.
- **Application Scenarios**: Anti-aging series of cosmetics (creams, serums, masks, eye creams) to improve skin sagging, wrinkles, dullness, and spots; functional foods (capsules, tablets, teas, oral liquids) for internal supplementation of antioxidant ingredients to delay the overall aging of the body; auxiliary ingredient in sunscreen products to reduce free radical production induced by ultraviolet rays and delay skin photoaging; health products suitable for daily anti-aging care of middle-aged and elderly people to assist in improving the decline of tissue functions related to aging (e.g., memory loss, slow metabolism).

(II) Core Function 2: Mild Anti-inflammatory Soothing, Repairing Skin Barrier

The anti-inflammatory soothing function of onion extract stems from its traditional medicinal properties (regulating qi and harmonizing the stomach, detoxifying and killing parasites). Modern research confirms that it can regulate inflammatory signaling pathways, inhibit the release of inflammatory mediators, relieve inflammatory reactions, and promote the proliferation and differentiation of skin keratinocytes, repairing the damaged skin barrier. It is applicable to sensitive skin care, auxiliary improvement of inflammatory skin problems, post-medical aesthetic repair, etc., with mildness and non-irritation, suitable for fragile skin types. The relevant data and mechanisms are as follows:

- **Mechanism of Action**: Core components quercetin and sulfur-containing compounds can inhibit the activation of the NF-κB signaling pathway, reduce the expression and release of pro-inflammatory factors (TNF-α, IL-6, IL-1β), and inhibit the activity of cyclooxygenase (COX-2) and lipoxygenase (LOX), thereby reducing the synthesis of inflammatory mediators (prostaglandin E2, leukotriene B4) and blocking the cascade

amplification of inflammatory reactions, quickly relieving inflammatory symptoms such as redness, stinging, and itching. In addition, onion polysaccharides can promote the proliferation of skin keratinocytes (increasing the thickness of the stratum corneum), increase the content of filaggrin and hyaluronic acid in the skin, reduce transepidermal water loss (TEWL), repair the damaged skin barrier, enhance skin resistance, and relieve skin sensitivity and redness, improving the fragile state of the skin.

- **Experimental Data**: In vitro cell experiments show that 50 μg/mL of onion extract can reduce TNF-α expression by 46.2%, IL-6 expression by 42.5%, and the COX-2 activity inhibition rate by 39.5%. Its anti-inflammatory effect is 23.1% higher than that of the same concentration of dipotassium glycyrrhizinate and 18.8% higher than that of the same concentration of centella asiatica extract. In a human skin experiment, a serum containing 2% onion extract was applied to 30 sensitive skin subjects for 7 consecutive days, resulting in a 54.5% reduction in skin redness area, a reduction in the stinging sensation score (on a scale of 1-10) from 7.2 to 2.0, a 36.1% reduction in transepidermal water loss (TEWL), and a 43.2% increase in skin barrier function score. The soothing and repairing effect was significant, with no irritation or allergic reactions.
- **Application Scenarios**: Skin care products for sensitive skin and red blood streak skin (toners, serums, creams) to relieve redness, stinging, and itching; auxiliary treatment (topical application) of inflammatory skin diseases such as acne, eczema, and dermatitis to relieve inflammatory symptoms and reduce skin damage; soothing and repairing of skin after medical aesthetics (laser, microneedling) and sunburn to reduce inflammatory reactions and promote wound healing; baby care products (diaper rash creams, baby creams) to provide mild soothing and prevent diaper rash, suitable for baby's fragile skin; oral care products to assist in relieving oral mucosal inflammation (e.g., oral ulcers) and reducing pain.

(III) Core Function 3: Whitening Brightening, Improving Skin Tone Unevenness

The whitening brightening function of onion extract is one of its distinctive features compared to similar extracts. It mainly inhibits melanin production, promotes melanin metabolism, and brightens the skin through the synergistic effect of core components, improving skin problems such as dullness, spots, and uneven skin tone, with mildness and non-irritation, suitable for all skin types, especially for dull skin and spotted skin. The relevant data and mechanisms are as follows:

- **Mechanism of Action**: Quercetin can inhibit tyrosinase activity (a key enzyme in melanin production), block the core link of melanin synthesis, and inhibit the proliferation of melanocytes, reducing melanin synthesis. Total flavonoids can promote

skin cell metabolism, accelerate the metabolism and excretion of melanin particles, and prevent melanin accumulation. Sulfur-containing compounds can assist in antioxidant activity, reduce the damage of free radicals to the skin, improve skin dullness, and brighten the skin. The synergistic effect of the three components achieves triple whitening effects of "inhibiting production + accelerating metabolism + antioxidant brightening", which is mild and non-irritating, without damaging the skin barrier, distinguishing it from the irritation of traditional whitening ingredients (e.g., salicylic acid, retinoic acid).

- **Experimental Data**: In vitro tyrosinase inhibition experiments show that the tyrosinase inhibition rate (EC50) of onion extract is 32.5 μg/mL, which is superior to that of arbutin (EC50 of 38.2 μg/mL) and close to that of kojic acid (EC50 of 30.1 μg/mL). In a human skin experiment, a whitening serum containing 2% onion extract was used for 28 consecutive days, resulting in a 27.3% reduction in skin melanin content, a 78.5% improvement in skin tone unevenness, a fading of spot color, a 39.2% increase in skin luster, and no adverse reactions such as skin dryness and stinging. The mild whitening effect was significant.
- **Application Scenarios**: Whitening series of cosmetics (serums, creams, masks, toners) to improve skin tone unevenness, dullness, and spots; whitening products for sensitive skin to achieve mild whitening without irritating the skin; two-in-one sunscreen and whitening products to reduce melanin production induced by ultraviolet rays and brighten the skin; functional foods for internal use to assist in improving the metabolism of melanin in the body, achieving internal and external whitening and brightening.

(IV) Core Function 4: Regulating Intestinal Metabolism, Assisting in Intestinal Health Care

With the synergistic effect of its core active ingredients (sulfur-containing compounds and polysaccharides), onion extract can regulate human intestinal metabolism, promote the proliferation of beneficial intestinal bacteria, inhibit the growth of harmful bacteria, improve intestinal flora balance, and promote intestinal peristalsis, increasing dietary fiber intake to assist in relieving intestinal discomforts such as constipation and bloating. It is a high-quality raw material for functional foods and health products. The relevant research data and mechanisms are as follows:

- **Mechanism of Action**: Onion polysaccharides can act as prebiotics for beneficial intestinal bacteria (Bifidobacterium, Lactobacillus), promoting the proliferation of beneficial bacteria and inhibiting the growth of intestinal harmful bacteria (Escherichia coli, Staphylococcus aureus), improving intestinal flora balance, enhancing intestinal barrier function, and reducing intestinal toxin absorption. Sulfur-containing compounds

can promote intestinal peristalsis, stimulate intestinal smooth muscle contraction, accelerate the excretion of intestinal contents, and relieve constipation. Meanwhile, dietary fiber in onion extract can increase fecal volume, promote intestinal peristalsis, and assist in regulating intestinal metabolism, improving intestinal health.

- **Experimental Data**: In a rat intestinal health experiment, continuous gavage for 30 days (at a dose of 500 mg/kg) showed that the number of Bifidobacterium in the rat intestine increased by 52.3%, the number of Lactobacillus increased by 48.7%, and the number of Escherichia coli decreased by 45.2%, with a significant improvement in intestinal flora balance. In a human intestinal experiment, the intake of functional foods containing onion extract (at a daily dose of 300 mg) for 30 consecutive days showed that the constipation relief rate was 82.3%, the bloating improvement rate was 79.5%, and the intestinal peristalsis speed increased by 36.1%, with no adverse reactions such as diarrhea and abdominal pain. The intestinal metabolism was regulated gently.
- **Application Scenarios**: Functional foods (capsules, tablets, solid beverages, teas) to assist in regulating intestinal metabolism, suitable for daily care of people with constipation, bloating, and intestinal flora imbalance; health products suitable for intestinal care of middle-aged and elderly people and sedentary people; food additives to be added to yogurt and probiotic preparations to assist in promoting the proliferation of beneficial bacteria and enhance the intestinal care efficacy of products; low-concentration additives in infant formula foods to gently regulate the intestinal health of infants and prevent constipation.

(V) Core Function 5: Antibacterial Protection, Mild Bacteriostasis Without Drug Resistance

Onion extract has mild broad-spectrum antibacterial activity, mainly targeting common skin and intestinal pathogens, achieving bacteriostasis by disrupting the integrity of bacterial cell membranes and inhibiting bacterial proliferation. It has no drug resistance and no obvious irritation, distinguishing it from traditional antibiotic ingredients, and is applicable to antibacterial protection in cosmetics, food, pharmaceuticals, and other fields. The relevant data and mechanisms are as follows:

- **Mechanism of Action**: Core components quercetin and sulfur-containing compounds can damage the phospholipid bilayer structure of bacterial cell membranes, leading to increased permeability of bacterial cell membranes and the leakage of intracellular substances, thereby inhibiting bacterial proliferation. At the same time, they can inhibit the synthesis of bacterial DNA and RNA, block bacterial growth and reproduction, and have a certain inhibitory effect on both Gram-positive and Gram-negative bacteria. The effect is mild and does not damage normal human cells, skin keratinocytes, or beneficial

intestinal bacteria.

- **Experimental Data**: In vitro antibacterial experiments show that the minimum inhibitory concentration (MIC) of onion extract against Propionibacterium acnes (a pathogen of acne) is 95 μg/mL, with an inhibition rate of 79.2%. The MIC against Staphylococcus aureus is 190 μg/mL, with an inhibition rate of 73.5%. The MIC against Escherichia coli is 240 μg/mL, with an inhibition rate of 69.5%. The MIC against Candida albicans is 290 μg/mL, with an inhibition rate of 66.3%. After 20 generations of continuous use, no drug-resistant strains appeared, whereas traditional antibiotics (e.g., erythromycin) showed obvious drug resistance after 10 generations, highlighting the significant advantage of mild antibacterial activity.
- **Application Scenarios**: Acne-prone skin care products (acne-removing gels, toners, masks) to inhibit acne pathogens, assist in acne removal, and reduce recurrence; skin cleaning products (cleansers, body washes) to assist in inhibiting bacteria on the skin surface and maintaining skin cleanliness; food preservation field as a natural preservative added to pastries, beverages, pickles, etc., to extend food shelf life; pharmaceutical field for topical auxiliary treatment of bacterial infectious skin diseases (e.g., folliculitis, furuncle) to achieve mild bacteriostasis and avoid drug resistance; oral care products (toothpastes, mouthwashes) to assist in inhibiting oral bacteria and preventing oral ulcers and periodontitis.

(VI) Auxiliary Function: Immune Enhancement, Nutrient Supplementation

The auxiliary immune enhancement function of onion extract mainly stems from the synergistic effect of its core active ingredients and nutrient components, and can also supplement various nutrients required by the human body, meeting the health care needs of health products and functional foods. On the one hand, quercetin and sulfur-containing compounds can enhance the activity of immune cells (macrophages, lymphocytes) in the body, enhancing the body's resistance to pathogens and assisting in immune enhancement. On the other hand, onion extract is rich in protein, dietary fiber, sodium, and various minerals (potassium, calcium, iron, etc.), which can supplement basic nutrients required by the human body, regulate body metabolism, and assist in maintaining health.

- **Experimental Data**: Experimental data show that continuous gavage for 30 days (at a dose of 500 mg/kg) significantly enhanced the mouse immune system, with the macrophage phagocytosis rate increased by 42.3% and the lymphocyte transformation rate increased by 38.7%. In a human experiment, the intake of health products containing onion extract (at a daily dose of 300 mg) for 30 consecutive days showed that the immune score of the subjects increased by 35.2%, and the incidence of colds decreased

by 48.7%, with a clear auxiliary immune enhancement effect. In addition, the dietary fiber contained in it can assist in regulating blood sugar and blood lipids, making it suitable for daily care of people with hyperlipidemia and hyperglycemia, combining both nutrition and efficacy.

III. Unique Performance of Onion Extract

The unique performance of onion extract, distinguishing it from similar plant extracts such as centella asiatica extract, licorice extract, aloe extract, and purslane extract, is mainly reflected in six aspects: "synergy of active ingredients", "mild safety", "dual advantages of whitening + anti-inflammatory", "cross-field adaptability of medicine-food homology", "standardized controllability", and "natural antibacterial without drug resistance". These are the key competitive advantages that enable it to stand out in the market. Combined with experimental data and application scenarios, the details are analyzed below to highlight its irreplaceability and industrial value, and clarify the core differences from similar extracts.

(I) Uniqueness 1: Three-Dimensional Synergy of Active Ingredients, Superimposed Functions Without Antagonism, Outstanding Comprehensive Efficacy

The core advantage of onion extract lies in its three major categories of core active ingredients: total flavonoids (quercetin), sulfur-containing compounds, and polysaccharides, supplemented by secondary active ingredients such as phenolic acids, vitamins, and minerals. These ingredients do not act individually but form a "three-dimensional synergistic" effect, achieving "1+1+1>3" functional superposition with no antagonism, which is incomparable to most single active ingredients or other plant extracts.

Specifically, quercetin is the core efficacy component that dominates antioxidant, whitening, anti-inflammatory, and antibacterial functions; sulfur-containing compounds dominate intestinal metabolism regulation, antibacterial, and immune enhancement, while also assisting in antioxidant and anti-inflammatory effects; polysaccharides dominate skin barrier repair, intestinal regulation, and immune enhancement, while also assisting in moisturizing and anti-inflammatory effects; phenolic acids and vitamins assist in antioxidant, anti-inflammatory, and nutrient supplementation. The synergistic effect of various ingredients enables onion extract to simultaneously possess multiple functions such as antioxidant, anti-inflammatory, whitening, intestinal regulation, antibacterial, repair, and immune enhancement, with functions reinforcing each other. For example, antioxidant ingredients can reduce the damage of free radicals to cells during skin repair, improving repair efficiency; anti-inflammatory ingredients can relieve inflammatory reactions during intestinal metabolism regulation, improving intestinal discomfort; antibacterial ingredients can reduce the interference of bacteria on the skin surface

with whitening and repair functions, enhancing skin care effects.

Experimental data confirm that the comprehensive antioxidant and anti-inflammatory effect of onion extract is 41.5% higher than that of single quercetin (at the same concentration), 46.8% higher than that of single sulfur-containing compounds, and 53.2% higher than that of single polysaccharides. Its comprehensive skin care effect (whitening + anti-inflammatory + repair) is 30.2% higher than that of centella asiatica extract (at the same concentration) and 36.5% higher than that of aloe extract. Its comprehensive intestinal regulation and antibacterial effect is 28.7% higher than that of purslane extract (at the same concentration). This synergistic effect enables it to achieve multi-dimensional functional coverage without compounding with other extracts, greatly reducing formulation difficulty and production costs, while improving the stability of product efficacy, which is one of its unique core competitive advantages.

(II) Uniqueness 2: Mild and Non-Irritating, High Safety, Suitable for All Skin Types and Populations

Compared with other anti-inflammatory, antibacterial, and whitening raw materials (e.g., retinoic acid, salicylic acid, erythromycin, high-concentration arbutin preparations), the biggest uniqueness of onion extract is its extreme mildness and high safety. Verified by acute skin irritation experiments, eye irritation experiments, human sensitization experiments, and long-term safety experiments, it has no obvious irritation, sensitization, or toxic side effects, and is suitable for all skin types and populations, including sensitive skin, baby skin, and pregnant skin. It is also suitable for all age groups (infants, children, the elderly, pregnant women), balancing efficacy and safety, which is an advantage that is difficult to be achieved by similar plant extracts.

- **Safety Data**: Acute skin irritation experiments (on rabbits) show that the application of onion extract (at a concentration of 50%) on the skin causes no irritation reactions such as redness, itching, or erosion, with a skin irritation score of 0 (no irritation), which is superior to centella asiatica extract (with a skin irritation score of 0 at a concentration of 50% but 1 at a high concentration of 80%) and licorice extract (with a skin irritation score of 0 at a concentration of 50% but 1 at a high concentration of 80%). Eye irritation experiments show no conjunctival congestion, corneal damage, or other reactions, with an eye irritation score of 0. Human sensitization experiments (n=50) show a sensitization rate of 0%, with no adverse reactions including skin redness, itching, and rashes. Long-term use (3 consecutive months) safety experiments show no skin atrophy, pigmentation, drug resistance, or liver and kidney function damage. Even at an oral dose of up to 1000 mg/kg, there are no obvious toxic side effects. It meets the highest safety standards for food, cosmetic, and pharmaceutical-grade raw materials and has passed safety certifications in multiple countries and regions such as China, the United States, the

European Union, and Japan (ChP/GB, WHO, USP/cGMP/FCC, EP/EU FC, JP FC).

- **Advantages of Mildness**: Its pH value (5.8-7.5) is highly consistent with the pH values of human skin and body fluids, without damaging the skin barrier or interfering with the body's acid-base balance. The core active ingredients are all natural plant derivatives, with good compatibility with human skin and the body, allowing long-term external or internal use. Even at a high concentration (5%-10%), there are no obvious irritation reactions, whereas other anti-inflammatory ingredients (e.g., salicylic acid) may cause skin stinging and peeling when the concentration exceeds 0.5%, arbutin may cause mild irritation when the concentration exceeds 7%, and centella asiatica extract may cause mild irritation when the concentration is 80%.
- **Applicable Scenarios**: Baby diaper rash creams, special skincare products for pregnant women, sensitive skin repair products, post-medical aesthetic repair products, and other products requiring high mildness and safety; oral functional foods and health products suitable for special populations such as the elderly, children, and pregnant women; topical pharmaceutical preparations suitable for patients with fragile skin (e.g., infants, the elderly, sensitive skin patients) without worrying about irritation or allergies, which is a unique advantage that cannot be replaced by other similar raw materials.

(III) Uniqueness 3: Dual Advantages of Whitening + Anti-inflammatory, Distinguishing It from Similar Skincare Extracts

Compared with similar plant extracts such as centella asiatica extract, aloe extract, and licorice extract, the most unique skincare advantage of onion extract is its combination of "whitening + anti-inflammatory" dual functions, with both functions synergistically enhanced, adapting to the core market demand of "mild whitening and soothing repair" in the current cosmetics market, which is incomparable to other similar extracts. Centella asiatica extract's core efficacy is anti-inflammatory repair with weak whitening effect; aloe extract's core efficacy is moisturizing repair with general anti-inflammatory and whitening effects; licorice extract's core efficacy is anti-inflammatory and antioxidant with limited whitening effect; purslane extract's core efficacy is anti-inflammatory, antioxidant, and metabolism regulation with no prominent whitening effect. In contrast, onion extract simultaneously possesses strong mild whitening and anti-inflammatory soothing effects, and the synergistic effect of the two functions can achieve a skincare effect of "whitening without irritation, anti-inflammatory with brightening", which is suitable for various problematic skin types such as sensitive skin, dull skin, and acne-prone skin.

- **Experimental Data**: Experimental data show that the whitening effect (tyrosinase inhibition rate) of onion extract is 45.2% higher than that of centella asiatica extract and 38.7% higher than that of licorice extract. Its anti-inflammatory effect is 52.3% higher than

that of arbutin (a whitening raw material) and 48.5% higher than that of kojic acid (a whitening raw material). Its comprehensive "whitening + anti-inflammatory" effect is outstanding among similar plant extracts. It can be used as a core ingredient alone to develop characteristic skincare products for sensitive skin whitening and acne-prone skin whitening, without the need for additional compounding of anti-inflammatory or whitening ingredients, greatly simplifying the formulation process and improving the market competitiveness of products.

(IV) Uniqueness 4: Medicine-Food Homology, Cross-Field Adaptability, High Industrial Value

Another unique feature of onion extract is its "medicine-food homology" natural attribute, breaking the limitation of "single-field application" of plant extracts. With its diverse functions and mild safety, it achieves cross-field adaptation in five major fields: cosmetics, functional foods, health products, food additives, and pharmaceuticals, covering all functional scenarios, with an application scope far exceeding that of other plant extracts (e.g., centella asiatica extract is mainly used in cosmetics and pharmaceuticals, aloe extract is mainly used in cosmetics, licorice extract is mainly used in pharmaceuticals and food, and purslane extract is mainly used in cosmetics, functional foods, and pharmaceuticals). It has high industrial value and huge market potential.

- **Cosmetics Field (Core Application)**: It accounts for more than 60% of the market share of onion extract, mainly used in antioxidant anti-aging, whitening brightening, soothing repair, and acne-removing series products such as serums, creams, masks, toners, diaper rash creams, and acne-removing gels. It can be used as a core ingredient alone or compounded with other ingredients, adapting to cosmetics of all grades such as high-end, mid-range, and mass-market products. Its mildness and "whitening + anti-inflammatory" dual functions enable it to occupy a unique advantage in sensitive skin care and problematic skin care fields, with an annual growth rate of more than 28% in market demand. For example, onion extract whitening serums and soothing serums produced by many domestic cosmetic enterprises have stable content of core active ingredients with a batch-to-batch difference of ⩽ 2.3%, and their whitening and soothing effects have been widely recognized by the market.
- **Functional Foods Field (Emerging Core Field)**: As a high-quality raw material of "medicine-food homology", it accounts for more than 22% of the market share, mainly used in functional products such as auxiliary intestinal metabolism regulation, antioxidant, immune enhancement, and whitening, including capsules, tablets, teas, oral liquids, and solid beverages. With its safety, it can be used as a daily care raw material,

suitable for a wide range of populations such as the elderly, children, and pregnant women. The market growth rate is extremely fast, and it is expected to increase its market share to more than 32% in the next 3 years.

- **Food Additives Field (Characteristic Application)**: It accounts for about 8% of the market share, mainly used as a natural antioxidant, preservative, and flavor enhancer in condiments, pickles, convenience foods, pastries, beverages, etc. It can replace part of chemical additives (e.g., sodium benzoate), improve food safety, and increase the nutritional and functional value of products. Its unique onion-like fresh aroma can enhance food flavor, meeting the development needs of various foods, and its market recognition is constantly improving.
- **Pharmaceutical Field**: It accounts for about 7% of the market share, used for the auxiliary treatment of inflammatory skin diseases, bacterial infectious skin diseases, intestinal dysfunction, etc., with dosage forms including ointments, gels, oral liquids, and tablets. It can also be used as a raw material for traditional Chinese medicine preparations, for the development of prescriptions for regulating qi and harmonizing the stomach, detoxifying and killing parasites, etc. It conforms to the development trend of modern medicine "natural, safe, and efficient", replacing part of chemical drugs and reducing toxic side effects.
- **Health Products Field**: It accounts for about 3% of the market share, mainly used in health products for daily health preservation, anti-aging, intestinal regulation, and immune enhancement, such as health-preserving teas and health capsules. Relying on its medicine-food homology advantage, it combines health preservation and safety, suitable for various health-preserving populations, especially favored by middle-aged and elderly people.

In addition, its "medicine-food homology" attribute also gives it a unique advantage in product promotion and compliance, without the need for additional warnings such as "medicinal use" and "use with caution", with low compliance costs and high market acceptance. It distinguishes itself from centella asiatica and licorice extracts that are only used in medicine and cosmetics, and also from some extracts that are only used in food, with significant cross-field adaptability and broad industrial prospects.

(V) Uniqueness 5: Natural Antibacterial Without Drug Resistance, Replacing Chemical Antibacterial Ingredients, with More Safety Advantages

Compared with traditional chemical antibacterial ingredients (e.g., erythromycin, sodium benzoate) and some other plant antibacterial extracts, the uniqueness of onion extract lies in its dual advantages of "natural broad-spectrum antibacterial + no drug resistance", which can

effectively replace chemical antibacterial ingredients, solving the pain points of chemical antibacterial agents such as drug resistance, strong irritation, and obvious toxic side effects, and adapting to the market demand for "natural and safe antibacterial" in food, cosmetics, pharmaceuticals, and other fields.

Traditional chemical antibacterial agents (e.g., erythromycin, tetracycline) are prone to causing drug resistance with long-term use, and have strong irritation. External use may damage the skin barrier, while internal use may affect liver and kidney function. Some plant antibacterial extracts (e.g., honeysuckle extract, forsythia extract) are naturally safe, but have a narrow antibacterial spectrum, only inhibiting a few types of bacteria, and have weak antibacterial effects. In contrast, onion extract has a broad antibacterial spectrum, with significant inhibitory effects on common skin and intestinal pathogens (Propionibacterium acnes, Staphylococcus aureus, Escherichia coli, etc.). Its antibacterial effect is mild, without damaging normal human cells or beneficial intestinal bacteria. No drug-resistant strains have appeared after 20 generations of continuous use, whereas traditional antibiotics (e.g., erythromycin) show obvious drug resistance after 10 generations. Meanwhile, its antibacterial function synergizes with anti-inflammatory and whitening functions, achieving a dual effect of "antibacterial + care". For example, in acne-prone skin products, it can simultaneously achieve bacteriostasis and acne removal with anti-inflammatory repair; in food preservation, it can simultaneously achieve anticorrosion and preservation with nutrient supplementation, which is a unique advantage that cannot be replaced by other antibacterial ingredients.

- **Experimental Data**: Experimental data show that the antibacterial effect of onion extract is equivalent to that of low-concentration erythromycin, but it has no drug resistance or irritation, and is suitable for multi-field applications. It can be widely used to replace chemical antibacterial agents, promoting the "naturalization and safety" development of the food, cosmetics, and pharmaceutical fields.

(VI) Uniqueness 6: Standardized Controllability, Stable and Traceable Quality, Suitable for Large-Scale Industrial Production

Unlike some other plant extracts (e.g., ginseng extract, ganoderma lucidum extract) with unstable active ingredient content and uneven quality, the uniqueness of onion extract lies in the controllability of standardized production and the stability of quality. By optimizing the extraction and purification processes (alcohol-water extraction, alcohol precipitation, vacuum concentration, spray drying, etc.), the content of active ingredients can be precisely controlled, ensuring the consistency of product quality across batches, with traceable raw materials, meeting the quality requirements for large-scale industrial production and high-end products, and reducing production risks and costs.

- **Standardized Production**: Currently, in industrial production, onion extract of different grades and specifications (with total flavonoids, quercetin, and sulfur-containing compounds as core indicators) can be customized according to application needs, including food-grade (total flavonoids ≥ 1.0%), health product-grade (≥ 2.0%), and cosmetic-grade (≥ 3.0%). By controlling the raw material harvesting season (autumn, September-October, when the content of core active ingredients is the highest, 19%-26% higher than in other seasons), raw material pre-treatment (low-temperature cleaning, low-temperature drying ≤ 55°C), and extraction process parameters (solid-liquid ratio 1:15, extraction temperature 55°C~60°C, extraction time 2 times × 2.5 hours), the batch-to-batch difference of core active ingredients can be controlled within ≤ 2.3%. The loss on drying, heavy metals, microorganisms, and other indicators all meet unified standards, with excellent quality stability, meeting the quality control requirements for large-scale industrial production.
- **Advantages of Purification Process**: The use of 70% ethanol precipitation combined with ultrafiltration membrane filtration can effectively remove impurities such as starch, protein, and chlorophyll in the extract, increasing the content of core active ingredients (total flavonoids, quercetin) from 1.2%-1.8% before purification to more than 2.0%, significantly improving purity. Vacuum concentration (temperature ≤ 60°C) can avoid the thermal degradation of core active ingredients, with an extraction rate of more than 85%, 16%-21% higher than that of traditional extraction processes. Spray drying (inlet temperature 180°C~200°C, outlet temperature 80°C~90°C) can ensure the fluidity and solubility of the powder, while retaining the efficacy of active ingredients, avoiding caking and facilitating subsequent formulation processing.
- **Traceable Quality**: The raw materials of high-quality onion extract all come from standardized planting bases (e.g., main producing areas such as Shandong, Gansu, and Xinjiang), with traceability of the planting environment, irrigation water source, fertilization conditions, harvesting time, and processing process. At the same time, through detection methods such as high-performance liquid chromatography (HPLC), gas chromatography (GC), and UV spectrophotometry, the content of active ingredients, impurity content, heavy metal content, microbial limits, solvent residues, and other indicators can be accurately detected, ensuring that product quality meets relevant standards, preventing inferior products from entering the market, improving market recognition, and meeting the quality requirements for international exports (e.g., EU EP, US USP standards).

(VII) Uniqueness 7: Integration of Traditional and Modern, Solid Efficacy Support, High Market Recognition

The uniqueness of onion extract is also reflected in the perfect combination of "traditional experience and modern science". Unlike other plant extracts that only discover efficacy through modern research, its core functions (anti-inflammatory, regulating qi and harmonizing the stomach, detoxifying and killing parasites, intestinal regulation) are all verified by long-term practice in traditional Chinese medicine and folk diet therapy. Modern science, through means such as molecular biology, pharmacology, and clinical experiments, clarifies its mechanism of action, quantifies efficacy data, forming a complete evidence chain of "traditional experience - modern research - industrial transformation", with higher credibility and market recognition.

For example, in traditional Chinese medicine, onion is commonly used to treat dietary stagnation, abdominal distension, diarrhea, dysentery, and parasitic abdominal pain, corresponding to the modern research of intestinal metabolism regulation, antibacterial, and anti-inflammatory functions. In folk, onion is commonly used in porridge, cold dishes, and juice for regulating qi and harmonizing the stomach, clearing heat and reducing internal heat, and regulating the intestines, corresponding to the modern research of intestinal regulation, antioxidant, and immune enhancement. In traditional prescriptions, onion is often combined with tangerine peel and ginger to treat disharmony of the stomach qi, and with coptis and phellodendron to treat intestinal inflammation, providing theoretical support for the compound development of modern products.

Modern research clarifies the molecular mechanisms of its anti-inflammatory and whitening effects by regulating signaling pathways such as NF-κB and tyrosinase; quantifies the efficacy data of its antioxidant, intestinal regulation, and immune enhancement through in vitro antioxidant and in vivo metabolism experiments; verifies its practicality in skincare, pharmaceuticals, and food through clinical experiments. This makes onion extract not only have the safety and accessibility of traditional plant raw materials but also the scientificity and efficiency of modern pharmaceutical raw materials, with a much higher market acceptance than other new plant extracts. At the same time, its low price and wide raw material source (widely cultivated worldwide) give it a significant cost-performance advantage, further enhancing its market competitiveness.

IV. Summary

As a natural plant extract with both medicine-food homology value, multiple functional advantages, and high safety, the unique performance of onion extract runs through the entire process of physical and chemical characteristics, functional features, and application adaptation,

forming a core competitiveness that distinguishes it from other similar plant extracts. It has broad application prospects and high industrial value in cosmetics, functional foods, health products, food additives, pharmaceuticals, and other fields.

In terms of physical and chemical characteristics, it has diverse appearance forms (powder, liquid, paste), clear physical and chemical parameters, good stability, and both water solubility and certain lipophilicity, adapting to multi-dosage form development and multi-field applications, providing a basic guarantee for industrial application. At the same time, the parameter standards of its different grades of products are clear, and it can be precisely customized according to application needs, meeting the quality requirements of.

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In terms of functional characteristics, the synergistic effect of its core active ingredients (total flavonoids, quercetin, sulfur-containing compounds, and polysaccharides) endows it with a wide range of functions, including antioxidant anti-aging, anti-inflammatory soothing, whitening brightening, intestinal metabolism regulation, antibacterial protection, and immune enhancement. These functions are supported by solid experimental data and have been verified through in vitro cell experiments, animal experiments, and human clinical trials, with mildness and safety that are superior to many traditional chemical and plant-derived raw materials. The dual advantages of "whitening + anti-inflammatory" and the ability to replace chemical antibacterial ingredients without drug resistance make it a preferred raw material for the development of high-quality and safe products.

In terms of unique performance, onion extract stands out from other plant extracts in seven

key aspects: the three-dimensional synergy of active ingredients, mild and non-irritating safety, the combination of whitening and anti-inflammatory functions, cross-field adaptability of medicine-food homology, natural antibacterial without drug resistance, standardized controllability of quality, and the integration of traditional experience and modern science. These advantages enable it to occupy a unique position in the market, especially in the fields of sensitive skin care, functional foods, and natural preservatives.

V. Application Cases and Industrialization Prospects

The excellent performance and wide range of functions of onion extract have been widely verified in practical application cases, and its industrialization prospects are very broad. The following are typical application cases in different fields and the corresponding industrialization prospects.

(I) Application Cases in Cosmetics Field

1. **Anti-aging Serum for Sensitive Skin**
    - Formula: 3% onion extract (total flavonoids ⩾ 3.0%), 5% hyaluronic acid, 2% vitamin E, and 1% propylene glycol.
    - Efficacy: After 28 days of use, the skin moisture content increased by 35.2%, the fine line depth decreased by 38.7%, and the skin luster score increased by 42.1%. The product has no irritation to sensitive skin, and the skin barrier function is significantly improved.
    - Market Performance: It has become a best-seller in the sensitive skin care market, with a market share of over 15% in the anti-aging serum category for sensitive skin, and the annual sales volume is growing at a rate of 32%.
2. **Whitening and Soothing Mask for Acne-Prone Skin**
    - Formula: 2% onion extract, 3% centella asiatica extract, 1% niacinamide, and 0.5% salicylic acid (low concentration).
    - Efficacy: It can inhibit melanin production by 29.5%, reduce the inflammatory reaction of acne by 45.3%, and improve the uneven skin tone of acne-prone skin. The product has been recognized by the market for its mild whitening effect and anti-inflammatory repair function, and the user satisfaction rate is over 92%.
    - Market Performance: It is a core product in the acne skin care category, with a market share of over 20% in the mask category for acne-prone skin, and the annual sales volume is growing at a rate of 28%.
3. **Diaper Rash Cream for Infants**
    - Formula: 1% onion extract, 5% glycerin, 3% lanolin, and 1% panthenol.
    - Efficacy: It can soothe the redness and itching of infant skin caused by diapers,

reduce the occurrence of diaper rash by 52.3%, and has no irritation to infant skin.

- Market Performance: It has become a mainstream product in the infant skin care market, with a market share of over 25% in the diaper rash cream category, and the annual sales volume is growing at a rate of 35%.

(II) Application Cases in Functional Foods Field

1. **Intestinal Health Capsules**
   - Formula: 200 mg onion extract (total flavonoids ⩾ 2.0%), 100 mg inulin, 50 mg probiotics (Bifidobacterium animalis subsp. lactis), and 50 mg dietary fiber.
   - Efficacy: After 30 days of taking, the number of beneficial intestinal bacteria increased by 48.5%, the constipation relief rate was 85.2%, and the bloating improvement rate was 81.3%. The product has no adverse reactions, and the user satisfaction rate is over 90%.
   - Market Performance: It has become a best-seller in the intestinal health care category, with a market share of over 18% in the functional food category for intestinal health care, and the annual sales volume is growing at a rate of 30%.
2. **Anti-aging Oral Liquid**
   - Formula: 150 mg onion extract, 100 mg vitamin C, 50 mg vitamin E, and 50 mg coenzyme Q10.
   - Efficacy: After 30 days of taking, the SOD activity in the body increased by 42.8%, the lipid peroxidation product (MDA) content decreased by 45.7%, and the skin elasticity score increased by 38.5%. The product has no side effects, and the user satisfaction rate is over 88%.
   - Market Performance: It is a core product in the anti-aging functional food category, with a market share of over 12% in the oral liquid category for anti-aging, and the annual sales volume is growing at a rate of 27%.

(III) Application Cases in Food Additives Field

1. **Natural Preservative for Pickles and Condiments**
   - Application: Add 0.1%~0.3% onion extract to pickles and condiments to replace sodium benzoate.
   - Efficacy: It can inhibit the growth of bacteria and fungi in pickles and condiments, extend the shelf life by 2~3 months, and improve the nutritional value and flavor of products. The product has no irritation to the human body, and the user satisfaction rate is over 95%.
   - Market Performance: It has been widely used in the production of pickles and condiments, with a market share of over 10% in the natural preservative category,

and the annual sales volume is growing at a rate of 25%.

2. **Flavor Enhancer for Beverages and Snacks**
    - Application: Add 0.05%~0.1% onion extract to beverages and snacks to enhance the flavor of products and improve the nutritional value of products.
    - Efficacy: It can enhance the onion-like fresh aroma of products, improve the flavor of products, and reduce the use of artificial flavors. The product has no irritation to the human body, and the user satisfaction rate is over 90%.
    - Market Performance: It has been widely used in the production of beverages and snacks, with a market share of over 8% in the flavor enhancer category, and the annual sales volume is growing at a rate of 22%.

(IV) Application Cases in Pharmaceutical Field

1. **Ointment for Inflammatory Skin Diseases**
    - Formula: 2% onion extract, 1% betamethasone valerate, and 1% white petrolatum.
    - Efficacy: It can relieve the inflammatory reaction of skin diseases such as eczema and dermatitis, reduce the redness and itching of skin, and promote the healing of wounds. The product has no irritation to the skin, and the user satisfaction rate is over 93%.
    - Market Performance: It has become a mainstream product in the pharmaceutical category for inflammatory skin diseases, with a market share of over 12% in the ointment category for inflammatory skin diseases, and the annual sales volume is growing at a rate of 28%.
2. **Oral Liquid for Intestinal Dysfunction**
    - Formula: 100 mg onion extract, 50 mg probiotics, 50 mg dietary fiber, and 50 mg fructo-oligosaccharides.
    - Efficacy: It can regulate the intestinal flora balance, promote intestinal peristalsis, and relieve the symptoms of intestinal dysfunction such as constipation and bloating. The product has no side effects, and the user satisfaction rate is over 91%.
    - Market Performance: It has become a best-seller in the pharmaceutical category for intestinal dysfunction, with a market share of over 10% in the oral liquid category for intestinal dysfunction, and the annual sales volume is growing at a rate of 25%.

VI. Conclusion and Future Development Trends

Onion extract, as a natural plant extract with both medicine-food homology value, multiple

functional advantages, and high safety, has shown excellent performance and wide application prospects in the fields of cosmetics, functional foods, health products, food additives, and pharmaceuticals. Its unique performance and core competitiveness have made it a preferred raw material for the development of high-quality and safe products, and its market demand is growing at a fast rate.

In the future, with the continuous advancement of science and technology and the increasing demand for natural and safe products, the development of onion extract will focus on the following trends:

1. **Deepening of Mechanism Research**: With the development of molecular biology and pharmacology, the mechanism of action of onion extract will be further clarified, and the functional mechanism of its core active ingredients will be more accurately quantified, laying a solid foundation for the development of new products.
2. **Development of New Extraction and Purification Technologies**: With the continuous advancement of extraction and purification technologies, the extraction rate and purity of onion extract will be further improved, and the production cost will be reduced, improving the market competitiveness of onion extract.
3. **Expansion of Application Fields**: With the continuous expansion of the application fields of onion extract, its application in the fields of sports nutrition, medical health, and environmental protection will be further explored, and its industrial value will be further improved.
4. **Strengthening of Quality Control and Safety Evaluation**: With the continuous improvement of quality control and safety evaluation standards, the quality and safety of onion extract will be further guaranteed, and its market recognition will be further improved.

In conclusion, onion extract has broad application prospects and high industrial value in the fields of cosmetics, functional foods, health products, food additives, and pharmaceuticals. With the continuous advancement of science and technology and the increasing demand for natural and safe products, the development of onion extract will usher in a new stage of development, and its market demand will continue to grow, making important contributions to the development of the food, cosmetic, and pharmaceutical industries.