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Exploring the Anti-inflammatory Potential of Blue-Green Algae: Formulation and Evaluation of Spirulina Ointment

Research Article

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Abstract

Blue-green algae, also known as cyanobacteria, are a diverse and ancient group of photosynthetic microorganisms that have been of great interest to scientists due to their nutritional, medicinal, and industrial applications. These microbes, some of the oldest organisms on our planet, are currently being discovered as a rich reservoir of bioactive compounds with applications ranging from nutrition to drug discovery. Spirulina and other cyanobacterial genera, in specific, have exhibited strong anti-inflammatory, antioxidant, and immunomodulatory activities and are potential drugs for topical and systemic therapy. Bioactives like phycocyanin, polysaccharides, and carotenoids are key players in exerting these properties and have been effectively added to ointments for better delivery and efficacy. Cyanobacteria exhibit significant utility in promoting human health and possess extensive applications in the field of cosmeceuticals due to their photoprotective properties and skin-regenerative capabilities. Furthermore, they are employed in bioremediation, biofuel generation, and nutraceutical synthesis, thereby constituting a vital component of sustainable biotechnological innovations. Despite these advantages, challenges such as the occurrence of cyanotoxins like microcystins, variability in bioactive compound content, and constraints associated with cultivation underscore the imperative for additional research and standardization efforts. The current investigation aimed to examine the anti-inflammatory properties of the blue-green algae Spirulina, alongside the formulation and evaluation of Spirulina-based ointments. This review endeavors to highlight recent advancements in the anti-inflammatory potential of blue-green algae, with particular focus on the formulation of topical ointments.

Keywords: Spirulina, Blue-Green Algae, Anti-inflammatory, Ointment, Microalgae, Skin Protection.

Introduction

Blue-green algae, also known as cyanobacteria, are among the oldest and most versatile microorganisms on Earth, with a history dating back over 3.5 billion years. These photosynthetic prokaryotes play a vital role in global ecological processes, such as nitrogen fixation and oxygen production, contributing significantly to the planet's biosphere and sustaining a wide range of life forms. In recent decades, their pharmacological and biotechnological potential has attracted increasing scientific interest, particularly for their production of diverse bioactive compounds.

One of the most prominent genera within cyanobacteria is Spirulina (Arthrospira platensis), renowned for its exceptional nutritional value, including high protein content, essential amino acids, vitamins, minerals, and pigments such as phycocyanin and chlorophyll. Beyond its dietary benefits, Spirulina has demonstrated significant therapeutic properties, especially in addressing inflammation, oxidative stress, immune modulation, and skin regeneration.

The anti-inflammatory potential of Spirulina is primarily attributed to phycocyanin, a blue pigment-protein complex known for inhibiting pro-inflammatory enzymes like COX-2 and reducing cytokine activity. Additionally, polysaccharides and essential fatty acids derived from Spirulina contribute to immune regulation and tissue repair. These bioactives make Spirulina a compelling candidate for topical use in dermatology, particularly in treating conditions such as eczema, psoriasis, and UV-induced skin damage.

With proven safety in toxicological studies, Spirulina is increasingly incorporated into pharmaceutical and cosmetic products. Its cultivation is cost-effective and sustainable, further supporting its use in large-scale biotechnological applications. Recent advancements have enabled the development of ointments and creams that utilize Spirulina extracts to deliver targeted therapeutic effects while also enhancing skin barrier function and photoprotection. (26, 27).

The anti-inflammatory effects of blue-green algae are mainly ascribed to their phytochemical diversity. Phytochemicals such as C-phycocyanin, polysaccharides, and essential fatty acids have been documented to modulate well the inflammatory response. C-phycocyanin, a blue pigment-protein

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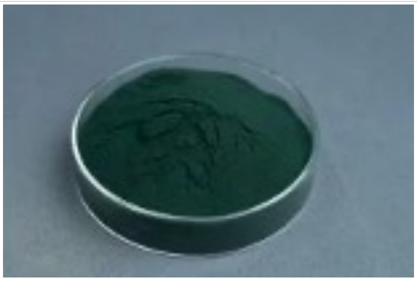
complex from Spirulina platensis, has been intensely studied for its effects on the inhibition of pro-inflammatory mediators such as cytokines and nitric oxide and antioxidants (27, 28, 31)

Figure 1. Spirulina powder



History and Significance of Blue-Green Algae

Blue-green algae or *cyanobacteria* are one of the earliest living organisms on our planet. Their history goes back more than 3.5 billion years, and they are one of the earliest groups of organisms to have evolved oxygenic photosynthesis a phenomenon that revolutionized the Earth's atmosphere and paved the way for the development of complex aerobic forms of life (1). Fossilized stromatolites composed of layered mats of *cyanobacteria* constitute direct proof of their existence and ecological role in the Precambrian period.

The name "blue-green algae" is due to the characteristic pigmentation of these microorganisms—specifically their phycocyanin (blue pigment) and chlorophyll-a (green pigment) content, which are responsible for their color and photosynthetic activity. *Cyanobacteria* are prokaryotic rather than true algae, with no membrane-bound organelles, but they occupy many of the same ecological niches as eukaryotic algae (1).

Historically, *cyanobacteria* not only contributed significantly to the creation of Earth's biosphere but were also pivotal in the establishment of contemporary agriculture and aquaculture. In premodern farm production, particularly in Asia, species like Nostoc and Anabaena contributed to soil fertility enrichment through nitrogen fixation in rice paddies long before the creation of synthetic fertilizers.

In the last few decades, scientific interest in blue-green algae has escalated because of their bioactive attributes. Among them, Spirulina (*Arthrospira platensis*) is the most economically important species. It came into international focus in the 20th century when NASA suggested that it be used as a nutritional additive for space explorers because of its higher protein content, rich vitamin composition, and higher biomass production (7).

Cyanobacteria synthesize a broad range of secondary metabolites such as toxins, pigments, polysaccharides, and fatty acids, most of which have anti-inflammatory, antimicrobial, antioxidant, and immunomodulatory activities (4,5,10).

Cyanobacteria also have a central role in environmental sustainability. Their capacity to survive under adverse conditions, absorb heavy metals, and produce biofuels has made them a critical component in bioremediation and green energy studies (12,20). Their capability for carbon sequestration, nutrient recycling, and wastewater treatment is also a key contribution towards the fight against climate change and minimizing ecological footprints.

Blue-green algae are becoming potential agents in topical preparations in the dermatological and medical sciences because of their skin-rejuvenating, sun-protection, and anti-inflammatory activities (8,17). Topical preparations using Spirulina extracts are now being researched for treatments ranging from eczema and psoriasis to photoaging of the skin.

Modern Applications

As a result of the development in biotechnology, blue-green algae emerged as an important element in nutrition. Their potential as a source of bioactive compounds leads to their diverse applications in pharmaceuticals, cosmetics, and environmental sustainability. They particularly show great significance in their ability to produce natural anti-inflammatory, antioxidant, and antimicrobial substances relevant to health and skincare industries (29, 30).

Ecological and Industrial Significance

Cyanobacteria play a role in fixing nitrogen in aquatic and terrestrial ecosystems, making the soil fertile and promoting agricultural productivity. They are also important in carbon sequestration as it prevents the worsening effects of climate change because cyanobacteria absorb carbon dioxide in the process of photosynthesis (31, 32).

In recent decades, there has been an increasing industrial interest in blue-green algae. These organisms are considered a significant potential sustainable resource for biofuels, bioplastics, and high-value nutraceuticals. Moreover, their cultivation does not need much land and water compared to other crops; therefore, they are a promising candidate for addressing global food and energy demands (33, 34)

Materials and Methods

Formulation of Spirulina ointment

Table 1: Composition of Spirulina ointment

Ingredients	Quantity	Percentage
Spirulina powder	1.5 gm	10.02%
Petrolatum (Vaseline)	1.5 gm	10.02%
Lanoline	4.5 gm	30.05%
Beeswax	1.5 gm	10.02%
Steric acid	0.75 gm	5.01%
Cetyl alcohol	0.75 gm	5.01%
Glycerin	1.5 gm	10.02%
Methyl paraben	0.02 gm	0.13%
Vitamin E	0.5 gm	3.34%
Ascorbic acid	0.2 gm	1.34%
Mint oil	1 ml/0.9 gm	6.68%
Xanthan gum	0.3 gm	2.00%
Phenoxyethanol	1.0 gm	1.0%

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Formulation of Spirulina ointment

Spirulina powder was solubilized in distilled water. The ointment base was formulated by melting together petrolatum, lanolin, and beeswax. The spirulina powder slurry was subsequently incorporated into the molten base progressively. Glycerin was introduced to enhance the emollience of the formulation. The preparation was then allowed to cool to 40°C. and melting point is petrolatum 35º C -45º C, lanolin 35º C -40º C , and beeswax 60º C Finally, methyl paraben and phenoxyethanol were incorporated into the mixture. Mint oil was added to impart fragrance. Upon reaching ambient temperature, the ointment was meticulously transferred into sterilized containers and stored in a cool and dark place.

Figure 2: Spirulina powder

Physical evaluation parameters

Preliminary assessment of formulation was conducted on various parameters such as;

- The organoleptic attributes, including color and odor of the formulation, were evaluated through visual inspection.
- pH: The pH levels of the different formulations were measured utilizing a digital pH meter. Specifically, 0.5 g of the formulation was dissolved in 50 ml of distilled water, and the pH value was recorded.
- Homogeneity: Each of the formulated ointments was assessed for homogeneity via visual examination, ensuring that the products exhibited no lumps.
- Washability: A quantity of 0.5 g of the formulated preparation was applied to the skin, and subsequently washed off with lukewarm water. The duration required for the complete removal of the preparation was noted.
- Viscosity: The viscosity of the prepared ointments was quantified using a Brookfield Viscometer. Each formulations viscosity was measured in triplicate, and the average values were subsequently reported.
- Spreadability: The assessment of spreadability was performed using a specialized apparatus consisting of a wooden block equipped with a pulley at one end. Through this methodology, spreadability was evaluated based on the slip and drag characteristics of the ointments. An excess quantity of approximately 2 g of the ointment under investigation was placed on the lower glass slides. The ointment was then sandwiched between this slide and an additional glass slide, which matched the dimensions of the fixed lower slide and included a hook. A weight of one kilogram was positioned on top of the slides for five minutes to eliminate air and ensure a uniform film of the ointment between the slides. Any surplus ointment was removed from the edges. The upper slide was then subjected to a force of 80 g via a string attached to the hook, and the time (in seconds) required for the upper slide to traverse a distance of 7.5 cm was recorded. A shorter duration signifies superior spreadability. It was calculated using the formula S = M x L/T, where S represents spreadability, M denotes the weight applied to the upper slide, L represents the length of the glass slide, and T represents the time required to completely separate the slides from one another.
- Stability study: Physical stability study of the spirulina herbal ointment was carried out for four weeks at different temperature conditions: 15ºC, 25 ºC, 37 ºC. The herbal ointment was found to be physically stable at different temperature i.e., 15ºC, 25ºC, 37ºC. for four weeks.

Results

Table 2: Evaluation parameters for spirulina herbal ointment

EVALUATION	OBSERVATION
Colour	Dark Green
Odour	Pleasant
Consistency	Smooth
pH	7
Spreadibility	Evenly spreadable
Washability	Easily washable
Irritancy	Non irritant
Stability study (15ºC to 37ºC)	Stable
Homogeneity	Homogenous
Microbial contamination	No growth of fungi and yeast was seen until one month
Storage condition	At room Temperature

The emulsifying ointment was used as the substrate to create herbal ointments in the current investigation. The formulations physical characteristics were then assessed. These physicochemical characteristics were acceptable. The formulations appeared to be stable based on the stability analyses that were conducted. In tabular form, the maximum dosages of compounded ointments are displayed (Table No. 2).

Discussion

The current investigation was conducted to formulate and evaluate a herbal ointment. The herbal formulation was prepared by incorporating spirulina extract into a prepared ointment base. It exhibited stability throughout the storage period. The physicochemical properties of the ointment were analyzed, yielding satisfactory results concerning extrudability, washability, spreadability, solubility, and loss on drying, among others. Stability assessments were performed under varying temperature conditions of 2°C, 25°C, and 37°C over a four-week duration. No alterations were detected in spreading ability, diffusion characteristics, or any irritant effects.

Conclusion

The study successfully highlights the potential of Spirulina-based ointments as a natural and effective alternative for managing inflammation. The findings encourage further exploration, including clinical trials and product development. With minor refinements in methodology presentation and expanded comparative analyses, this research could form the foundation for a new class of algae-derived topical therapies in the pharmaceutical and cosmeceutical industries. The article requires minor revisions for publication in the IJAM

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