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Study on the preservative properties of glycol on food

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Abstract

Propylene glycol (PG) is a substance commonly used in many cosmetic products or as an additive in foods. Food officials in the United States and Europe have stated that oral consumption of this substance is generally safe. However, there is a lot of discussion about PG. Reports of PG poisoning are mostly related to inappropriate intravenous use or accidental overuse by children. Because of its low risk of food poisoning, it is recognized by the Food and Drug Administration (FDA) as a relatively safe substance as a food additive such as frozen desserts, ice cream and frozen foods. This article examines what is oral propylene glycol and why is it used? Also, in the current study, it was tried to answer this question: Is it dangerous for the body or not? It's found that while there have been incidents of intoxication from this material due to the usage of extremely high doses, it is not regarded a harmful or poisonous substance in general.

Keywords: propylene glycol; food additive; food poisoning; food safety.

Practical Application: Propylene glycol and its application in food industry.

1 Introduction

The ingredients in some food products belong to a chemistry lab instead of in grocery stores. Propylene glycol (PG) is an example of this substance found in thousands of products, from salad dressings to cosmetics and antifreeze. PG with the chemical formula $C_3H_8O_2$ is a clear, viscous liquid, absorbent, solvent of aromatic substances, and water-insoluble dyes that, like glycerol and sorbitol, prevent the evaporation of food moisture (Wei et al., 2018). It is used as a solvent for materials, perfumes, and dyes. It is highly hygroscopic and soluble in water, alcohols, esters, and amines (Zhang et al., 2018). It is also slightly soluble in halogenated hydrocarbons but not soluble in fatty hydrocarbons. This synthetic chemical, which is generally considered safe for use in food, helps products maintain their moisture, strength, and texture. For this reason, it is usually found in packaged consumables and household products. Because PG has numerous potentially useful properties for packaged foods, it is quite common to use it in food products designed for long shelf life (Wu et al., 2018; Zou et al., 2020).

PG is a synthetic food additive which belongs to the same chemical group as alcohol. PG is a slightly syrupy, odorless, slightly thicker liquid than water, and has virtually no taste. In addition, PG may dissolve some substances better than water and is also useful in retaining moisture. These properties have made it a very useful food additive (Liu et al., 2018). Therefore, it can be found in a wide range of processed foods and beverages. Other names for PG include trimethyl glycol, methyl ethyl glycol, dihydroxypropane, and propanidol.

PG is sometimes confused with ethylene glycol (EG) because both of these materials are used in antifreeze production due to their low melting point. But it should always be noted that these two substances are not the same. EG is very toxic to the human body and for this reason EG is not used in food products (Wei et al., 2018).

PG is commonly used as an additive to help process food and improve its texture, taste, appearance, and shelf life. In food, oral PG can be used in the following ways (Morshed et al., 1989):

- **Anti-scum agent:** Helps prevent different food components from sticking together and creating lumps such as scum in foods such as grated cheese or dry soups.
- **Antioxidants:** Increases the shelf life of foods by protecting them from oxygen spoilage.
- **Solvent:** Dissolves other additives used in processing, such as dyes, flavorings, or antioxidants.
- **Dough booster:** It strengthens the starch and gluten in the dough and increases its stability.
- **Emulsifier:** Prevents the separation of foods such as vinegar and oil in salad dressings.

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- **Moisture retainer:** Helps food maintain a stable level of moisture and thus prevents them from drying out.
- **Assist in the processing process:** Used to increase the attractiveness of food, for example, to brighten the color of liquids.
- **Stabilizer and thickener:** It can hold food ingredients together or thicken them during and after processing.
- **Tissue:** This substance can change the appearance or taste of food in the mouth.

PG is commonly found in many packaged foods such as beverages, sauces, dry soups, ready-made cakes, soft drinks, popcorn, fast foods, breads, and dairy products. Pre-cooked desserts with wide distribution contain this substance. Some ice cream flavors even contain Mon PG. Dried coconut and some nuts contain PG, as it helps maintain acceptable moisture levels in these foods. As mentioned earlier, this substance can be used as a sedative, solvent, and food preservative (Mehr et al., 2020). Therefore, it is used in several food items such as soft drinks, dairy products, ice cream, liquid sweeteners, and coffee drinks. It is also used in injectable drugs such as lorazepam and in some creams and ointments that are rubbed on the skin, such as corticosteroids. In addition, due to its chemical properties, this substance is also found in various health and cosmetic products. In addition, it is used in industrial products such as paints, antifreeze, artificial smoke, and electronic cigarettes (LaKind et al., 1999; Xu et al., 2006). Figure 1 shows the global PG market in 2017 by end-use industry and Figure 2 shows the global PG capacity by region (Pagliaro, 2017).

The purpose of this article is to explain what oral propylene glycol is and why it's utilized. In addition, the current study attempted to answer the question of whether or not it is harmful to the body.

As a food additive, propylene glycol is widely utilized. It aids in the preservation of moisture while also assisting in the dissolution of colors and tastes. Some pharmaceuticals, cosmetics, antifreeze, and other industrial items contain it. The most popular application segment in 2017 was personal care, which accounted for 46.5 percent of total volume. The demand for personal care products is increasing as people become more aware of their health and cleanliness, particularly in industrialized countries like North America. According to L'Oréal's 2017 Annual Report, the expanding population of the upper middle class is driving the luxury cosmetics sector. The second most important application industry is food and beverage. Food contains a lot of polyglycerol and its derivatives. In the manufacturing of low-fat spreads, Polyglycerol Polyricinoleate (PGPR) is employed as an emulsifier. The growing use of emulsifiers in items such as peanut butter and frozen desserts is expected to raise demand for PGPR, propelling the market forward. Propylene glycol, a chemical molecule, has caused a lot of anguish and misunderstanding in past years. It's included in a variety of products in different proportions and some believe it's completely safe while others think it's to blame for catastrophic medical conditions.

2 Propylene glycol production and its applications

PG, also known as propane-1,2-diol, is an organic compound. It is a sticky, colorless liquid that is almost odorless or has a relatively sweet odor. Since the polymer has two alcohol groups, it belongs to the category of diols. It can dissolve well in a variety of solvents (such as chloroform, acetone, and water). Glycols are generally insensitive and have low toxicity and evaporation. PG is produced in large quantities to be used to make polymers. The US Food and Drug Administration has declared the substance safe and also confirms that the polymer can be used as a food additive. This compound is sometimes referred to as alpha PG to distinguish it from the isomer Propane-1,3-diol or PG beta. A racemate is mainly used in commercial processes. The S isomer is produced by axis-based biotechnology methods (Qin et al., 2012).

2.1 Industrial production

PG is produced industrially from propylene oxide (for food use). According to available sources, 2.16 million tons of this substance will be produced annually in 2018. Manufacturers of non-catalytic processes at high temperatures - between 200 ° C to 220 ° C or 392 to 428 ° F or catalytic methods at 150 to 180 ° C

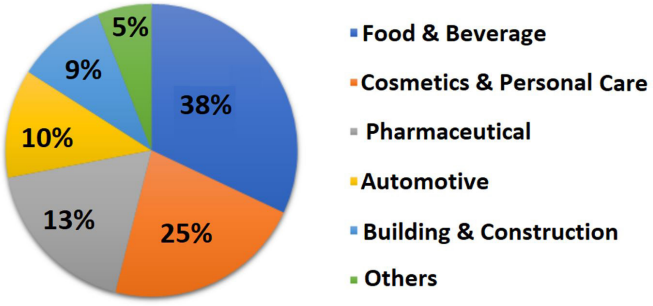

Figure 1. Global PG Market in 2017, by End-Use Industry (Pagliaro, 2017).

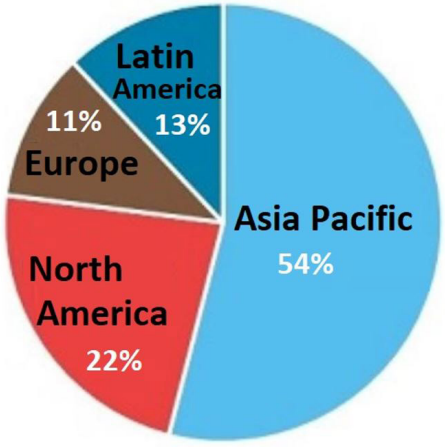

Figure 2. Global PG capacity by region (Pagliaro, 2017).

or 302 to 356 ° F in the presence of Ion exchange resins use small amounts of sulfuric acid or alkalis.

The final products contain 20% PG. Further purification also produces final and industrial types of this material or grades of USP / JP / EP / BP PG, which contain 99.5% or more of this material. It is also possible to obtain the polymer from glycerol (a by-product of biodiesel production). This raw material is usually used for industrial purposes because the final product has a special smell and taste.

2.2 Laboratory production

S-Propanediol is obtained by fermentation methods. Lactaldehyde and lactic acid are also common mediators used. Dihydroxyacetone phosphate, which is one of the products obtained from the decomposition of Fructose 1,6-bisphosphate, is the raw material of methylglyoxal. This change is the basis of a potential biotechnology-oriented pathway to a chemical called Propane-1,2-diol.

2.3 What products are used to produce PG?

1. **Polymers:** 45% of the mentioned polymer is used as primary chemical storage in the production of unsaturated polyester resins. In this regard, PG reacts with a combination of unsaturated maleic anhydrides and isophthalic acid to form a kind of polymer. This semi-unsaturated polymer also finds cross-links to form a thermoset plastic. It also reacts with propylene oxide to form polymers and oligomers that are involved in the production of polyurethane. PG is used in acrylic and blue architectural paintings to increase the drying time of the paint. Because the surface evaporation rate of this material is lower than that of water, they evaporate at a slower rate.
2. **Food Products:** PG is also used to make a variety of foods, such as soft drinks, dairy products, ice cream, liquid sweeteners, and coffee drinks. Vaporizers used to deliver medicines or personal care products usually contain PG in their structure. In alcohol-based hand sanitizers, it also retains moisture and prevents dry skin. The polymer is also used as a solvent in many drugs, including oral, injectable, and topical. Many water-soluble therapies use this type of polymer as a solvent and carrier, and benzodiazepine tablets are an example of this. In addition, the polymer acts as a solvent and carrier for a large number of pharmaceutical and therapeutic capsules. Also, in special formulations of artificial tears, PG is used as one of the ingredients (Song & Xu, 2012).
3. **Antifreeze:** PG generally has an antifreeze role for aircraft. In fact, when water combines with PG, its freezing point decreases. As mentioned before, this substance acts as a liquid that is used as an antifreeze for aircraft. The combination of the polymer with water is pink in color to indicate that the compound is relatively non-toxic and is also sold under the brand name RV or marine antifreeze. It is often used as a substitute for EG in a variety of automotive antifreeze that has low toxicity and is also environmentally friendly**.**
4. **Other uses:** PG, which has already been mentioned, has various uses, including the following:

* As a solvent for a large number of substances (both natural and synthetic) and as substances that retain moisture.
* As oral medications for the treatment of Hyperketonemia in ruminants.
* In the field of beauty, this substance is used as a carrier or main substance in the production of various cosmetic products.
* This polymer is also used as a carrier for substances such as nicotine and cannabinoids and creates smoke, which is similar to cigarette smoke.
* In order to produce cinematic vapors in attractive movies and entertainment scenes. In fact, smoke generators evaporate a mixture of polyethylene glycol and water to create an imaginary image of smoke. Many of these cars use polyethylene glycol fuel, but some also use oil. Machines that use polyethylene glycol as a fuel have a similar process to how e-cigarettes work, using thermal elements to produce a dense vapor. The steam produced by this process and machines has a kind of aesthetic aspect similar to cigarette smoke. The difference is that it does not expose performers and spectators to damage or the smell of real cigarette smoke.

3 Propylene glycol in food: is this additive safe?

3.1 Is it dangerous to use PG in food products?

PG is generally recognized as a safe substance by FDA. In the United States, it can be used as a indirect and direct food additive. But in Europe, factories are only allowed to use a maximum of 0.45 grams per pound (1 gram per kilogram) in the final product of this substance as a solvent in paints, emulsifiers, antioxidants, and enzymes (Cawley, 2001; Zar et al., 2007).

The World Health Organization has announced a maximum daily intake of 11.4 mg per pound of body weight (25 mg per kilogram of body weight). The estimated exposure to oral PG through food in the United States is about 15 mg per pound of body weight (34 mg per kilogram of body weight) per day (Spencer, 2005).

People who experience symptoms of intoxication receive 213 grams of PG daily. This number is 120 pounds (60 kg) for an adult, which is more than 100 times what is found in a normal diet. In general, apart from people with allergies and one case of poisoning from an overdose, no other cases of adverse or toxic effects of oral PG have been reported in the world. However, because people's current intake is estimated to be higher than recommended, you may want to reduce your food intake as

much as possible, especially if you eat a lot of processed foods. There is a lot of conflicting information about the dangers of taking oral PG. Some websites have stated that this substance is safe. Others claim that it causes heart attacks, kidney and liver failure, and brain problems (Fowles et al., 2013).

3.2 How toxic is PG?

The number of cases of PG poisoning is very small. It has not yet been shown to cause cancer, damage to genes, or impair fertility or reproduction. In addition, there are no reports of deaths due to the use of this substance. In mice, the average lethal dose is 9 grams per pound of body weight (20 grams per kilogram). Compare this number with sugar, whose lethal dose is 13.5 grams per pound (29.7 grams per kilogram) of body weight, or salt, which is only 1.4 grams per pound (3 grams per kilogram) of it is lethal (McGowan et al., 2018).

About 45% of oral PG is excreted unchanged by the kidneys, and the rest is converted to lactic acid in the body. If you use too much of this substance, the resulting lactic acid production can lead to acidosis and kidney failure. Acidosis occurs when the body cannot excrete acid quickly. Thus, the acid begins to accumulate in the blood and interferes with the proper functioning of the body. The main symptoms of this type of intoxication are decreased activity of the central nervous system, and its symptoms include slower breathing, decreased heart rate, and loss of consciousness. Poisoning cases can be treated with medication or hemodialysis by removing the substance from the blood. However, oral PG poisoning is very rare (Cunningham et al., 2015).

3.3 Risks of using PG for people with kidney and liver diseases

Oral PG is broken down in adults with normal liver and kidney function and is excreted relatively quickly. On the other hand, in patients with kidney or liver disease, this process may not work. This can lead to the accumulation of PG and lactic acid in the bloodstream and cause symptoms of poisoning (Neale et al., 2005).

In addition, because there is no virtual dose for the use of this substance in drugs, in some cases, a very large amount of this substance can be received with the help of drugs. For example, one study found that 19% of sensitive patients treated with lorazepam had symptoms of PG poisoning. For patients with kidney or liver disease, alternative drugs without PG may be used if needed. There is no evidence that the amount of PG in the diet causes symptoms in these patients (Cock et al., 2014).

3.4 Risks of using PG for infants and pregnant women

Pregnant women, children, and infants under the age of four have a lower body enzyme called alcohol dehydrogenase. This enzyme is essential for the breakdown of PG. Therefore, if these people are exposed to large amounts of oral PG through medication, they may be at risk of poisoning (Allegaert et al., 2010; Lim et al., 2014).

Babies are more at risk. Because it takes up to three times longer in their bodies than in adults to remove PG, therefore, this group may be particularly sensitive to the effects of this substance on the central nervous system. There have been reports of premature infants with seizures due to high doses of vitamins containing PG. However, one study found that the dose was 15.4 mg per pound (34 mg per kg) of body weight. The body excretes PG from the baby within 24 hours (MaCDonald et al., 1987; Lim et al., 2014).

3.5 Risk of heart attack

Some websites claim that PG increases the risk of heart disease and heart attack. This claim is somewhat true because when too much or too fast PG is ingested, it can cause low blood pressure and arrhythmias in the heart. Animal studies have shown that high doses of PG can quickly reduce heart rate, lower blood pressure, and even stop the heart from moving. However, the amount of PG in a normal diet can not cause heart problems in children or adults and is not a cause for concern (Sungpud et al., 2019; Smith et al., 2020).

3.6 Nervous symptoms

There have been reports that PG has caused brain-related symptoms. For example, one report states that a woman with epilepsy developed recurrent seizures and stuttering due to PG poisoning from an unknown source. Although these symptoms may seem scary, it should be emphasized that many different medications and foods, if taken in moderation, can not cause poisoning. There are no reports of neurological changes due to the consumption of oral PG in the world (Lolin et al., 1988).

3.7 Skin and allergic reactions

Experts from the American Contact Dermatitis Association introduced PG as an allergen in 2018. In fact, it is estimated that between 0.8 and 3.5 percent of people have a skin allergy to PG. The most common skin reaction or dermatitis is a rash on the face or in a generalized scattered pattern on the body. Systemic dermatitis has been reported after eating foods and taking oral medications and intravenous drugs containing PG. In a study of 38 susceptible individuals who had access to PG orally, 15 of them experienced skin rashes within 3 to 16 hours of ingestion (Tocci et al., 2015).

In addition, PG can cause irritating contact dermatitis. In this case, the skin of sensitive people gets a rash when it comes in contact with products that contain this substance, such as shampoos or moisturizers. People who already have a skin condition or sensitive skin are at risk for allergies to these additives. For people with allergic dermatitis, it is best to avoid oral PG altogether (Al Jasser et al., 2011; Carrer et al., 2020). Table 1 shows the maximum NOAEL (no-observed-adverse-effect levels) values for propylene glycol following cutaneous exposure, as well as all valid LOAEL (lowestobserved-adverse-effect levels) values for systemic effects and time categories.

Table 1. Levels of Significant Exposure to Propylene Glycol.

Exposure/ Duration	System	NOAEL	Less Serious	Serious	Reference
5 d 1x/d	Hemato	6100 mg/kg			Commens, 1990
70 hr	Resp Cardio Metab			9000 M (acute respiratory acidosis)	Fligner et al., 1985
20-24 hr	Dermal		3.2% (irritation reaction)		Hannuksela et al., 1975
48 hr	Dermal		10 mg (50% solution, skin edema and erythema)		Kinnunen & Hannuksela, 1989
7 d 2x/d	Dermal	104 M mg			Trancik & Maibach, 1982
48 hrs	Dermal		2.5% (erythema, induration, vesiculation)		Warshaw & Herrmann, 1952
48 hr	Dermal	15 mg M	31 mg M (faint, patchy erythema with edema)		Willis et al., 1988
48 hr	Dermal		16 mg M ("basket weave" pattern to stratum corneum)		Willis et al., 1988

4 Conclusions

PG is a beneficial chemical found in a variety of products in the food, pharmaceutical, cosmetic, and health industries. While there are cases of intoxication with this substance due to the use of very high doses of the drug, but in general, it is not considered a dangerous and poisonous substance. A small percentage of people are allergic to PG and may need to avoid any food or non-food containing PG. However, for most people, it is safe to consume oral PG, which is found in foods. Keep in mind that most foods containing PG are fully processed foods. Therefore, following a fresh and complete diet will minimize the entry of this substance into the body.

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