ORIGINAL PAPER

NATURAL OIL-IN-WATER EMULSION WITH HYDROGLYCERIC TURMERIC EXTRACT: FORMULATION AND FUNCTIONAL CHARACTERIZATION

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Abstract. *The present study aimed to develop and evaluate a 100 % natural oil-in-water (O/W) emulsion containing hydroglyceric Curcuma longa L. (turmeric) extract for topical application. The formulation was prepared using sunflower oil, Olliva as an emulsifying agent, Xanthan gum as a stabiliser, and glycerin as a humectant, without incorporating synthetic active substances. The hydroglyceric turmeric extract was phytochemically characterized through spectrophotometric determination of total phenolic content and dicinnamoylmethane derivatives expressed as curcumin. The antioxidant activity of the developed emulsion was evaluated using the ABTS radical scavenging assay. The obtained emulsion was characterized by organoleptic evaluation, pH determination, viscosity analysis, spreadability assessment, centrifugation testing, creaming index determination, thermal stress evaluation, droplet size analysis, and freeze-thaw cycle testing. The developed formulation showed good physical stability, homogeneous appearance, and promising antioxidant potential, suggesting that it may represent a suitable natural-based topical delivery system for cosmetic and pharmaceutical applications.*

Keywords: *Curcuma longa; hydroglyceric extract, oil-in-water emulsion, physicochemical stability, antioxidant capacity.*

1. INTRODUCTION

In recent years, increasing attention has been directed toward the development of topical pharmaceutical and cosmetic formulations containing natural bioactive compounds, due to their therapeutic potential and favorable safety profile [1]. Among medicinal plants, *Curcuma longa* L. (turmeric) has attracted considerable interest due to its wide range of biological activities, mainly attributed to curcuminoids, especially curcumin, the principal active constituent of turmeric [2-5].

Turmeric has been extensively investigated for its antioxidant, anti-inflammatory, antimicrobial, and wound-healing properties [6,7]. These biological effects make turmeric a promising candidate for incorporation into topical formulations intended for skin protection and maintenance [8]. In addition, natural extracts are increasingly preferred in cosmetic and

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dermatological products due to the growing demand for plant-based, biocompatible ingredients [9].

However, the topical use of curcumin and turmeric-derived bioactive compounds may be limited by poor aqueous solubility, low stability, susceptibility to degradation, and challenges related to their homogeneous distribution within semisolid formulations. Therefore, incorporating turmeric extracts into colloidal systems, such as oil-in-water (O/W) emulsions, is a useful strategy to improve topical applicability, formulation homogeneity, and physicochemical stability [10,11].

O/W emulsions are suitable carriers for topical delivery due to their favorable sensory properties, ease of application, and enhanced spreadability on the skin surface. Moreover, these systems can facilitate the uniform distribution of lipophilic bioactive compounds within the formulation, while providing a pleasant texture and good user acceptability.

The stability of topical emulsions is an essential parameter influencing product quality, efficacy, and patient or consumer acceptability. Therefore, the evaluation of physicochemical characteristics such as pH, viscosity, spreadability, thermal stability, and resistance to phase separation is necessary for the development of stable and effective formulations.

The present study aimed to formulate and characterize an O/W emulsion containing hydroglyceric turmeric extract for topical application. The hydroglyceric extract was phytochemically characterized in terms of total phenolic content and dicinnamoylmethane derivatives expressed as curcumin equivalents, while the developed emulsion was evaluated for antioxidant activity and physicochemical stability through organoleptic, rheological, and stability investigations.

2. MATERIALS AND METHODS

2.1. MATERIALS

Curcuma longa rhizomes of Turkish origin were purchased from a local herbal supplier. Folin–Ciocalteu reagent, gallic acid, sodium carbonate, 2,4,6-tripyridyl-s-triazine (TPTZ), 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and potassium persulfate were purchased from Sigma-Aldrich Chemie GmbH (Sigma- Aldrich, Germany). Glycerin, xanthan gum, vitamin E, and Cosgard were obtained from an internal commercial source (Elemental, Romania). Distilled, purified water (Milli-Q system, Merck Millipore, Germany) was used as the aqueous phase of the O/W emulsion.

2.2. METHODS

2.2.1. Preparation of Hydroglyceric Turmeric Extract

The hydroglyceric turmeric extract was obtained from powdered *Curcuma longa* rhizomes using a glycerol-water mixture (40:60, w/w) as extraction solvent, at a vegetal product-to-solvent ratio of 1:10 (w/w). The turmeric powder was dispersed in the solvent mixture and subjected to ultrasonic-assisted extraction in an ultrasonic bath (Witeg Labortechnik, Germany) at 40°C for a defined period to enhance the release of bioactive

compounds from the vegetal material (Figure 1). Subsequently, the mixture was maintained under continuous stirring and protected from direct light to ensure efficient extraction. After extraction, the mixture was filtered (through Whatman filter paper), resulting in a homogeneous yellow-orange extract suitable for incorporation into the emulsion formulation. The obtained extract was stored in amber containers under refrigerated conditions (4°C) until further use.

Figure 1. Representative images of raw turmeric rhizomes, dry and ground, powdered turmeric, and the extraction procedure.

2.2.2. Chemical Characterization of Turmeric Extract

Determination of Total Phenolic Content

The total phenolic content of the turmeric hydroglyceric extract was determined using the Folin–Ciocalteu colorimetric method described by Singleton and Rossi [12]. Briefly, 0.5 mL of extract was mixed with 2.5 mL of 10% Folin–Ciocalteu reagent. After 5 min, 2.0 mL of 7.5% sodium carbonate solution was added. The reaction mixture was incubated in the dark at room temperature for 30 min, and the absorbance was measured at 765 nm using a VWR UV-6300 PC spectrophotometer (VWR International, Austria). Calibration curves were prepared using gallic acid and caffeic acid as reference standards. The total phenolic content was expressed as milligrams of gallic acid equivalents per gram of extract (mg GAE/g extract) and milligrams of caffeic acid equivalents per gram of extract (mg CAE/g extract). All tests were performed in triplicate, and the results were expressed as mean ± standard deviation.

Determination of Curcuminoids Expressed as Curcumin Equivalents

The content of dicinnamoylmethane derivatives expressed as curcumin was determined according to the method described in the European Pharmacopoeia, with minor modifications [13]. Prior to analysis, an appropriate dilution of the hydroglyceric extract was prepared in 96% ethanol to ensure adequate solubilization of curcuminoid compounds and to keep absorbance values within the spectrophotometer's linear range. The absorbance was measured at 425 nm using 96% ethanol as the blank, with a VWR UV-6300 PC spectrophotometer. The percentage of dicinnamoylmethane derivatives, expressed as curcumin, was calculated using the following equation:

$$Curcumin\ derivatives\ (\%) = \frac{A\ x\ 5000}{1607\ x\ m} \quad (1)$$

where: *A* represents the absorbance at 425 nm, *m* is the amount of plant material (g) corresponding to the hydroglyceric extract (g), *5000* is the correlation factor, and *1607* is the

specific absorbance of curcumin at 425 nm. All determinations were performed in triplicate, and the results were expressed as mean ± standard deviation.

2.2.3. Preparation of the O/W emulsion

The O/W emulsion using hydroglyceric extract was formulated using the ingredients listed in Table 1.

Table 1. Composition of the O/W emulsion using hydroglyceric extract

Ingredients	% (g)	Role in formulation
Hydroglyceric turmeric extract	1.0	Active ingredient
Sunflower oil	10.0	Oil phase
Olliva	4.0	Emulsifying agent
Glycerin	5.0	Humectant
Xanthan gum	0.2	Stabilizing and gelling agent
Vitamin E	0.3	Antioxidant
Cosgard	0.8	Preservative
Distilled water	Up to 100	Aqueous phase

The aqueous phase was prepared at 70°C by dispersing xanthan gum in glycerin under continuous stirring until complete homogenization was achieved. Distilled water was gradually added, followed by the incorporation of the hydroglyceric turmeric extract. The system was stirred for 20-30 minutes to ensure complete hydration of the polymer and the formation of a uniform gel.

The oily phase was prepared separately, also at 70°C. Sunflower oil was mixed with the olive oil (when the temperature reached 40°C). The oily phase was stirred until a homogeneous mixture was obtained. Vitamin E and Cosgard were added when the temperature reached 40°C.

Prior to emulsification, both phases were adjusted to the same temperature (40°C). The oily phase was slowly incorporated into the aqueous phase under mechanical stirring (700-800 rpm) for 10-15 minutes. A homogeneous yellow O/W emulsion was obtained and stored in opaque containers at 4-8°C and 25°C for stability studies.

2.2.4. Organoleptic evaluation

The organoleptic characteristics of the developed turmeric-loaded emulsion were evaluated by assessing appearance, colour, odour, texture, consistency, and homogeneity [14,15].

All evaluations were performed under standardized conditions at room temperature, ensuring constant lighting and environmental parameters. Each characteristic was qualitatively analyzed using predefined descriptive criteria to obtain a comprehensive characterization of the formulation.

Particular attention was given to parameters such as structural uniformity, phase separation, and spreadability behavior. The emulsion was additionally examined for possible changes in color, odor, or consistency during the storage period. The organoleptic evaluation provided important information on the formulation's physical stability, sensory properties, and suitability for topical application. The emulsion was monitored for 30 days and subsequently extended to 3 months.

2.2.5. pH determination

The pH values of the emulsion were monitored over 90 days to evaluate its chemical stability and compatibility for topical application, using a calibrated portable pH meter Consort 3040 (Consort, Bruxelles, Belgium). Measurements were performed on a diluted sample mixed with distilled water (1:10, w/w). Tests were done in triplicate, and the results were expressed as mean ± standard deviation.

2.2.6. Creaming index

The creaming index was determined to evaluate the tendency of the dispersed phase to migrate and form a separate layer during storage [16]. The emulsion samples were maintained at room temperature and analyzed after 24, 48, and 72 h.

The creaming index is calculated using the following formula:

$$IC(\%) = \frac{H_1}{H_2} \cdot 100 \quad (2)$$

where H_1 represents the height of the separated layer, H_2 represents the total height of the emulsion.

All determinations were performed in triplicate, and the results were expressed as mean ± standard deviation.

2.2.7. Centrifugation test

The physical stability of the formulation was additionally assessed by centrifugation at approximately 5 g of O/W emulsion at 3000 rpm for 30 minutes, using a benchtop centrifuge Hettich Micro 220R (Hettich Zentrifugen, Germany). Following centrifugation, the samples were visually examined for potential instability, such as phase separation or coalescence. Tests were done in triplicate, and the results were expressed as mean ± standard deviation.

2.2.8. Thermal stress test

The stability of the emulsion was investigated under different temperature conditions (4°C, 25°C, and 37°C) over a monitoring period of 30 days, subsequently extended to 3 months. The samples were periodically evaluated for modifications in appearance, consistency, and occurrence of instability phenomena [4]. Experiments were done in triplicate, and the results were expressed as mean ± standard deviation.

2.2.9. Freeze-thaw cycle test

Accelerated stability testing was performed by repeated freeze-thaw cycles to evaluate the emulsion's resistance to extreme temperature variations. The samples (approximately 10 g) were subjected to three successive cycles between –20 °C and +40 °C, each cycle lasting 24 h. Tests were done in triplicate, and the results were expressed as mean ± standard deviation.

2.2.10. Rheological behavior

The viscosity of the emulsion was determined using a FungiLab Smart rotational viscometer (Funilab, Spain), using spindle no. 7 at three rotational speeds (100, 150, and 200 rpm). Measurements were carried out at room temperature immediately after preparation (T_0) and during different time periods, in triplicate [17].

2.2.11. Spreadability evaluation

The spreadability of the emulsion was evaluated using Ojeda-Arbussa's method [17,18]. A 1 g sample was placed between two glass plates and subjected to increasing weights ranging from 10 to 200 g. The diameter of the spread area was measured after 1 minute, using the following formula:

$$Si = \frac{\pi \cdot di^2}{4} \quad (3)$$

where: S_i (mm²) is the spreading area obtained under the applied mass i (g), d_i is the mean diameter (mm) reached by the sample. Experiments were done in triplicate, and the results were expressed as mean ± standard deviation.

2.2.12. Droplet size

The droplet size distribution of the emulsion was evaluated using optical microscopy [4]. A small amount of the sample was placed on a glass slide and observed under the microscope, and the diameters of 100 droplets were measured using image analysis software. The mean droplet size and size distribution were expressed as mean ± SD, where n = 100.

2.2.13. Antioxidant activity

The *in vitro* antioxidant activity of the O/W turmeric emulsion was assessed using the adapted ABTS radical scavenging method, based on the ability of antioxidant compounds to decolorize the ABTS•+ radical [9].

For this, 5 g of emulsion was mixed with 25 mL of ethanol and mechanically stirred for 10 min. Then, the extraction process was further enhanced by sonication at 40°C for 30 min, followed by centrifugation at 5000 rpm for 10 min. The obtained supernatant was subsequently filtered and brought to a final volume of 25 mL.

The ABTS•+ radical solution was obtained by reacting ABTS with potassium persulfate, then incubating in the dark at room temperature for 12–16 h. Before use, the solution was diluted with ethanol to obtain an absorbance of 0.70 ± 0.02 at 734 nm.

Subsequently, 0.05 mL of different dilutions of supernatant was mixed with 4.95 mL of ABTS•+ reagent, and absorbance was recorded at 734 nm after 6 min of reaction, using a VWR UV-6300 PC spectrophotometer (VWR International, Austria). Tests were done in triplicate, and the results were expressed as mean ± standard deviation.

2.2.14. Statistical analysis

All results are presented as mean ± standard deviation (SD) from three independent experiments (n = 3). Statistical analysis was performed using XLSTAT software (version

2022.4.5). One-way analysis of variance (ANOVA) was used to evaluate the effect of storage time on pH and viscosity values. Differences were considered statistically significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1. Chemical Characterization of Turmeric Extract

Total polyphenolic content

The hydroglyceric extract of *Curcuma longa* L. exhibited a total phenolic content of 2.51 mg GAE/g extract and 2.86 mg CAE/g extract. These values confirm the presence of phenolic constituents in the obtained extract, indicating that the glycerol–water extraction system can recover bioactive compounds from turmeric. The detected phenolic content may contribute to the antioxidant potential of the extract and, consequently, to the functional properties of the developed O/W emulsion [19, 20].

Curcuminoid Content (Expressed as Curcumin Equivalents)

The hydroglyceric extract of *Curcuma longa* L. contained 59.5 mg/100 g extract of dicinnamoylmethane derivatives, corresponding to 0.0595%, expressed as curcumin equivalents. This value indicates the presence of curcuminoid compounds in the obtained extract. Although lower than those commonly reported for concentrated ethanolic or alcoholic turmeric extracts, the result suggests that the glycerol–water extraction system recovered curcumin-related constituents. Moreover, the use of a hydroglyceric solvent system is relevant for the development of biocompatible formulations intended for topical application [21-23].

3.1.2. Organoleptic characterization

The prepared emulsion exhibited a homogeneous semisolid appearance, with a creamy consistency and slightly glossy surface (Fig. 2). No phase separation or visible particles were observed during the evaluation period. The formulation presented a pale-yellow color characteristic of turmeric extract incorporation and a mild odor specific to the vegetal components and sunflower oil.

The emulsion spread uniformly across the surface without forming aggregates or discontinuities, indicating good homogeneity and adequate consistency for topical administration.

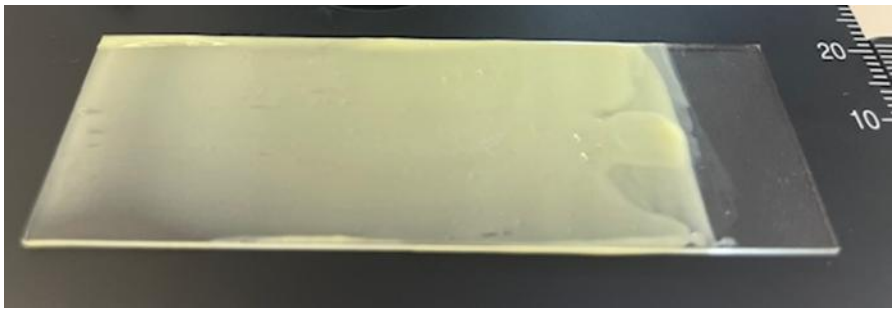

Figure 2. Homogeneous appearance and semisolid consistency of the developed O/W emulsion.

The emulsion remained homogeneous throughout the three-month storage period, with no evidence of phase separation, color changes, or alterations in consistency (Table 2). These findings indicate satisfactory long-term physical stability of the developed formulation.

Table 2. Long-Term Stability of the Turmeric-Loaded O/W Emulsion over a Three-Month Storage Period.

Time	Appearance	Phase separation	Color changes	Consistency
T0	Homogeneous	Absent	Absent	Creamy
T30	Homogeneous	Absent	Absent	Unchanged
T60	Homogeneous	Absent	Absent	Unchanged
T90	Homogeneous	Absent	Absent	Unchanged

3.1.3. pH Evaluation

The pH values of the turmeric-loaded O/W emulsion were monitored over a 90-day storage period to assess the formulation's chemical stability and suitability for topical application. The data obtained are presented in Table 3.

The pH values ranged from 6.18 ± 0.03 at T0 to 5.79 ± 0.01 at T90. A gradual decrease in pH was observed during the first 60 days of storage, followed by stabilization of the values between T60 and T90. Despite this slight reduction, all recorded values remained within the skin's physiological pH range, indicating good compatibility of the formulation for topical application.

The low standard deviation values recorded throughout the study demonstrate good reproducibility of the measurements and homogeneity of the emulsion system. Moreover, the absence of abrupt pH fluctuations suggests satisfactory chemical stability during long-term storage. The stabilization of pH values after 60 days further indicates that no significant degradation processes occurred within the emulsion matrix over the 90-day evaluation period.

Table 3. Evolution of pH values of the turmeric-loaded O/W emulsion during 90 days of storage.

Time	pH values (n = 3)			Mean ± SD
T0	6.18	6.21	6.15	6.18 ± 0.03
T7	6.11	6.12	6.13	6.12 ± 0.01
T14	6.09	6.06	6.03	6.06 ± 0.03
T21	5.92	5.94	5.96	5.94 ± 0.02
T30	5.89	5.85	5.87	5.87 ± 0.02
T60	5.77	5.75	5.76	5.76 ± 0.01
T90	5.78	5.79	5.80	5.79 ± 0.01

A gradual decrease in pH was observed up to day 60, followed by stabilization of the values until day 90, indicating good long-term chemical stability of the emulsion. The relatively low SD values across all determinations demonstrate good reproducibility of the measurements and homogeneity of the emulsion system (Fig. 3). Although pH decreased

slightly over time, no abrupt variations were observed, and all values remained within the physiological pH range of the skin. One-way ANOVA revealed a statistically significant decrease in pH during storage ($p < 0.05$); however, the magnitude of this change was limited and did not compromise the formulation's suitability for topical application.

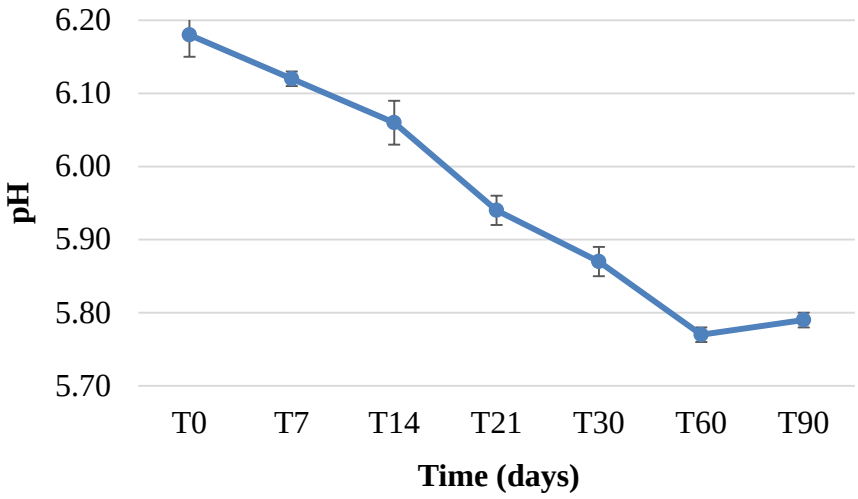

Figure 3. pH stability profile of the turmeric-loaded O/W emulsion during 90 days of storage. Error bars represent standard deviation (mean ± SD, n = 3).

3.1.4. Creaming Index

The calculated creaming index was 2%, indicating a low degree of phase separation and good physical stability of the emulsion system. The limited creaming observed may be associated with the presence of xanthan gum, which increases the viscosity of the continuous phase and reduces droplet mobility, as well as with the emulsifying properties of Olivem® 1000, which contribute to the stabilization of the oil–water interface. These results suggest that the selected formulation components effectively maintained the physical stability of the emulsion during the evaluation period [24].

3.1.5. Centrifugation Test

No visible phase separation or significant changes in appearance were observed after centrifugation. The O/W emulsion maintained its initial homogeneity and consistency, confirming good resistance to mechanical stress conditions.

3.1.6. Thermal stress test

The formulation maintained a relatively homogeneous appearance across all tested temperatures (4 °C, 25 °C, and 37 °C), with no evident phase separation. No significant changes in color or consistency were observed during storage, indicating satisfactory thermal stability of the emulsion. These findings demonstrate the ability of the formulation to withstand temperature variations without undergoing visible destabilization.

In addition, the formulation was monitored for up to 90 days under storage at 4 °C, 25 °C, and 37 °C. No visible phase separation, creaming, color changes, or consistency alterations were observed during the evaluation period, confirming the long-term physical stability of the developed emulsion.

3.1.7. Freeze-thaw cycle test

Visual analysis performed after each cycle showed no evidence of phase separation, color modification, or loss of homogeneity. The results demonstrated that the emulsion maintained its physical stability under severe thermal stress.

3.1.8. Rheological behavior

The results (Table 4) revealed a progressive decrease in viscosity with increasing rotational speed for all monitoring intervals, indicating pseudoplastic flow behavior characteristic of semisolid emulsified systems. At 100 rpm, viscosity values decreased from 2890 ± 18.52 mPa·s (T0) to 2397 ± 2.00 mPa·s (T90). Similar trends were observed at 150 rpm, where viscosity values decreased from 2044 ± 18.68 mPa·s to 1544 ± 2.00 mPa·s, and at 200 rpm, where values decreased from 1715 ± 2.00 mPa·s to 1168 ± 2.00 mPa·s over the same storage period. Although viscosity decreased significantly during storage ($p < 0.05$), the observed changes were gradual and did not compromise the formulation's physical stability.

Table 4. Viscosity values of the turmeric-loaded O/W emulsion at different rotational speeds.

Time [days]	Mean ± SD		
	100 rpm	150 rpm	200 rpm
T0	2890 ± 18.52	2044 ± 18.68	1715 ± 2.00
T7	2810 ± 22.54	1928 ± 8.72	1574 ±13.53
T14	2738 ± 15.52	1721 ± 12.49	1387 ± 4.58
T21	2441 ± 22.72	1641 ± 8.00	1262 ± 9.17
T30	2415 ± 17.52	1574 ± 14.42	1182 ± 6.00
T60	2412 ± 1.00	1558 ± 3.00	1177 ± 1.00
T90	2397 ± 2.00	1554 ± 2.00	1168 ± 2.00

A gradual reduction in viscosity (Figure 4) was observed during the first 30 days of storage, followed by stabilization of the rheological parameters between T60 and T90.

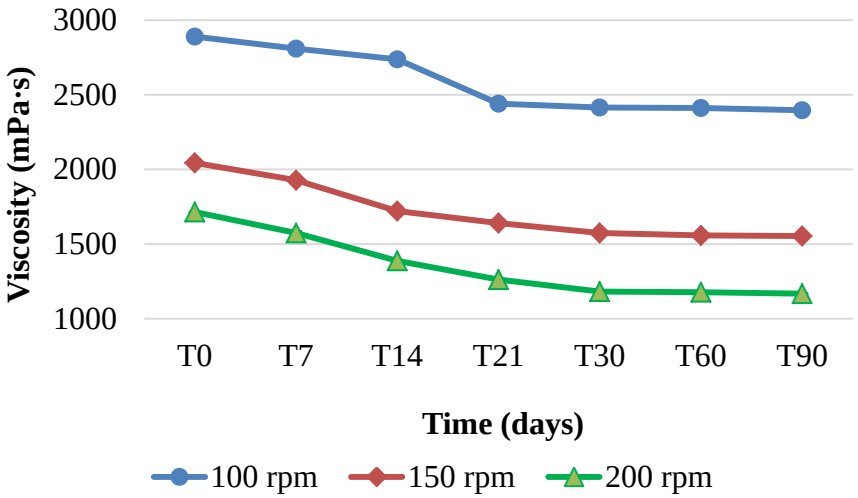

Figure 4. Rheological profile of the turmeric-loaded O/W emulsion at different rotational speeds during storage. Error bars represent standard deviation (mean ± SD, n = 3).

This behavior suggests that the emulsion maintained good rheological stability throughout the three-month evaluation period. Furthermore, the pseudoplastic flow behavior is advantageous for topical application, facilitating both product spreading and retention on the skin surface.

3.1.9. Spreadability evaluation

The spreadability area increased progressively with the applied weight, from 748.94 mm^2 at 10 g to 3032.72 mm^2 at 200 g (Table 5). The obtained results indicate good extensibility of the formulation and its ability to spread uniformly on the skin surface under low mechanical stress. The gradual increase in spreading area with increasing applied mass suggests appropriate rheological characteristics for topical administration.

Table 5. Spreadability parameters of the turmeric-loaded O/W determined by the Ojeda-Arbussa method.

Time [s]	Mass [g]	Diameter [mm]	Spreadability area [mm^2]
60	10	30.88	748.94
60	20	32.18	813.32
60	30	34.02	908.99
60	50	37.09	1080.45
60	100	47.15	1746.04
60	150	59.39	2770.23
60	200	62.14	3032.72

The high coefficient of determination (R^2 = 0.9788) indicates a nearly linear relationship between the applied mass and the spreadability area, demonstrating the ability of the formulation to distribute uniformly under increasing mechanical stress (Fig. 5). This behavior is characteristic of stable O/W emulsions intended for topical pharmaceutical and cosmetic applications.

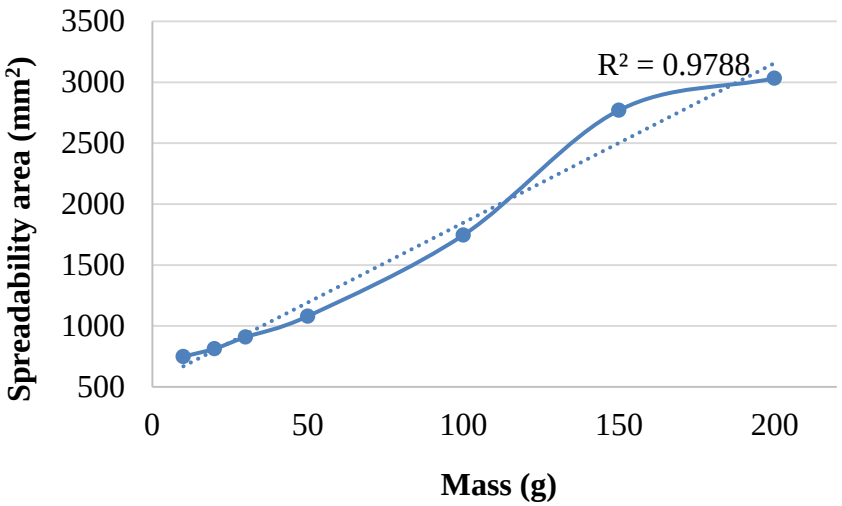

Figure 5. Relationship between the applied mass and the spreadability area of the turmeric-loaded O/W emulsion.

3.1.10. Droplet size

The emulsion exhibited a relatively homogeneous droplet-size distribution, with a mean droplet diameter of 8.6 ± 2.1 µm (n = 100), indicating adequate dispersion of the oily phase within the hydrophilic continuous phase. The obtained mean droplet diameter is consistent with values commonly reported for topical cosmetic emulsions containing plant-derived ingredients, such as those described by Stanciu et al. in emulsions enriched with botanical extracts [24].

3.1.11. Antioxidant activity

The antioxidant activity of the turmeric-loaded emulsion was assessed using the ABTS radical scavenging assay. The formulation exhibited the ability to neutralize ABTS•+ radicals, with the highest inhibition percentage (67.26%), recorded for the 0.8 mL sample volume. This result indicates a considerable free-radical scavenging capacity of the developed emulsion.

3.2. DISCUSSIONS

The hydroglyceric extract of *Curcuma longa* L. exhibited a total phenolic content of 2.51 mg GAE/g extract and 2.86 mg CAE/g extract. Considering the extraction ratio employed (1 g plant material/10 mL extraction solvent), the phenolic content corresponded to approximately 27.6 mg GAE/g plant material. This value is within the range reported in the literature for turmeric extracts obtained using aqueous, hydroalcoholic, or other polar solvent systems [25].

Variations in the total phenolic content reported for *Curcuma longa* are commonly attributed to differences in cultivar, geographical origin, post-harvest processing, extraction solvent composition, extraction time, temperature, and analytical methodology. In general, hydroalcoholic extracts tend to yield higher concentrations of phenolic compounds than aqueous extracts, whereas hydroglyceric systems provide a useful balance between extraction capacity, biocompatibility, and suitability for topical formulation.

The phenolic content obtained in the present study indicates that the glycerol–water extraction system effectively recovered significant amounts of phenolic constituents from turmeric. These compounds, together with curcuminoids, contribute to the antioxidant properties of turmeric extracts and may partly explain the radical-scavenging activity observed in the ABTS assay. Therefore, the hydroglyceric extract can be considered a suitable source of natural bioactive compounds for incorporation into topical O/W emulsion systems.

The developed turmeric-loaded O/W emulsion exhibited satisfactory physicochemical stability throughout the evaluated storage period. The absence of visible phase separation and the low creaming index indicate efficient emulsification and adequate stabilization of the dispersed phase. These results may be related to the combined contribution of the emulsifying system and xanthan gum, which can increase the viscosity of the continuous phase and reduce droplet mobility.

The pH values remained within the physiological range for skin, which is essential for topical formulations intended for dermal application. Similar pH stability profiles have been reported for turmeric-based emulsified systems described in previous studies, supporting the compatibility of curcumin-containing formulations with topical use.

Rheological analysis showed pseudoplastic behavior, with viscosity decreasing as shear rate increased. This flow behavior is advantageous for topical formulations, facilitating product spread during application while maintaining adequate consistency at rest. Spreadability results further confirmed the formulation's suitability for dermal use, indicating good extensibility and uniform distribution on the skin surface.

Stability tests under centrifugation, thermal stress, and freeze–thaw conditions demonstrated that the emulsion system resisted mechanical and temperature- induced instability. Overall, these findings suggest that the developed O/W emulsion may be a

promising carrier for turmeric bioactive compounds in cosmetic and topical pharmaceutical applications.

The antioxidant activity of the turmeric- loaded emulsion can be attributed to phenolic compounds and curcuminoids extracted from Curcuma longa L. These bioactive constituents act as radical scavengers via hydrogen atom transfer and electron donation, thereby reducing reactive radicals. The total phenolic content of the hydroglyceric extract, together with the presence of dicinnamoylmethane derivatives expressed as curcumin equivalents, supports the antioxidant effect observed in the ABTS assay.

The 67.26% inhibition observed for the 0.8 mL sample indicates a substantial radical-scavenging capacity of the developed formulation. Similar studies have reported that turmeric extracts exhibit significant antioxidant activity, closely associated with their phenolic and curcuminoid composition. Yang et al. reported a positive correlation between the phenolic profile of Curcuma longa extracts and their antioxidant potential, while Choi et al. demonstrated that curcuminoid- rich turmeric extracts effectively neutralize free radicals through electron- transfer reactions [26, 27].

Although direct comparison with literature data is difficult due to differences in extraction procedures, solvent systems, extract concentrations, and assay conditions, the antioxidant activity observed in the present study suggests that the hydroglyceric extract retained its bioactive properties after incorporation into the O/W emulsion system. This finding is particularly relevant to topical formulations, where antioxidant compounds may help protect against oxidative stress and support skin barrier function [28-31].

A limitation of the present study is the absence of a control emulsion without turmeric extract, which would allow a more precise assessment of the extract's contribution to the formulation's antioxidant activity and physicochemical properties. Future studies will include blank formulations and different extract concentrations to better elucidate the role of turmeric-derived bioactive compounds in the overall performance of the emulsion. In addition, further biological evaluations, including in vitro cytocompatibility, wound- healing, anti-inflammatory, and skin permeation studies, will be performed to assess the potential applicability of the formulation in cosmetic and dermatological products.

4. CONCLUSIONS

The present study demonstrated the feasibility of developing a turmeric-loaded O/W emulsion with suitable physicochemical and functional properties for topical application. The hydroglyceric extract obtained from *Curcuma longa L.* contains phenolic compounds and curcuminoid derivatives, confirming its potential as a natural bioactive ingredient. The developed turmeric-loaded hydroglyceric O/W emulsion combines good physicochemical stability, appropriate rheological behavior, skin-compatible pH, and relevant antioxidant activity, supporting its potential use as a natural topical formulation for cosmetic and dermopharmaceutical applications. Further biological and dermatological investigations are required to confirm its efficacy and safety for topical use.

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