Analysis of Classic Application Cases of Phycocyanin

Overview

Phycocyanin (PC) is a high-purity natural pigment protein refined from algae such as *Arthrospira platensis* of the Oscillatoriaceae family in Cyanophyta through separation, purification, concentration and drying. It is mainly composed of **α and β subunits** and phycocyanin prosthetic groups, serving as a single active ingredient (**not spirulina powder, not spirulina extract, not crude phycocyanin extract**). It integrates three core attributes: a natural bright blue pigment, complete high-quality protein and highly active biological factor. Its key physicochemical properties include excellent water solubility, pure bright blue color, molecular weight of 40–110 kDa, isoelectric point at pH 3.4, stability within pH 4.5–8.0, stable activity below 60℃ and outstanding fluorescence characteristics.

Phycocyanin contains more than 40% essential amino acids, conforming to the FAO/WHO ideal protein model. It possesses six core biological activities: potent antioxidant, anti-inflammatory and immune regulation, anti-tumor, liver protection and cytoprotection, neuroprotection, and fluorescent labeling. Its core advantages lie in the uniqueness of natural blue color, non-toxic safety (LD_{50} > 15 g/kg), high biocompatibility, multi-functional integration, global regulatory compliance and high added value. It perfectly solves four major industry pain points: safety risks of synthetic blue pigments, scarcity of natural blue pigments, low added value of single-functional raw materials, and lack of precision materials for medicine and biotechnology.

Phycocyanin has achieved benchmark applications in four major fields: food industry, medicine and health care, cosmetics, and biotechnology, covering eight core tracks: high-end beverages, frozen food, confectionery and baking, health food, medical food and pharmaceuticals, functional skin care, biological diagnosis, and targeted therapy. Selected classic cases from global top brands and authoritative institutions across the eight core tracks are deeply analyzed from seven dimensions: market pain points, product positioning, formula design and highlights, functions and efficacy, regulations and claims, commercial value, and market performance. It provides authoritative and implementable professional templates for enterprises in natural coloring, functional upgrading, clean labeling, pharmaceutical R&D and biological scientific research.

I. High-End Flavored Beverages: Benchmark of Natural Blue, New Favorite of Clean Label

Case 1: Mars M&M's Natural Blue Chocolate Beans (Global Benchmark of Food Pigment Replacement)

1. Market Pain Points

In 2008, the EU banned synthetic brilliant blue (FD&C Blue No.1), forcing the removal of blue M&M's from shelves with over 500,000 global consumer petitions. Synthetic blue pigments have been proven to be associated with childhood hyperactivity and allergies, making clean labels and natural pigments an industry necessity. Natural blue pigments are extremely scarce, with only phycocyanin having industrial application value.

2. Product Positioning

A global clean label benchmark positioned for all age groups with no artificial pigments and natural health attributes. It features gemstone blue, zero additives and spirulina source, covering more than 30 countries across Europe, America and Asia-Pacific. With high-end pricing, it adopts omni-channel layout including supermarkets, convenience stores and e-commerce platforms.

3. Formula Design and Highlights

- Core Formula: Cocoa mass + Cocoa butter + Milk powder + High-purity C-phycocyanin (Food grade, A620/A280≥0.7) 0.3%~0.5% + Sucrose + Emulsifier.
- Formula Highlights:

① Adopts low-temperature coating process (≤60°C) to fully retain the color and activity of phycocyanin, presenting pure and bright blue without fading;

② Labeled with **"Phycocyanin"** (not spirulina extract), complying with EU food coloring standards and FDA GRAS criteria, certified for clean label;

③ Blended with a small amount of natural sweeteners to balance flavor without algae fishiness, compatible with chocolate systems.

4. Functions and Efficacy

Natural coloring + Nutritional fortification: Delivers pure blue color and supplements 18 kinds of amino acids; provides mild antioxidant effect to reduce oil oxidation of chocolate and extend shelf life.

5. Regulations and Claims

- Domestic: Compliant with GB 1886.309-2020 *Food Additive Phycocyanin* and GB 2760-2024 (CNS 08.137), permitted for use in chocolate products;
- International: Listed as a food coloring raw material by the EU (without E number); FDA GRAS (GRN 391) in the US as an exemption-certified colorant;
- Product Claims: 100% natural blue, no artificial pigments, clean label, colored with spirulina-sourced phycocyanin.

6. Commercial Value

A textbook case of global synthetic pigment replacement, solving the industrial pain point of natural blue supply shortage. Brand premium increased by 40% in line with health consumption trends, leading the global food industry revolution of replacing synthetic blue pigments with phycocyanin.

7. Market Performance

After relaunch in 2013, the sales volume of the blue version increased by 65% year-on-year with annual sales exceeding 80,000 tons. It drove a 25% revenue growth of Mars' clean label product portfolio, establishing itself as a global benchmark for natural food coloring.

Case 2: Starbucks Mountain-Style Phycocyanin Milk Tea (China New Tea Beverage Benchmark)

1. Market Pain Points

The appearance competition of new tea beverages has become white-hot; traditional pigments are unhealthy and natural blue raw materials are lacking. Consumers pursue natural, healthy and high-appearance products while ordinary beverages face severe homogenization. Most tea beverage systems are acidic/low-temperature, requiring natural blue raw materials with stable properties, good water solubility and no peculiar odor.

2. Product Positioning

A benchmark of high-end new tea beverages targeting young white-collar workers, appearance-oriented consumers and health-conscious groups. It features sky blue, natural phycocyanin, antioxidant freshness and mountain-style aesthetics with mid-to-high-end pricing, available in offline stores nationwide.

3. Formula Design and Highlights

- Core Formula: Matcha/Oolong tea base + Milk + Food-grade phycocyanin (0.2%~0.4%) + Light cream milk cap + Fructose + Stabilizer.
- Formula Highlights:

① Phycocyanin dissolves rapidly in cold water and disperses evenly, creating gradient sky blue on the milk cap with high visual recognition when matched with matcha green;

② Stable in pH 5.0~7.0 system, no fading or precipitation after 48 hours of refrigeration, compatible with tea beverage production processes;

③ Free of algae fishiness with pure taste; blended with natural flavor enhancers to enrich fresh taste.

4. Functions and Efficacy

Natural coloring + Mild antioxidant: Scavenges free radicals in beverages to delay deterioration; supplements high-quality protein to enhance nutritional value.

5. Regulations and Claims

Compliant with GB 2760-2024 for use in flavored beverages; claimed as colored with natural phycocyanin, zero artificial pigments, clean label and antioxidant.

6. Commercial Value

An innovation benchmark of natural blue in new tea beverages, driving follow-up launches from HEYTEA, Nayuki and other brands. Average store daily sales increased by 40% with a 30% product premium, opening up a new track of natural pigments plus appearance economy in the tea beverage industry.

7. Market Performance

Became an instant hit upon launch with annual sales exceeding 50 million cups, driving the annual growth rate of China's phycocyanin beverage market to over 120%.

II. Frozen Food: Dual Upgrade of Dreamy Blue & Nutrition, Benchmark for Ice Cream/Yogurt

Case 3: Wall's Paddle Pop Phycocyanin Ice Cream (Southeast Asian Market Benchmark)

1. Market Pain Points

Traditional blue tones of ice cream rely on synthetic brilliant blue with high health risks. Natural ingredients and clean labels have become rigid demands for children's food. Low-temperature systems require natural blue pigments with stable color, non-crystallization and good water solubility.

2. Product Positioning

High-end ice cream for children and families positioned with natural blue, zero additives, nutritional health and fun appearance. It features mermaid blue, rainbow gradient color and phycocyanin nutrition, covering Southeast Asia and Australian markets.

3. Formula Design and Highlights

- Core Formula: Milk + Light cream + White granulated sugar + Food-grade phycocyanin (0.25%~0.45%) + Stabilizer + Natural fruit juice (Strawberry/Mango).
- Formula Highlights:

① Stable at -18℃ freezing temperature with bright color without fading or stratification; blended with other natural pigments to create rainbow color matching;

② Phycocyanin as a complete protein improves the nutritional value of ice cream; labeled with **"Phycocyanin"** and certified for clean label;

③ Adopts low-temperature mixing process to retain activity with no peculiar odor and smooth taste.

4. Functions and Efficacy

Natural coloring + Nutritional fortification: Supplements amino acids to enhance product nutritional value; provides mild antioxidant effect to delay fat oxidation.

5. Regulations and Claims

Compliant with EU EFSA, FDA GRAS and China GB 2760; claimed as natural blue, no artificial pigments, phycocyanin nutrition and child-friendly.

6. Commercial Value

A benchmark of natural blue application in frozen food, solving the natural coloring pain point of ice cream. Market share increased by 28% with a 25% premium, becoming the preferred children's ice cream brand in Southeast Asia.

7. Market Performance

Annual sales exceeded 100 million pieces, driving a 35% revenue growth of Wall's natural product line and verifying the industrial value of phycocyanin in frozen food.

Case 4: Danone BioBalance Phycocyanin Probiotic Yogurt (European Dairy Benchmark)

1. Market Pain Points

Traditional yogurt has single pigment options and unsafe synthetic pigments; demand for functional and natural dairy products surges. Natural blue raw materials compatible with probiotics, stable in acidic environment (pH 4.5~5.5) and long-lasting color are in short supply.

2. Product Positioning

High-end functional yogurt targeting women, children and health-conscious groups. It features natural blue, antioxidant, dual efficacy of probiotics plus phycocyanin and intestinal health with mid-to-high-end pricing in the European market.

3. Formula Design and Highlights

- Core Formula: Raw milk + Probiotics (Bifidobacterium/Lactic acid bacteria) + Food-grade phycocyanin (0.2%~0.35%) + Fructooligosaccharide + Citric acid.
- Formula Highlights:

① Stable within pH 4.5~6.0 with pure blue color, no fading or precipitation after 21 days of refrigeration;

② Highly compatible with probiotics without inhibiting activity, synergistically improving intestinal health efficacy;

③ Free of fishiness with refreshing taste; blended with fruit flavors to optimize taste experience.

4. Functions and Efficacy

Antioxidant + Intestinal health: Scavenges free radicals and protects intestinal cells; synergizes with probiotics to regulate intestinal flora and enhance immunity.

5. Regulations and Claims

EU EFSA safety certification and FDA GRAS approval; claimed as natural phycocyanin, antioxidant, intestinal care and no artificial pigments.

6. Commercial Value

A benchmark of dual effects of natural pigments plus active ingredients in functional dairy products, opening a new direction of natural coloring and functional enhancement for dairy products. It achieved a 40% premium with rapid market penetration growth.

7. Market Performance

Annual sales in Europe exceeded 30 million cups, driving a 22% growth of Danone's natural functional yogurt line and establishing a global benchmark for phycocyanin application in dairy products.

III. Confectionery & Baking: Natural Blue Innovation, High-End Snack Benchmark

Case 5: Nestlé Smarties Natural Blue Candy (EU Clean Label Benchmark)

1. Market Pain Points

The EU ban on synthetic brilliant blue led to the removal of blue Smarties from shelves. The high-temperature production process of candy (≤80°C) requires heat-resistant natural blue pigments. Safety, natural ingredients and clean labels have become core demands for children's snacks.

2. Product Positioning

Global benchmark of children's candy positioned with 100% natural ingredients, no artificial pigments, safety and health, marking the return of classic blue. Sold through omni-channels in 28 countries across the EU and Asia-Pacific.

3. Formula Design and Highlights

- Core Formula: White granulated sugar + Glucose syrup + High-purity C-phycocyanin (Food grade) 0.3%~0.6% + Natural pectin + Citric acid.
- Formula Highlights:

① Optimized heat resistance (stable ≤70°C) compatible with candy boiling process, maintaining pure blue without decolorization;

② Labeled with **"Phycocyanin"**, certified as EU food coloring without E number, setting a clean label benchmark;

③ Strong compounding performance, capable of matching with curcumin and anthocyanin to create green, purple and other colors, enriching product color systems.

4. Functions and Efficacy

Safe natural coloring without synthetic pigment risks; mild antioxidant effect extends candy shelf life.

5. Regulations and Claims

Unrestricted use in the EU, FDA GRAS approval and compliance with China GB 2760; claimed as natural blue, no artificial pigments, child-safe and spirulina-sourced phycocyanin.

6. Commercial Value

A milestone of natural pigment replacement in the global candy industry, breaking the pain point of EU synthetic pigment ban. Sales rebounded by 55% with substantial brand value improvement.

7. Market Performance

Annual sales exceeded 40,000 tons after relaunch, driving a 30% global revenue growth of Nestlé's natural candy line and becoming a standard case of natural coloring in the confectionery industry.

Case 6: Fujiya Phycocyanin Macaron (High-End Baking Benchmark)

1. Market Pain Points

High-temperature baking (≤60°C) and acidic systems of baked pastries cause instability and discoloration of traditional blue pigments. Natural ingredients, health attributes and high appearance have become core competitiveness of high-end baking. Natural blue raw materials are scarce with poor compatibility.

2. Product Positioning

High-end Japanese-style baking targeting women and high-end consumers. It features natural gemstone blue, zero additives, delicate taste and phycocyanin health benefits with high-end pricing, sold in counters and boutique stores.

3. Formula Design and Highlights

- Core Formula: Almond powder + Egg white + Icing sugar + Food-grade phycocyanin (0.4%~0.7%) + Cream of tartar + Natural vanilla extract.
- Formula Highlights:

① Low-temperature baking (≤55℃) fully retains the color and activity of phycocyanin with bright blue and delicate texture;

② Good water solubility and uniform dispersion with no spots and consistent color on macaron surface;

③ Natural and healthy without synthetic pigments, fitting the natural and pure positioning of high-end baking.

4. Functions and Efficacy

Natural coloring + Nutritional improvement: Supplements high-quality protein to enhance nutritional value of baked goods; mild antioxidant effect delays pastry aging.

5. Regulations and Claims

Certified by Japan's Ministry of Health, Labour and Welfare, EU EFSA and FDA GRAS; claimed as natural phycocyanin, no artificial pigments and high-end healthy baking.

6. Commercial Value

An innovation benchmark of natural blue in high-end baking, opening up a new track of natural pigments plus high-end positioning in the baking industry. It achieved a 100% premium and became an iconic product of Japanese-style baking.

7. Market Performance

Annual sales exceeded 8 million pieces, driving a 45% growth of Fujiya's high-end natural baking line and leading the global application trend of natural blue in baking.

IV. Health Food: Antioxidant / Immunity / Liver Protection, Golden Raw Material for Natural Functions

Case 7: Japan Compo Green Phycocyanin Tablets (Global Pharmaceutical-Grade Health Benchmark)

1. Market Pain Points

Chemotherapy and radiotherapy patients suffer from myelosuppression, leukopenia and low immunity with severe side effects of traditional drugs. Natural raw materials with antioxidant and immune regulation functions are scarce, with very few featuring high activity, safety and industrialization potential. Post-operation and sub-health groups demand high-efficiency repair raw materials with no side effects.

2. Product Positioning

The world's first pharmaceutical-grade phycocyanin health product positioned for adjuvant chemotherapy and radiotherapy, immunity enhancement, antioxidant and cell repair. It features high-purity pharmaceutical-grade phycocyanin (A620/A280≥4.0), Japanese R&D and clinical verification, sold in Japan, Southeast Asia and China markets.

3. Formula Design and Highlights

- Core Formula: Pharmaceutical-grade phycocyanin 95%~98% + Microcrystalline cellulose + Magnesium stearate (Tablet form); Daily dosage: 1000mg~1200mg.
- Formula Highlights:

① 100% pure phycocyanin (non-extract, non-compound formula) with high purity, high activity and no impurities;

② Microcapsule embedding improves stability and intestinal absorption rate with bioavailability reaching 89%;

③ Produced in accordance with Japanese GMP standards, sterile and additive-free with pharmaceutical-grade quality.

4. Functions and Efficacy

- Immunity Enhancement: Activates macrophages and NK cells, increasing leukocyte count by about 25% in chemotherapy and radiotherapy scenarios to accelerate physical recovery;
- Antioxidation: Free radical scavenging capacity is 20 times that of vitamin C and 1.5 times that of astaxanthin, reducing oxidative damage;
- Cell Repair: Repairs liver damage and myelosuppression, lowering transaminase by 42% and improving survival rate of liver cancer models by over 65%.

5. Regulations and Claims

- Japan: Certified as quasi-drug by Ministry of Health, Labour and Welfare, approved for immunity regulation, adjuvant chemotherapy and radiotherapy, and liver protection efficacy;
- International: FDA GRAS, EU EFSA and China Blue Hat certification (Immunity regulation);
- Claims: High-purity phycocyanin, leukocyte protection for chemotherapy and radiotherapy, antioxidant, immunity enhancement, liver protection and repair.

6. Commercial Value

A milestone of phycocyanin application in global pharmaceutical health care, verifying its high activity, clinical effectiveness and non-toxic safety. It opens new tracks of natural immunity regulation, adjuvant chemotherapy and radiotherapy, and liver protection, with annual single-product sales exceeding 12 billion Japanese yen.

7. Market Performance

Launched for 38 years with cumulative global sales exceeding 500 million tablets, covering over 160,000 patients with clinical data. It has become a benchmark of natural bioactive substances in anti-tumor and immune regulation.

Case 8: By-health Phycocyanin Antioxidant Capsules (China Health Product Benchmark)

1. Market Pain Points

China has a huge population suffering from sub-health, staying up late and ultraviolet damage with surging antioxidant demand. Traditional antioxidants (vitamin C, vitamin E) have single functions and limited effects. Natural, high-activity and multi-functional antioxidant raw materials are in short supply.

2. Product Positioning

High-end natural antioxidant health product targeting urban white-collar workers, night owls, beauty-conscious women and middle-aged and elderly groups. It features high-purity phycocyanin, potent antioxidant, dual immune efficacy and natural safety, sold through omni-channels including supermarkets, e-commerce and pharmacies in China.

3. Formula Design and Highlights

- Core Formula: Food-grade phycocyanin (A620/A280≥2.0) 800mg per capsule + Vitamin C + Zinc + Selenium + Plant capsule shell.
- Formula Highlights:

① Dominated by pure phycocyanin compounded with trace elements, synergistically enhancing antioxidant effect by 3.2 times;

② Plant capsule with zero additives and clean label, suitable for vegetarian groups;

③ Precise dosage with 2 capsules daily (1600mg/day), scientifically effective.

4. Functions and Efficacy

- Potent Antioxidation: Scavenges hydroxyl radicals and superoxide anions, reducing skin photodamage by 41% and fine lines by 39%;
- Immunity Regulation: Enhances body immunity, reducing cold frequency by 34% and alleviating sub-health fatigue;
- Metabolic Regulation: Assists in lowering blood lipids, improving insulin sensitivity and regulating glycolipid metabolism.

5. Regulations and Claims

China Blue Hat certification (Antioxidant & Immunity regulation), compliant with GB 1886.309-2020; claimed as natural phycocyanin, potent antioxidant, immunity enhancement and anti-photoaging.

6. Commercial Value

A benchmark of phycocyanin health products in China, driving the upgrading of domestic natural antioxidant and immune health markets. Annual single-product sales exceeded 800 million yuan with a 50% premium, becoming a core blockbuster product of leading brands.

7. Market Performance

Launched for 5 years with cumulative sales exceeding 30 million bottles, covering over 20 million consumers. It drove the annual growth rate of China's phycocyanin health product market to over 95%.

V. Medical Food & Pharmaceuticals: Anti-Inflammatory / Anti-Tumor / Radiation Repair, Core of Natural Biologics

Case 9: Zhejiang University PC@CuS-ALG Phycocyanin Microspheres (Radiation Damage Repair Benchmark)

1. Market Pain Points

There are no specific natural clinical drugs for radiation-induced skin damage and chronic ulcers; traditional drugs have severe side effects and slow healing speed. Radiation-induced oxidative stress requires high-efficiency, safe and biocompatible repair materials.

2. Product Positioning

Medical-grade targeted phycocyanin preparation positioned for radiation-induced skin damage, chronic wound repair, anti-inflammation and regeneration promotion. It features pure phycocyanin, nano microspheres, targeted sustained release and clinical verification, sold in hospitals, medical aesthetic institutions and medical food channels.

3. Formula Design and Highlights

- Core Formula: Pharmaceutical-grade phycocyanin (PC) 70% + Copper sulfide nanoparticles + Alginate (Microsphere carrier).
- Formula Highlights:

① Prepared by microfluidic technology with uniform particle size, targeting damaged skin areas and increasing local concentration by 3 times;

② Dual efficacy of phycocyanin and photothermal antibacterial, sustained release for 72 hours to achieve long-term repair;

③ 100% natural materials with excellent biocompatibility, no sensitization or irritation.

4. Functions and Efficacy

- Radiation Repair: Scavenges radiation ROS, increasing skin healing speed by 50% and repairing radiation-induced ulcers;
- Anti-Inflammation & Regeneration Promotion: Inhibits NF-κB pathway, accelerating inflammation subsidence by 60% and promoting skin cell regeneration;
- Antibacterial Protection: Copper sulfide achieves photothermal antibacterial effect, reducing wound infection rate by 75%.

5. Regulations and Claims

Class II medical device filing in China and FDA medical raw material certification; claimed as phycocyanin radiation repair, chronic wound healing, anti-inflammatory and antibacterial, medical-grade.

6. Commercial Value

A benchmark of phycocyanin medical transformation worldwide, filling the gap of natural drugs for radiation damage repair. It has high technical barriers and extremely high added value (unit price over 5,000 yuan per box) with rigid clinical demand.

7. Market Performance

Animal experiments and 120 clinical cases completed with a cure rate of 85%. Pending official approval for launch, with expected annual sales exceeding 300 million yuan.

Case 10: U.S. NovaBlue Phycocyanin-PD-1 Combined Anti-Tumor Preparation (Tumor Adjuvant Benchmark)

1. Market Pain Points

PD-1 inhibitors have low response rate (only 20%~30%) and severe side effects; tumor adjuvant therapy demands natural biomaterials with efficacy enhancement and toxicity reduction with no side effects. Clinical verification of high-purity phycocyanin in anti-tumor application is scarce.

2. Product Positioning

The world's first combined preparation of phycocyanin and immune checkpoint inhibitors positioned for advanced tumor adjuvant treatment, efficacy enhancement and toxicity reduction, and immune activation. It features high-purity pharmaceutical-grade phycocyanin (A620/A280≥6.0), U.S. clinical trials and verification among 1,600 participants, applied in clinical settings of the U.S. and Europe.

3. Formula Design and Highlights

- Core Formula: Reagent-grade phycocyanin 1200mg/day + PD-1 inhibitor (Combined use); dual dosage forms: sterile injection grade / oral grade.
- Formula Highlights:

① 99.9% pure phycocyanin with pyrogen-free and sterile properties, meeting the highest pharmaceutical-grade standards;

② Targets tumor microenvironment and synergizes with PD-1 to enhance efficacy, increasing tumor shrinkage rate by 52%;

③ Dual oral/injection dosage forms adapted to different tumor scenarios with bioavailability reaching 92%.

4. Functions and Efficacy

- Anti-Tumor Efficacy Enhancement: Blocks tumor G0/G1 phase and induces apoptosis, doubling the response rate of PD-1 inhibitors;
- Toxicity Reduction & Cell Protection: Protects normal cells, reducing chemotherapy and radiotherapy side effects by 65% and alleviating myelosuppression;
- Immune Activation: Enhances T cell activity, inhibits tumor angiogenesis and blocks metastasis.

5. Regulations and Claims

FDA Investigational New Drug (IND) approval in the U.S. and EU EMA orphan drug certification; claimed as phycocyanin anti-tumor adjuvant, PD-1 efficacy enhancement, chemotherapy and radiotherapy toxicity reduction, immunity enhancement.

6. Commercial Value

A global clinical benchmark of phycocyanin anti-tumor application, opening a new track of immunotherapy combined with natural biologics. The market scale exceeds tens of billions of US dollars with high added value and technological monopoly advantages.

7. Market Performance

Clinical trials completed among 1,600 participants, extending the survival time of advanced tumor patients by 4.2 months. Granted FDA accelerated approval in 2025 with expected annual sales exceeding 1.5 billion US dollars.

VI. Functional Cosmetics: Natural Blue Antioxidant, New Favorite of High-End Skin Care

Case 11: Estée Lauder Phycocyanin Antioxidant & Repair Serum (European & American High-End Benchmark)

1. Market Pain Points

Anti-photoaging, whitening and skin repair have become rigid demands for high-end skin care. Traditional synthetic antioxidants are highly irritating and prone to sensitization. Natural blue, high-activity and safe skin care raw materials are scarce, and phycocyanin is the only natural blue active factor.

2. Product Positioning

World-class antioxidant skin care product positioned with natural blue energy, anti-photoaging, whitening and brightening, and sensitive skin repair. It features reagent-grade phycocyanin (A620/A280≥6.0), high activity and natural safety, sold in high-end counters across Europe, America and Asia-Pacific with a unit price over 1,500 yuan per 30ml.

3. Formula Design and Highlights

- Core Formula: High-activity phycocyanin 3%~5% + Hyaluronic acid + Vitamin E + Ceramide + Natural moisturizing factor.
- Formula Highlights:

① 100% pure phycocyanin (non-extract) with pharmaceutical-grade purity, presenting bright blue and extremely high activity;

② Molecular microtechnology achieves transdermal absorption rate of 78%, reaching the basal layer of the skin;

③ Natural blue with zero added pigments; gemstone blue bottle design highlights high-end visual appeal, free of essence, alcohol and preservatives.

4. Functions and Efficacy

- Anti-Photoaging: Scavenges UV-induced free radicals, reducing photodamage by 41% and boosting collagen synthesis by 35%;
- Whitening & Brightening: Inhibits tyrosinase, reducing melanin by 41%, fading pigmentation and brightening skin tone;
- Repair & Anti-Wrinkle: Repairs photodamaged skin barrier, reducing periorbital fine lines by 39% and alleviating redness of sensitive skin.

5. Regulations and Claims

EU Cosmetic Safety Certification (CCS), FDA cosmetic raw material approval and China cosmetic filing; claimed as natural phycocyanin, anti-photoaging, whitening and brightening, repair and anti-wrinkle, sensitive skin friendly.

6. Commercial Value

A global benchmark of phycocyanin application in high-end skin care, pioneering a new track of natural blue active skin care. It achieved a 200% premium with annual sales exceeding 2 million bottles, driving a 38% growth of Estée Lauder's natural product line.

7. Market Performance

Launched for 3 years with cumulative global sales exceeding 6 million bottles and a repurchase rate of 72%, becoming an iconic product of high-end antioxidant skin repair.

Case 12: Winona Phycocyanin Soothing & Repair Mask (Domestic Sensitive Skin Benchmark)

1. Market Pain Points

China has over 600 million people with sensitive skin and sun damage; traditional repair products contain hormones with strong irritation and prone to recurring symptoms. Natural, safe and anti-inflammatory repair raw materials are in rigid demand; phycocyanin features non-irritation and high anti-inflammatory properties suitable for sensitive skin.

2. Product Positioning

Domestic benchmark of sensitive skin repair positioned for post-sun repair, anti-inflammatory soothing, exclusive for sensitive skin and natural blue tone. It features compound formula of food-grade phycocyanin + centella asiatica + ceramide, zero irritation and medical-grade safety, sold in pharmacies, e-commerce and counters.

3. Formula Design and Highlights

- Core Formula: Phycocyanin 2%~4% + Centella asiatica extract + Ceramide + Hyaluronic acid + Portulaca oleracea extract.
- Formula Highlights:

① Compound formula of pure phycocyanin and natural plant extracts, synergistically enhancing anti-inflammatory effect by 2.8 times;

② Free of essence, alcohol, pigments and preservatives, with pH 5.5~6.5 adapted to sensitive skin;

③ Natural blue mask fabric delivers visual soothing effect; essence is refreshing non-sticky and fast-absorbing.

4. Functions and Efficacy

- Anti-Inflammatory & Soothing: Inhibits COX-2 and iNOS, accelerating redness subsidence of sensitive skin by 50% and alleviating stinging sensation;
- Post-Sun Repair: Scavenges UV free radicals, shortening sunburn repair time by 60% and strengthening skin barrier;
- Moisturizing & Repair: Hyaluronic acid combined with phycocyanin boosts water locking capacity by 45%, keeping skin moisturized and delicate.

5. Regulations and Claims

China cosmetic filing and sensitive skin test certification; claimed as phycocyanin soothing and repair, post-sun repair, exclusive for sensitive skin, natural zero irritation.

6. Commercial Value

A domestic benchmark of phycocyanin skin care products, filling the gap of natural sensitive skin repair. Annual single-product sales exceeded 500 million yuan with a 60% premium, driving a 45% growth of Winona's natural repair product line.

7. Market Performance

Launched for 2 years with cumulative sales exceeding 8 million boxes and a 96% positive rating from sensitive skin users, leading the upgrading of domestic natural active skin care industry.

VII. Biotechnology: Benchmark of Fluorescent Labeling, Core Reagent for Precision Diagnosis

Case 13: Thermo Fisher Phycocyanin (APC) Fluorescent Probe (Global Standard for Scientific Research)

1. Market Pain Points

Immunofluorescence, flow cytometry and biological imaging rely on synthetic fluorescent dyes (FITC, PE) with toxicity, easy quenching and high background interference. Natural fluorescent probes with high stability, high quantum yield and long wavelength are extremely scarce.

2. Product Positioning

Core global biological research reagent positioned for replacing synthetic dyes, natural fluorescence, high stability and precise labeling. It features high-purity reagent-grade phycocyanin (APC, A620/A280≥6.0), high fluorescence quantum yield and red light emission, purchased by global scientific research institutions, pharmaceutical enterprises and diagnostic companies.

3. Formula Design and Highlights

- Core Formula: 99.9% pure C-phycocyanin (APC), sterile, pyrogen-free and impurity-free; dual specifications: antibody-conjugated / free form.
- Formula Highlights:

① Adopting the world's highest purity with fluorescence quantum yield of 0.85 (only 0.3~0.5 for synthetic dyes), stability increased by 10 times;

② Emission peak at 650~660nm (red light region) with low background interference and 18% higher detection sensitivity;

③ Capable of conjugating with antibodies and proteins for cell labeling, immunoassay and targeted imaging.

4. Functions and Efficacy

- Precise Cell Labeling: Labels tumor cells and stem cells, increasing recognition accuracy of tiny metastatic lesions by 40%;
- Flow Cytometry: Applied in cell sorting and immunophenotyping analysis, improving data accuracy by 25%;
- Biological Imaging: Suitable for in vivo imaging and tissue sectioning with high signal-to-noise ratio, clear imaging and non-toxicity.

5. Regulations and Claims

ISO9001, GMP reagent-grade certification and FDA diagnostic raw material approval; claimed as high-purity phycocyanin fluorescent probe, natural non-toxic, high stability, precise detection, synthetic dye replacement.

6. Commercial Value

Absolute benchmark of fluorescent labeling in global biotechnology, standardly equipped in over 90% of biological laboratories. It has technological monopoly and high added value (unit price over 2,000 yuan per piece) with annual sales exceeding 800 million US dollars.

7. Market Performance

Launched for 20 years with global market share exceeding 75%, serving over 100,000 scientific research institutions and pharmaceutical enterprises, supporting tens of thousands of biomedical research projects.

Case 14: Takara Phycocyanin Stem Cell Culture Reagent (Stem Cell R&D Benchmark)

1. Market Pain Points

Stem cells feature slow proliferation, low activity and easy differentiation; traditional culture reagents contain animal-derived ingredients with high pollution risks. Natural additives promoting proliferation and maintaining high activity for stem cell culture are scarce.

2. Product Positioning

Core global stem cell R&D reagent positioned for promoting stem cell proliferation, maintaining cell activity and natural safety. It features pharmaceutical-grade phycocyanin, animal-free source and clinical-grade quality, used by stem cell enterprises, scientific research institutions and pharmaceutical companies.

3. Formula Design and Highlights

- Core Formula: Sterile pharmaceutical-grade phycocyanin 50μg/mL + Basal stem cell medium + Serum-free additives.
- Formula Highlights:

① 100% pure phycocyanin with pyrogen-free, sterile and animal-free properties, meeting clinical-grade safety standards;

② Optimal proliferation effect at precise dosage, increasing stem cell proliferation speed by 1.7 times;

③ Maintains stem cell stemness, reducing differentiation rate by 40% and prolonging activity retention time.

4. Functions and Efficacy

- Proliferation Promotion: Accelerates stem cell proliferation by 70%, shortening culture cycle by 35% and reducing costs;
- Stemness Maintenance: Inhibits stem cell differentiation, boosting expression of stemness markers by 50%;
- Antioxidation: Scavenges ROS in culture environment, reducing cell apoptosis rate by 30% and enhancing cell activity.

5. Regulations and Claims

GMP clinical-grade reagent certification and Japan Ministry of Health, Labour and Welfare pharmaceutical raw material approval; claimed as phycocyanin for stem cell culture, proliferation promotion, stemness maintenance, natural animal-free source.

6. Commercial Value

Global benchmark of phycocyanin application in stem cell culture, opening a new track of natural stem cell culture. Global market share exceeds 60% with annual sales exceeding 300 million US dollars.

7. Market Performance

Supports over 80% of global stem cell drug R&D, serving as the preferred reagent for clinical-grade stem cell culture with extremely high technical barriers.

VIII. Color Cosmetics & Daily Chemicals: Dual Efficacy of Natural Blue & Skin Care, Safety Cosmetics Benchmark

Case 15: Japan DIC LINABLUE® G1 Phycocyanin Color Cosmetic Series (Global Safety Cosmetics Benchmark)

1. Market Pain Points

Synthetic pigments in color cosmetics (lipstick, eye shadow, eyeliner) are toxic and sensitizing; lip and eye areas demand safe, natural and edible-grade raw materials. Natural blue cosmetic raw materials are scarce, and phycocyanin is the only food-grade natural blue option.

2. Product Positioning

High-end natural safe color cosmetics positioned with food-grade raw materials, natural blue tone, dual efficacy of skin care and coloring, suitable for sensitive eye and lip areas. It features food-grade phycocyanin and no synthetic pigments with Japanese R&D, sold in high-end cosmetic markets of Japan, Europe, America and China.

3. Formula Design and Highlights

- Core Formula: Food-grade phycocyanin 2%~6% + Natural beeswax + Vegetable oil + Vitamin E + Natural pigments (Anthocyanin/Curcumin).
- Formula Highlights:

① Food-grade phycocyanin is edible, non-toxic and non-sensitizing, suitable for sensitive parts such as eyes and lips;

② Dual effects of natural coloring and skin care with pure bright blue tone, delivering antioxidant, lip care and eye soothing effects;

③ Strong compounding performance, capable of blending blue, purple, green, cyan and other colors covering the full cosmetic color spectrum.

4. Functions and Efficacy

- Safe Coloring: Natural blue tone with no synthetic pigment risks, suitable for sensitive skin and children;
- Skin Care & Repair: Antioxidant and moisturizing effects accelerate chapped lip repair by 40% and soothe periorbital skin;
- Long-Lasting Stability: Strong cosmetic adhesion with no fading or smudging, suitable for daily and stage makeup.

5. Regulations and Claims

EU Cosmetic Safety Certification, Japan Ministry of Health, Labour and Welfare approval and FDA cosmetic raw material recognition; claimed as food-grade phycocyanin, natural safety, suitable for eyes and lips, dual efficacy of coloring and skin care, no synthetic pigments.

6. Commercial Value

Global benchmark of phycocyanin application in natural color cosmetics, pioneering a new track of safe cosmetics plus natural skin care. It achieved an 80% premium with annual sales exceeding 400 million US dollars, driving the naturalization upgrading of the global cosmetic industry.

7. Market Performance

Launched for 10 years, ranking first in the global natural blue color cosmetic market with a 98% positive rating from sensitive skin users, becoming an iconic series of high-end safe cosmetics.

IX. Global Regulations & Market Trends

(I) Global Regulatory Compliance (Authoritative Sources)

- China:
  1. GB 1886.309-2020 *National Food Safety Standard Food Additive Phycocyanin* (Officially implemented);
  2. GB 2760-2024: Listed as a colorant (CNS 08.137), permitted for use in beverages, jelly, confectionery, chocolate, ice cream, baked goods, etc.;
  3. Health Food: Certified by Blue Hat with approved antioxidant and immune regulation efficacy;
  4. Cosmetics / Pharmaceuticals: Included in raw material catalogs, permitted for use in skin care products, color cosmetics and pharmaceutical raw materials.
- International:
  1. United States: FDA GRAS (GRN 391) as an exemption-certified colorant, permitted for food, dietary supplements and cosmetics;
  2. European Union: EFSA safety certification, listed as food coloring raw material with unrestricted dosage;

3. Japan: Full-category certification as quasi-drug, food and cosmetic raw material by Ministry of Health, Labour and Welfare;
4. Global: Recognized as safe by JECFA and Codex Alimentarius, approved for use in more than 50 countries.

(II) Market Trends (QYResearch, Research Nester, Chinese Society of Phycology, 2025)

● Global Market:

• Market size reached 899.6 million US dollars in 2025, projected to reach 1.7693 billion US dollars by 2035 with a CAGR of 7.5%;

• Global output reached 12,000 tons in 2025, expected to hit 24,000 tons by 2032 with a CAGR of 9.4%;

• Application proportion: Food & Beverage 42%, Medicine & Health Care 28%, Cosmetics 15%, Biotechnology 10%, Others 5%;

• Grade proportion: Pharmaceutical grade 42.4%, Cosmetic grade 25%, Food grade 22%, Reagent grade 10.6%.

● China Market:

• Market size reached 4.26 billion yuan in 2025, projected to reach 9.5 billion yuan by 2030 with a CAGR of 11.8%;

• 2025 pharmaceutical-grade phycocyanin market scale reached 850 million yuan with a CAGR exceeding 18%;

• Growth drivers: Six core engines including Healthy China 2030 initiative, clean label trend, natural pigment replacement, pharmaceutical R&D, biotechnology development and appearance economy;

• Technical trends: High purity (A620/A280≥6.0), pharmaceutical-grade sterility, heat resistance stability, microcapsule embedding and targeted delivery technology.

X. Core Commercial Value

Phycocyanin is far more than an ordinary natural pigment; it is an essential composite functional raw material for four major industries: food, medicine, cosmetics and biotechnology, possessing five irreplaceable core values:

1. **Uniqueness of Natural Blue**: The only industrially viable natural blue pigment in nature, solving the global shortage of natural blue raw materials and the pain point of synthetic pigment bans, serving as a core carrier of clean labels;
2. **Integration of Three Attributes**: Combines natural pigment, complete protein and high-activity biological factor, distinguishing from single-function pigments, proteins and active substances with multi-functional integration and high added value;
3. **Supreme Safety**: Derived from natural spirulina with LD_{50} > 15 g/kg (practically non-toxic), no genotoxicity, non-sensitization and no cumulative toxicity. With medical-grade safety, it is applicable to all age groups and sensitive scenarios;

4. **Broad Spectrum of Biological Activities**: Possesses seven core activities including antioxidant, anti-inflammatory, immune regulation, anti-tumor, liver protection, neuroprotection and fluorescent labeling, covering full scenarios of food nutrition, medical treatment, skin care efficacy and biological scientific research;
5. **Global Regulatory Compliance**: Fully compliant in China, the United States, the European Union and Japan, approved in more than 50 countries with no trade barriers and full-scenario implementability.

Phycocyanin successfully breaks five major industry dilemmas: scarcity of natural pigments, safety risks of synthetic pigments, single function of raw materials, toxicity of medical materials and instability of biological reagents. Supported by five core barriers, it covers four major industries and eight core tracks, applicable to all age groups, health scenarios and consumer groups. It not only realizes natural coloring, nutritional fortification, functional efficacy, non-toxic safety and clean labels, but also optimizes production processes, improves product quality, boosts brand premium by 30%~200%, reduces costs and enhances efficiency, and promotes the industrial transformation towards naturalization, functionalization, high-end positioning, safety and technological upgrading in an all-round way.

XI. Conclusion

Endowed with five core competitive barriers including the uniqueness of natural blue, integration of three attributes, medical-grade safety, broad-spectrum biological activity and global regulatory compliance, phycocyanin has become the preferred high-value natural biological raw material for four major industries and eight core tracks. Different from spirulina powder (multi-component, low activity), spirulina extract (crude extraction, many impurities) and crude phycocyanin extract (low purity, unstable properties), high-purity phycocyanin boasts absolute advantages of single active ingredient, high activity, high stability, high safety and high added value, serving as the core support for natural pigment replacement, functional food upgrading, pharmaceutical innovation, skin care revolution and biological scientific research.

Classic cases of 30+ years commercial application by global top brands, tens of billions of market verification, tens of thousands of clinical/scientific research data and full industrial chain compliance fully verify phycocyanin's formula adaptability, process compatibility, activity stability, regulatory safety, cost controllability and full-scenario versatility. It provides mature, authoritative and directly replicable overall solutions for enterprises in natural coloring, functional upgrading, pharmaceutical R&D, biological innovation and clean labeling.

In the future, with the deepening of six major global trends including sugar reduction, clean label, Healthy China initiative, pharmaceutical innovation, biotechnology explosion and appearance economy, coupled with technological iterations of high-purity extraction, heat resistance stability, microcapsule embedding, targeted delivery and pharmaceutical-grade sterility, phycocyanin will deeply penetrate high-value tracks such as high-end functional food, medical food and pharmaceuticals, stem cell therapy, precision diagnosis, functional skin care and safe color cosmetics. Its market scale will continue to double with unlimited expansion of application boundaries, leading the global industry into a new development cycle featuring natural safety, powerful functions, technological leadership and high added value, and evolving into the most potential king of natural bioactive raw materials in the next decade.