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*Original Research Article*

# Formulation Development and Skin Evaluation of Gel-Based Cream Containing Tamarind Gum

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ABSTRACT

Tamarind gum (TG) is a natural polysaccharide rich in phenolic and flavonoid compound constituents that provide potent antioxidant activity. This study aimed to develop a gel-based cream containing TG and investigate various skin-related parameters for cosmetic applications. TG was extracted from the seed of tamarind with distilled water. The phenolic and flavonoid contents were quantified using the Folin-Ciocalteu and colorimetric methods. A formulation comprising 0.3% w/v of TG was prepared by loading it into an oil-in-water (O/W) gel-based cream. A benchmark product was used as a control for comparison. *In vivo* investigations were performed over four weeks on the forearms of 26 healthy female volunteers aged 30-55. The product's effects on transepidermal water loss (TEWL), skin color, skin hydration, and skin elasticity were assessed by skin analyzer (Cortex Technology, model DermaLab® Combo). The total phenolic and flavonoid contents of TG were 44.60±14.01 mg GAE/g and 194±27.22 mg QE/g, respectively. The gel-based cream containing 0.3% w/v TG exhibited substantially higher TEWL percentage changes in week four. The skin melanin index decreased and skin lightening increased. Skin hydration gradually increased throughout the study period. Moreover, elasticity improved in all parameters, including Young's modulus (E), retraction time (R), and viscoelasticity (VE). In summary, TG is a sustainable natural resource with potential antioxidant activities. It is an effective cosmetic active ingredient that may address skin health issues and improve overall skin appearance.

***Keywords:*** Tamarind gum, Transepidermal water loss, Skin melanin index, Skin hydration, Skin elasticity.

## Introduction

Natural polymers are highly valued for their distinctive attributes, including bioavailability, biodegradability, and non-toxicity, unlike synthetic polymers, which often entail high costs, toxicity concerns, and environmental issues[1]. Tamarind Gum (TG), also known as tamarind seed polysaccharide (TSP), is the primary natural polysaccharide obtained from the seed powder of the *Tamarindus indica L.* tree[2]. Many research studies have been conducted to repurpose waste from tamarind seeds due to their favorable properties, positioning it as a valuable excipient in numerous applications[3]. One promising property of TG is xyloglucan, a polysaccharide with desirable characteristics such as high viscosity, broad pH tolerance, thermal stability, biocompatibility, and high drug-holding capacity[4]. Owing to its remarkable characteristics, it has emerged as a subject of interest in a diverse mix of industries such as pharmaceuticals, food technology, cosmetics, and biomedical industries[5].

Antioxidants serve a crucial function in protecting the body from free radicals, oxidative stress, and the aging process of the skin[6-7]. TG is rich in phenolic compounds and is a natural source of antioxidants[8] such as2-hydroxy-3',4'-dihydroxy acetophenone, methyl 3, 4-dihydroxy benzoate, 3, 4-dihydroxyphenylacetate, (-) epicatechin, and oligomeric proanthocyanins, all of which contribute significantly to the antioxidant activity exhibited by TSP[9]. TG exhibits many beneficial properties, including potential roles as an anti-wrinkle agent, skin hydration enhancer, and skin-lightening agent[10]. Notably, the presence of compounds such as oligomeric procyanidin trimer, tetramer, and pentamer, procyanidin B5, and (-)-epicatechin bestows TG with robust antioxidant properties that exceed those of vitamins C and E. These constituents also significantly reduce melanin production, thereby facilitating skin-lightening[11].

The cosmetic industry has acknowledged the potential advantages of xyloglucan in enhancing skin health, highlighting its importance as a resource for developing sustainable and efficacious cosmetic products[12]. TG, in particular, has attracted attention due to its potential as an antioxidant, skin-softening and moisturizing agent, as well as skin-lightener[13]. It is rich in essential vitamins, including vitamin B complex for moisture retention and skin brightening, and vitamins C and K for stimulation of collagen production and skin damage repair[14]. One water-in-oil (W/O) emulsion cosmetic product incorporating TG demonstrated skin-lightening effects by reducing melanin levels and regulating sebum production, which can aid in acne treatment[15]. As a result, it is crucial to highlight the diverse and underexplored properties of TG extracts that can be further harnessed for skincare applications.

Despite these promising attributes, there is limited research focusing on TG in skincare product development. Therefore, in this study, we developed a TG skincare product and employed noninvasive techniques to assess various skin-related parameters, such as melanin index, erythema, color measurements using the Commission Internationale de L'Eclairage (CIE) L* a* b* system, skin elasticity, and skin hydration, and compared these results with a benchmark product.

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## Materials and Methods

*Raw Materials and Chemical Reagents*

Tamarind seeds were collected from a single source in December 2021 in Phetchabun province, Thailand (GPS coordinates: 16.743802, 101.019831). The plants were identified according to their botanical and taxonomic characteristics, as outlined in the Flora of Thailand (volume four, part one). A voucher specimen of *Tamarindus indica* L. (code ABH36) has been deposited at Chao Phya Abhai Bhubejhr Hospital Foundation, 163 Moo 17, Noenhom subdistrict, Mueang district, Prachinburi, 25230, Thailand. Xanthan gum (XG), Carbopol, Butylated hydroxytoluene (BHT), Propylene glycol (PG), Triethanolamine (TEA), Sodium benzoate, and Sodium lauryl sulfate (SLS) were purchased from Namsiang (Bangkok, Thailand). All reagents used were analytical grade. Finn Chamber® on Scanpor® Tape (100x10/8mm) was purchased from Allertech Co., Ltd., Bangkok, Thailand.

*Extraction and Preparation of Tamarind Gum*

The extraction method was modified from a previous study[16]. Tamarind seed coats were removed, and the seed kernels were washed and boiled in distilled water at a ratio of 1:3 for 1 h and left at ambient temperature for 6 h. The obtained viscous solution was precipitated with 95% v/v ethanol. The resulting residue was carefully squeezed through a cotton filter, collected, and left at ambient temperature overnight. The collected precipitate was then dried in a hot air oven (Forced Convection Oven, Delta Lab Tech, LDO-150F, South Korea) at a controlled temperature of 50°C for 4 h. The resulting dried polymer was stored in a sealed container at ambient temperature, ensuring its preservation and suitability for subsequent application.

*Physical characteristics of Tamarind Gum*

The pH of 1% w/v TG was measured at room temperature using a pH meter (Model Starter 2200, Ohaus, USA). The visual appearance was evaluated, including the powder's color, aroma, and consistency[17].

*Viscosity of Tamarind Gum*

The viscosity of a 1% w/v solution of TG was assessed using a Brookfield viscometer (Model DV-III+Pro, Brookfield Engineering Laboratories Inc., MA, USA) with a no. 34 spindle at a rotation speed of 40 rpm at room temperature (25±2°C)[18].

*Determination of Total Phenolic Content*

The total phenolic content of TG was quantified using the Folin-Ciocalteu assay with gallic acid as a standard. The reaction mixture comprised 1 mL of 0.3% w/v TG solution, 1.5 mL of 10% (v/v) Folin-Ciocalteu's reagent, and 1.2 mL of 7.5% (w/v) sodium carbonate. After incubation in darkness for 30 minutes, the absorbance was measured at 765 nm using a Shimadzu UV1201 spectrophotometer and concentration was calculated from a calibration curve using gallic acid concentrations ranging from 1 to 100 µL[19]. The phenolic contents in the extracts are expressed as mg of gallic acid equivalents per gram extract. The standard curve equation was $y = 0.007x + 0.0093, R^2 = 0.9997$.

*Determination of Total Flavonoid Content*

The determination of total flavonoid content was adapted from a previous study[20]. A quercetin calibration curve was constructed from the absorbance values at 415 nm from 0 to 100 µL volumes of a 0.1 mg/mL methanolic quercetin primary standard solution. Reaction mixtures consisted of 1 mL of 0.3% w/v TG solution, 0.3 mL of 5% (w/v) $NaNO_2$, 0.3 mL of 10% (w/v) $AlCl_3$, and 2 mL of 1M NaOH. The flavonoid content of the extracts are expressed as milligrams of quercetin equivalents per gram of dry extract. The standard curve equation was $y = 0.0001x + 0.0015, R^2 = 0.9945$.

*Formulation of Gel-Based Cream Containing TG*

An oil-in-water (O/W) emulsion formulation containing 0.3% w/v of TG was prepared. The water phase was prepared by incorporating 2.0% (w/v) Carbopol 940 and 0.2% (w/v) XG (4:1 w/v), vitamin B3 (Niacin), vitamin B5 (Panthenol), TG, PG, sodium benzoate, sodium metabisulfite, Pemulen TR-1, TEA, and purified water. The oil phase, containing tween 20 and BHT, was heated to 40°C in a water bath (Delta Lab Tech, LSB-030S, South Korea) and added with vitamin E acetate. The water phase mixture was then added gradually to the oil phase with continuous agitation until homogenization was achieved.

*Study Design*

This four-week study was approved by the Ethics in Human Research Committee of Khon Kaen University (Protocol number: HE661293). All participating volunteers provided written informed consent. Twenty-seven healthy females aged 30-55 were recruited for the research study. Exclusion criteria included severe illness, presence of a wound in the test area, pregnancy and breastfeeding, excessive physical activity, and allergies to cosmetic products. Each volunteer received three products, including a gel-based cream with TG (Cream A), a gel-based cream without TG (Cream B), and a benchmark product (Cream C). They were instructed to apply the provided sample gel-based cream to the forearm area twice a day (morning and evening), and the applied area was characterized weekly.

*Skin Patch Test*

Skin irritation was assessed in a skin patch test. Creams A, B and C were applied to the upper back area of a cohort of 27 volunteers under Finn Chamber® occlusive patches (0.015 mL/cm$^2$). A positive control chamber of 2.0% w/v sodium lauryl sulfate (SLS) was also applied. The patch was removed after 48 h and reactions were visually evaluated at 72 h[21].

*Skin Evaluation Methods*

To investigate the dermatological effects of the formulations, the functional skin parameters Transepidermal Water Loss (TEWL), melanin index, erythema index, the Commission Internationale de L'Eclairage (CIE) *L*a*b* colorimeter parameters, skin hydration, and skin elasticity measurements were evaluated using the Cortex DermaLab® Skin Analyzer (Hadsund, Denmark).

The water loss assessment relied on the diffusion principle within an open chamber ensuring minimal impact on the skin. A 10 mm hollow cylinder probe with humidity and temperature sensors was placed on the tested areas. Both local relative humidity and temperature were recorded. The results are expressed in grams per square meter per hour (g/m$^2$/h)[22].

The melanin index, erythema index, and skin color measurements were based on the principle of two angled white LEDs. The melanin index and erythema index indicate pigmentation and redness, respectively[23]. *L*a*b* is a concept from the CIE-color space. Each letter represents the correlation of the color space and the human skin. $L^*$ gives information about the black-white luminance, $a^*$ is located on the red-green axis, and $b^*$ indicates the yellow-blue axis[24].

Skin hydration level was based on the conductance principle and was measured with an 8-spring loaded probe. The level of hydration is expressed in micro-Siemens units (µS)[25].

Skin elasticity was measured using a non-invasive suction cup technique with an adherent double adhesive sticker applied to the skin. The fundamentals of the suction technique involve the generation of real-time curves of skin elevation and the amount of pressure applied to the designed skin area. Young's modulus (E) was utilized in the analysis of elasticity. This modulus signifies the force disparity required to elevate the skin's surface by 1.5 mm. The higher the value of E (MPa), the better the skin elasticity. Skin retraction time (R) refers to the duration in seconds necessary for the skin to revert to its initial state. A lower (R) value signifies better elasticity[26].

Individual plastic stencils with four circular cutouts were used to frame the product application areas. The plastic also wrapped around the ventral forearm for skin evaluation.

*Statistical Analysis*

All experiments were performed in triplicate. Data from three independent experiments were presented as the mean ± SD. The statistical analysis between the means of each group was performed using the one-way analysis of variance (one-way ANOVA) with post-hoc tests with least significant differences (LSD) correction was used to analyze the mean difference of each sample formulation by IBM® SPSS® Statistics 28.0 (Chicago, IL, USA). The statistical significance was considered at $p<0.05$.

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Percentage changes in the parameters were calculated each week by the following equation (1):

$$Percentage\ changes = \frac{(mean\ value\ at\ baseline - mean\ value\ at\ each\ week)}{(mean\ value\ at\ baseline)}\ x\ 100 \quad (1)$$

## Results and Discussion

*Physical Characteristics*

The pH of the TG (1% w/v solution) was 6.74 ± 0.02, indicating a slightly acidic nature. The color of the gum was dark brown with a characteristic aroma. The viscosity of the 1.0% w/v TG solution was 1.19 ± 16.20 cP.

*Determination of Total Phenolic and Total Flavonoid Contents*

The total phenolic content of the aqueous tamarind seed extract was 44.60 ± 14.01 mg gallic acid equivalents/g extract. The total flavonoid content was 194 ± 27.22 mg quercetin equivalents/g extract (Table 1).

**Table 1:** Total phenolic contents and total flavonoid contents of tamarind seed extract

| Results | Amount |
|---|---|
| Total Phenolic Contents | 44.60 ± 14.01 mg GAE/g |
| Total Flavonoid Contents | 194 ± 27.22 mg QE/g |

The results reveal the presence of phenolic and flavonoid compounds in the TG extract, indicating the extract to be a health-beneficial source suitable for numerous applications, particularly in cosmetic products. Despite this, the incorporation of TG in skincare products remains limited. In the current study, TG extract was incorporated into a gel-based cream formulation as the primary active compound and its impact on various skin-related parameters was evaluated.

*Skin Patch Test*

No allergic reactions to the gel-based cream samples were found among any of the participants. According to the ICDRG criteria, the formulated gel-based cream samples were considered non-irritating as they showed negative (-) reactions at 48 h and 72 h. In contrast, the 2.0% w/v SLS caused a mild irritation reaction (+) at the 72-hour mark (Figure 1).

*Participants*

Twenty-seven volunteers were enrolled in the skin analysis study, but one participant could not be contacted for the second week of the study and was excluded[27] (Figure 2). Thus, the final dataset consisted of data from 26 participants for analysis (n=26).

*Skin Evaluation*

*Transepidermal Water Loss (TEWL)*

As shown in Figure 3, the application of all creams improved transepidermal water loss (TEWL) after 4 weeks compared to the baseline in week 0. Cream A, which contains TG, exhibited the most substantial reduction in skin water loss among all cream samples ($p < 0.05$).

The reduced TEWL seen after four weeks for Cream A could result from the intrinsic phenolic and flavonoid antioxidants within the TG contributing to improved skin barrier function and hydration[28]. Among these compounds, polyphenols such as proanthocyanidins and procyanidins have previously been shown to have an effect on collagen synthesis. An earlier study on healthy human skin keratocytes showed that a formulation containing procyanidin reduced TEWL by 53% and mitigated skin barrier disruption resulting from SLS irritation.[29]

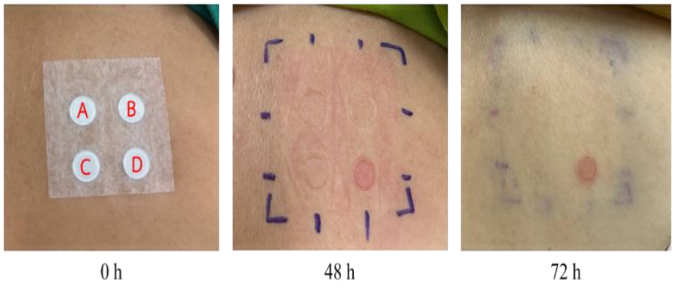


**Figure 1:** Skin patch test of gel-based cream containing TG on 0, 48, and 72 h compared to 2% w/v SLS. (A) Cream A, (B) Cream B, (C) Benchmark product, and (D) 2% w/v SLS (Protocol number: HE661293)

Cream B also showed a significant decrease in TEWL after four weeks treatment compared to the benchmark product Cream C ($p<0.001$), indicating that the decrease in TEWL was likely to be influenced by factors beyond those found in TG alone. This emphasizes the need to consider the impact of other ingredients such as panthenol (vitamin B5), which is known for its humectant properties[30]. Previous studies have shown that formulations with 1.0% w/w and 5.0% w/w panthenol effectively reduce TEWL and preserve skin barrier function, even at low concentrations[31].

*Skin Color*

*Melanin Index*

All formulations showed a statistically significant reduction in the mean melanin index at one week compared to baseline. However, only Cream A (containing TG) showed a statistically significant decrease from week 1 to week 3 (Table 2). Notably, Cream A, the gel-based cream with TG, exhibited a higher cumulative percentage reduction in the melanin index at week 4 (5.67%) than the benchmark product Cream C (4.51%), relative to baseline. Cream B, the gel-based cream without TG, also demonstrated a moderate decrease in melanin index after 4 weeks of application (5.11%). Statistical analysis revealed a significant difference among all formulations ($p \leq 0.05$).

*Erythema Index*

The percentage changes in the erythema index after the initial week of application were consistently negative across all formulations. However, no statistically significant differences ($p > 0.05$) were observed at any time point compared to the initial week (Table 2). This pattern persisted for the duration of the study. In week 4, there was a slight improvement in Cream A (0.97%) and Cream B (0.20%).

*CIE L*a*b*

The black-white luminance (L*) mean changes were most pronounced after using the gel-based cream with TG for 4 weeks, showing a shift of 6.16%, while the gel-based cream without TG and the benchmark had shifts of 5.37% and 4.09%, respectively (Table 3). Statistical analysis showed significant differences among all creams ($p \leq 0.05$). Interestingly, the increase in L* corresponded to a decrease in melanin index.

The parameter a*, which represents the redness of the skin color, showed a substantial decrease after applying Cream A ($p<0.001$) and Cream C ($p<0.001$) in the first week. These findings suggest that Cream A and C effectively diminished skin redness within the initial week of application. Conversely, Cream B showed no significant effect on reducing skin redness (Table 3).

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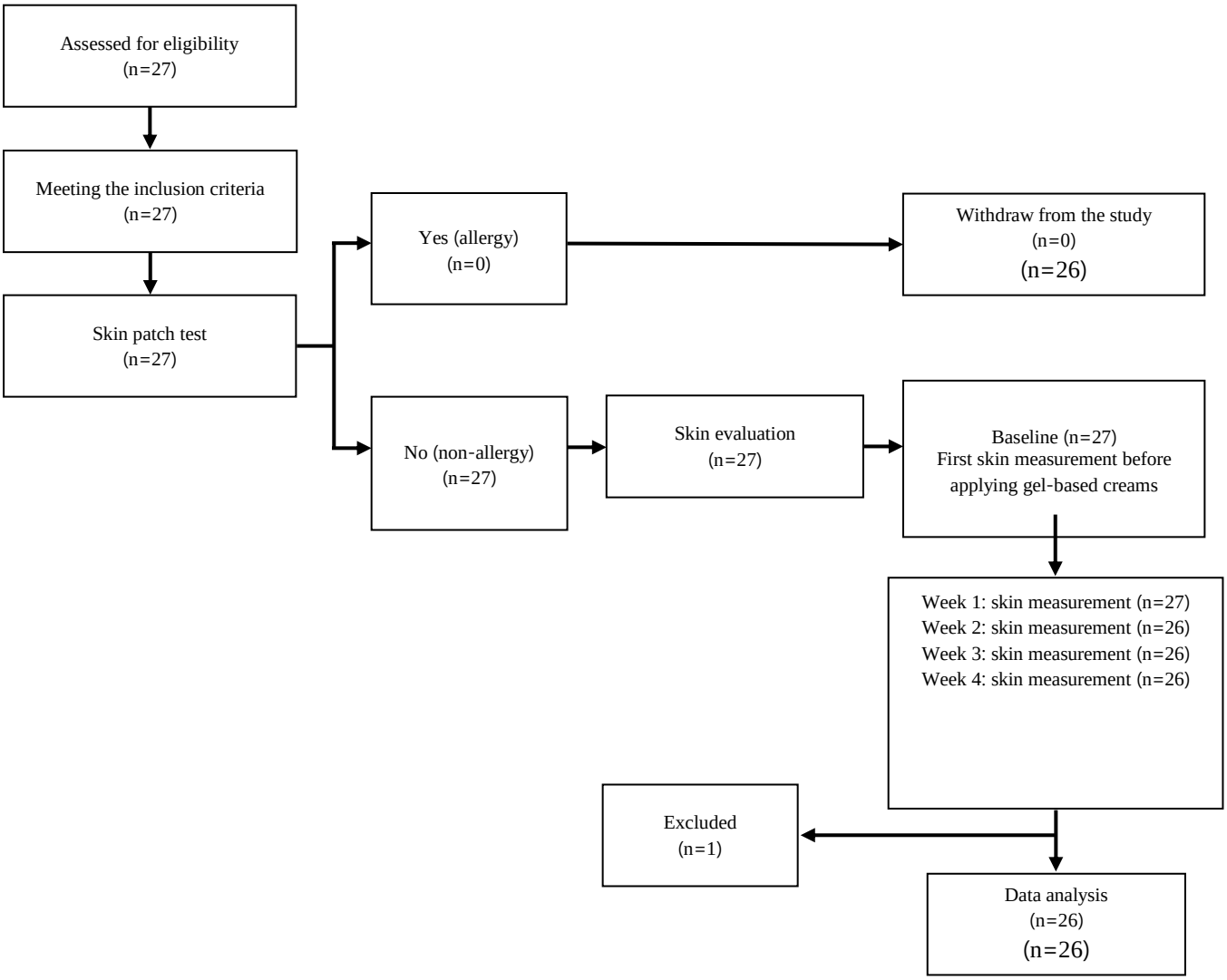


**Figure 2:** Consolidated standards of skin analysis diagram [27]

A significant reduction in skin yellowness (b*) occurred after the first week with Cream A ($p<0.003$) and Cream C ($p<0.03$). Cream B showed no significant reduction or noteworthy change in skin yellowness. However, comparing formulations showed significant differences ($p\leq0.05$). Overall, after 4 weeks, all formulations followed a similar pattern to baseline (Table 3).

Regarding skin color, the gel-based cream containing TG (Cream A) demonstrated superior improvement in skin melanin index, erythema index, as well as color parameters L* (lightness) and a* (erythema/redness) after 4 weeks of application, surpassing the effects observed with other formulations. The inverse relationship between the melanin index and the L* index is often studied as an indicator of skin lightening, suggesting that reduced melanin index is associated with increased skin lightening. The skin lightening effect of Cream A is possibly due to its polyphenolic contents, including 2-hydroxy-30, 40-dihydroxy acetophenone, methyl 3,4-dihydroxybenzoate, 3,4-dihydroxyphenyl acetate, epicatechin, and procyanidins[32]. These polyphenols have been shown to reduce melanin production by inhibiting tyrosinase activity. This reduces skin pigmentation and highlights TG's potential for promoting brighter and more even skin Tone.[33-34] Evidence from a study on TG's tyrosinase and cyclooxygenase inhibition activities supports its anti-melanogenic effects, indicating a potential for reducing melanin production without toxicity[35]. A clinical study with 4.0% w/w TG showed significant melanin reduction after 12 weeks of application, indicating the ability of the phenolic contents in TG to directly counteract free radicals and indirectly reduce melanin production. While UV-induced reactive oxygen species (ROS) generation has been shown to increase melanin production in skin[36], TG extract has been shown to offer protection against oxidative stress as well as reduced stress-free melanogenesis in a diacylglycerol 1-oleoyl-2-acetyl-sn-glycerol (OAG)[37]. This indicates that TG extract inhibits both melanogenesis and counteracts the impact of oxidative stress on melanogenesis. Reduced oxidative stress is linked to decreased melanogenesis, offering a pathway to skin lightening. TG reduced both melanin production and oxidative stress, potentially contributing to skin-lightening. The synergistic effects of additional ingredients in the gel-based cream were notable, with Cream B showing superior changes to the benchmark product. Vitamin E and B3's synergy in Cream B may explain its superiority.

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**Table 2:** Skin changes in melanin index and erythema index at 0, 1, 2, 3, and 4 weeks

| Sample | Week | Melanin index | | | Erythema index | | |
|---|---|---|---|---|---|---|---|
| | | Mean | p-value | Decrement (%) | Mean | p-value | Decrement (%) |
| Cream A | 0 | 44.44±5.32 | - | - | 11.53±2.78 | - | - |
| | 1 | 43.12±5.31 | <.001* | 2.97 | 12.89±7.15 | .305 | -11.80 |
| | 2 | 42.47±5.29 | <.001* | 4.43 | 11.73±2.84 | .368 | -1.77 |
| | 3 | 42.01±5.20 | <.001* | 5.47 | 11.58±2.63 | .231 | -0.40 |
| | 4 | 41.92±5.25 | .591 | 5.67 | 11.42±2.60 | .245 | 0.97 |
| Cream B | 0 | 44.07±5.39 | - | - | 11.32±2.78 | - | - |
| | 1 | 42.70±5.29 | <.001* | 3.12 | 11.45±2.70 | .468 | -1.12 |
| | 2 | 42.30±5.44 | .058 | 4.02 | 11.43±2.91 | .932 | -0.99 |
| | 3 | 42.01±5.54 | .118 | 4.69 | 11.34±2.65 | .512 | -0.17 |
| | 4 | 41.82±5.19 | .366 | 5.11 | 11.30±2.67 | .786 | 0.20 |
| Cream C | 0 | 43.07±5.37 | - | - | 11.60±2.50 | - | - |
| | 1 | 41.98±5.44 | <.001* | 2.53 | 11.98±2.46 | .019* | -3.22 |
| | 2 | 41.66±5.64 | .098 | 3.27 | 12.00±2.81 | .919 | -3.38 |
| | 3 | 41.42±5.38 | .294 | 3.81 | 11.75±2.42 | .154 | -1.23 |
| | 4 | 41.12±5.12 | .223 | 4.51 | 11.81±2.50 | .618 | -1.76 |

* Significant difference of time points compared to baseline within each sample (*<0.05). Results were analyzed by one-way ANOVA and expressed as mean ± SD (n=26)

A study conducted on Indian women (n=124) showed that daily use of a facial lotion with vitamin B3, vitamin E, and provitamin B5 reduced hyperpigmentation and enhanced skin tone and texture[38]. Our results align with Cream A and Cream B both reducing melanin levels and improving skin lightness (L*) from baseline to week 4. Considering these factors, it can be concluded that TG showed synergistic effects with other ingredients to contribute to a more effective enhancement of skin color parameters.

*Skin Hydration*

After four weeks, skin hydration notably improved across all formulations. Improvement began rapidly in the first week, with a slight decrease in week 2, and reached its peak at 38.26% for Cream A and 34.22% for Cream B after 4 weeks, with differences significant ($p<0.05$). Cream A outperformed Cream B in enhancing skin hydration, while Cream C showed superior sustained efficacy compared to Cream A and B (Figure 4).

The impact of the gel-based formulation containing TG on skin hydration can be attributed to oligomeric proanthocyanidins (OPCs), which enhance moisture retention, fortifying the skin's natural barrier functions and supporting hydration levels by preventing water loss from the stratum corneum[39]. In one study, topical formulations and dietary supplements containing OPCs increased skin hydration by nearly 20% after just one week of regular use[40]. A 12-week study involving 100 healthy Japanese women who consumed a daily beverage rich in OPCs also demonstrated improved water content in the stratum corneum, effectively preventing skin dryness[41]. Thus, OPCs were likely to contribute to the observed increase in skin hydration levels following the application of Cream A[42]. Although Cream A improved skin hydration compared to Cream B, the benchmark cream showed significantly more improvement than either. Environmental humidity significantly influences skin hydration levels, as higher humidity enhances conductivity[43].

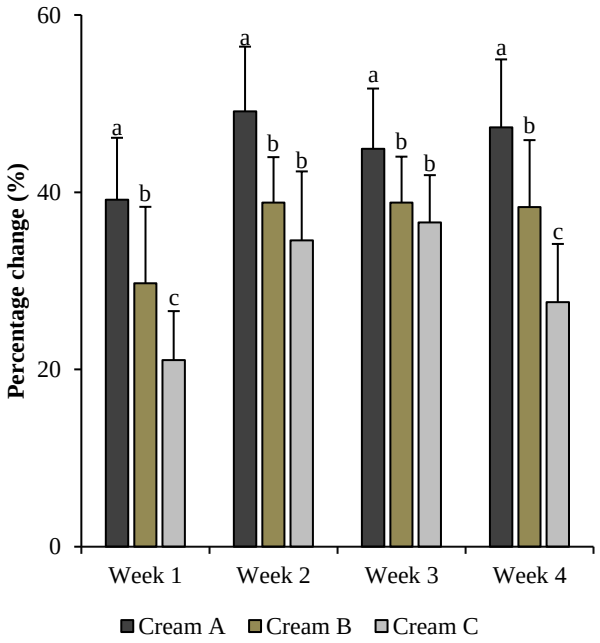


**Figure 3:** Percentage of TEWL after 4 weeks of application compared to baseline within each sample (n=26). Different letters (a-c) indicate a significant difference between samples in each week ($p < 0.05$)

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**Table 3:** Skin change in CIE $L^*a^*b^*$ at 0, 1, 2, 3, and 4 weeks

| Sample | Week | L* | | | a* | | | b* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | p-value | Increment (%) | Mean | p-value | Decrement (%) | Mean | p-value | Increment (%) |
| Cream A | 0 | 30.18±5.09 | - | - | 11.70±1.76 | - | - | 15.08±1.29 | - | - |
| | 1 | 31.06±5.24 | <.001* | 2.92 | 12.10±1.77 | <.001* | -3.42 | 15.33±1.40 | .214 | 1.66 |
| | 2 | 31.48±5.22 | .010* | 4.31 | 12.40±1.86 | .057 | -2.48 | 15.57±1.04 | .154 | 3.21 |
| | 3 | 31.88±5.09 | .008* | 5.63 | 12.37±1.69 | .814 | 0.24 | 15.45±1.32 | .392 | 2.47 |
| | 4 | 32.04±5.17 | .290 | 6.16 | 12.21±1.75 | .324 | 1.29 | 15.58±1.40 | .349 | 3.32 |
| Cream B | 0 | 30.53±5.23 | - | - | 11.63±1.87 | - | - | 14.69±1.30 | - | - |
| | 1 | 31.46±5.17 | .001* | 3.05 | 11.98±1.73 | .052 | -3.01 | 15.30±1.40 | .003* | 4.15 |
| | 2 | 31.79±5.50 | .171 | 4.15 | 12.02±2.00 | .852 | -0.33 | 15.37±1.18 | .733 | 4.63 |
| | 3 | 32.07±5.38 | .117 | 5.05 | 12.05±1.74 | .837 | -0.25 | 15.47±1.25 | .528 | 5.34 |
| | 4 | 32.17±5.16 | .658 | 5.37 | 12.07±1.77 | .938 | -0.17 | 15.18±1.57 | .113 | 3.35 |
| Cream C | 0 | 31.09±5.12 | - | - | 12.19±1.49 | - | - | 14.83±1.49 | - | - |
| | 1 | 31.68±5.18 | .025* | 1.90 | 12.88±1.55 | <.001* | -5.66 | 15.34±1.40 | .030* | 3.45 |
| | 2 | 31.97±5.47 | .168 | 2.83 | 12.85±1.72 | .888 | 0.23 | 15.30±0.97 | .799 | 3.16 |
| | 3 | 32.20±5.22 | .210 | 3.57 | 12.75±1.57 | .557 | 0.78 | 15.32±1.37 | .876 | 3.32 |
| | 4 | 32.37±5.10 | .468 | 4.09 | 12.95±1.59 | .235 | -1.57 | 15.32±1.55 | .985 | 3.29 |

* Significant difference of time points compared to baseline within each sample (*<0.05). Results were analyzed by one-way ANOVA and expressed as mean ± SD (n=26)

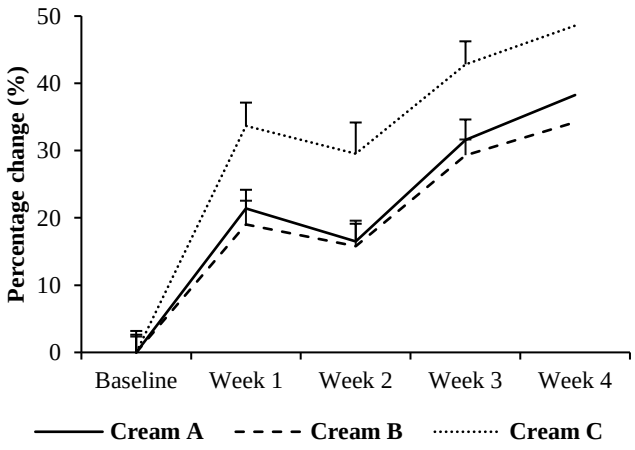


**Figure 4:** Percentage change in skin hydration after 4 weeks of application compared to baseline within each sample (n=26). (24℃ to 25℃ / 44% to 52% RH) (Cream A: gel-based cream with TG, Cream B: gel-based cream without TG, Cream C: benchmark product

The relative humidity (RH) ranged from 44% to 52% during the current study, with a notable decrease to 44% RH in the second week, which is likely to have contributed to reduced skin hydration levels during this period. However, this RH range is within acceptable limits.
Cravello and Ferri (2008) found a strong correlation between skin moisture and environmental parameters, particularly ambient temperature and RH, highlighting their significant impact.[44]

*Skin Elasticity*
In the context of Young's modulus (E) parameter, reductions of 11.38%, 3.81%, and 5.16% were observed for Creams A, B and C, respectively (Figure 5A). Cream A demonstrated a significant increase in percentage change after 4 weeks, compared to Cream B and Cream C. All cream types showed improved percentage changes in retraction time (R). However, in week 1, there was no improvement in the percentage changes of skin elasticity observed in Cream B and C (Figure 5B). Concerning the changes in viscoelasticity (VE), the benchmark product displayed a notably higher response in percentage change across all weeks of use, followed by the gel-based cream containing TG (Cream A) and the gel-based cream without TG (Cream B) (Figure 5C).
After 4 weeks of consistent application, skin elasticity was significantly enhanced relative to the baseline using Cream A. The observed improvement of Cream A can be attributed to the presence of potent phenolic compounds, specifically proanthocyanins (PAs), found in TG[45]. These compounds promote collagen synthesis, aiding in the transformation of soluble collagen to insoluble collagen, which offers enduring structural support and sustains the skin's extracellular matrix during skin maturation[46]. TG could also help to maintain cell membrane integrity by neutralizing free radicals and oxygen molecules, which is crucial for improving skin elasticity[47]. The antioxidant properties of TG counteract oxidative stress, contributing significantly to skin health and resilience. Various factors influence skin elasticity[48]. As people age, there was a noticeable decrease in skin elasticity[49], leading to signs of aging. Reduced elastin production leads to collagen and elastin clustering, diminishing skin viscoelasticity[50]. In a study involving 27 Asian females aged between 35 and 59, there was a noticeable enhancement in skin elasticity parameters following treatment with sunscreen formulation containing GSE for 6-weeks, particularly among participants over 40. This improvement was attributed to the polyphenolic structure of proanthocyanidins, which enabled cross-linking between collagen and elastin via multiple hydrogen and

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covalent bonds[51]. The findings suggest the potential of proanthocyanidins to impact skin elasticity, especially in older individuals. Another study revealed a strong correlation between age and changes in skin elasticity, particularly among women aged between 20 and 61. As individuals age, their skin gradually loses its ability to revert to its original structure after being stretched or deformed.

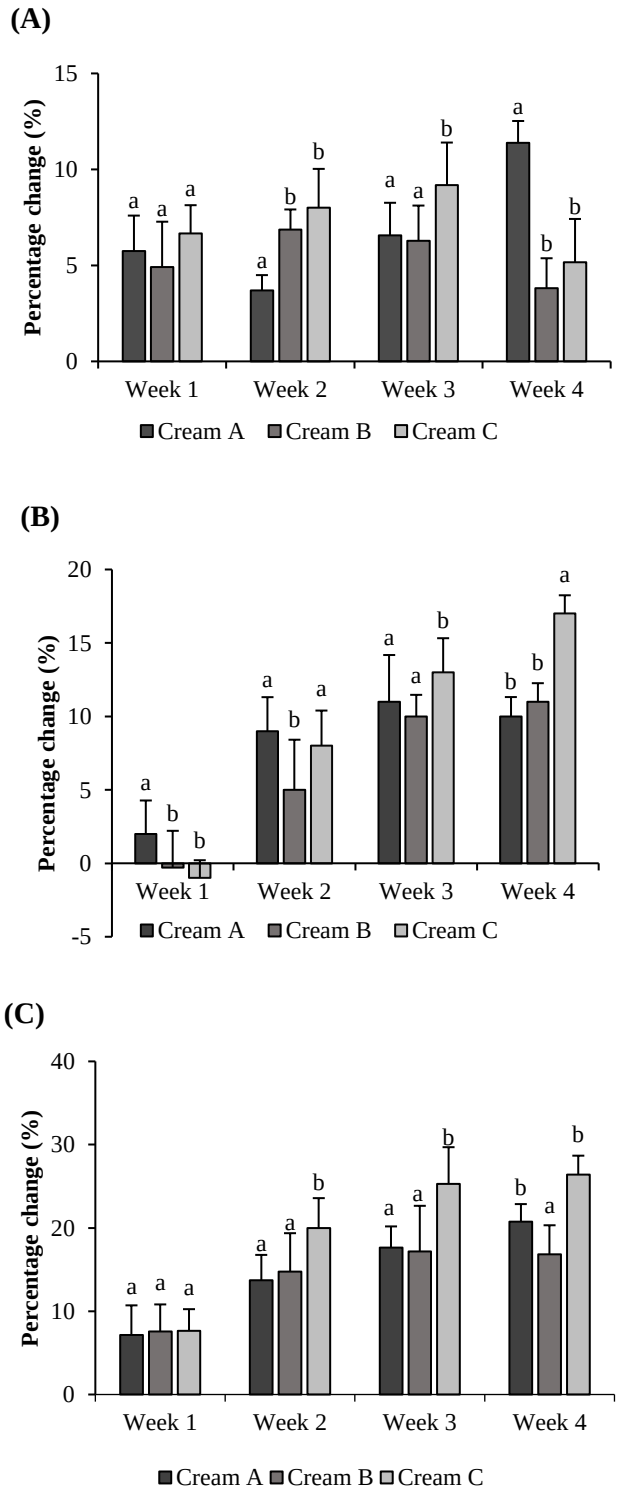


**Figure 5:** Percentage changes in skin elasticity after 4 weeks of application compared to baseline within each sample (n=26). Different letters (a-c) indicate a significant difference between samples in each week ($p < 0.05$)

This decrease in skin elasticity results in a diminished capacity to recover from wrinkles, folds, and other forms of deformation, a typical characteristic of aging skin.[52]

However, various other parameters and characteristics may also contribute to determining the resilience and suppleness of the skin. Exposure to the environment, specific anatomical regions, and genetic predispositions can all contribute to the overall condition and elasticity of the skin[53]. In our study, some participants reported frequent exposure to sunlight and detergent solutions due to their working conditions. At the same time, some of them were engaged in indoor work, and adhered to a more protective skincare regimen. This divergence in environmental exposure and skincare practices within the study population suggests that these lifestyles could contribute to skin aging variation. A comprehensive study involving 100 healthy subjects aged between 18 and 27 found that a regular use of moisturizers and sunscreen was correlated with improved skin elasticity, as attributed to a shorter R parameter. This effect was due to the hydrophilic nature of products that enhanced water retention in the stratum corneum and helped maintain skin elasticity[54]. Skin hydration is also associated with improved skin elasticity. While Cream A showed improvement across all skin elasticity parameters, it is interesting that Cream C demonstrated slightly superior improvement. Our study provided results consistent with others, showing that an improvement in skin hydration correlated with enhanced skin elasticity. The benchmark (Cream C) exhibited higher levels of skin hydration and improved skin elasticity compared to Creams A and B. Adequate hydration helps maintain the skin's natural moisture barrier, essential for preserving elasticity and promoting overall skin health[55]. According to Waqas et al. (2017), the application of TG extract in a water-in-oil (W/O) emulsion increased stratum corneum water content in 12 healthy male volunteers. This increase provided a smoother appearance and protected skin elasticity[56]. Increased hydration in both the epidermis and dermis loosens skin fiber connections, adding fluid to the dermal space and reducing tissue density. As a result, the skin becomes more fluid-like and less rigid, resulting in improved elasticity and flexibility.

## Conclusion

This study illustrates that tamarind gum could be successfully isolated from tamarind seeds and incorporated into a gel-based cream that improved overall skin appearance. The tamarind gum formulation showed skin-lightening effects by reducing the skin melanin index and increased stratum corneum water content, which helps to improve skin hydration, provide a smoother appearance, and protect skin elasticity. TG is a potentially valuable cosmetic active ingredient as well as a sustainable natural resource. Future research should focus on optimizing the formulation texture at higher TG concentrations, to balance efficacy with consumer appeal.

## Conflict of Interest

The authors declare no conflict of interest.

## Authors' Declaration

The authors hereby declare that the works presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.

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