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Development of a Green Tea Emulsion Infused Hydrogel

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***Abstract*—The study focused on the development of a hydrogel based herbal eye patch. This study aims to evaluate the benefits of green tea, coconut oil, and the surfactant in creating an emulsion based eye patch. A complete literature analysis was carried out to understand the present research related to nanoemulsions and preparation methods, herbal components, hydrogels, surfactants, and their uses in skincare. The experiment utilizes the water-in-oil emulsion method to prepare the emulsion formulation. The basic materials, green tea, coconut oil, and surfactant were carefully selected based on their antioxidant, anti-inflammatory, and moisturizing qualities for addressing under-eye issues. The emulsions were examined using Malvern Zetasizer (nano-ZS) and optical microscope analysis. The participants' subjective input was also obtained through a questionnaire. Then the prepared emulsion was used to make a hydrogel of carcoxymethyl cellulose (CMC). As future work, improvement of emulsion droplet sizes to nanosizes, comparison of anti-oxidant activities of encapsulated and neat green tea infusions in hydrogel and conducting the user trials after ethical clearance is required.**

Keywords— Emulsion, Green Tea, Coconut Oil, Hydrogel

I. INTRODUCTION

Under-eye dark circles, it is called orbital hyperpigmentation, a common cosmetic problem characterized by the appearance of darkish discoloration or shadows below the eyes [1]. They could have an effect of all ages and skin types and can be temporary or persistent. Under-eye dark circles, a common cosmetic challenge, can arise from various factors. The thinness of the skin around the eyes compared to other facial regions permit underlying blood vessels and tissues to become more visible, growing the appearance of dark circles. Low blood circulation in the under-eye area can cause the accumulation of deoxygenated blood, contributing to their development. Excessive melanin production or uneven distribution of pigmentation in the under-eye location can cause hyperpigmentation, further darkening the skin. Moreover, genetic predisposition might also play a role in a few people. As we age, the skin loses collagen and turns thinner, making blood vessels and dark circles extra prominent. Factors including lack of sleep, fatigue, allergic reactions, and nasal congestion can dilate blood vessels and contribute to the appearance of dark circles [1]. Excessive solar exposure triggers melanin production and might worsen under-eye hyperpigmentation. Furthermore, consistent rubbing or scratching of the below-eye area can cause skin infection, exacerbating the problem. Dehydration also can cause the under-eye skin to appear dull and accentuate the visibility of dark circles. Understanding those contributing factors is essential in addressing under-eye dark circles and adopting suitable preventive measures and treatments to improve their appearance.

Natural herbal extracts have garnered huge interest in skin care due to their potential health advantages and minimal side outcomes. Amongst those, green tea has emerged as a popular natural element with antioxidant-rich properties [6]. The utility of green tea in skincare formulations has proven promise in reducing puffiness, inflammation, and hyperpigmentation, making it a perfect candidate for targeting dark circles under the eye. Conventional under-eye treatments, including creams, serums, and patches, frequently suffer from limited skin penetration and delivery of active components, leading to suboptimal efficacy. As a result, developing an innovative drug delivery system that can enhance the bioavailability and skin penetration of herbal extracts is crucial to addressing below-eye dark circles effectively.

Nanoemulsions, as stable and transparent structures with small droplet sizes, have emerged as a promising technology to enhance the delivery of bioactive compounds to targeted skin areas. With decreasing droplet sizes to the nanoscale, nanoemulsions offer advanced solubility, stability, and controlled release of active components [4]. These characteristics present a method that can address the challenges faced by conventional under-eye treatments.

II. MATERIALS AND METHODOLOGY

A. Materials

Initially, the green tea and coconut oil were purchased from SPAR Supermarket Kelaniya. Further Soya Lecithin was obtained from Glor Chem (Pvt) Ltd. Other chemical component and equipment were obtained from the

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Laboratory of the faculty of Computing and Technology of the University of Kelaniya.

B. Methodology

Three distinct approaches were examined for emulsion creation.

1) High shear mixing method

a) Step 1 - Green Tea Infusion Preparation: The first step involved the preparation of green tea extract, acquired via a carefully calibrated extraction technique. This extract would serve as a potent source of bioactive compounds to be incorporated into the formulation. In this step, create a green tea infusion by sonicating (using sound waves) a mixture of 1g of green tea and 40 ml of distilled water at a temperature of 60 °C for a duration of 15 minutes. This process helps extract the active compounds from the green tea into the water, forming a concentrated solution.

b) Step 2 – Mixing oil phase with surfactants: Coconut Oil (76.9% w/w), Tween 80 (4.1% w/w), and Soya lecithin (0.04% w/w) were mixed together in separate containers, heated, and stirred using the magnetic stirrer until a homogeneous mixture was obtained. As part of the heating and mixing processes, both magnetic stirrers and solutions were heated to temperatures between 139 °C and 78 °C while being stirred at 1500 RPM using temperature-controlled magnetic stirrers.

c) Step 3: Slowly Adding Green Tea Infusion to the Oil Mixture: The concentrated green tea infusion (18.96 w %) from Step 1 was slowly added to the oil mixture with the mixture. This step was conducted gradually with continuous stirring to ensure an even distribution of the infused water into the oil mixture. The emulsifiers help to prevent the separation of the oil and water phases, forming a fine dispersion of the tea-infused water within the oil mixture.

2) Phase Inversion Temperature (PIT) Method

In the PIT method, surfactant spontaneous curvature is inversed by changing temperature. Non-ionic surfactants undergo dehydration which makes it more lipophilic and leads to changes in curvature of the surfactant. Thus, phase inversion occurs and emulsion is produced. For efficient phase inversion rapid cooling and heating is required. Rapid cooling and heating made kinetically stable emulsions.

3) Sonication Method

a) Weighing the ingredients: The green tea, coconut oil, Tween 80, and soya lecithin were weighed based the nano emulsion formulation.

b) Prepare the GT infusion: A green tea infusion was prepared by sonicating a mixture of 1g of green tea and 40ml of distilled water at a temperature of 60 °C for a duration of 15 minutes. This process helped to extract the active compounds from the green tea into the water.

c) Preparing the Oil Phase: In a beaker, coconut oil and soya lecithin were combined. The mixture was heated gently while stirring to ensure to mix the soya lecithin in the oil.

d) Preparing the Aqueous Phase: In a separate container, green tea extract and Tween 80 were mixed.

e) Emulsification: The aqueous phase (green tea extract and Tween 80) was slowly added into the oil phase (coconut oil and soya lecithin) while continuously stirring and heating the mixture.

f) Phase Inversion: Once the desired temperature is reached, noticed a change in appearance.

g) Rapid Cooling: Once the phase inversion is achieved, rapidly cool the emulsion to under the room temperature. This heating and cooling steps were repeated for several rounds.

4) Characterization of emulsion

Particle size and emulsion stability were analyzed using Malvern PSA (Zetasizer, USA). Emulsion morphology was analyzed using a x400 magnification optical microscope (Nikon, Japan). This microscopy examination provided a more detailed visual assessment of the particle samples, yielding valuable insights into their characteristics.

A drop of the sample was placed on a clean glass slide and covered with a coverslip. The slide was then mounted on the microscope and the x40 objective lens was used for observation. The image was captured using a digital camera. During this microscopy examination, clear and well-defined images were obtained for four distinct samples. These samples corresponded to those prepared using high-energy methods as well as the phase inversion temperature technique.

5) Hydrogel Preparation and Incorporation

Carboxymethylcellulose (CMC) was added to the water to make a hydrogel. The hydrogel was incorporated into the emulsion which shown the best stability. Hydrogel was made by mixing the CMC gel with the previously prepared emulsion.

III. RESULTS AND DISCUSSION

1) Comparison of stability

The emulsion prepared using high shear mixing method exhibited dark brownish color, transparent solution, and thin brownish layer under the solution (Figure 1).

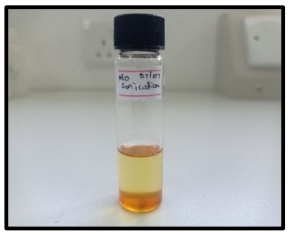

Fig. 1. The emulsion formed by high shear mixing technique

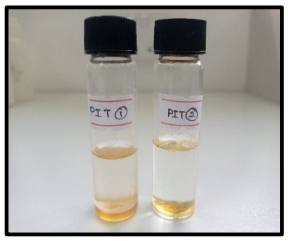

Fig. 1. PIT method emulsion

The emulsion formulated using PIT method was more transparent solution than ultrasonication (Figure 2).

2) Particle size analysis

The observed multi-modal error indicates that the sample contains multiple subpopulations of particles with distinct sizes (Figure 3). This presence of different particle sizes introduces complexity to the analysis and raises concerns about the accuracy of the derived distributions. The quality of the data collected raises concerns as well. The data may not possess the necessary level of precision and consistency required for a comprehensive distribution analysis.

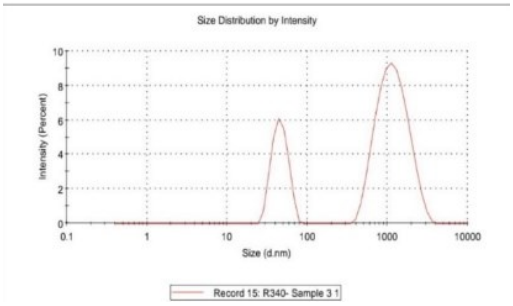

Fig. 2. The particle distribution curve

A significant contributing factor to these challenges is the polydispersity index of the sample. Polydispersity refers to the wide range of particle sizes present in the sample.

3) Morphological analysis of emulsion

The utilization of optical microscopy (Figure 4) served as a complementary approach to our particle analysis, offering a visual perspective that complemented the data obtained from the Malvern Zetasizer. The combination of these two techniques provided a more comprehensive understanding of the particle samples and their underlying properties.

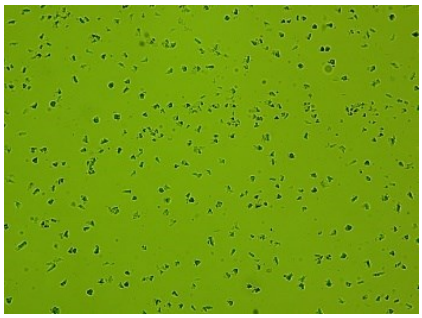

Fig. 4. The optical microscope image of emulsion (x400)

The clarity of these images enhanced our ability to observe and document the inherent features and structural attributes of the particles in these specific sample.

IV. CONCLUSION

The green tea emulsion was prepared using three techniques: high shear mixing, sonication and phase inversion temperature method. The best stable emulsion was obtained from the phase inversion temperature method. The emulsion droplet sizes were poly-dispersed having both nano and micro sized droplets. The incorporation of emulsion was successfully done to make a hydrogel of carboxymethyl cellulose. This hydrogel stands as a user friendly approach of utilizing the encapsulated tea polyphenols for cosmetic applications. As future work, improvement of emulsion droplet sizes to nanosizes, comparison of anti-oxidant activities of encapsulated and neat green tea infusions in hydrogel and conducting the user trials after ethical clearance is required.

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