applied sciences

MDPI

Article

Diversity Challenge in Skin Care: Adaptations of a Simple Emulsion for Efficient Moisturization across Multiple Geographies

Alicia Roso *, Catherine Kern, Sophie Cambos and Christine Garcia

Research & Innovation, Seppic, 127 Chemin de la Poudrerie, 81100 Castres, France
* Correspondence: alicia.roso@airliquide.com; Tel.: +33-563726969

Featured Application: The development of inclusive skin care products could be inspired by the flexibility of the formulation with fewer ingredients at lower doses and the robustness of the moisturizing effect observed on a wide range of skins and environments.

Abstract: Moisturization is a primary need in skin care. This study aimed to investigate whether the C12-C20 glucolipid emulsifier could provide minimalist water-in-oil emulsions (i.e., a minimum number of ingredients, in reasonable quantities) with a significant moisturizing effect across multiple geographies even if the emulsion structure needed to be adapted to meet local expectations. Four structures were tested containing a stabilizer and an oily phase that were adapted to address consumers' skin feel expectations in each location. In vivo corneometry and transepidermal water loss (TEWL) measurements were carried out on volunteers with dry skin up to 24 h after application (leg or forearm; phototypes I to VI). The first investigation was completed in France comparing corneometry measurements to the control without the emulsifier and an untreated area. Studies were then performed in Brazil, India and Mauritius, combining corneometry and TEWL assessments. Significant increase in skin capacitance was observed in the four countries, compared to the untreated area, at 5/6/8 h after application and up to 24 h. The effect was also significant versus the control in the French study at 5 h. A significant decrease in TEWL compared to the untreated area was observed concurrently in Brazil, India and Mauritius.

Keywords: skin care; cosmetic formulation; emulsion; moisturization; skin barrier; in vivo; multiple geographies; few ingredients; glucolipid emulsifier

Citation: Roso, A.; Kern, C.; Cambos, S.; Garcia, C. Diversity Challenge in Skin Care: Adaptations of a Simple Emulsion for Efficient Moisturization across Multiple Geographies. *Appl. Sci.* **2023**, *13*, 13175. https://doi.org/10.3390/app132413175

Academic Editor: Anna Waszkielewicz

Received: 17 November 2023
Revised: 30 November 2023
Accepted: 4 December 2023
Published: 12 December 2023

1. Introduction

Hydration is a fundamental need in skin care all over the world as evidenced by regular reviews on moisturizing agents, both for cosmetic and therapeutic uses [1–3]. Water content, ideally between 10% and 15%, is essential to maintain skin health, with optimized barrier function. Skin moisturization also supports mechanical properties of the skin (plasticity) and a smooth surface appearance [4]. Some areas of the body such as the face and extremities are more likely to dry out; localized, drier facial skin was also found on subjects presenting with a "normal skin" condition, without visible signs of roughness [5,6]. Aging also increases the propensity for skin dryness, with disparities depending on the body area [7–9]. Environmental factors (e.g., climatic conditions) additionally impact skin health. While climatic change and the consequences of global warming on humans are a matter of debate, excessive temperature and reduction in relative humidity caused by the land warming faster than the sea, at least during transient extreme climatic events, would result in more people with dry skin and an increased need for moisturizing care [10].

This background is driving the development of new active ingredients, targeting different levels of biological moisturization mechanisms and multifunctional ingredients to ensure long-term biological efficacy. In parallel, increasing consumer demands for immediate instant efficacy have been observed in recent decades. The advent of social

media and selfies reinforced these expectations of immediacy. Beyond its role to deliver the active ingredient, the formulated vehicle (also called the excipient) can bring instant effects at the skin surface [11]. Excipients can have visible actions, such as blurring lines, or perceivable effects, such as softened–moisturized–replenished skin or a sensation of comfort. In some applications, such as daily body moisturizers, formulations often do not contain any moisturizing active ingredient [10], especially when affordability is becoming an issue, so excipients should be selected carefully.

Containing both oil and water, emulsions are the most used vehicles when looking for moisturization [3,11,12]. The emulsion composition brings three mechanisms into play: occlusive film-forming, emollience (i.e., improved skin plasticity and texture typically brought by oils and hydrophobic compounds) and attracting/holding water in the skin through humectant (hygroscopic) ingredients. While water-in-oil emulsions are sometimes used for very dry skins, oil-in-water (O/W) emulsions are the preferred versatile formulations for moisturization purposes. The wide variety of achievable textures make it possible to adapt for any skin type, any functionality (e.g., sun protection, make-up) and any application area (e.g., face care, body care). Moreover, the adjustable external aqueous phase content, resulting in varying degrees of freshness on contact, makes it suitable for all types of climates, including hot and humid regions [12].

Multiple surfactant structures are available to stabilize these O/W emulsions. Among classes of non-ionic environmentally friendly compounds, alkyl polyglucosides (APG) have achieved a dominant position in the last two decades. In Europe, APGs accounted for around a 23% share of the global sugar-based surfactants market at the end of 2021 [13]. APGs are glucolipid molecules based on renewable glucose and fatty alcohol. Those with short and medium-length fatty chains (e.g., C8–C10, C12–C16) exhibit foaming properties, and longer C16–C18 chains have an emulsifying capacity and are widely used in the cosmetic industry. An O/W emulsifier based on C16–C18 alcohol (INCI: cetearyl alcohol (and) cetearyl glucoside) was found to create both lamellar liquid crystalline bilayers around the oil droplets, visualized as a birefringent Maltese cross by polarized light microscopy, and lamellar gel networks built in the continuous aqueous phase, substantiated by transmission electron microscopy (TEM) observation. This dual organization lies behind its ability to stabilize a wide range of oil types and concentrations. Lamellar structures around oil droplets help to prevent coalescence and viscoelastic lamellar gel imparts suspending properties. Moreover, some water can be partially fixed inside the gel network, between the lamellae, supported by hydrogen bonds [14,15]. The “entrapped water”, acting as a water reservoir, was assumed to play a role in skin hydration. In vivo moisturizing effects of simple placebo emulsions containing 5% and 7% emulsifier, combined with 17% and 20% emollient, respectively, were confirmed using corneometry and measurements of transepidermal water loss (TEWL) [16,17]. Significant effects were described 15 min [16] and 60 min [17] after a single application on the forearm. The contribution of C16–C18 APG in skin moisturizing was also reported in the presence of various active ingredients, when used as a single emulsifier, and when coupled with a similar glucolipid structure based on a C20–C22 fatty chain [18,19].

Glucolipid emulsifier based on wide fat cuts, from medium C12 chains to long C22 chains (i.e., INCI: C14–C22 alcohols (and) C12–C20 alkyl glucoside) is less known and poorly documented in the literature. Its main specificity lies in obtaining stable sprayable to thick textures depending on the emulsion composition, associated with a characteristic light skin feel, very different from the C16–C18 variant [20]. Varying the texture and consistency allows multiple applications, on the whole body, small and large areas, including the face and difficult to reach areas such as those with hair. One publication reported the use of C12–C20 glucolipid emulsifier (at 2%) in combination with short cut C20–C22 glucolipid emulsifier (at 8%) to formulate stable emulsions with up to 10% glycolic acid [21]. Microscopic observation of the placebo with polarized light revealed lamellar phases formed by the emulsifying system surrounding oil droplets. A short-term moisturizing effect using assessment of transepidermal water loss (TEWL) was also visualized 30 min

and 1 h after application of the placebo cream. The absence of irritation in human studies with 10% glycolic acid led to the assumption that the vehicle based on these emulsifying combinations could contribute to reducing the undesirable effects of glycolic acid. A second paper [22] displayed formulations combining the C12–C20 glucolipid emulsifier (at 2%) and other APGs from C16–C18 or C12–C18 (at 4%) to stabilize mineral waters (thermal spring waters). Significant moisturizing properties were reported using in vivo corneometry measurements 1 h and 24 h after application, for all formulations. Mineral waters enhanced the moisturizing effect compared to the placebo. In both cases, the C12–C20 glucolipid emulsifier was not used alone. Moreover, the studies reporting moisturizing effects were conducted in the same European country. Therefore, this work aimed to investigate the immediate moisturizing effect of four minimalist O/W emulsion structures, using C12–C20 glucolipid emulsifier alone at a realistic dosage of 3%, on various skin types subjected to different climates and environments on a daily basis. The C12–C20 glucolipid emulsifier was selected for its light skin feel, suitable for warm climates. The emulsion structures reflected the formulation habits in different geographical locations. The formulations had different dosages and nature of oils to meet local consumers' sensorial expectations and contained a stabilizing rheology modifier at the concentration required for stability. As the selection of oily phase was supposed to have an influence on the result, high concentrations of the oily phase and oils with long fatty chains were hypothesized to be the most favorable conditions for achieving a moisturizing effect. Experiments were conducted in four locations: Brazil, France, India and Mauritius. Investigations were performed soon after application and followed up a few hours later, up to 24 h. The study intended to determine whether C12–C20 glucolipid emulsifier would allow the composition to be varied (to adapt to different skin types, environmental conditions, and use preferences) while providing a significant moisturizing effect of the emulsions, across multiple geographies.

2. Materials and Methods

2.1. Compositions and Characteristics of the Formulations

Four simple O/W emulsions, with as few ingredients as possible and without any active ingredient, were prepared. The compositions described in Table 1 contained a low dose of (C14–C22 alcohols (and) C12–C20 alkyl glucoside) emulsifier (Figure 1). The final ingredient retained the excess fatty alcohol used in the glycosylation reaction. Keeping formulations as simple as possible was necessary to understand the contribution of ingredients. The emulsion structure was adapted to be as close as possible to formulation habits and consumer expectations in the geographical region in which the product was evaluated. The skin feel was tailored to be more or less light depending on the climate by choosing a suitable oily phase (nature of oils/emollients, and dosage) [23–26]. To restrict the variations and number of ingredients, local expert formulators were requested to swap between 4 oils: one mixed decanoyl and octanoyl glycerides (INCI: caprylic/capric triglyceride), one linear ester (INCI: coco-caprylate/caprate), two branched esters (isononyl isononanoate and cetearyl ethylhexanoate). As the purpose was to determine whether C12–C20 glucolipid emulsifier would allow the composition to be varied while providing a significant moisturizing effect, oils without known occlusive effect were preferred to minimize their interference, assuming that if versatility could be demonstrated on these oils, it would be even more true with occlusive "heavier" oily phases. Esters with different fatty chain lengths were proposed to modulate the skin feel based on the previous sensory ranking of expert panelists (medium light: cetearyl ethylhexanoate, ester of C16–C18 fatty alcohol and branched C8 fatty acid; light: coco-caprylate/caprate, ester of C12–C16 fatty alcohol and C8–C10 fatty acid: very light: isononyl isononanoate, ester of branched C9 fatty alcohol and branched C9 fatty acid). Caprylic/capric triglyceride was proposed as one of the most frequently used emollients in skin care formulas worldwide but was not used alone due to its lack of glide and too rich skin feel, as reported by the formulators. For the study in France, cetearyl ethylhexanoate alone was chosen for its balanced medium light skin feel and good spreading properties (E1, Table 1). Caprylic/capric triglyceride was basically

chosen for its popularity in Brazil and India. Both Brazil and India chose to combine it with coco-caprylate/caprate to improve spreading. In Brazil, isononyl isononanoate was also added at the minimum concentration to speed-up the absorption time (E2, Table 1; caprylic/capric triglyceride and coco-caprylate/caprate were used at a higher dosage than isononyl isononanoate due to their natural origin). For India, the formulator preferred to keep the 2 oils of natural origin and reduced the total content in the oily phase to lighten the skin feel (E3, Table 1). The highest concentration of oily phase, adapted to a lower temperature, was chosen for the study in France. Oily phase content was reduced for warmer climates to avoid tackiness and oily sensation (Figure A1 in Appendix A visualizes the formulation adaptations according to the targeted geographical area). For the study in Mauritius, as less interest was expressed in caprylic/capric triglyceride, it was decided to keep a simple bio-based emulsion with a light ester with good spreading properties: coco-caprylate/caprate (E3, Table 1). Skin sensory profile was not assessed but, depending on the oil phase composition, the skin feel was expected to be from medium light to very light (opposite to rich) with the following relative positioning on the "light" criterion: E4 (10% light ester) > E3 (10% combination of medium light triglyceride with very light ester) > E2 (12% combination of medium light triglyceride with light esters) > E1 (20% medium light ester based on a longer fatty chain).

Table 1. Formulations tested.

Ingredients % (*w*/*w* AS *)/Formula Code	E0	E1	E2	E3	E4
Demineralized Water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100
C14–C22 Alcohols (and) C12–C20 Alkyl Glucoside	0.0	3.0	3.0	3.0	3.0
Cetearyl Ethylhexanoate [a]	20.0	20.0	0.0	0.0	0.0
Caprylic/Capric Triglyceride [b]	0.0	0.0	5.0	5.0	0.0
Coco-caprylate/Caprate [c]	0.0	0.0	4.0	5.0	10.0
Isononyl Isononoate [d]	0.0	0.0	3.0	0.0	0.0
ATBS rheology modifier [e]	0.8	0.2	0.8	0.6	0.7
Preservative system [f]	1.5	1.5	1.5	1.5	1.5
pH at D1/M3 **	6.2/6.2	6.2/6.2	6.1/6.1	5.9/6.0	6.2/6.1
Viscosity (Brookfield™ LV Speed 6 in mPa.s) at D1	72,000	7500	23,300	67,000	65,000
Stability at Room temperature	Stable M3	Stable M3	Stable M3	Stable M3	Stable M3
Stability at 45 °C	Stable M1 ***	Stable M3	Stable M3	Stable M3	Stable M3

* AS: active substance; ** D1/M3: 1 day after manufacturing/3 months after manufacturing. M1 ***: 3 months after manufacturing a: Oil phase (Seppic, La Garenne-Colombes, France). b: Oil phase (Stéarinerie Dubois, Boulogne-Billancourt, France). c: Oil phase (Seppic, France). d: Oil phase (Seppic, France). e: Stabilizing polymer based on acrylamide tertiary-butyl sulfonic acid (Seppic, France). f: Preservative system: phenoxyethanol and ethylhexylglycerin 0.8% + phenyl propanol and caprylyl glycol and propanediol and tocopherol 0.5% (Schulke & Mayr, Norderstedt, Germany).

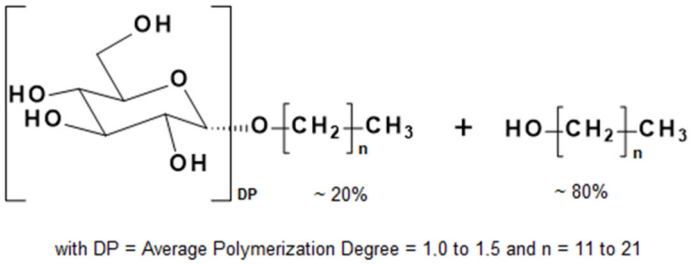

Figure 1. Structure of C12–C20 glucolipid emulsifier. Average molecular weight: 333 g·mol^{-1}.

A stabilizing polymer was added at the concentration required to stabilize the formulation for at least three months at room temperature and 45 °C (variations from 0.2% AS—active substance—to 0.8% depending on composition). Stability of formulations was followed by a periodic macroscopic observation both at room temperature and after storing

in an oven at 45 °C (observation time: one day, seven days, one month and three months after manufacturing). All the formulas studied were stable up to 3 months after manufacturing (Table 1) except the control formulation E0, which was only stable up to one month at 45 °C. Stability was confirmed by the technician before starting measurements. In addition, pH monitoring confirmed the stability of the materials during aging in accordance with small viscosity variations (less than the error of the device around 20%). This kind of rheology modifier is widely used for its soft and non-sticky skin feel and is not known to trigger any moisturizing effect. A control formulation without the glucolipid emulsifier (E0) containing only the rheology modifier (at the maximum concentration used in the emulsions) and the emollient was added in the first study in France to check any potential effects. The respective controls of each formulation with the same oily phase as E2, E3, E4 (without emulsifier) were not stable enough to be tested but it was hypothesized that if a moisturizing effect was not visible to E0, there was very little chance that it would be visible to other controls with a lower concentration of ingredients.

All formulations were prepared by emulsifying the oily phase, containing the emulsifier and the rheology modifier, in water at 75 °C using a rotor/stator turbine for 10 min. Emulsions were then cooled under stirring, and a preservative was added at 30 °C. The pH was adjusted around 6.0 (±0.2) after complete cooling using citric acid.

A safety assessment was conducted on all formulations by an expert toxicologist (ERT) on all formulations, according to the toxicological profile of each ingredient. Microbiological cleanliness was also verified and a single patch test protocol, applied for 48 h, confirmed good skin tolerance of each formulation prior to the study.

2.2. Design of Clinical Studies

Nowadays, with populations moving all over the world, trying to fix skin types becomes more and more complex. In this context, skin phototype, a clinical ranking developed by Thomas B. Fitzpatrick [27], and based on self-reported sensitivity to the damage induced by ultraviolet exposure, was used as a tool to reflect skin diversity. The countries in which the studies were carried out were therefore chosen to represent the diversity of both phototypes and living conditions (climate: variations in temperature and humidity; environment: wind, pollution). Recruitment in France focused on phototypes II to IV, in Brazil on phototypes III to V, in Mauritius on phototypes IV to VI, and in India on phototypes III to V (Table 2). Measurements were taken from dry skin areas according to corneometry inclusion criteria [28].

Table 2. Summary of the design of the studies.

Country of the Study		France	Brazil	India	Mauritius
Number of Volunteers		20	22	36	19
Age		44 to 65	19 to 58	18 to 40	19 to 52
Phototypes		II, III, IV	III, VI, V	III, IV, V	IV, V, VI
Inclusion criteria: Dry skin	Corneometry (a.u.)	<50	≤40	<30	≤40
	TEWL ($g/m^2/h$)	ND *	≥6	ND *	≥6
Tested area		Leg 35 cm^2	Forearm 10 cm^2	Forearm 9 cm^2	Forearm 24 cm^2
Controlled environment	Temperature	22 ± 2 °C	22 ± 2 °C	20 to 25 °C	22 ± 2 °C
	Relative humidity	50 ± 10%	55 ± 5%	50 ± 10%	50 ± 10%
Tested formula		E1, E0	E2	E3	E4
Applied dose		5.7 µL/cm^2	2 µL/cm^2	2 µL/cm^2	2 mg/cm^2
Outcomes	Skin capacitance	T0/1 h 30/5 h	T0/8 h/24 h	T0/6 h/24 h	T0/6 h/24 h
	TEWL	ND *	T0/8 h/24 h	T0/6 h/24 h	T0/6 h/24 h

* Not Done.

The studies were carried out, using non-invasive biophysical measurements, in accordance with ethical rules, following the principles of the Helsinki declaration and local rules in each country. Volunteers gave written informed consent to participate and all steps were taken to protect the privacy rights and welfare of the participants. Each study was monocentric and randomly conducted after a wash-out period of 48 h: no personal care products were applied in the 48 h preceding the inclusion visit.

The studies were deployed in other geographical regions after obtaining the results of the study carried out in France which represented the most favorable formulation conditions for skin moisturization considering the oily phase composition and dose (ester based on a long fatty chain at the highest dosage: 20%). This progression in the development of the work explains why the measurement points were extended from the first study carried out in France only up to 5 h (corneometry assessment only) to later measurement points up to 24 h in the subsequent studies (corneometry and TEWL).

2.2.1. Clinical Study in France

The products were double-blind tested on the legs (IDEA, Bordeaux, France; study performed in spring). Twenty women volunteers from phototypes II to IV were recruited, aged from 44 to 65 years old (mean age: 53 years) presenting with dry skin on the legs: corneometer value at inclusion <50 a.u. At T0, a 0.2 mL single dose of E0 (control) and O/W emulsion E1 (described in Table 1) were applied by the study technician on an area of 35 cm^2 (7 cm $\times$ 5 cm) on the anterior-outer part of the legs, according to the randomization. An untreated area was selected on each leg. The evaluations were carried out under a controlled temperature (22 $\pm$ 2 °C) and relative humidity (50 $\pm$ 10%) at T0 (before any application), then one and a half hours (T1h30) and 5 h (T5h) after application.

2.2.2. Clinical Study in Brazil

The study was planned and conducted per the determinations of Resolution 466/12 of the National Health Council for Regulatory Guidelines and Standards for Research Involving Humans (Kosmoscience, Campinas, Brazil; study performed in spring). Twenty-two Brazilian women volunteers were recruited, aged from 19 to 58 years old (mean age: 46) and phototype III to V (15 phototype III, 3 phototype IV and 4 phototype V). They had to present dry to very dry skin on the forearms: at inclusion, corneometer value $\leq$40 a.u. (68% dry skin, between 30 a.u and 40 a.u., and 32% extra dry skin, <30 a.u.) and TEWL value $\geq$6 g/m^2/h. At T0, a single 20 µL single dose of O/W emulsion E2 (described in Table 1) was applied by the study technician on an area of 2.5 cm $\times$ 4 cm on the inner forearms, according to the randomization. An untreated area was selected on each forearm. The evaluations were carried out under a controlled temperature (22 $\pm$ 2 °C) and relative humidity (55% $\pm$ 5) at T0 (before any application), then 8 h (T8h) and 24 h (T24h) after application.

2.2.3. Clinical Study in India

This study was carried out in compliance with the most recent recommendations of the World Medical Association (64th WMA Declaration of Helsinki, Fortaleza, Brazil, October 2013). This study complied with the "Schedules of the Drugs and Cosmetics Act". Thirty-six Indian women volunteers were recruited, aged from 18 to 40 years old (Mascot Spincontrol, Mumbai, India; study performed in rainy/Monsoon season) and phototype III to V (4 phototype III, 29 phototype IV and 2 phototype V). Volunteers had to present very dry skin on the forearms with a Corneometer value at inclusion <30 a.u. At T0, a 18 µL single dose of O/W emulsion E3 (described in Table 1) was applied by the study technician on an area of 3 cm $\times$ 3 cm in the inner forearms, according to the randomization. An untreated area was selected on each forearm. The evaluations were carried out under a controlled temperature (20 °C to 25 °C) and relative humidity (50 $\pm$ 10%) at T0 (before any application), then 6 h (T6h) and 24 h (T24h) after application.

2.2.4. Clinical Study in Mauritius

The study complied with the Mauritius Data Protection Act 2017 and Clinical Trial Act (N°8, 2011); Government of Mauritius. Nineteen women volunteers with phototypes IV–VI (nine phototypes IV, seven phototypes V and three phototypes VI) were recruited (CIDP, Curepipe, Mauritius, study performed in dry winter season), aged from 19 to 52 years old (mean 39 years). Volunteers had to display very dry skin and altered skin barriers on the forearm: at inclusion, corneometer value $\leq$ 40 a.u. and TEWL $\geq$ 6 g/m^2/h. At T0, a single dose of 2 mg/cm^2 of O/W emulsion E4 (described in Table 1) was applied by the study technician on an area of 6 cm $\times$ 4 cm of the inner forearms, according to the randomization. An untreated control area was also selected. The evaluations were carried out under a controlled temperature (22 $\pm$ 2 °C) and relative humidity (50 $\pm$ 10%) at T0 (before any application), then 6 h (T6h) and 24 h (T24h) after application.

2.3. Outcome Assessment

A 30-min acclimatization period in the air-conditioned room was ensured prior to the measurements. Volunteers remained acclimatized in standard room conditions on the first day of study.

2.3.1. Skin Capacitance

The measurements were taken using a CM 825 PC Corneometer® (Courage & Khazaka, Köln, Germany). Each measurement was repeated three times on each test site and the mean was calculated. The corneometer measures the dielectric capacity of the epidermis, reflecting the amount of water in the top layers of the skin. Values are expressed in arbitrary units (a.u.) ranging from approximately 0 (no water at all) to 120 (on water).

2.3.2. TEWL

The measurements were taken using a Tewameter® 300 probe (Courage & Khazaka, Germany). One TEWL measurement was taken on each test area. Results, reflecting the rate of water loss from the skin surface, were expressed in g/m^2/h.

2.4. Analysis of Results

The descriptive data (mean, SEM) were calculated for each measurement time and product. Percentage variation was calculated on the means.

The statistical analyses were performed with ANOVA two-way repeated-measures (factors time and product), followed by a Tukey test for pairwise comparisons. Variations were considered significant when the p value was <0.05.

3. Results

3.1. Study Carried out in France

The control formula without emulsifier, E0, significantly increased skin capacitance at T1h30, by +13% compared to baseline (i.e., T0; $p < 0.001$), but the change was no more significant at T5h. E0 did not show any significant effect compared to the untreated area, whatever the measurement time (Figure 2).

Skin capacitance increased significantly 1 h 30 min and 5 h after application of E1 emulsion compared to baseline, by +33% and +20%, respectively ($p < 0.001$ at both measurement times). The increase was also significant compared to the untreated area ($p < 0.001$ at T1h30; $p < 0.05$ at T5h). Moreover, skin hydration was significantly higher compared to the effect of formula E0, without emulsifier ($p < 0.001$ at T1h30; $p < 0.05$ at T5h).

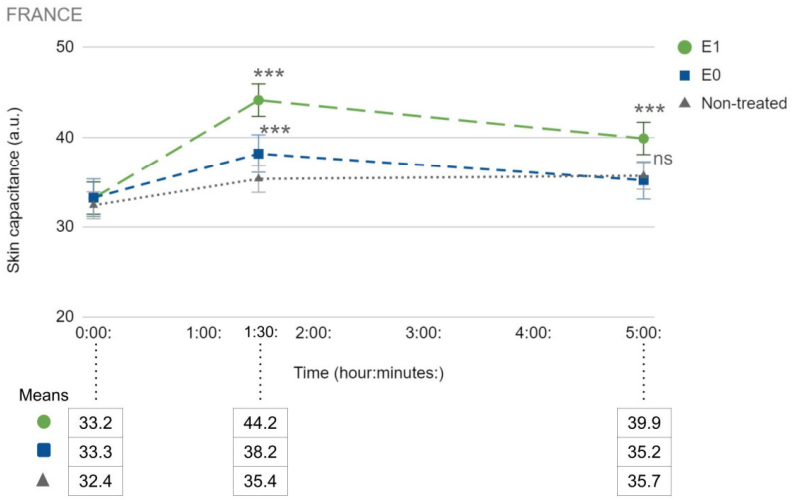

Figure 2. Changes in skin capacitance during the study carried out in France. Corneometry measurements (a.u.) at T0, 1 h 30 min and 5 h after a single application. Values are expressed as mean ± SEM; ns: not significant, *** $p < 0.001$ vs. T0.

3.2. Study Carried Out in Brazil

The E2 emulsion increased skin capacitance, while decreasing transepidermal water loss (TEWL) compared to baseline (T0), while no change was found on the untreated area. A statistically significant increase in skin hydration was demonstrated by corneometry 8 h and 24 h after application of E2, by +21.5% and +9.8%, respectively ($p < 0.001$ at both measurement times; Figure 3). E2 also significantly improved skin barrier function compared to T0, as indicated by the decrease in TEWL of −9.9% at T8h and −3.8% T24h ($p < 0.001$ at both measurement times; Figure 4). In addition, changes in values of skin capacitance and TEWL versus the untreated area were found to be significant, both at T8h ($p < 0.001$) and T24h ($p < 0.01$).

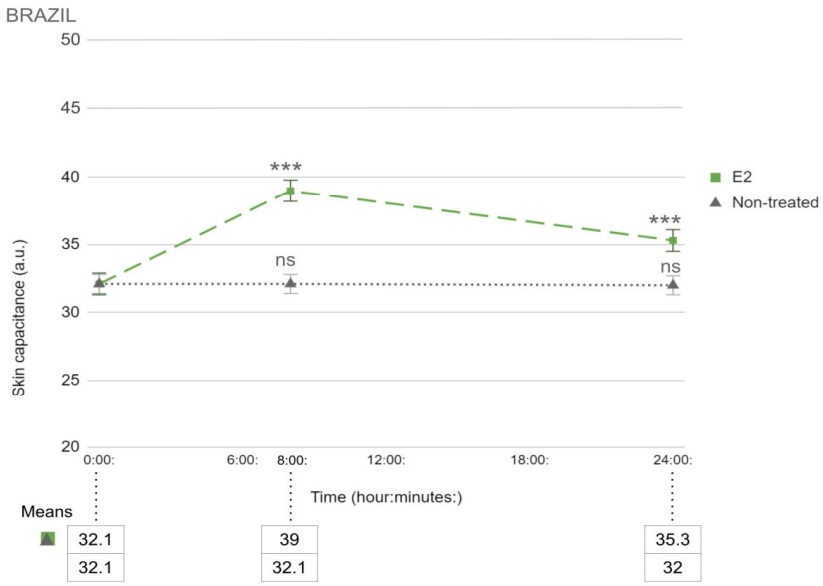

Figure 3. Changes in skin capacitance during the study carried out in Brazil. Corneometry measurements (a.u.) at T0, 8 h and 24 h after a single application. Values are expressed as mean ± SEM; ns: not significant, *** $p < 0.001$ vs. T0.

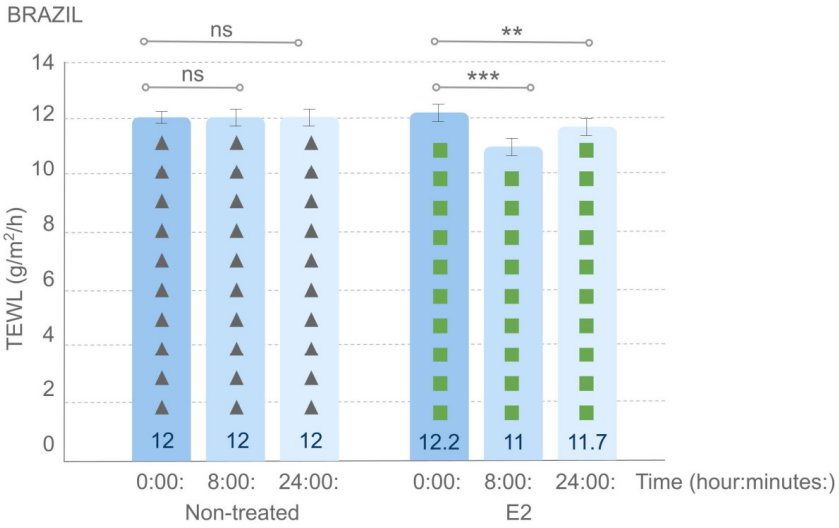

Figure 4. Changes in TEWL during the study carried out in Brazil. Tewametry measurements ($g/m^2/h$) at T0, 8 h and 24 h after a single application. Values are expressed as mean ± SEM; ns: not significant, ** $p < 0.01$ vs. T0, *** $p < 0.001$ vs. T0.

3.3. Study Carried Out in India

Increased skin moisturization (Figure 5) and strengthened barrier function (Figure 6) were highlighted at T6h and T24h after application of the E3 emulsion compared to T0 (before application). The absence of effect at the same time was observed for the untreated area. At 6 h after E3 application, skin capacitance was significantly increased by +27.6% (Figure 5) compared to T0 ($p < 0.001$ for both measurements). After 24 h, skin capacitance was significantly higher by 14.8% (Figure 5) and TEWL decreased by −5.4% (Figure 6) compared to T0 ($p < 0.001$ for both parameters). Moreover, increases in skin capacitance versus the corresponding untreated area were significant, 6 h and 24 h after E3 application ($p < 0.001$ for both changes). TEWL showed a reducing trend versus the corresponding untreated area at T6h, but the reduction was significant at T24h.

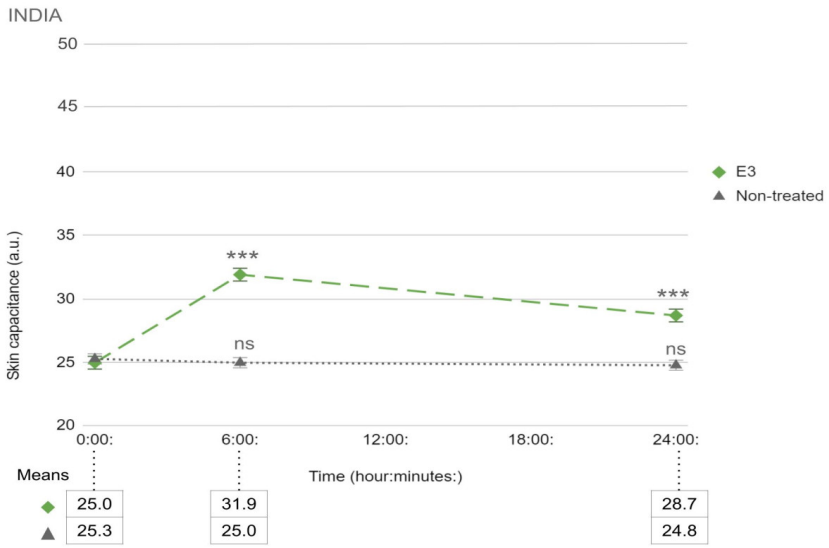

Figure 5. Changes in skin capacitance during the study carried out in India. Corneometry measurements (a.u.) at T0, 6 h and 24 h after a single application. Values are expressed as mean ± SEM; ns: not significant, *** $p < 0.001$ vs. T0.

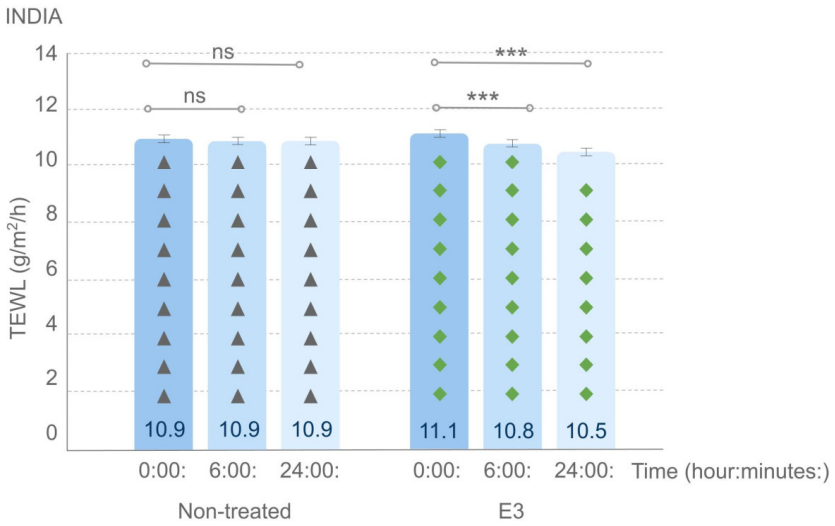

Figure 6. Changes in TEWL during the study carried out in India. Tewametry measurements ($g/m^2/h$) at T0, 6 h and 24 h after a single application. Values are expressed as mean ± SEM; ns: not significant, *** $p < 0.001$ vs. T0.

3.4. Study Carried Out in Mauritius

Application of E4 significantly increased skin capacitance by 30.6% after 6 h and by 24.5% after 24 h compared to baseline ($p < 0.001$ for both measurements; Figure 7). No effect was found for the untreated area at the same time. In addition, the changes were also found to be significant when compared to the untreated area ($p < 0.001$ at both times, T6h and T24h). E4 emulsion also significantly decreased TEWL compared to baseline ($p < 0.01$ and $p < 0.05$ at T6h and T24h, respectively; Figure 8). Changes compared to the untreated area were also significant at both times ($p < 0.001$).

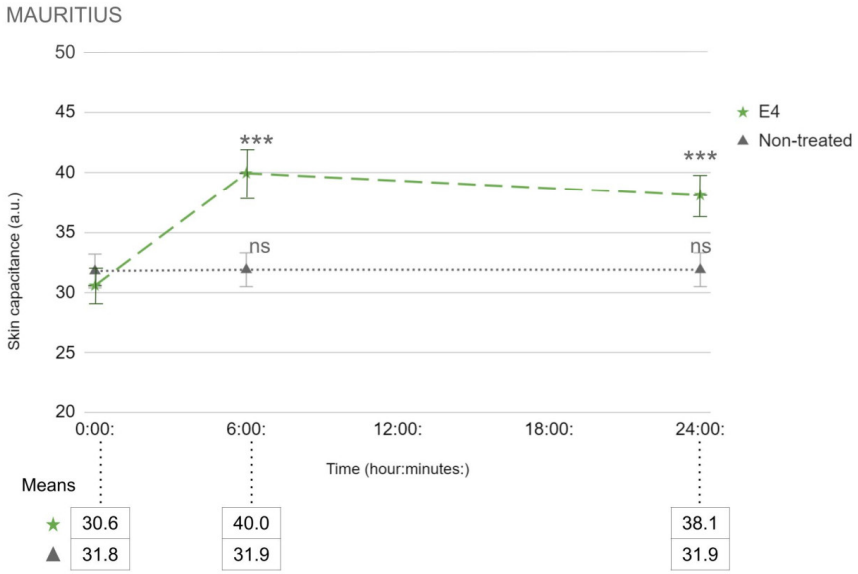

Figure 7. Changes in skin capacitance during the study carried out in Mauritius. Corneometry measurements (a.u.) at T0, 6 h and 24 h after a single application. Values are expressed as mean ± SEM; ns: not significant, *** $p < 0.001$ vs. T0.

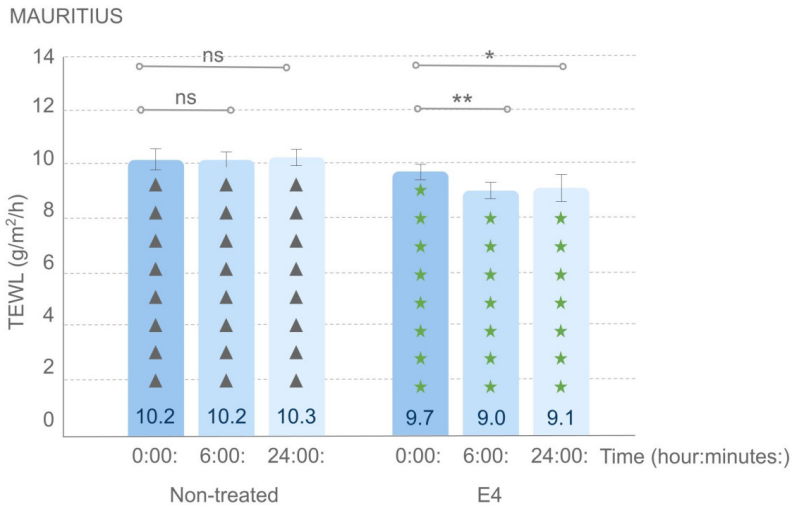

Figure 8. Changes in TEWL during the study carried out in Mauritius. Tewametry measurements ($g/m^2/h$) at T0, 6 h and 24 h after a single application. Values are expressed as mean ± SEM; ns: not significant; * $p < 0.05$, ** $p < 0.01$ vs. T0.

4. Discussion

The research intended to investigate if C12–C20 glucolipid emulsifier, used as the sole emulsifier at a realistic dosage of 3%, would allow flexibility in the formulation of moisturizing emulsions across different geographies or if the desired moisturizing effect would be strongly dependent on the emollient composition and/or user skin type and climatic conditions. Investigations were conducted on O/W emulsions with a reduced number of ingredients for an easier understanding of their contribution. Apart from this technical consideration, "minimalist formulation" is a topical subject, reported as a consumer-requested solution for a more sustainable approach and communication transparency [29]. Digitally connected consumers are keen to know more about the ingredients and their role in the formulation. At the same time, a great deal of research is being conducted on consumer motivations for a more sustainable consumption [30]. Shrinking the ingredient list is one way to reduce dependency on materials [29]. An analysis of personal care products launched on the market reflects the development of that trend: the number of products that include the word "minimalist" or "minimalism" in their descriptions was multiplied by six between 2017 and 2022, driven by the European and Asia-Pacific area [31]. In this context, interest in studying the efficacy of simple formulations has resurged, as formulation requirements have evolved compared to the literature. More inclusivity is expected. Lower doses have become the norm and represent a challenge to ensure stability, a positive sensory experience and efficacy. Pleasant skin feel and efficacy are linked for a positive consumer perception. A recent study performed on the forearms of thirty female volunteers showed that increase in stratum corneum hydration measured by skin capacitance enhanced the pleasantness rating when submitted to a gentle brushing movement [32]. But to be pleasant, skin feel should be appropriate to skin type and environmental conditions. Therefore, the ability of a modernized emulsion base to withstand changes in composition while keeping its targeted moisturization efficacy is of interest.

Carrying out more inclusive tests was the first step to complete knowledge compared to the literature on APGs. One of the concerns for any formulator is whether one selected ingredient and the resulting formulation could have the same effect, moisturization in the present case, on very different users seeking the same skin benefit [33]. Variations in degree of skin moisturizing efficacy versus baseline, using corneometric measurements, were pointed out in a multicentric study (349 volunteers in six centers in Germany, Switzerland and USA) one day after two applications of the same O/W emulsion base [28], despite a similar standardized protocol. In the current work, recruitment of volunteers with the full range of phototypes was firstly taken as a way to involve as diverse a panel of many users

as possible, based on their own perception of their skin [34]. For example, self-perception of facial aging of more than 3000 multinational women aged 18 to 75 years, collected by comparison with photonumeric scales, was found to be correlated to phototypes. Women with phototypes V/VI and III/IV reported facial aging characteristics 10 to 20 years later than those with phototypes I/II. Most women reported using facial moisturizers: 63% among phototypes I/II to 39% among phototypes V/VI [35]. Secondly, the user's daily environment influences the state of their skin upon arrival and may contribute to the variation in individual responses when applying a cosmetic product [36]. Environmental factors are known to have a decisive influence on skin biophysical parameters [33,37]. Past publications have shown that a humid climate increases skin moisturization (corneometric measurements) and friction behavior with more sticky sensations; stronger effects were observed on the forearm compared to the cheek [38,39]. More recent investigations demonstrated a clear influence of seasonal climate variation on skin biophysical parameters of volunteers living in the same country and city [40,41]. Impacts of air temperature, relative humidity, amount of precipitation, air pressure and duration of sunshine were found on skin scaliness (Visioscan® analysis, Courage & Khazaka, Köln, Germany) and moisturization (corneometer) in a cohort of 89 Korean women, 20 minutes' acclimatization at 22 ± 2 °C and 50 ± 5% relative humidity [40]. A second analysis, carried out in China on 178 women with phototypes II to IV, resulted in a positive correlation between skin hydration (corneometer) and temperature and to a lesser extent with humidity [41]. In the same work, TEWL was negatively correlated with average temperature and, to a lesser extent, with humidity and ultraviolet radiation levels.

The current studies were conducted between April and September which represented very different climatic conditions depending on the location, as featured in Table 3. The Brazilian volunteers lived in a polluted megacity with large temperature fluctuations (amplitude of 24 °C) and a high amount of sunshine. The French volunteers lived in a medium-sized city near the ocean and were subjected to the lowest temperatures (average of 13 °C; amplitude of 25.5 °C), associated with the lowest relative humidity and the highest amount of sunshine. The Indian volunteers lived in a polluted megacity and were exposed to the most humid conditions with very high precipitation levels and the most stable temperature (amplitude of 11 °C; low amount of sunshine). The Mauritian volunteers lived in the lowest polluted environment with the most temperate weather (dry winter season, low amount of sunshine). Only volunteers from Mauritius were exposed to constant windy conditions at an average speed of 42.5 km/h, because of their location in the Indian Ocean (wind speed ≤ 25 km/h in other locations). The common point between these different natural surroundings was a high relative humidity.

Table 3. Average climatic conditions in the month before each test (year of the study).

Country	Brazil	France	India	Mauritius
City	Sao Paulo	Bordeaux	Mumbai	Curepipe
Lowest temperature (°C)	9 [i]	2.5 [i]	24 [i]	15 [i]
Highest temperature (°C)	33 [i]	28 [i]	35 [i]	25 [i]
Mean temperature (°C)	19 [i]	13 [i]	29.7 [i]	20 [i]
Air pressure at sea level (hPa)	1017 [i]	1015 [i]	1004 [i]	1018 [i]
Relative humidity (%)	81 [j]	71 [j]	83 [j]	79 [n]
Cumulative precipitations (mm)	143 [i]	40 [i]	487 [m]	73 [i]
Cumulative sunshine (h)	102 [i]	197 [i]	55 [k]	43 [k,m]

i: infoclimat.fr; j: weatheronline.co.uk; k: world-weather.info; m: fr.climate-data.org; n: historique-meteo.net.

Given the diversity of volunteers to which cultural and individual variability must be added, consistent effects were observed.

Experiments were conducted on two body sites: leg and forearm. Both areas are likely to be exposed to the sun which could affect skin hydration [8]. In the literature, volunteers who were located in diverse geographical areas consistently showed no variation in TEWL

between the two body sites, even across different age groups and gender [42,43]. Conversely, a tendency of higher skin conductivity was reported [42], while in the second publication significantly higher skin conductivity was reported in two groups of volunteers from 25 to 50 years old [43]. Thus, the site of the body could affect the result. Previous studies on glucolipid emulsifiers were conducted on forearms [16–19,21]. Therefore, the effects observed on leg and forearm contributed to showing the ability to achieve the desired outcome with flexibility.

The research's pragmatic nature can be criticized as emulsion compositions were introduced as a second variable. The adaptation of the skin feel to each geographical region could be considered as a bias in analysis and prevents comparing the results between the data sets. However, testing a formula that corresponds to realistic conditions is equally important. Indeed, evaluating the effects of a formula that would contain 20% of a "heavy" oil with a long fatty chain in a country where the proposed formulations instead contain 10% oils with a lighter touch due to a hot and humid climate, could lead to a misleading conclusion disconnected from reality.

Different oil compositions associated with different doses of stabilizing polymer resulted in different viscosities. However, a pronounced shear thinning profile, supported both by the glucolipid emulsifier and stabilizing rheology modifier, suggested a minor impact on spreading properties. As illustrated by the examples of flowing profiles in Figure 9a, viscosity of the emulsions subjected to shear, regardless of its value when the formula is in its packaging, was below 100 mPa·s when the shear rate exceeded 100 s^{-1}, which is representative of the shear applied when spreading on skin [44]. This is the case with all the oils studied and is even reinforced when the dose of stabilizing polymer increases (the examples here represent the lowest polymer concentration). In addition, this shear thinning characteristic is stable over time, as illustrated in Figure 9b. This pronounced shear thinning profile associated with a low thixotropic character (i.e., quick recovery of viscosity initial value, visualized in Figure 9 by the gap between up and down ramps) suggests an easy and even distribution at the skin surface with no difference between the studied emulsions [45]. Emulsion viscosity was also reported to have no effect on moisturizing properties (skin capacitance and TEWL measured on hand) in a previous study using acrylate-based polymers of different natures and at different concentrations [46].

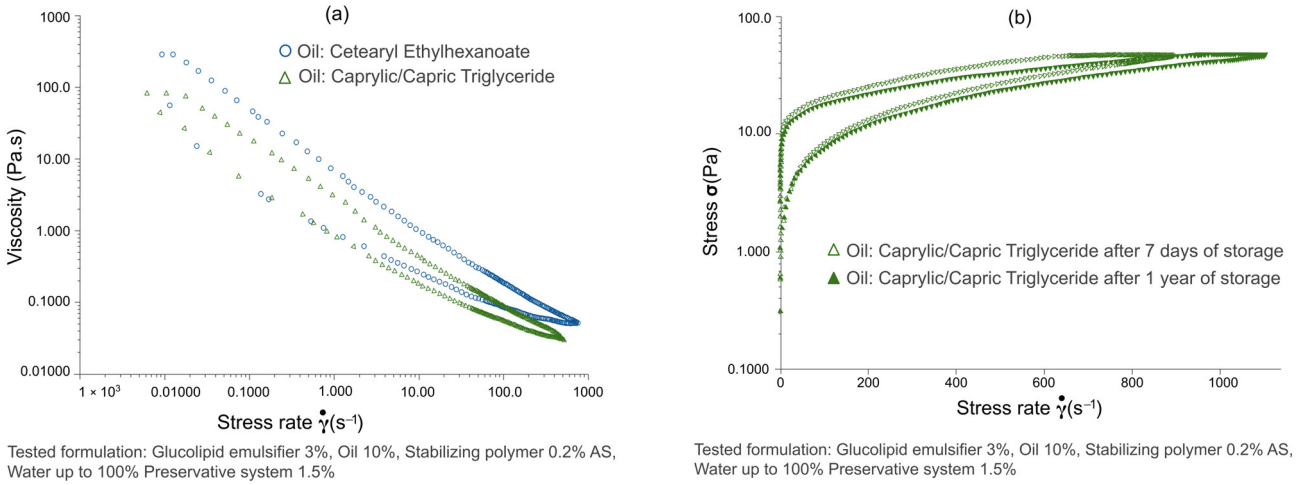

Figure 9. (**a**,**b**) Emulsion flowing profiles at 25 °C using a controlled stress rheometer (AR 2000; TA Instruments, New Castle, DE, USA; cone-plate geometry 4 cm/2°; 2 min shear rate ramp, 1 min at maximum shear rate before down ramp); (**a**) Measurements conducted after 7 days of storage at room temperature on two examples of simple emulsions. Viscosity is expressed as a function of shear rate; (**b**) Comparison of measurements after seven days and one year after storage of one example of simple emulsion to show the stability of the shear thinning profile expressed by the evolution of the shear stress as a function of the shear rate.

On the contrary, the impact of variations in the oil phase composition cannot be ignored [26,47,48]. The four emollients are not expected to provide strong occlusive properties as described for mineral and silicone oils with a high molecular weight [2,3,11,49] but partial occlusive effects cannot be excluded. Caprylic/capric triglyceride could be classified as occludent by some authors [11] while esters were generally reported to act by filling the spaces between corneocytes leading to smoother skin [4,11,50]. The characteristics of the four emollients in Table 4 seem to converge to suggest a greater penetrating ability for isononyl isononanoate followed by coco-caprylate/caprate and the resulting lower propensity to maintain a continuous film over the skin surface. Molecules with a low molecular weight, low viscosity and low polarity tend to penetrate more easily in the stratum corneum [51]. Results reported by Berkey et al. [51] showed a linear correlation between emollient penetration volume and improvement of the stratum corneum's mechanical properties (i.e., with an emollient softening role) but did not show data supporting the direct correlation with TEWL. Isononyl isononanoate shows the lowest molecular weight and viscosity, while logP (increasing with decreasing polarity) does not seem to vary much compared to coco-caprylate/caprate. Depending on the oil composition of the emulsions, variations in the partial occlusive effect would be expected with the most likely contribution for E1, probably followed by E2 and E3 combining caprylic/capric triglyceride (highest viscosity and molecular weight) with other emollients. E4, containing coco-caprylate/caprate alone (at 10% only), would be expected to bring the lowest occlusive contribution. However, E2, E3 and E4 significantly reduced the TEWL, compared to baseline and compared to the untreated area. Further investigation of the film-forming capacity through advanced scanning electron microscope observation (i.e., SEM-FEG) and characterization of the eventual film formed using the atomic force microscopy (AFM) technique could be an interesting perspective to support the hypotheses discussed. All the formulations demonstrated a significant moisturizing effect, regardless of the chosen oily phase, including one that only contains 10% of the isononyl isononanoate, which is most quickly absorbed during spreading. Microscopic examination with an optical microscope (ECLIPSE NI-U; Nikon, Tokyo, Japan) did not show significant differences between emulsions: oil droplet size ranged from 1 µm to around 8 µm for larger ones. Birefringent structures around the oil droplets observed under polarized light indicated the presence of lamellar liquid crystalline bilayers regardless of chosen oily phase (examples of microscopic appearance with oils having the highest and lowest molecular weight can be seen in Appendix B, Figure A2). The droplet size is relatively small compared to a previous publication in combination with a C20–C22 APG that showed a size from around 10 µm to 50 µm [22] and a second work with C16–C18 APG that reported a size from around 5 µm to around 40 µm [14]. Although C12–C20 glucolipid emulsifier was used alone and at a much lower dosage than that reported in previous publications [21,22], the lamellar phases could play a role in the moisturizing effect.

Table 4. Emollient characteristics.

Ingredient (INCI Name)	Average Molecular Weight ($g \cdot mol^{-1}$)	Viscosity [g] at 20 °C (mPa·s)	LogP [h]
Caprylic/Capric Triglyceride	500	30	8.2–10.9
Cetearyl Ethylhexanoate	369	14.5	>10
Coco-caprylate/caprate	335	11	6.76–8.72
Isononyl Isononanoate	285	5	6.92–7.90

g: ECHA, Europa registration dossier; h: Estimated by QSAR calculations with KOWWIN (v1.68).

Another formulation adjustment related to the dose of rheology modifier used to ensure optimum stability of the formulation. This type of widely used polymer is not known to trigger any moisturizing effect. Polymer concentration was also reported to have no significant impact on emulsion skin capacitance containing an increasing concentration of three acrylate-based polymers [46]. In addition, in the study conducted in France,

the control formulation E0, containing the highest dose of oil (20%) combined with this stabilizer but without the glucolipid emulsifier, did not show any significant effect on skin capacitance, compared to the untreated area. A rapid effect was observed compared to baseline, but was no more significant after 5 h. This finding suggests that the emulsion organization provided by the glucolipid surfactant is necessary to obtain a significant moisturizing effect a few hours after application. As E1 emulsion represents the most favorable structure to a possible effect of the oil due to the highest rate of oily phase and its nature (ester with the longest fatty chain), this deduction can likely be extended to other tested formulations. This initial study will have to be duplicated for TEWL evaluation and monitoring up to 24 h.

All investigations have shown a significant increase in skin capacitance compared to before treatment and compared to the untreated area, at 5 or 6 or 8 h and up to 24 h after application of the emulsion. A significant decrease in TEWL was observed concurrently in studies in Brazil, India and Mauritius.

It would be interesting to complete this work with investigations in countries with a cold and dry climate. Systematic collection of volunteers' perceptions during their stay in the controlled humidity room could also be added to the measurements.

5. Conclusions

Minimalist O/W emulsions (with a low number of ingredients in reasonable quantities) were able to provide significant in vivo moisturizing effects throughout the day and up to 24 h after application. The limited number of ingredients highlighted the key role of the emulsifier in the effect with less dependence on the nature and concentration of the oily phase: esters or triglyceride or combination thereof from 10 to 20%. Building on the entire set of results, C12–C20 glucolipid emulsifier used as sole emulsifier at a realistic dosage of 3% allowed flexibility in the formulation of moisturizing emulsions across different geographies. The effects were observed on a great diversity of volunteers, from phototypes I to VI, living in four countries with different lifestyles, climates and geographical environments (Brazil, France, India and Mauritius), after application on the leg (in France) and the forearm (in other locations). Corneometer measurements showed a significant increase in skin moisture compared to baseline and the untreated area. TEWL measurements (in Brazil, India and Mauritius) highlighted a strengthened skin barrier whatever the chosen emollients' composition.

In the current economic context, this work using recognized measurement methods, can offer a robust and inclusive basis for more complete formulations with additional claims as well-hydrated skin is known to be more receptive to other active ingredients.

Author Contributions: Conceptualization, C.K.; data curation, C.K.; formal analysis, A.R. and C.K.; investigation, C.K.; methodology, C.K. and S.C.; project administration, C.K.; resources, S.C.; software, C.K.; supervision, C.G.; validation, C.K.; visualization, A.R.; writing—original draft, A.R.; writing—review and editing, A.R., C.K. and S.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding by Seppic.

Institutional Review Board Statement: Ethical review and approval were waived for this study as each study follows the local cosmetic regulations. Local regulations do not require an ethics committee to review clinical studies for cosmetic purposes.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the studies.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to confidentiality restrictions.

Acknowledgments: The authors acknowledge the Stéarinerie Dubois and Schulke & Mayr companies for supplying formulation materials. The authors also warmly thank their former colleague, Elsa Hernandez, without whom this work would not have been possible.

Conflicts of Interest: Alicia Roso, Catherine Kern, Sophie Cambos and Christine Garcia are employed by Seppic. The funder was not involved in the collection, analysis, interpretation of data.

Appendix A

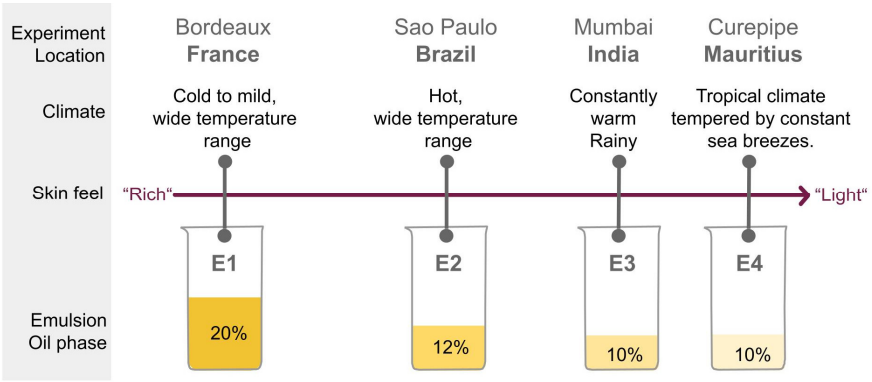

Figure A1. Representation of the correspondence between the place where the experiment was intended to be carried out (with respective climatic conditions) and oil phase concentration in the formulation with expected ranking of skin feel.

Appendix B

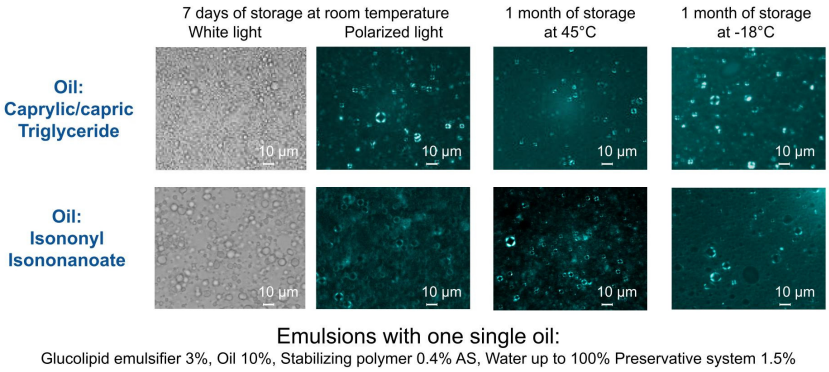

Figure A2. Examples of microscopic appearance illustrating the low influence of the nature of the oil on the lamellar liquid crystalline structures in the emulsions stabilized with C12–C20 glucolipid emulsifier (optical microscope with white and polarized light; magnification 400×).

References

1. Giam, Y.C.; Hebert, A.A.; Dizon, M.V.; Van Bever, H.; Tiongco-Recto, M.; Kim, K.-H.; Soebono, H.; Munasir, Z.; Diana, I.A.; Luk, D.C.K. A review on the role of moisturizers for atopic dermatitis. *Asia Pac. Allergy* **2016**, *6*, 120–128. [CrossRef]
2. Purnamawati, S.; Indrastuti, N.; Danarti, R.; Saefudin, T. The Role of Moisturizers in Addressing Various Kinds of Dermatitis: A Review. *Clin. Med. Res.* **2017**, *15*, 75–87. [CrossRef]
3. Mawazi, S.M.; Ann, J.; Othman, N.; Khan, J.; Alolayan, S.O.; Al Thagfan, S.S.; Kaleemullah, M. A Review of Moisturizers; History, Preparation, Characterization and Applications. *Cosmetics* **2022**, *9*, 61. [CrossRef]
4. Draelos, Z.D. The science behind skin care: Moisturizers. *J. Cosmet. Dermatol.* **2018**, *17*, 138–144. [CrossRef] [PubMed]
5. Voegeli, R.; Rawlings, A.V.; Seroul, P.; Summers, B. A novel continuous colour mapping approach for visualization of facial skin hydration and transepidermal water loss for four ethnic groups. *Int. J. Cosmet. Sci.* **2015**, *37*, 595–605. [CrossRef] [PubMed]
6. Voegeli, R.; Gierschendorf, J.; Summers, B.; Rawling, A.V. Facial Skin Mapping: From Single Point Bio-Instrumental Evaluation to Continuous Visualization of Skin Hydration, Barrier Function, Skin Surface PH, and Sebum in Different Ethnic Skin Types. *Int. J. Cosmet. Sci.* **2019**, *41*, 411–424. [CrossRef] [PubMed]
7. Proksch, E.; Berardesca, E.; Misery, L.; Engblom, J.; Bouwstra, J.A. Dry skin management: Practical approach in light of latest research on skin structure and function. *J. Dermatol. Treat.* **2019**, *31*, 716–722. [CrossRef] [PubMed]
8. Diridollou, S.; De Rigal, J.; Querleux, B.; Leroy, F.; Holloway Barbosa, V. Comparative study of the hydration of the stratum corneum between four ethnic groups: Influence of age. *Int. J. Dermatol.* **2007**, *46* (Suppl. 1), 11–14. [CrossRef]

9. Man, M.Q.; Xin, S.J.; Song, S.P.; Cho, S.Y.; Zhang, X.J.; Tu, C.X.; Feingold, K.R.; Elias, P.M. Variation of Skin Surface pH, Sebum Content and Stratum Corneum Hydration with Age and Gender in a Large Chinese Population. *Skin Pharmacol. Physiol.* **2009**, *22*, 190–199. [CrossRef]
10. Llamas-Velasco, M.; García-Díez, A. Climatic Change and Skin: Diagnostic and Therapeutic Challenges. *Actas Dermosifiliogr.* **2010**, *101*, 401–410. [CrossRef]
11. Barnes, T.M.; Mijaljica, D.; Townley, J.P.; Spada, F.; Harrison, I.P. Vehicles for Drug Delivery and Cosmetic Moisturizers: Review and Comparison. *Pharmaceutics* **2021**, *13*, 2012. [CrossRef] [PubMed]
12. Polaskova, J.; Pavlackova, J.; Egner, P. Effect of vehicle on the performance of active moisturizing substances. *Skin Res. Technol.* **2015**, *21*, 403–412. [CrossRef] [PubMed]
13. Fact.MR. Europe Alkyl Polyglucoside Market Trend Analysis, 2022, Global Insights 2032. Available online: https://www.factmr.com/report/europe-alkyl-polyglucoside-market (accessed on 4 June 2023).
14. Savic, S.; Vuleta, G.; Rolf, D.; Müller-Goymann, C.C. Colloidal microstructure of binary systems and model creams stabilized with an alkylpolyglucoside non-ionic emulsifier. *Colloid Polym. Sci.* **2005**, *283*, 439–451. [CrossRef]
15. Terescenco, D.; Picard, C.; Clemenceau, F.; Grisel, M.; Savary, G. Influence of the emollient structure on the properties of cosmetic emulsion containing lamellar liquid crystals. *Colloids Surf. A Physicochem. Eng. Asp.* **2018**, *536*, 10–19. [CrossRef]
16. Faucheux, E.; Picard, C.; Grisel, M.; Savary, G. Residual film formation after emulsion application: Understanding the role and fate of excipients on skin surface. *Int. J. Pharm.* **2020**, *585*, 119453. [CrossRef] [PubMed]
17. Savic, S.; Weber, C.; Savic, M.M.; Müller-Goymann, C. Natural surfactant-based topical vehicles for two model drugs: Influence of different lipophilic excipients on in vitro/in vivo skin performance. *Int. J. Pharm.* **2009**, *381*, 220–230. [CrossRef]
18. Savic, S.; Tamburic, S.; Jancic, B.; Milic, J.; Vuleta, G. The impact of urea on the colloidal structure of alkylpolyglucoside-based emulsions: Physicochemical and in vitro in vivo characterization. In *Book Colloids in Cosmetics and Personal Care: Colloids and Interface Science*, 1st ed.; Tadros, T.F., Ed.; Wiley-VCH Verlag GmbH & Co. KGaA: Weinheim, Germany, 2008; Volume 4, pp. 259–274. [CrossRef]
19. Ilis, D.; Cvetkovic, M.; Tasic-Kostov, M. Emulsions with alkyl polyglucosides as carriers for off-label topical spironolactone—Safety and stability evaluation. *Pharm. Dev. Technol.* **2021**, *26*, 373–379. [CrossRef]
20. Duprat-de-Paule, S.; Guilbot, J.; Roso, A.; Cambos, S.; Pierre, A. Augmented bio-based lipids for cosmetics. *OCL* **2018**, *25*, D503. [CrossRef]
21. Lukic, M.; Filipovic, M.; Pajic, N.; Lunter, D.; Bozic, D.; Savic, S. Formulation of topical acidic products and acidification of the skin—Contribution of glycolic acid. *Int. J. Cosmet. Sci.* **2021**, *43*, 419–431. [CrossRef]
22. Pajic, N.; Milankovic, V.; Lukic, M. Influence of thermal spring water on cosmetic creams' physicochemical properties and moisturizing effect—Preliminary studies. In Proceedings of the Skin Forum Annual Meeting, Course n°. 6833, Malmo, Sweden, 21–22 June 2022.
23. Douguet, M.; Picard, C.; Marechal, P.; Merlaud, F.; Loubat-Bouleuc, N.; Grisel, M.; Savary, G. Sensory identity cards of emollient esters from Searinerie Dubois definition and results. In Proceedings of the 28th IFSCC Congress "Cosmetic Innovation and Performance for Beauty and Well-Being", Paris, France, 27–30 October 2014; pp. 3860–3867.
24. Altieri, E. Emollients in personal care: Our songs to create your formulation playlists. *HPC Today* **2020**, *15*, 50–53.
25. Çağla Bektaş, C.; Kafadar, B. Sensory mapping for common special esters in cream products. *TOJSAT* **2020**, *10*, 152–157.
26. Anonymously Vantage. Why replacing silicones might be easier than you think. *Glob. Cosmet. Ind.* **2019**, 187. Available online: https://www.gcimagazine.com/ingredients/regulatory/article/21848865/vantage-specialty-ingredients-9670-why-replacing-silicones-might-be-easier-than-you-think (accessed on 18 June 2019).
27. Fitzpatrick, T.B. The validity and practically of sun-reactive skin type I through VI. *Arch. Dermatol.* **1988**, *124*, 869–871. [CrossRef]
28. Heinrich, U.; Koop, U.; Leneveu-Duchemin, M.-C.; Osterrieder, K.; Bielfeldt, S.; Chkarnat, C.; Degwert, J.; Häntschel, D.; Jaspers, S.; Nissen, H.-P.; et al. Multicentre comparison of skin hydration in terms of, -physical, -physiological and product-dependent parameters by the capacitive method (Corneometer CM825). *Int. J. Cosmet. Sci.* **2003**, *25*, 45–53. [CrossRef]
29. Expert Opinions. Skin minimalistic formulating and skininmalism: Solid form, skip care, synergies, microbiome, skinification, 'BYO Water' and more. *Cosmet. Toilet.* **2022**, *137*, 16–21.
30. Suárez, E.; Hernández, B.; Gil-Giménez, D.; Corral-Verdugo, V. Determinants of frugal behavior: The influences of consciousness for sustainable consumption, materialism, and the consideration of future consequences. *Front. Psychol.* **2020**, *11*, 567752. [CrossRef] [PubMed]
31. Mintel Market Research Online Database. Super-Category: Beauty & Personal Care/Product Description: "Minimalist" or "Minimalism". From 2017 to 2022. Available online: https://clients.mintel.com/ (accessed on 30 October 2023).
32. Porcheron, A.; Adarsh Makdani, A.M.; Latreille, J.; Bardel, M.-H.; McGlone, F. The impact of skin hydration on pleasant touch: What the nerves tell the brain. In Proceedings of the 33rd IfSCC Congress, Integration of Cosmetic Sciences, Barcelona, Spain, 4–7 September 2023.
33. Calixto, L.S.; Picard, C.; Savary, G.; Maia Campos, P.M.B.G. Skin characterization and immediate effects of different dermocosmetic treatments in French and Brazilian skin. *J. Cosmet. Dermatol.* **2020**, *19*, 466–472. [CrossRef] [PubMed]
34. Maresca, V.; Flori, E.; Picardo, M. Skin phototype: A new perspective. *Pigment Cell Melanoma Res.* **2015**, *28*, 378–389. [CrossRef]
35. Andrew, F.A.; Grimes, P.; Boyd, C.; Downie, J.; Drinkwater, A.; Garcia, J.K.; Gallagher, C.J. Racial and Ethnic Differences in Self-Assessed Facial Aging in Women: Results from a Multinational Study. *Dermatol. Surg.* **2019**, *45*, 1635–1648. [CrossRef]

36. Singh, B.; Maibach, H. Climate and Skin Function: An Overview. *Skin Res. Technol.* **2013**, *19*, 207–212. [CrossRef]
37. Mercurio, D.G.; Jdid, R.; Morizot, F.; Masson, P.; Maia Campos, P.M.B.G. Morphological, structural and biophysical properties of French and Brazilian photoaged skin. *Br. J. Dermatol.* **2016**, *174*, 553–561. [CrossRef]
38. Hendriks, C.P.; Franklin, S.E. Influence of Surface Roughness, Material and Climate Conditions on the Friction of Human Skin. *Tribol. Lett.* **2010**, *37*, 361–373. [CrossRef]
39. Derler, S.; Gerhardt, L.-C. Tribology of Skin: Review and Analysis of Experimental Results for the Friction Coefficient of Human Skin. *Tribol. Lett.* **2012**, *45*, 1–27. [CrossRef]
40. Nam, G.W.; Baek, J.H.; Koh, J.S.; Hwang, J.-K. The seasonal variation in skin hydration, sebum, scaliness, brightness and elasticity in Korean females. *Skin Res. Technol.* **2015**, *21*, 1–8. [CrossRef] [PubMed]
41. Wan, M.-J.; Su, X.-Y.; Zheng, Y.; Gong, Z.-J. Seasonal variability in the biophysical properties of forehead skin in women in Guangzhou City, China. *Int. J. Dermatol.* **2015**, *54*, 1319–1324. [CrossRef] [PubMed]
42. Firooz, A.; Sadr, B.; Babakoohi, S.; Sarraf-Yazdy, M.; Fanian, F.; Kazerouni-Timsar, A.; Nassiri-Kashani, M.; Naghizadeh, M.M.; Dowlati, Y. Variation of Biophysical Parameters of the Skin with Age, Gender, and Body Region. *Sci. World J.* **2012**, *2012*, 386936. [CrossRef] [PubMed]
43. Mehta, H.H.; Nikam, V.V.; Jaiswal, C.R.; Mehta, H.B. A cross-sectional study of variations in the biophysical parameters of skin among healthy volunteers. *Indian J. Dermatol. Venereol. Leprol.* **2018**, *84*, 521. [CrossRef]
44. Brummer, R. *Rheology Essentials of Cosmetic and Food Emulsions*; Springer Laboratory: Berlin, Germany, 2006; p. 30.
45. Kwak, M.S.; Ahn, H.J.; Song, K.W. Rheological investigation of body cream and body lotion in actual application conditions. *Korea-Aust. Rheol. J.* **2015**, *27*, 241–251. [CrossRef]
46. Kislalioglu, M.S.; Breuer, M. The Effect of Rheological Properties of Experimental Moisturizing Creams/Lotions on Their Efficacy and Perceptual Attributes. *Int. J. Cosmet. Sci.* **1999**, *21*, 167–188. [CrossRef]
47. Perez, R.; Romero, A. Evaluation of the influence of moisturizers on the hydration kinetics of the skin. In Proceedings of the XVII COLAMIQC-Congreso Latinoamericano E Iberico De Quimicos Cosmeticos, Cusco, Peru, 4–7 September 2005.
48. Kang, B.Y.; Lee, S.I.I.; Kim, H.J.; Chun, J.H.; Kim, H.K.; Kang, H.H. Development of in vitro measurement of inhibition of water loss, degree of hydration and emolliency controlled by novel skin moisturizers. In Proceedings of the 24th IfSCC Congress, Integration of Cosmetic Sciences, Osaka, Japan, 16–19 October 2006.
49. Stojiljković, D.; Arsić, I.; Tasić Kostov, M.; Jovanović, Z.; Tadić, V.; Đorđević, S. Investigation of the Effects of Different Emollients on the Structure and Skin Moisturizing Potential of the Cosmetic Creams. *Acta Fac. Med. Naissensis* **2013**, *30*, 193–200. [CrossRef]
50. Idalgo Vasques, L.; Ricci Leonardi, G. User Experience in Cosmetics: Perception Analysis Regarding the Use of an Anti-Aging Moisturizer. *Cosmetics* **2023**, *10*, 33. [CrossRef]
51. Berkey, C.; Kanno, D.; Mehling, A.; Koch, J.P.; Eisfeld, W.; Dierker, M.; Bhattacharya, S.; Dauskardt, R.H. Emollient structure and chemical functionality effects on the biomechanical function of human stratum corneum. *Int. J. Cosmet. Sci.* **2020**, *42*, 605–614. [CrossRef] [PubMed]