

“POLYGLYCEROL POLYRICINOLEATE (PGPR, E-476): A REVIEW OF ITS CHEMICAL PROPERTIES, FORMULATION TECHNOLOGY, AND COSMETIC APPLICATIONS”

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Abstract:

Polyglycerol polyricinoleate (PGPR; E-476) is an amphiphilic polyglyceryl ester made from glycerol and fatty acids derived from castor oil. It is mainly known as a food-grade emulsifier. Recent developments in formulation science have shown its strong potential in cosmetic and personal care uses due to its excellent emulsifying ability, gentle nature, and biodegradability. Due to its low hydrophilic-lipophilic balance (HLB = 1-3) and superior interfacial activity, PGPR effectively stabilises water-in-oil (W/O) emulsions. It improves texture, spreadability, and long-term stability in a wide range of products, including creams, sunscreens, and lipsticks.

The studies indicate that emulsions made with PGPR perform better in terms of droplet size and homogeneity than emulsions made with common surfactants like sorbitan esters. PGPR can have plant-based origins and can be produced using enzymatic methods, which align with modern product manufacturing's clean beauty and sustainability goals. The toxicological assessments from the European Food Safety Authority (EFSA) and the U.S. Food and Drug Administration (FDA) show that PGPR is only slightly toxic and compatible in cosmetics.

The purpose of this review is to summarise the present state of knowledge surrounding structure–function relationships of PGPR and advantages of formulation, safety, and market opportunities, emphasising its potential as a next-generation, sustainable emulsifier for novel cosmetic formulations.

Keywords: Polyglycerol polyricinoleate (PGPR), Water-in-oil emulsions, Cosmetic formulations, Lipophilic emulsifier, Skin compatibility.

INTRODUCTION

Polyglycerol polyricinoleate (PGPR) also known as food additive E476 and is a range of mixed esters from the condensation of polyglycerols with ricinoleic acid that is derived from castor oil. It is a yellowish, viscous liquid and exhibits a strong affinity for lipids. PGPR is insoluble in water and ethanol and soluble in fats and oils [1].

It is primarily produced through two routes - conventional chemical synthesis and enzymatic methods. Both involve the esterification of polyglycerol with polyricinoleic acid, where ricinoleic acid, the dominant fatty acid in castor oil (80–90%), forms the hydrophobic backbone of the molecule [1]. It

consists of ricinoleic acid (80%-90%), with smaller contributions of oleic acid (3%-8%), linoleic acid (3%-7%) and stearic acid (0%-2%). Due to their milder operating conditions and adherence to green chemistry principles, enzymatic production routes have attracted increasing attention. PGPR, which was first created for the food industry, has been widely used to stabilise water-in-oil (W/O) emulsions and lower viscosity in confections, especially in the production of chocolate. Cosmetic formulators have taken notice of its performance in these applications and have started investigating its potential in personal care products where stable W/O systems are crucial.

This review examines the chemical structure, physicochemical properties, formulation behaviour, cosmetic applications, and regulatory safety of PGPR and with the aim of evaluating its potential as a next-generation, sustainable emulsifier in cosmetic formulations.

CHEMICAL STRUCTURE AND PHYSICOCHEMICAL PROPERTIES

Polyglycerol polyricinoleate is a complex mixture of lipophilic esters produced by the condensation of polyglycerols (mainly diglycerol to decaglycerol) with polyricinoleic acid. It is a result of the polymerisation of ricinoleic acid, which is a hydroxy fatty acid derived from castor oil. [3]

The esterification is a chemical reaction which forms a heterogeneous blend of esters with varying chain lengths and degrees of substitution between hydroxyl groups of polyglycerol and the carboxylic acid groups of polymerised ricinoleic acid. [3,4]

Multiple hydrophilic hydroxyl groups (from the glycerol backbone) and extensive hydrophobic chains (from ricinoleic moieties), giving the compound a low hydrophilic-lipophilic balance (HLB) typically ranging between 1 and 3, distinguish the structure of PGPR molecules. [2] It makes PGPR particularly effective as a water-in-oil(W/O) emulsifier due to the low HLB value, which confers strong lipophilicity, stabilising dispersed aqueous droplets within the continuous oil phases. [2,3] PGPR has an amphiphilic structure, which allows it to lower interfacial tension significantly and enhance emulsion stability even at low concentrations (typically 0.2–2% w/w) [2]

PGPR physicochemically appears as a viscous, brownish liquid at room temperature with a viscosity typically around 8–10 Pa·s at 25 °C, which depends on the degree of polymerisation [2]. It has a density of 0.96–0.98 g/cm³ and an acid value below 6 mg KOH/g, indicating limited free fatty acids [2]. The iodine value shows the amount of unsaturation and ranges from 80 to 100. This is due to the unsaturated ricinoleic chains, which may affect oxidative stability [2,3]. The refractive index, measured at 1.46 to 1.48 at 25 °C and combined with the amber colour, indicates the presence of conjugated unsaturation and some oxidation of the ricinoleate chains.

When it comes to PGPR's physicochemical profile, it has a lower HLB, higher viscosity, and interfacial activity, making it suitable for food applications as well as for cosmetic formulations that require stable W/O systems, such as rich creams, foundations, and sunscreens. It enhances smoothness, spreadability, and water resistance. Its lipophilic fatty acid-derived chains contribute to a soft skin feel [2].

SAFETY, TOXICOLOGY, AND REGULATORY STATUS

Polyglycerol polyricinoleate (PGPR; E-476) is a polyglyceryl ester of ricinoleic acid. It is well-known for its strong safety record, which comes from food and pharmaceutical studies. The toxicological data indicate low acute and chronic toxicity, with a NOAEL of 2500 mg/kg bw/day. The acceptable daily intake (ADI) of 7.5 mg/kg bw/day is confirmed by EFSA (2017; 2022). It breaks down through enzymatic

hydrolysis into polyglycerols and ricinoleic acid, both of which are naturally metabolised by the body. It shows no signs of being mutagenic, carcinogenic, or harmful to reproduction [5,6].

Its safe structure, made from vegetable-based glycerol and castor oil fatty acids, supports its use in topical products. The cosmetic-grade PGPR (e.g., Dermofeel® PGPR, Akoline® PGPR) is sold as a mild, non-sensitising emulsifier for water-in-oil (W/O) creams, foundations, and sunscreens [2,7]. It helps create a smooth texture, improves spreadability, and adds water resistance without irritating.

Currently, there is limited refereed data on dermal or sensitisation testing, representing a key research gap. It is considered safe and well-tolerated for cosmetic use based on its chemical origin, metabolic behaviour, and lack of systemic toxicity. It meets global regulatory standards for non-toxic, biodegradable emulsifiers.

PGPR IN COSMETICS AND PERSONAL CARE: APPLICATIONS AND EVIDENCE

Although PGPR is well known in the food industry, it is becoming more popular in cosmetics and personal care because of its properties. These properties make it good at mixing water and oil, which is useful for making products like creams and lotions. PGPR has an HLB value of 1-3 and is good at working with oils and waxes, making it a good choice for making products that need to feel smooth and work well over time. [1, 2]

Its ability to keep water droplets in oil makes it useful for products like rich creams, lotions, lipsticks, foundations and sunscreens. These products need water in oil systems to work well and feel good on the skin.

It is already used in some products, like Dermofeel® PGPR and Akoline® PGPR. It is added at levels of 0.5 to 3.0% in these products. This shows that PGPR can be used in different types of products. [2, 7,10]

The most direct evidence of PGPR's cosmetic performance comes from Taylor (2011) at the University of Birmingham and who evaluated PGPR in lipstick emulsions. The study demonstrated that emulsions prepared with PGPR were more stable and exhibited smaller, more uniform droplet sizes compared to those stabilised with Span 80 or a Span 80/Tween 80 blend. PGPR worked effectively in cosmetics in the relevant concentration of about 1-2%, which produced stable emulsions that maintained structural integrity during storage.

“The PGPR emulsions were shown to be more stable and had smaller droplet sizes and droplet size distributions than those prepared with Span 80 and the blend of Span 80 with Tween 80.” [10]

This discovery confirms PGPR’s potential in cosmetics formulations, particularly where long-term stability and smooth textures are required. [2,10]

Table 1.1 Current PGPR Applications in Cosmetic Formulations

Product Category	Typical Conc. (%)	Primary Function in Formulation	Key Benefits	References
Lipsticks	1.0-2.0	W/O emulsion stabiliser	Improved texture, enhanced structural integrity during storage	[10]
Face creams/ Rich Emollients	0.8-1.5	Primary emulsifier/co-emulsifier	Finer droplet size, smooth application	[1]
Body Lotions/ Milky Lotions	0.5-1.2	Co-emulsifier/stabiliser	Better spread, improved long-term emulsion stability	[1]
Baby Care/ Sensitive skin products	1.0-2.5	Gentle emulsifier	Mildness, low irritation	[8]
Sunscreen/ Water-resistant Systems	1.5-3.0	Stability enhancer	Water resistance, improved sensory feel	[2,7]
Multiple Emulsions / Active Delivery	0.5–2.0	Lipophilic emulsifier in W/O/W systems	Encapsulation and stabilisation of bioactive ingredients	[4]

The lipstick formulations represent one of the more demanding w/o systems in cosmetics, as they require continuous thermal stability, mechanical strength, and structural integrity during storage and use. The exceptional performance of PGPR over conventional sorbitan esters in this context is therefore particularly significant, and as it suggests broader applicability across other challenging cosmetic formats, including colour cosmetics, barrier creams, and water-resistant sun care products where comparable stability demands exist. [2, 3,10].

FORMULATION AND TECHNOLOGICAL ASPECTS

Polyglycerol polyricinoleate (PGPR) is a potent lipophilic emulsifier with strong interfacial activity and a low hydrophilic-lipophilic balance (HLB=1-3) employed in water-in-oil (W/O) systems. It is important in stabilising emulsions, modifying texture and sensory properties such as resistance to water, spreadability, and smoothness in cosmetic formulations [2,7].

3.1 Mechanism of Emulsion Stabilisation

PGPR works as an emulsifier by gathering at the oil-water boundary. The polyglycerol parts go into the water while the polyricinoleate chains reach into the oil. This setup lowers the interfacial tension [3]. The formation of this interfacial film inhibits aqueous droplet fusion and contributes to the development of a stable W/O emulsion with a small droplet distribution. The ability to stabilise at low concentrations (0.2%-2%) offers even more appeal for certain cosmetic applications such as foundations, barrier creams, sunscreens, and makeup bases [2].

3.2 Synergistic Use with Co-Emulsifiers

In cosmetics, PGPR frequently is combined with co-emulsifiers, like beeswax, cetyl dimethicone copolyol or polyglyceryl-4 iso-stearate to modify the texture, thickness, and feel of emulsions. This combination can be used to improve emulsion stability, especially in low viscosity emulsion systems, high water emulsions, or at higher temperatures. The studies on complex emulsions suggest that the addition of PGPR can improve the droplet uniformity and phase stability in emulsions formulated with hydrophilic surfactants [4]. In multiple emulsions (W/O/W), PGPR functions as the predominant lipophilic emulsifier. It also stabilises the internal droplets and protects encapsulated actives such as vitamins or polyphenols [4].

3.3 Processing and Compatibility

The oil phase preparation at temperatures between 70–80 °C incorporated PGPR to ensure complete dissolution before emulsification. It is compatible with plant oils, esters, silicones, and waxes, making it suitable for both natural and synthetic cosmetic systems. PGPR provides thermal stability (over 250 °C) and oxidation stability, which enables PGPR to maintain its emulsification functionality during high-temperature processing and long storage [12]. It maintains emulsion stability, transforming an invertible emulsion into a stable one; therefore, this is useful in formulating durable and water-resistant formulations.

3.4 Formulation Advantages

When used in topical products, It will provide lightness of texture, a non-greasy finish, increased skin adhesion, and help stabilise in humid conditions. Furthermore, It will contribute to improved emulsion quality (compared to W/O emulsifiers such as sorbitan esters) and reduce oil separation, enhancing the user's sensory experience [2, 3]. Finally, PGPR is effective in stabilising pigments and UV filters in cosmetic colour and sun care formulations.

3.5 Formulation Limitations

In spite of PGPR's numerous benefits, its highly lipophilic properties limit its use in high-water-containing systems, likely requiring the addition of co-emulsifiers or structuring agents to improve viscosity. PGPR's dark amber colour and characteristic odour may present challenges for applications that are sensitive to colour and/or fragrance [2]. It is often suggested to be mixed with other natural emulsifiers or hydrogenated oils for optimum cosmetic performance.

SKIN COMPATIBILITY AND SAFETY ON TOPICAL USE

Polyglycerol polyricinoleate (PGPR) shows great skin compatibility because it comes from plants. Its components, polyglycerols and ricinoleic acid, are natural and easily processed by the body. Most toxicological data come from studies focused on food and drug safety. These studies strongly back its safe use on skin [5,6,8].

PGPR illustrate non-irritation to skin and doesn't promote sensitivity. In studies using animals or human studies, there were no indications of acute skin toxicity or contact sensitivity [6]. Furthermore, the compound maintains stability, has no evaporative potential, and does not react with ease. This helps reduce the risk of damaging the skin barrier or initiating an allergic response. A hydroxyl-rich polyglycerol backbone exhibits gentle moisturization properties, especially when included in topical emulsions to aid hydration to the skin while also improving skin barrier function [3].

In the field of cosmetics, PGPR is used in low concentrations, usually between 0.2 and 2%, in water-in-oil creams, makeup, and sunscreens. It aids in spreadability and a nice sensory feel without clogging pores or leaving an oily film [2,7]. It based on dermatological assessments of polyglyceryl esters with analogous structures, the esters exhibited favourable skin tolerability and no evidence of comedogenicity, which supports the application of PGPR-like agents in products that are designed specifically for sensitive or dry skin [7].

Although specific dermatological studies on PGPR are limited, the available toxicology evidence, its composition, and long-term industrial use suggest that PGPR is safe and well-tolerated for topical cosmetic use. This is in line with EU Cosmetic Regulation (EC No. 1223/2009) and current safety standards for biodegradable, non-ionic emulsifiers.

FUTURE PERSPECTIVES OF PGPR IN COSMETICS

PGPR offers effective potential as a sustainable w/o emulsifier in cosmetics due to its renewable castor oil origin and biodegradability [2]. Its production includes both chemical processes and enzymatic synthesis methods [1]. Tailoring polyglycerol chain length and estolide content enables HLB (1-3) customisation for specific formulation needs [2-3].

In multiple emulsions, PGPR facilitates lipophilic active delivery and provides superior internal droplet stabilisation versus sorbitan esters [4]. The commercial grades (Dermofeel® PGPR, Akoline PGPR) demonstrate efficacy in lipsticks, sunscreens, and rich creams at 0.5-3.0% [2,7,10]. The pigment stabilisation and water resistance represent emerging applications [12].

Despite supportive toxicology data (ADI 7.5 mg/kg bw/day) [5,6], targeted dermal safety studies remain limited. The future research should prioritise in vitro human skin models for long-term compatibility validation across skin types.

CONCLUSIONS

PGPR is a very effective lipophilic emulsifier and has significant potential for use in formulations for personal care and cosmetics. It is especially suitable for stabilising water-in-oil emulsions due to its distinct amphiphilic structure, low hydrophilic-lipophilic balance (HLB), and strong interfacial activity. It produces products like lipsticks, rich creams, sunscreens, and other topical formulations that help to have better emulsion stability, smaller droplets, better spreadability, and favourable sensory qualities. PGPR

has a strong safety record based on toxicological tests and regulatory reviews. It is not toxic, breaks down easily, and is safe for skin.

The increasing demand for sustainable and high-performance cosmetic ingredients further strengthens the relevance of PGPR and especially given its plant-derived origin from castor oil and the possibility of enzymatic production routes. Even though current evidence points to good skin tolerability and formulation versatility, more focused dermatological and long-term compatibility studies would improve our scientific knowledge of how it works in topical applications. In general, PGPR is a promising multifunctional emulsifier for modern cosmetic formulations. It combines safety, efficiency, and sustainability in technology, and it will probably play a bigger role in making new cosmetic products in the future.

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