JOURNAL OF TROPICAL PHARMACY AND CHEMISTRY
Journal Homepage : https://jtpc.ff.unmul.ac.id

Volume 9.1

Research Article

Development of a Spirulina-Infused Patch for Oil Control in the T-Zone of face: A Novel Approach to Skin Care.

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Abstract

The objective of this research was to develop a spirulina-based patch aimed at regulating sebum production and improving skin health, specifically targeting oiliness in the T-zone region. Spirulina, a blue-green algae rich in antioxidants, anti-inflammatory agents, antimicrobial compounds, and sebum-regulating properties, was selected as the principal active ingredient. The experimental approach involved optimizing a patch formulation for adequate adhesion, flexibility, sustained release of active components, and enhanced oil absorption. Characterization studies were conducted to evaluate mechanical strength, surface pH, moisture retention, elasticity, and user comfort. In vitro studies confirmed the patch's effectiveness in reducing sebum levels without causing irritation or excessive dryness. Preliminary user trials demonstrated a visible reduction in T-zone oiliness and improvements in skin texture and appearance. The developed patch offers a natural, sustainable, and user-friendly alternative to conventional oil-control products. It provides targeted delivery, minimizes the risk of skin barrier disruption, and enhances skincare efficacy. Further research will focus on long-term performance evaluation and formulation refinements.

Keywords: Spirulina-based patch; Sebum regulation; T-zone oiliness

Accepted: 22 July 2025
Approved: 20 August 2025
Publication: 1 September 2025

Citation : M.R. Narkhede, Y.S. Nachan, S.D. Pande, "Development of a Spirulina-Infused Patch for Oil Control in the T-Zone of face: A Novel Approach to Skin Care", JTPC, vol. 9, no. 1, pp-101-108, Sept. 2025, doi : 10.30872/jtpc.v9i1.282

Doi: 10.30872/jtpc.v9i1.282

1 Introduction

Sebum is an oily, waxy substance secreted by sebaceous glands found predominantly in the skin, particularly concentrated in areas like the face and scalp[1]. Its primary role is to protect and moisturize the skin, creating a barrier against environmental threats and preventing water loss. The composition of sebum is complex, including a blend of lipids that contribute to its protective properties and influence various skin conditions[2].Key Components of Sebum, Triglycerides and Free Fatty Acids (51%): Triglycerides make up a significant portion of sebum. When broken down by enzymes on the skin's surface, they yield free fatty acids, which help maintain the acidic pH of the skin, forming a protective barrier against harmful bacteria. However, excessive free fatty acids can contribute to skin irritation and inflammation, potentially leading to acne[3][4]. Wax Esters (26%): Wax esters provide a longer-lasting moisture barrier compared to other lipids, helping to reduce water loss from the skin. These molecules are unique to sebum and are not produced elsewhere in the body. Wax esters also have structural similarities to the skin's natural lipids, making them crucial for skin barrier integrity[5]. Squalene (12%): Squalene is an unsaturated hydrocarbon that acts as a powerful antioxidant. It helps protect the skin from oxidative damage caused by UV radiation and pollution, both of which accelerate aging. However, squalene can oxidize when exposed to air, potentially contributing to comedones formation and acne[6]. Cholesterol and Cholesterol Esters (11%): Cholesterol plays an important role in maintaining skin elasticity and flexibility. It supports cell membrane function and, in combination with other lipids, helps keep the skin barrier intact. Although it's present in lower concentrations, cholesterol is essential for healthy skin structure and resilience[7].

The composition and amount of sebum can vary depending on factors like age, genetics, hormones, and environmental conditions[8]. For example, during puberty, hormonal changes increase sebum production, which often leads to oilier skin and a higher likelihood of acne. Those with oily skin generally have larger sebaceous glands that produce higher amounts of sebum, whereas individuals with drier skin types produce less sebum, resulting in less protection against moisture loss. Impact of Sebum Composition on Skin Health Sebum plays a dual role—it's both protective and potentially problematic. While it moisturizes and shields the skin, excessive sebum production, particularly in the T-zone (forehead, nose, and chin), can lead to an accumulation of oils, dead skin cells, and bacteria[9]. This can result in clogged pores, acne, and increased shininess, which is why sebum regulation is crucial for managing oily and acne-prone skin.

In summary, sebum is essential for skin health due to its unique composition of triglycerides, wax esters, squalene, and cholesterol. This lipid-rich blend protects the skin, but when overproduced, it can contribute to oily skin conditions, underscoring the need for balanced sebum control, especially in the T-zone[10]. Oily skin develops when the sebaceous glands generate too much sebum, the natural oil that helps keep the skin moisturized[11]. However, when this oil production becomes excessive, it can lead to several skin issues that impact both appearance and skin health. The forehead, nose, and chin, is especially prone to oiliness due to the higher concentration of sebaceous glands in these areas[12]. Managing oily skin requires a delicate balance, aiming to reduce sebum production without causing excessive dryness or irritation.

Excessive oil production contributes to various skin concerns. Acne Breakouts, The overproduction of sebum is one of the leading causes of acne, as the excess oil combines with dead skin cells and bacteria to clog pores[13]. Clogged pores create an ideal environment for bacteria, especially *Cutibacterium acnes*, which thrive in oily conditions[14]. This can lead to various types of acne, including blackheads (open comedones), whiteheads (closed comedones), and inflammatory lesions like papules, pustules, and cysts[15]. Addressing this involves regular cleansing with gentle, non-comedogenic products that help remove oil without stripping the skin's natural barrier. Products containing salicylic acid, benzoyl peroxide, and tea tree oil can further help in reducing acne by controlling bacteria and aiding in exfoliation[16]. Shiny Appearance, Excess oil on the skin surface can create a persistent shine, often leading people with oily skin to feel self-conscious, especially in social or professional settings. This shiny

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appearance is usually most prominent in the T-zone and can make the face look greasy and unrefined[17]. Many people resort to blotting papers, mattifying powders, or oil-absorbing primers to manage the shine throughout the day. Clay-based masks and lightweight, oil-free moisturizers with mattifying agents (like silica and kaolin) can also help control oil levels, allowing the skin to look balanced without appearing overly shiny[18]. Enlarged Pores, Oily skin is often associated with enlarged pores, especially around the nose, cheeks, and forehead. Excess sebum production forces the pores to widen as they attempt to release the oil, causing them to become visibly larger over time. Pore size is primarily determined by genetics, but oil buildup can exacerbate the appearance[19]. Regular exfoliation with products containing AHAs (alpha hydroxy acids) and BHAs (beta hydroxy acid) can prevent oil and dead skin from clogging the pores, thereby helping them appear smaller[20]. Niacinamide is another helpful ingredient, as it can regulate oil production and improve skin texture, reducing the appearance of large pores[21]. Skin Irritation, Continuous oil buildup on the skin can lead to irritation, as excessive sebum can disrupt the skin's natural pH, making it more prone to redness, itchiness, and even rashes. The skin may become inflamed and sensitive, particularly when environmental factors like pollution mix with the excess oil on the skin, creating a layer that clogs pore and irritates the surface. For people with oily skin, it's important to use gentle, non-irritating products that can balance the skin's pH. Opting for alcohol-free toners and lightweight, calming moisturizers with soothing ingredients like aloe vera, chamomile, or *centella asiatica* can help keep irritation at bay. Reduced Makeup Longevity, People with oily skin often struggle with makeup longevity, as sebum can break down makeup, causing it to fade, separate, or become patchy. This can result in a less polished appearance and necessitates frequent touch-ups, which can be inconvenient. To counter this, people with oily skin may benefit from oil-free and long-wearing makeup products, as well as primers designed to mattify and create a smooth base for makeup application. Setting powders and sprays can further lock makeup in place, providing longer-lasting results. Some people also incorporate blotting papers throughout the day to absorb excess oil without disturbing makeup[22]. Seborrheic Dermatitis, In some cases, excessive oil production can lead to more severe skin conditions like seborrheic dermatitis[23]. This chronic condition is characterized by red, scaly, itchy patches, especially in areas with a high concentration of sebaceous glands, such as the scalp, eyebrows, and T-zone. The condition is often aggravated by stress, seasonal changes, and even the body's response to certain fungi like Malassezia, which thrive in oily environments. Managing seborrheic dermatitis may require antifungal treatments or medicated creams prescribed by a dermatologist. Additionally, mild cleansers and hydrating, oil-free moisturizers can help keep the condition under control without exacerbating oil production[24].

Managing Oily Skin is an effective oily skin management routine is essential to prevent these issues from escalating. This routine typically includes, Cleansing: Using gentle, oil-free cleansers to remove excess oil and impurities without stripping the skin barrier, Exfoliating: Regular but gentle exfoliation (2-3 times a week) helps in removing dead skin cells and preventing clogged pores. Ingredients like salicylic acid (BHA) are beneficial for oily skin as they penetrate the pores and dissolve oil. Hydration: Despite common misconceptions, oily skin still requires proper hydration. Using lightweight, oil-free moisturizers can help maintain skin balance and reduce excess oil production[11]. Diet and Lifestyle: A diet low in sugars and refined carbohydrates and high in omega-3s can support balanced oil production. Staying hydrated and managing stress can also play a role, as stress hormones can increase sebum production[25].

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2 Method

Table no I. Formula Table

Ingredient	Role	F1	F2	F3
Micronized Spirulina powder	API (Active Pharmaceutical Ingredients)	100mg	100mg	100mg
Distilled water	Solvent	3ml	3ml	3ml
HPMC	Film Forming Agent	150mg	100mg	50mg
Propylene Glycol	Plasticiser	2ml	2ml	2ml
Ethanol	Solvent	2.5ml	2.5ml	2.5ml
Chloroform	Solvent	2.5ml	2.5ml	2.5ml

Method (Plan of Work)

The formulation of the Spirulina Patch was successfully prepared in 3 batches by following a structured procedure:-

Step 1

Weighing of Spirulina and Other Ingredients

Spirulina was accurately weighed and distributed into three separate Petri dishes, each containing the specified quantity of spirulina along with the designated volumes of water, ethanol, and chloroform[47].

Step 2

Incorporation of HPMC

HPMC (Hydroxypropyl Methylcellulose) was added in varying concentrations as per the formulation table. All components were mixed thoroughly to ensure uniform dispersion and homogeneity of the formulation[48].

Step 3

Drying and Cutting of Patches

The patch formation process was allowed to proceed for approximately 3 to 4 hours. Upon complete drying, the formed patches were carefully removed and cut into shapes suitable for application on the T-zone region of the face.

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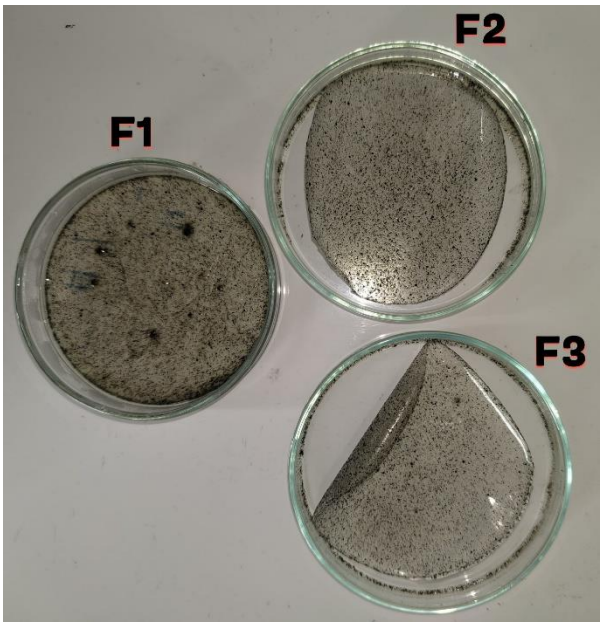

Fig III. Ready Formulation.

Evaluation Studies:

- Visual Appearance:

The patch appears to be smooth surface from one side and rough surface (adhesive part) on other side due to micronized spirulina powder.
Colour is dark green of the patch.
Odourless patch[49].

- Thickness

The thickness was measured of the patches of all 3 batches by using a digital vernier calliper and results found are as follows:

Table no II. Thickness of the batch

F1	F2	F3
0.15mm	0.20mm	0.22mm

- Weight uniformity

The weight uniformity was measured of the patches of all 3 batches by using a mg sensitive weighing balance and results found are as follows:

Table no III. Weight Uniformity data.

F1	F2	F3
263mg	264mg	270mg

- pH studies:

pH studies were carried out by dissolving a part of the patch in water and measuring its pH using pH paper. And the pH was resulted around 5-6 whereas, reference pH suitable for facial skin falls in between 5.5-6.5[50].

- Folding endurance:

The patch was not teared when it was folded for more than 6 times on the same point. Hence, result of folding endurance was interpreted as 6.

- Oil Absorption Capacity & Microscopic evaluation:

The oil absorption capacity of the spirulina patch was evaluated using a gravimetric method[51]. Initially, the dry patch was accurately weighed. A synthetic sebum mixture comprising 25% oleic acid, 25% palmitic acid, and 50% paraffin oil was prepared and uniformly spread on a flat platform. The pre-weighed spirulina patch was then placed on the sebum-coated surface and allowed to interact

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for 5 to 10 minutes. Following this, the patch was reweighed, and the increase in weight was attributed to oil absorption. Additionally, microscopic evaluation was performed to observe the swelling behaviour of micronized spirulina particles post-absorption.

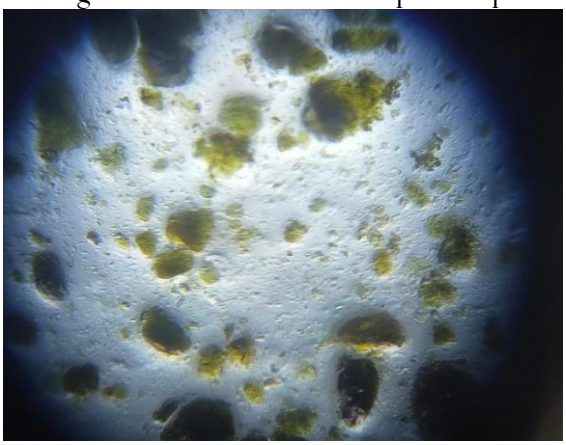

Fig IV. Before oil absorption

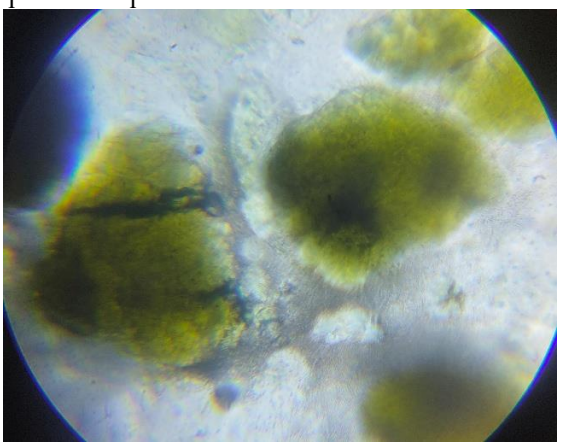

Fig V. After Oil Absorption

Table no IV. Oil Absorption data

Formulation	Patch Area (cm^2)	Initial wt (W_1 mg)	Final wt (W_2 mg)	Oil Absorbed (mg) (W_1-W_2)	Absorption Capacity (mg/cm^2)
F1	37.39	263	459	196	5.24
F2	37.39	264	422	158	4.23
F3	38.48	270	491	221	5.74

3 Result and Discussion

The developed patch containing micronized spirulina powder showed promising results in controlling excess oil in the T-zone area of the face, which is typically more prone to oiliness. After application, a noticeable reduction in skin greasiness was observed, and the skin appeared smoother, less shiny, and more balanced in texture. Users found the patch easy to apply and comfortable to wear, which adds to its practicality for routine skincare.

Spirulina, used as the active ingredient in this formulation, significantly contributed to these outcomes. Known for its rich nutritional profile including proteins, amino acids, and antioxidants spirulina supports skin health by promoting collagen production and providing essential nutrients. Its presence in the patch not only helped with oil control but also offered added skin benefits, such as hydration, nourishment, and improved elasticity. Overall, the patch proved to be an effective and convenient solution for managing oily skin, especially in the T-zone, while simultaneously supporting overall skin health.

4 Conclusion

The finalized patch formulation demonstrated effective oil control and provided a smooth, uniform application with ease of removal. The patch adhered well to the skin and gradually released the active ingredients, offering targeted benefits to the T-zone. The patch's application was convenient, and it left the skin feeling refreshed, oil-free, and hydrated. The project successfully achieved its objectives, providing a practical and effective formulation for oil control and skincare. Future modifications could include the inclusion of natural preservatives and fragrance to enhance user experience and shelf life.

5 Declarations

5.1 Author contributions

The names of the authors listed in this journal contributed to this research.

5.2 Funding Statement

This research was not supported by any funding sources.

5.3 Conflict of Interest

Conflicts of Interest: The authors declare no conflict of interest.

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