German Federal Institute for Risk Assessment

**Opinion** 004/2025

doi https://doi.org/10.17590/20250331-114214-0

18 February 2025

# Glycerol in slush ice drinks can cause undesirable health effects

**In brief**

- The German Federal Institute for Risk Assessment (BfR) has carried out a health risk assessment of measured glycerol levels in slush ice drinks (also known as slush or slushy).
- Glycerol is authorised as food additive E 422 for use in several food categories including flavoured drinks, but not as a sweetener. The BfR has no information from manufacturers about the technological function of glycerol in slush ice drinks.
- No maximum numerical level is specified for use in food; as much glycerol as necessary may be used (*"quantum satis"*). A dose of 250 milligrams (mg) per kilogram (kg) of body weight (bw) was used for the health risk assessment in this opinion. This is the lowest dose at which a therapeutic effect was shown (reduction of increased intracranial pressure).
- The assessment of the measured glycerol concentrations in a total of 62 slush ice samples showed that younger children can already ingest amounts of glycerol that correspond to or exceed the therapeutically effective dose when consuming quantities of less than 200 millilitres (mL).
- From the BfR's point of view, there are health concerns if the consumption of a slush ice drink leads to an intake that corresponds to or exceeds the therapeutically effective dose.
- In scientific studies on the efficacy and metabolism of glycerol, undesirable side effects occurred, including headaches, nausea, vomiting, diarrhoea and lightheadedness.
- In the course of two enquiries to the German poison centres in 2024, one case was reported in which the reported symptoms were possibly related to the effects of glycerol in slush ice. Internationally, two cases are known from 2021 and 2022 in which children were hospitalised after consuming slush ice.

– Symptoms such as nausea, diarrhoea and headaches may not be associated with the consumption of slush ice drinks. In this respect, it seems plausible that not all such cases become apparent. This could lead to an underestimation of the health risk.

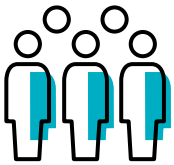
**How does Glycerol enter the body?**

The intake of glycerol takes place **orally** through the consumption of slush ice.

**Is there a health-based guidance value?**

A value for an acceptable daily intake (ADI), compliance with which is not expected to result in impairment of health, has not been established for the food additive glycerol (E 422).

**Is there a health risk?**



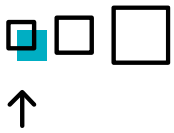
No generally valid statement can be made on the probability of health impairments, because the risk varies in relation to the

- Glycerol concentration in the slush ice drink
- the quantity consumed and
- the body weight of the consumer.

From the BfR's point of view, there are health concerns if the consumption of a slush ice drink leads to a glycerol intake that corresponds to or exceeds the therapeutically effective dose of 250 mg/kg bw (to reduce increased intracranial pressure).

Calculations show that an approximately 5-year-old child with a body weight of 20 kg consuming just under 200 mL of slush ice with an average glycerol concentration of about 26 g/L (which is the average value on which the present assessment is based) ingests an amount of glycerol corresponding to the therapeutically effective dose.

**What is the quality of the data?**



The quality of the data is **low.** Only few data are available on the toxicity of glycerol after oral intake by children. Furthermore, it cannot be assessed with certainty whether glycerol leads to a reduction in intracranial pressure in healthy children to the same extent as in children with increased intracranial pressure because the BfR does not have any corresponding data. In the sense of a conservative approach and taking into account the osmotic properties of glycerol, the BfR makes the assumption that glycerol leads to a reduction in intracranial pressure to the same extent in healthy children.

**How can the health risk from slush ice be reduced?**

**Producers** could check whether the use of glycerol in slush ice drinks is necessary (around a third of the samples measured contained no glycerol) or whether the glycerol content can at least be reduced (the glycerol-containing samples had concentrations ranging from less than 1 g/L to 142 g/L).

**Consumers** can do without slush ice.

# 1 Subject of the assessment

The German Federal Institute for Risk Assessment (BfR) was asked by the Federal Ministry of Nutrition and Agriculture (BMEL) to carry out a risk assessment of measured values of glycerol content in slush ice drinks. The measured values were collected by official food control authorities in several German federal states and summarised and statistically evaluated by the Federal Office of Consumer Protection and Food Safety (BVL). A total of 62 test results, which were collected in the period from 4 November 2023 to 11 October 2024, were transmitted by the BVL to the BfR via the BMEL.[1]

The investigations were prompted by discussions in the European Commission's Working Group on Food Additives (COM Working Group on Food Additives) in September 2023 and January 2024, during which Ireland reported the presence of elevated levels of glycerol in slush ice drinks. According to Regulation (EC) No 1333/2008, the use of glycerol as food additive E 422 is authorised *quantum satis* for several food categories, including food category 14.1.4 (flavoured drinks). According to information published by the competent

[1] In its report, the BVL pointed out that this is data from the current reporting year 2024, which is to be treated as provisional and unaudited.

authorities in Great Britain and Ireland on their websites[2] and to which the Irish delegation drew attention during the discussions in the COM Working Group on Food Additives, high concentrations of glycerol in slush ice drinks (approx. 50 g/L) have been detected in analyses in Great Britain in recent years. Two cases from 2021 and 2022 were also reported in which health impairments in children receiving clinical treatment in Scotland were attributed to the consumption of such drinks.

# 2 Result

The aspects relevant to the risk assessment can be summarised as follows:

## 2.1 Measured concentrations

A total of 62 test results collected in the period from 4 November 2023 to 11 October 2024 were submitted to the BfR. The mean value of all measurement results is 26.24 g/L (lower bound, i.e. the non-quantifiable measurement results are included in the calculation of the mean value with the value 0). About 10 % of the measurement results are at a value of 73.9 g/L and higher and about 5 % at a value of 92.3 g/L and higher. Glycerol could not be detected in 20 samples (approx. 32 %) (< limit of detection) and no quantitative measurement could be determined in four samples (< limit of quantification). In eight samples (approx. 13 %), the quantitative measured value was below 1 g/L. A glycerol content of more than 25 g/L was detected in 30 samples (approx. 48 %) and a glycerol content of more than 50 g/L was detected in ten samples (approx. 16 %). The highest measured value (142 g/L) was reported for a "beverage syrup", which is a ready-to-drink beverage.

## 2.2 Relevant toxicological reference point

The dose of 250 mg/kg body weight (bw) is used as the reference point for risk characterisation. It represents the lowest dose (calculated on the basis of mean body weights and then rounded) that was therapeutically effective (in reducing increased intracranial pressure) in the human study by Wald and McLaurin (Wald & McLaurin 1982).

## 2.3 Toxicological assessment of glycerol concentrations in slush ice drinks

From the BfR's point of view, there are health concerns if the consumption of a slush ice drink leads to an exposure that corresponds to or exceeds the therapeutically effective dose of 250 mg/kg bw.

For risk characterisation purposes, the BfR has calculated the amount consumed in millilitres (mL) that leads to an exposure corresponding to the dose at the reference point for a given glycerol concentration at a given body weight. A mathematical formula with which this can be easily calculated is given in chapter 3.1.4.

[2] https://www.food.gov.uk/news-alerts/news/not-suitable-for-under-4s-new-industry-guidance-issued-on-glycerol-in-slush-ice-drinks
https://www.foodstandards.gov.scot/consumers/food-safety/buying-food-eating-out/glycerol-in-slush-ice-drinks
https://www.fsai.ie/news-and-alerts/latest-news/fsai-provides-advice-on-slush-ice-drinks-for-young

At a glycerol concentration of 26.24 g/L, the mean value of the 62 reported measurement results, 191 mL of the slush ice drink would lead to an exposure corresponding to the therapeutically effective dose of 250 mg/kg bw for a five-year-old child with a body weight of 20 kg, for example. At a glycerol concentration of 73.9 g/L, the 90th percentile of the 62 reported measurement results, this would be 68 mL and at a glycerol concentration of 92.3 g/L, the 95th percentile of the 62 reported measurement results, 54 mL. At the highest measured concentration of 142 g/L, 35 mL of the slush ice drink would already lead to an exposure corresponding to the therapeutically effective dose of 250 mg/kg bw in a five-year-old child with a body weight of 20 kg. For younger children (with a correspondingly lower body weight), this calculated volume is correspondingly lower.

# 3 Rationale

## 3.1 Risk assessment

The focus here is on the risk assessment following acute exposure. With regard to a risk assessment based on longer-term exposure, reference is made to the relevant information in the opinion of the European Food Safety Authority (EFSA) on the use of glycerol as a food additive (EFSA 2017).

### 3.1.1 Hazard identification

3.1.1.1 Chemical and physical characterisation

Glycerol (synonym: glycerine) is a polyalcohol with three hydroxy groups. The chemical substance name is 1,2,3-propanetriol. The CAS number is 56-81-5.

Glycerol is liquid at room temperature, the freezing point is 18°C and the solubility in water is stated as "miscible" (OECD 2002). According to RÖMPP [Online], glycerol is miscible with water and alcohol in any ratio (RÖMPP [Online] 2024). Further physicochemical properties are described, for example, in the EFSA opinion (EFSA 2017) and in an OECD Screening Information Dataset (OECD 2002).

3.1.1.2 Occurrence and use in the food sector

Glycerol is a component of vegetable and animal fats and oils. Glycerol is also formed as an intermediate product during the alcoholic fermentation of sugar-containing solutions; therefore, wine also contains glycerol (6-8 g/L); glycerol is also found bound in lecithins, phospholipids, teichoic acids and some glycolipids (glycosyldiacylglycerols) (RÖMPP [Online] 2024). According to the database "Volatile Compounds in Food", glycerol concentrations of 4,900 to 27,800 ppm (mg/kg) were measured in wine and concentrations of 1,090 to 2,500 ppm (mg/kg) in beer (VCF online 2024).

According to Regulation (EC) No 1333/2008, the use of glycerol as food additive E 422 is authorised *quantum satis* for several food categories, including food category 14.1.4 (flavoured drinks). The specification is regulated in Regulation (EU) No 231/2012.

According to the Handbook of Food Additives, glycerol is used in food production "*as a sweetener with a sweetening power of 60% of sucrose; as a humectant, adhesion promoter and plasticiser in coatings made from gelatine, alginates, CMC and starch derivatives; sausage casings; as a solvent, carrier and solubiliser for flavourings, dyes, antioxidants,*

*enzymes, etc.*". (Behr's online 2024). The use as a sweetener is mentioned in the food additive handbook before all other uses, but glycerol does not belong to the sweeteners authorised according to Annex II of Regulation (EC) No 1333/2008.

The BfR has no information from manufacturers about the technological function of glycerol in slush ice beverages.

### 3.1.2 Hazard characterisation

The use of glycerol as a food additive has been assessed by several international expert committees. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) assessed glycerol in 1976. The JECFA did not consider it necessary to derive a numerical acceptable daily intake (ADI) and accordingly the result of the assessment was "ADI not specified" (JECFA 1976). The European Commission's Scientific Committee on Food (SCF), which was responsible in the European Union until 2003, assessed the use of glycerol as a food additive in 1981 and agreed with the JECFA assessment (SCF 1981). In 1997, however, the SCF had health concerns about the use of glycerol as a sweetener in concentrations of 5 to 15% in beverages intended for children (SCF 1997). The European Food Safety Authority (EFSA) assessed the use of glycerol as a food additive in 2017 as part of the programme for the re-evaluation of authorised food additives (EFSA 2017).

The EFSA came to the result that

- glycerol is rapidly and almost completely absorbed from the gastrointestinal tract,
- the accute toxicity of glycerol is low and local irritant effects in the gastrointestinal tract, which were observed in some animal studies after administration by gavage, are probably due to hygroscopic and osmotic effects,
- there are no concerns regarding genotoxicity and carcinogenicity,
- the studies on reproductive and developmental toxicity only allow a conclusion on reproductive toxicity but no dose-dependent adverse effects were observed and
- no adverse effects were observed in any animal study.

EFSA concluded that there was no need to derive a numerical ADI and that the exposure assessment based on the reported uses and use levels did not raise health concerns for the general population. However, it conservatively estimated the dose of 125 mg/kg bw per hour as the lowest oral dose required for a therapeutic effect of glycerol and emphasised that infants (12 weeks to 11 months) and young children (12 to 35 months) can reach this dose with less than 330 mL of a flavoured beverage.

For food category 14.1.4 (flavoured drinks), no use levels were communicated to EFSA by the food industry. The highest concentration reported by the Member States for this food category was 12.700 mg/kg.

EFSA considered two human studies regarding the absorption of glycerol: (McCurdy *et al.* 1966) and (Pelkonen *et al.* 1967).

In the study by McCurdy et al. (McCurdy *et al.* 1966), the effect of glycerol in therapeutic use for the reduction of intraocular pressure was investigated. Eight volunteers (apparently healthy ("normal human volunteers"), otherwise no details reported) drank a 50 % glycerol solution at a dose of 1.0 - 1.27 g glycerol/kg bw. Serum glycerol concentration was

measured before glycerol ingestion and then after glycerol ingestion every 20 minutes over a period of 140 minutes. The mean glycerol concentration in serum before glycerol intake (control) was 0.51 mmol/L (47 mg/L). After glycerol ingestion, the mean serum glycerol concentration increased to 7.7 mmol/L (710 mg/L) after 20 minutes and reached a maximum value of 16.2 mmol/L (1490 mg/L) after 80 minutes. The mean intraocular pressure decreased from 12.6 mm Hg in the control to a value of 9.0 mm Hg after 20 minutes and reached a minimum value of 7.2 mm Hg after 60 minutes. Two of the eight subjects reported transient mild headaches and mild nausea.

In the study by Pelkonen et al. (Pelkonen *et al.* 1967), the metabolism of glycerol in diabetic patients was investigated with 17 diabetic patients (4 female, 13 male, age 18 - 62 years). The control group consisted of 15 non-diabetic patients (5 female, 10 male, age 15 - 58 years) who were hospitalised due to other minor illnesses (in some cases also due to stomach complaints). Serum glycerol concentrations were measured after oral administration and after intravenous injection. Ten non-diabetic subjects (body weight not reported) were given 5 g glycerol (as a 5 % aqueous solution) orally (at a body weight of 70 kg, this corresponds to 71 mg/kg bw). Serum glycerol concentrations were measured every 15 minutes over a period of 60 minutes. The mean maximum concentration in these ten subjects was reached after 15 minutes with a value of 0.4 mmol/L (37 mg/L). As the participants in this study were not healthy subjects, the results can only be of limited relevance with regard to glycerol absorption in healthy individuals.

The pharmacokinetics of glycerol were also investigated in a human study on 10 healthy volunteers (two female, eight male, body weight 58 - 90 kg, age 23 - 47 years) (Sommer *et al.* 1993). The fasting volunteers drank an 85 % glycerol solution (glycerol 85 % DAB 9) mixed with lemon juice as a single dose of 1.2 g/kg bw. Venous blood samples were taken every 15 minutes for the first 90 minutes and every 30 minutes for the following six and a half hours. Maximum serum concentrations of 1285 to 2238 mg/L (median 1770 mg/L) were reached after 1 - 2 hours (mean 1.4 hours). Half-maximal serum concentrations were reached after about 15 - 30 minutes. The terminal elimination half-life was 0.61 - 1.18 hours (Sommer *et al.* 1993).

These studies show that glycerol is rapidly absorbed, as stated in the EFSA opinion. Although a study by Sun et al. (Sun *et al.* 1988) showed that cold drinks with a temperature of 4°C remain in the stomach slightly longer than drinks with a temperature of 37°C, the half-lives of the retention time in the stomach were not statistically significantly different. Therefore, it can be assumed that the cold temperature of the slush ice drinks has no significant impact on the velocity of glycerol absorption.

The EFSA also considered other human studies in its opinion. These include ten studies in which glycerol was used for therapeutic purposes in patients with eye diseases and corresponding control groups orally as a bolus dose in the dose range of 1000 to 1500 mg/kg bw, with the total dose per day not exceeding 120,000 mg (about 1700 mg/kg bw). The EFSA pointed out that no side effects were observed in some of these studies and that nausea, headache and/or vomiting were observed in others (EFSA 2017).

EFSA also considered a publication by van Rosendal et al. (van Rosendal *et al.* 2010) with recommendations on the use of glycerol for the purpose of hyperhydration and rehydration in athletes. In the review by van Rosendal *et* al. (van Rosendal *et al.* 2010), 28 studies were evaluated in which glycerol was administered orally in doses of 0.5 - 1.5 g/kg bw to a total of

238 subjects. According to van Rosendal et al. (van Rosendal *et al.* 2010), in three studies ((Latzka *et al.* 1997) ≈ 1 g/kg bw (1.2 g/kg lean body weight); (Latzka *et al.* 1998) ≈ 1 g/kg bw (1.2 g/kg lean body weight); (Anderson *et al.* 2001) 1 g/kg bw), in which glycerol was administered rapidly as a bolus followed by fluid intake, adverse effects were reported by a total of six subjects. In two of these studies (Latzka *et al.* 1997, 1998), a total of four subjects reported nausea, which caused them to discontinue participation in the study, whereas in the study by Anderson et al. (Anderson *et al.* 2001), two subjects developed diarrhoea after 24 hours. In three other of the 28 studies, a low incidence of gastrointestinal complaints (bloatedness) or light-headedness was reported, but these did not lead to discontinuation of participation in the study (van Rosendal *et al.* 2010).

The use of glycerol for the purpose of hyperhydration and rehydration in athletes was also evaluated in a systematic review by Jardine et al. (Jardine *et al.* 2023) on the basis of 38 studies with a total of 403 participants (361 of whom were male) with regard to athletic performance, physiological parameters and gastrointestinal effects. Gastrointestinal effects were reported in 26 of the studies analysed. The dosages ranged from 1 to 2 g/kg bw. According to Jardine et al. (Jardine *et al.* 2023), the symptoms included bloating (mild and soon subsiding (Coutts *et al.* 2002; Dini *et al.* 2007; Scheadler 2010)), nausea (mild and soon subsiding, but which in some cases led to discontinuation of participation ((Coutts *et al.* 2002) 1.2 g/kg bw; (Latzka *et al.* 1997) 1.2 g/kg bw; (Scheadler 2010) 1.2 g/kg bw), diarrhoea ((Anderson *et al.* 2001) 1.0 g/kg bw), vomiting ((Latzka *et al.* 1997) approx. 1 g/kg bw (1.2 g/kg lean body mass)) and stomach fullness persisting for 15 to 20 minutes ((Lyons *et al.* 1990) 1.0 g/kg bw). After seven days of administration at a dose of 1.0 g/kg bw (twice a day), gastrointestinal discomfort was reported by one of the 23 subjects in the study by Easton et al. ((Easton *et al.* 2007) 1.0 g/kg bw plus 11.4 g creatine), and in a similar study by Beis et al. ((Beis *et al.* 2011) 1.0 g/kg bw plus 10 g creatine and 75 g glucose), one of the 15 subjects discontinued participation due to gastrointestinal complaints. In the study by Latzka et al. ((Latzka *et al.* 1997) 1.2 g/kg bw), one of nine subjects was unable to drink the glycerol-containing solution without experiencing nausea and therefore did not participate in the study; two other subjects vomited but did not discontinue participation. In the study by Polyviou et al. (Polyviou *et al.* 2012), in which glycerol was administered at a dose of 1.0 g/kg bw (twice a day) together with creatine and glucose over a period of 7 days, one of nine participants reported headaches. On the other hand, according to Jardine et al. (Jardine et al. 2023), no gastrointestinal symptoms were reported after glycerol intake in 13 studies (Lyons *et al.* 1990; Montner *et al.* 1996; Hitchins *et al.* 1999; Goulet *et al.* 2002; Marino *et al.* 2003; O'Brien *et al.* 2005; Goulet *et al.* 2006; Goulet *et al.* 2008; McCullagh *et al.* 2013; Koehler *et al.* 2014; Savoie *et al.* 2015; Savoie *et al.* 2016; Goulet *et al.* 2018). Eleven of these studies are also included in the review by van Rosendahl et al. (van Rosendal *et al.* 2010), namely (Lyons *et al.* 1990; Montner *et al.* 1996; Latzka *et al.* 1997; Hitchins *et al.* 1999; Anderson *et al.* 2001; Coutts *et al.* 2002; Goulet *et al.* 2002; Marino *et al.* 2003; Goulet *et al.* 2006; Easton *et al.* 2007; Goulet *et al.* 2008). In the studies considered by Jardine et al. (Jardine *et al.* 2023), gastrointestinal effects were observed in some studies even at the lowest dose of 1.0 g/kg bw used for hyperhydration.

In a human study in which glycerol was administered orally to 12 patients with ear disease at a dose of 0.51 g/kg bw, 11 patients reported nausea and headaches of varying intensity (Padoan 2003).[3]

Based on a study by Wald and McLaurin (Wald & McLaurin 1982), in which glycerol was administered orally to patients in bolus doses of 500 - 1000 mg/kg bw at 3 to 4 hour intervals for the treatment of traumatic intracranial hypertension, the EFSA calculated that the therapeutic dose required to reduce intracranial pressure was in the range 125 - 333 mg/kg bw per hour. EFSA therefore considered that, conservatively, the lowest oral bolus dose of glycerol required for a therapeutic effect is 125 mg/kg bw per hour and that side effects (nausea, headache and/or vomiting) were also observed in some patients at this dose (EFSA 2017). The EFSA had divided the dose of 500 mg/kg bw by 4 and the dose of 1000 mg/kg bw by 3 (500 : 4 = 125; 1000 : 3 = 333), apparently not focussing on acute exposure but on average exposure after multiple doses of glycerol, which may be relevant for the assessment of the use as a food additive. From the BfR's point of view, the dose of 125 mg/kg bw per hour calculated by the EFSA cannot be regarded as the acute exposure of the subjects in this study. It can be assumed that the test subjects received a dose of 500 to 1000 mg/kg bw at intervals of 3 to 4 hours (as described in the publication) and in this respect the doses of 500 to 1000 mg/kg bw are to be regarded as acute exposure[4]. However, the publication by Wald and McLaurin (Wald & McLaurin 1982) contains a table in which the individual age and sex of the 15 test subjects and the corresponding glycerol doses in grams are listed. This table shows that three of the 15 subjects were children aged 3, 4 and 9 years. As the glycerol doses are not reported in grams per kg body weight in this table and no body weights are given, the BfR calculated the doses in grams per kg body weight for the test subjects up to the age of 17 years on the basis of the mean body weights stated in the German Health Interview and Examination Survey for Children and Adolescents (Stolzenberg *et al.* 2007) and for the older test subjects on the basis of 70 kg body weight as default value according to EFSA (EFSA 2012) (Table 1).

[3] This study is not described in EFSA's 2017 opinion.
[4] In this respect, the BfR agrees with the Food Standards Agency Ireland (FSAI), which has communicated its considerations on this aspect to the BfR.

**Table 1:** Calculated individual dosages for the subjects in the human study by Wald and McLaurin (Wald & McLaurin 1982).

| Subject[a] | Age (years), sex[a] | Glycerol dose (g)[a] | Body weight (kg)[b] | Calculated dose (mg/kg bw) |
|---|---|---|---|---|
| 1 | 26, M | 60 | 70 | 857 |
| 2 | 19, F | 50 | 70 | 714 |
| 3 | 19, M | 60 | 70 | 857 |
| 4 | 19, M | 60 | 70 | 857 |
| 5 | 33, M | 50 | 70 | 714 |
| 6 | 21, M | 60, 50[c] | 70 | 714 |
| 7 | 27, M | 70, 50[c] | 70 | 714 |
| 8 | 28, F | 50 | 70 | 714 |
| 9 | 17, M | 60, 25[c] | 71,6 | 349 |
| 10 | 28, F | 50 | 70 | 714 |
| 11 | 34, F | 50 | 70 | 714 |
| 12 | 33, M | 60 | 70 | 857 |
| 13 | 9, F | 40, 20[c] | 33,8 | 592 |
| 14 | 4, M | 30, 20[c] | 18,4 | 1087 |
| 15 | 3, F | 4 | 15,8 | 253 |

[a] Data according to Wald and McLaurin (Wald & McLaurin 1982)

[b] As individual body weights (bw) are not reported in the publication by Wald and McLaurin (Wald & McLaurin 1982) , mean body weights were reported for subjects aged up to 17 years according to the results of the German Health Interview and Examination Survey for Children and Adolescents (KiGGS) (Stolzenberg *et al.*2007) , and for subjects aged more than 17 years the body weight of 70 kg was used as default value according to EFSA (EFSA 2012) .

[c] These subjects appear to have received two different doses. The lower dose was used to calculate the dose in mg/kg bw (in the sense of a conservative approach to identify the lowest therapeutically effective dose).

According to Figure 2 from the study by Wald and McLaurin (Wald & McLaurin 1982), the mean intracranial pressure in the three children examined was reduced from 650 mm $H_2O$ (at the start of treatment) to a value of around 410 mm $H_2O$ after 30 minutes, was around 320 mm $H_2O$ after 60 minutes and then rose again. Individual measurements are not reported in this publication, but it can be assumed that the dose of 253 mg/kg bw was also therapeutically effective in the three-year-old child. This conclusion is based on the fact that according to Wald and McLaurin (Wald & McLaurin 1982) (i) a total of 396 trials (glycerol administration with subsequent measurement of intracranial pressure) of all subjects were evaluable, (ii) no therapeutic effect was observed in 11 of 396 trials *("Eleven trials (3 %) resulted in sustained elevation of ICP.*") and (iii) Table 1 of this publication shows that 52 trials were evaluated in the three-year-old child. This means that even under the unlikely assumption that the 11 trials are all attributable to the three-year-old child, at least 41 trials must have shown a therapeutic effect in this child. The BfR therefore assumes that the dose of 253 mg/kg bw in the study by Wald and McLaurin (Wald & McLaurin 1982) was the lowest therapeutically effective dose.

Of the 15 subjects in the study by Wald and McLaurin (Wald & McLaurin 1982), one had acute renal failure, it is however not described which subject this was. In this respect, it seems conceivable that, in the worst case, the kidney failure occurred in the child who received the lowest dose of 253 mg/kg bw. However, it is unclear whether a pre-existing medical condition was present in the kidney failure described. Therefore, this renal failure cannot be used as a reliable effect for the determination of a reference dose for adverse effects of glycerol. Gastrointestinal effects were not reported by the subjects in the study by Wald and McLaurin (Wald & McLaurin 1982).

In 1997, the Scientific Committee on Food (SCF) had health concerns about the use of glycerol as a sweetener in concentrations of 5 to 15% in beverages intended for children (SCF 1997). The SCF justified the health concerns by stating that the intended concentrations would lead to exposures of children corresponding to doses that are also used for therapeutic purposes and for which adverse effects have also been observed in clinical studies. Referring to several publications, the SCF emphasised that the main side effects of oral intake of glycerol are headaches, nausea and vomiting, and less frequently diarrhoea, thirst, dizziness and mental confusion.

The food additive handbook points out that osmotic diarrhoea and mucosal damage are possible at intake levels above 50 g (Behr's online 2024). This intake amount corresponds to a dose of 714 mg/kg bw for a body weight of 70 kg and a dose of 2500 mg/kg bw for a body weight of 20 kg. However, the food additive handbook does not explain what this statement is based on.

According to the drug information of the German Federal Institute for Drugs and Medical Devices (BfArM) and the European Medicines Agency (EMA), the package leaflet must contain the statement "*Glycerol may cause headache, stomach upset and diarrhea*" for oral use from 10 g/dose (BfArM 2016; EMA 2024). The dose of 10 g corresponds to 143 mg/kg bw for a bw of 70 kg and 500 mg/kg bw for a bw of 20 kg. It is not clear on which database this medicinal product information is based. According to Bobillot et al. (Bobillot *et al.* 2024), the provision regarding the information in the package leaflet is based on the studies described in their review.

According to Jardine et al. (Jardine *et al.* 2023), glycerol was added to the list of prohibited substances by the World Anti-Doping Agency (WADA) in 2010 due to its potential to increase plasma volume (because this effect was suspected of making the detection of certain doping practices more difficult), but was removed from this list in 2018 after it was shown that any potential masking effect in this regard is only slight at best.

In the studies analysed by van Rosendal et al. (van Rosendal *et al.* 2010) and Jardine et al. (Jardine *et al.* 2023), in some of which side effects were reported, the glycerol doses were in the ranges 0.5 - 1.5 and 1 - 2 g/kg bw respectively. The lowest therapeutically effective dose used in the study by Wald and McLaurin (Wald & McLaurin 1982) was 253 mg/kg bw.

The BfR does not have any relevant data on the question of whether glycerol leads to a reduction in intracranial pressure in healthy children to the same extent as in children with increased intracranial pressure. In the sense of a conservative approach and taking into account the osmotic properties of glycerol, it is assumed in this risk assessment that glycerol leads to a reduction in intracranial pressure in healthy children to the same extent as in

children who are treated with glycerol for medical reasons due to increased intracranial pressure.

Decreased intracranial pressure can result in several symptoms, e.g. headache, nausea, vomiting, dizziness, cranial nerve palsies, double vision (diplopia) and impairment of hearing (Inamasu & Guiot 2006). In a study by Stoskuviene et al. (Stoskuviene *et al.* 2023) on 80 normal-tension glaucoma patients, it was shown that reduced intracranial pressure correlates with reduced intraocular pressure and reduced systolic blood pressure. From the authors' point of view, reduced intracranial pressure could lead to glaucomatous damage.

In the clinical picture of spontaneous intracranial hypotension, the most common symptoms are orthostatic headache, nausea and neck pain/stiffness (D'Antona *et al.* 2021). As one of several possible diagnostic criteria for headache due to spontaneous intracranial hypotension, Schievink et al. (Schievink *et al.* 2011) defined an opening pressure at lumbar puncture of ≤ 60 mm $H_2O$. This criterion (< 60 mm $H_2O$ of cerebrospinal fluid pressure) is also mentioned in the third edition of the "International Classification of Headache Disorders" of the International Headache Society (IHS 2018).

There are only a few case reports of adverse effects following the consumption of slush ice drinks.

According to information published by the competent authorities in Great Britain and Ireland on their websites[5] , high concentrations of glycerol in slush ice drinks (approx. 50,000 mg/L) have been detected in analyses in Great Britain in recent years. This information also mentions two cases from 2021 and 2022 in which health impairments in children receiving clinical treatment in Scotland were attributed to the consumption of such drinks.

In February 2024, the BfR conducted a survey among German poison centres regarding possible enquiries about slush ice drinks. Five out of seven poison centres responded. None of the centres were aware of any such cases. Four of the seven poison centres responded to a new survey in mid-November. In three of the centres, it was still not possible to identify any cases when searching the respective database. Four cases were identified at one centre. However, three of the inquiries related to the material in the rim of special slush ice cups for producing slush ice at home in the freezer. According to research by the relevant poison information center, this is a cold mixture with table salt in the cup shell, which causes the drink to freeze inside the cup. In the fourth case from 2024, an eight-year-old child developed nausea, diarrhoea and fever after ingesting an unknown amount of a slush ice drink (severity assessment by the poison center: mild). At the time of the call, eight days after exposure, there was still a cough. Causality is considered questionable by the poison centre. One centre did not respond to either of the two surveys, so it cannot be ruled out that there were enquiries there.

From the BfR's point of view, there is uncertainty regarding the causality of such case reports. However, the symptoms described in these case reports indicate that a potential causality should at least be taken into account.

[5] https://www.food.gov.uk/news-alerts/news/not-suitable-for-under-4s-new-industry-guidance-issued-on-glycerol-in-slush-ice-drinks
https://www.foodstandards.gov.scot/consumers/food-safety/buying-food-eating-out/glycerol-in-slush-ice-drinks
https://www.fsai.ie/news-and-alerts/latest-news/fsai-provides-advice-on-slush-ice-drinks-for-young

The BfR considers it conceivable that symptoms such as nausea, diarrhoea and headaches may not be associated with the consumption of slush ice drinks. Furthermore, it is not to be expected that a possible reduction in intracranial pressure will be noticed by the affected persons themselves and identified as such an effect. In this respect, it seems conceivable that such cases may not become known.

To answer the question whether undesirable effects such as headache are to be expected at an exposure of 250 mg/kg bw (the lowest therapeutically effective dose in the study by Wald and McLaurin (Wald & McLaurin 1982)), the following information and considerations were taken into account.

In a study by Avery et al. (Avery *et al.* 2010), the reference range for cerebrospinal fluid opening pressure (CSF-OP) at lumbar punctures was determined in 197 children (aged 1-18 years). The children did not suffer from diseases that could have an impact on the CSF-OP. In this study, a mean CSF-OP of 19 cm $H_2O$, a 90th percentile of 28 cm $H_2O$ and a 10th percentile of 11.5 cm $H_2O$ were determined. The authors defined the 90th and 10th percentile as the threshold for unusually high and low pressure respectively. This means that the values for children and adolescents aged 1 - 18 years are normally in the range of 11.5 - 28 cm $H_2O$.

The intracranial pressure measured in the study by Wald and McLaurin (Wald & McLaurin 1982) with a signal transmitter (epidural fiberoptic ICP transducer) in the skull differed only insignificantly from the cerebrospinal opening pressure (CSF-OP) measured in parallel during lumbar puncture. In this respect, it can be assumed that the intracranial pressure measured in this study corresponds to the cerebrospinal opening pressure. In the study by Wald and McLaurin (Wald & McLaurin 1982), the intracranial pressure in the three children examined after oral administration of glycerol fell on average by a good 50 % from 65 to around 31 cm $H_2O$ after 60 minutes. If the pressure in healthy children with an intracranial pressure in the reference range of 11.5 - 28 cm $H_2O$ is reduced by 50 % after consumption of slush ice containing glycerol, as in the study by Wald and McLaurin (Wald & McLaurin 1982), a pressure of 5.75 - 14 cm $H_2O$ would result. This means that at least some of the children can be expected to have an intracranial pressure that is below the reference range and in some cases may also reach the value of the diagnostic criterion of 6 cm $H_2O$ for headache due to spontaneous intracranial hypotension (Schievink *et al.* 2011; IHS 2018). In these children, undesirable effects such as headaches, nausea and neck pain/stiffness etc. can be expected to occur.

The BfR agrees with the EFSA (EFSA 2017) that the use of glycerol as a food additive should not lead to an exposure corresponding to a therapeutically effective dose. In addition, reduced intracranial pressure can result in various symptoms. Therefore, the dose of 250 mg/kg bw, the lowest dose (calculated on the basis of mean body weights and then rounded) therapeutically effective (to reduce intracranial pressure) in the study by Wald and McLaurin (Wald & McLaurin 1982), is used as a reference point for risk characterisation in Chapter 3.1.4.

### 3.1.3 Exposure

3.1.3.1 Measured values for glycerol concentrations in slush ice drinks

Measured values on glycerol concentrations in slush ice drinks were collected by official food control authorities in several German federal states and summarised and statistically

evaluated by the Federal Office of Consumer Protection and Food Safety (BVL). A total of 62 test results collected in the period from 4 November 2023 to 11 October 2024 were transmitted by the BVL to the BfR via the BMEL.[6]

The mean value of all measurement results submitted is 26.24 g/L (lower bound, i.e. the non-quantifiable measurement results are included in the calculation of the mean value with the value 0). Around 10 % of the measurement results were at a value of 73.9 g/L and higher and around 5 % at a value of 92.3 g/L and higher.

Glycerol could not be detected in 20 samples (approx. 32 %) (< limit of detection) and no quantitative measured value could be determined in four samples (< limit of quantification). In eight samples (approx. 13 %), the quantitative measured value was below 1 g/L.

A glycerol content of more than 25 g/L was detected in 30 samples (approx. 48 %), and a glycerol content of more than 50 g/L was detected in ten samples (approx. 16 %).

The highest measured value (142 g/L) was reported for a "beverage syrup". After consultation with the laboratory, it was confirmed that this measured value can be attributed to a sample of a ready-to-eat beverage on offer.

3.1.3.2 Exposure estimation and exposure assessment

There are no reliable data on consumption quantities of slush ice drinks that could be used to estimate acute exposure to glycerol. In addition, portion sizes can vary. Therefore, assumptions on portion sizes and an exposure assessment are omitted and instead, in Chapter 3.1.4, the consumption amount is calculated which, at a given glycerol concentration and a certain body weight, leads to an exposure that corresponds to the dose at the reference point.

### 3.1.4 Risk characterisation

The dose of 250 mg/kg body weight (bw) is used as the reference point for risk characterisation. It represents the lowest therapeutically effective dose (for the reduction of increased intracranial pressure) calculated on the basis of mean body weights and then rounded (see Chapter 3.1.2).

Since no reliable data are available on consumption quantities of slush ice drinks that could be used to estimate acute exposure to glycerol and portion sizes can vary, assumptions on portion sizes are not made and instead the consumption quantity is calculated that leads, at a given glycerol concentration and a given body weight, to an exposure that corresponds to the dose at the reference point. Table 2 shows, as examples, the volumes of slush ice drinks that, at different glycerol concentrations, lead to an exposure corresponding to the therapeutically effective dose of 250 mg/kg bw for a body weight of 15, 20, 30 or 70 kg (approximately 2½, 5 or 8 year old children or adults respectively).

[6] In its report, the BVL pointed out that this is data from the current reporting year 2024, which is to be treated as provisional and unaudited.

**Table 2:** Volumes of slush ice drinks that, at various exemplarily selected glycerol concentrations, lead to an exposure corresponding to the therapeutically effective dose of 250 mg/kg bw at a body weight (bw) of 15, 20, 30 or 70 kg (approximately 2½, 5 or 8 year old children or adults).

| **Glycerol concentration in slush ice (mg/L)** | **Volume of slush ice drink resulting in exposure equivalent to the therapeutically effective dose of 250 mg/kg bw (mL)** | | | |
|---|---|---|---|---|
| | **15 kg bw (approx. 2½ years old)** | **20 kg bw (approx. 5 years old)** | **30 kg bw (approx. 8 years old)** | **70 kg bw (adults)** |
| 25 000 | 150 | 200 | 300 | 700 |
| 50 000 | 75 | 100 | 150 | 350 |
| 75 000 | 50 | 67 | 100 | 233 |
| 100 000 | 37,5 | 50 | 75 | 175 |

The volumes in Table 2 were calculated as follows:

$$\frac{\text{Body weight (kg) x 250 mg glycerol/kg body weight}}{\text{Glycerol concentration (mg/1000 mL)}} = \text{volume (mL)}$$

In this way, for each measured concentration and body weight, the volume of a slush ice drink resulting in an exposure corresponding to the therapeutically effective dose can be calculated.

At a glycerol concentration of 26.24 g/L, the mean value of the 62 reported measurement results, 191 mL of the slush ice drink would result in an exposure corresponding to the therapeutically effective dose of 250 mg/kg bw for a five-year-old child with a body weight of 20 kg, for example. At a glycerol concentration of 73.9 g/L, the 90th percentile of the 62 reported measurement results, this would be 68 mL and at a glycerol concentration of 92.3 g/L, the 95th percentile of the 62 reported measurement results, 54 mL. At the highest measured concentration of 142 g/L, just 35 mL of the slush ice drink would result in an exposure corresponding to the therapeutically effective dose of 250 mg/kg bw for a five-year-old child with a body weight of 20 kg. For younger children (with a correspondingly lower body weight), this calculated volume is correspondingly lower.

From the BfR's point of view, there are health concerns if the consumption of a slush ice drink leads to an exposure that corresponds to or exceeds the therapeutically effective dose of 250 mg/kg bw.

### 3.1.5 Uncertainties with regard to potential overestimation and underestimation of the health risk

Few data are available on the toxicity of glycerol after oral exposure of children. Only a limited number of children were examined in the existing studies. In addition, the children were treated for medical reasons in these studies. Furthermore, it cannot be assessed with certainty whether glycerol leads to the same degree of reduction in intracranial pressure in healthy children as in children with increased intracranial pressure because the BfR does not have any corresponding data. This could lead to an overestimation of the health risk. In the sense of a conservative approach and taking into account the osmotic properties of glycerol,

it is assumed in this risk assessment that glycerol has the same effects in healthy children as in children who have been treated with glycerol for medical reasons.

In the study by Wald and McLaurin (Wald & McLaurin 1982), the body weight of the three-year-old girl is not reported. A body weight was therefore assumed that corresponds to the mean body weight of 15.8 kg for three-year-old girls from the German Health Interview and Examination Survey for Children and Adolescents (Stolzenberg *et al.* 2007). At a higher body weight, the calculated dose would be less than 253 mg/kg bw, and at a lower body weight it would be greater than 253 mg/kg bw.

There are only a few case reports. In addition, causality has not been proven in these cases. On the other hand, consumers may not associate symptoms such as nausea, diarrhea and headaches with the consumption of slush ice drinks and corresponding cases may therefore not become known. This could lead to an underestimation of the health risk.

Side effects or undesirable effects were not systematically investigated in all human studies. This could also lead to an underestimation of the health risk.

# 4 References


Anderson M. J., Cotter J. D., Garnham A. P., Casley D. J., Febbraio M. A. (2001). Effect of glycerol-induced hyperhydration on thermoregulation and metabolism during exercise in the heat. International Journal of Sport Nutrition 11: 315-333.

Avery R. A., Shah S. S., Licht D. J., Seiden J. A., Huh J. W., Boswinkel J., Ruppe M. D., Chew A., Mistry R. D., Liu G. T. (2010). Reference Range for Cerebrospinal Fluid Opening Pressure in Children. New England Journal of Medicine 363: 891-893.

Behr's online, Begründet von Glandorf K., Kuhnert P., Lück E. (2024). Handbuch Lebensmittelzusatzstoffe. Vol. 142. Aktualisierungs-Lieferung 10/2024, Behr's Verlag, Hamburg.

Beis L. Y., Polyviou T., Malkova D., Pitsiladis Y. P. (2011). The effects of creatine and glycerol hyperhydration on running economy in well trained endurance runners. Journal of the International Society of Sports Nutrition 8: 24.

BfArM (Bundesinstitut für Arzneimittel und Medizinprodukte) (2016). Glycerol (E 422). https://www.bfarm.de/SharedDocs/Downloads/DE/Arzneimittel/Zulassung/amInformationen/Besonderheitenliste/Glycerol.html.

Bobillot M., Delannoy V., Trouillard A., Kinowski J. M., Sanchez-Ballester N. M., Soulairol I. (2024). Potentially Harmful Excipients: State of the Art for Oral Liquid Forms Used in Neonatology and Pediatrics Units. Pharmaceutics 16: 119.

Coutts A., Reaburn P., Mummery K., Holmes M. (2002). The effect of glycerol hyperhydration on olympic distance triathlon performance in high ambient temperatures. International Journal of Sport Nutrition 12: 105-119.

D'Antona L., Jaime Merchan M. A., Vassiliou A., Watkins L. D., Davagnanam I., Toma A. K., Matharu M. S. (2021). Clinical Presentation, Investigation Findings, and Treatment Outcomes

of Spontaneous Intracranial Hypotension Syndrome: A Systematic Review and Meta-analysis. JAMA Neurology 78: 329-337.

Dini M., Corbianco S., Rossi B., Lucacchini A. (2007). Hyperhydrating with glycerol: Effects on thermoregulation, hydration and athletic performance during specific exergonic exercise in a warm-humid environment. Sport Sciences for Health 2: 1-7.

Easton C., Turner S., Pitsiladis Y. P. (2007). Creatine and glycerol hyperhydration in trained subjects before exercise in the heat. International Journal of Sport Nutrition and Exercise Metabolism 17: 70-91.

EFSA (European Food Safety Auhtority: EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS)) (2017). Re-evaluation of glycerol (E 422) as a food additive. EFSA Journal 15(3): 4720.

EFSA (European Food Safety Auhtority: Scientific Committee) (2012). Guidance on selected default values to be used by the EFSA Scientific Committee, Scientific Panels and Units in the absence of actual measured data. EFSA Journal 10(3): 2579.

EMA (European Medicines Agency) (2024). Annex to the European Commission guideline on 'Excipients in the labelling and package leaflet of medicinal products for human use'. https://www.ema.europa.eu/en/annex-european-commission-guideline-excipients-labelling-package-leaflet-medicinal-products-human-use.

Goulet E., Gauthier P., Labrecque S., Royer D. (2002). Glycerol hyperhydration, endurance performance, and cardiovascular and the rmor egulatory responses: A case study of a highly trained triathlete. Journal of Exercise Physiology Online 5: 19-28.

Goulet E. D. B., Robergs R. A., Labrecque S., Royer D., Dionne I. J. (2006). Effect of glycerol-induced hyperhydration on thermoregulatory and cardiovascular functions and endurance performance during prolonged cycling in a 25 °C environment. Applied Physiology, Nutrition and Metabolism 31: 101-109.

Goulet E. D. B., Rousseau S. F., Lamboley C. R. H., Plante G. E., Dionne I. J. (2008). Pre-exercise hyperhydration delays dehydration and improves endurance capacity during 2 h of cycling in a temperate climate. Journal of Physiological Anthropology 27: 263-271.

Goulet E. D. B., De La Flore A., Savoie F. A., Gosselin J. (2018). Salt + glycerol-induced hyperhydration enhances fluid retention more than salt- or glycerol-induced hyperhydration. International Journal of Sport Nutrition and Exercise Metabolism 28: 246-252.

Hitchins S., Martin D. T., Burke L., Yates K., Fallon K., Hahn A., Dobson G. P. (1999). Glycerol hyperhydration improves cycle time trial performance in hot humid conditions. European Journal of Applied Physiology and Occupational Physiology 80: 494-501.

IHS (Headache Classification Committee of the International Headache Society) (2018). The International Classification of Headache Disorders, 3rd edition. Cephalalgia 38: 1-211.

Inamasu J. and Guiot B. H. (2006). Intracranial hypotension with spinal pathology. The Spine Journal 6: 591-599.

Jardine W. T., Aisbett B., Kelly M. K., Burke L. M., Ross M. L., Condo D., Périard J, D., Carr A. J. (2023). The effect of pre-exercise hyperhydration on exercise performance, physiological

outcomes and gastrointestinal symptoms: A systematic review. Sports Medicine 53: 2111-2134.

JECFA (Joint FAO/WHO Expert Committee on Food Additives) (1976). Toxicological evaluation of certain food additives. WHO Food Additives Series 10. WHO Technical report series NO 599. Glycerol and glycerol di-acetate.

Koehler K., Braun H., de Marees M., Geyer H., Thevis M., Mester J., Schaenzer W. (2014). Glycerol administration before endurance exercise: Metabolism, urinary glycerol excretion and effects on doping-relevant blood parameters. Drug Testing and Analysis 6: 202-209.

Latzka W. A., Sawka M. N., Montain S. J., Skrinar G. S., Fielding R. A., Matott R. P., Pandolf K. B. (1997). Hyperhydration: Thermoregulatory effects during compensable exercise- heat stress. Journal of Applied Physiology 83: 860-866.

Latzka W. A., Sawka M. N., Montain S. J., Skrinar G. S., Fielding R. A., Matott R. P., Pandolf K. B. (1998). Hyperhydration: tolerance and cardiovascular effects during uncompensable exercise-heat stress. Journal of Applied Physiology 84: 1858-1864.

Lyons T. P., Riedesel M. L., Meuli L. E., Chick T. W. (1990). Effects of glycerol-induced hyperhydration prior to exercise in the heat on sweating and core temperature. Medicine and Science in Sports and Exercise 22: 477-483.

Marino F. E., Kay D., Cannon J. (2003). Glycerol hyperhydration fails to improve endurance performance and thermoregulation in humans in a warm humid environment. Pflugers Archiv European Journal of Physiology 446: 455-462.

McCullagh J., Munge J., Gamble K. (2013). Physiological and performance effects of glycerol hyperhydration for world championship distance duathlons in hot conditions. International Journal of Sport and Health Sciences 7: 351-355.

McCurdy D. K., Schneider B., Scheie H. G. (1966). Oral Glycerol: The Mechanism of Intraocular Hypotension. American Journal of Ophthalmology 61: 1244-1249.

Montner P., Stark D. M., Riedesel M. L., Murata G., Robergs R., Timms M., Chick T. W. (1996). Pre-exercise glycerol hydration improves cycling endurance time. International Journal of Sports Medicine 17: 27-33.

O'Brien C., Freund B. J., Young A. J., Sawka M. N. (2005). Glycerol hyperhydration: Physiological responses during cold-air exposure. Journal of Applied Physiology 99: 515-521.

OECD (Organisation for Economic Co-Operation and Development) (2002). Glycerol. Screening Information Dataset (SIDS) Initial Assessment Report For SIAM 14 Paris, France, 26-28 March 2002. UNEP PUBLICATIONS: 1-178.

Padoan S. (2003). Oral Versus I.v. Administration of the Glycerol Test: Side-effects and Usefulness. Acta Oto-Laryngologica 123: 482-487.

Pelkonen R., Nikkila E. A., Kekki M. (1967). Metabolism of glycerol in diabetes mellitus. Diabetologia 3: 1-8.

Polyviou T. P., Easton C., Beis L., Malkova D., Takas P., Hambly C., Speakman J. R., Koehler K., Pitsiladis Y. P. (2012). Effects of glycerol and creatine hyperhydration on doping-relevant blood parameters. Nutrients 4: 1171-1186.

RÖMPP [Online], RÖMPP Redaktion, Schwab E., F. Böckler, B. Dill, G. Eisenbrand, F. Faupel, B. Fugmann, T. Gamse, P. Heretsch, R. Matissek, G. Pohnert, A. Rühling, S. Schmidt, Sprenger G. (abgerufen November 2024). Glycerol, RD-07-01466 (2019). https://roempp.thieme.de/lexicon/RD-07-01466.

Savoie F. A., Dion T., Asselin A., Goulet E. D. B. (2015). Sodium-induced hyperhydration decreases urine output and improves fluid balance compared with glycerol- and water-induced hyperhydration. Applied Physiology, Nutrition and Metabolism 40: 51-58.

Savoie F. A., Asselin A., Goulet E. D. B. (2016). Comparison of sodium chloride tablets-induced, sodium chloride solution-induced, and glycerol-induced hyperhydration on fluid balance responses in healthy men. Journal of Strength and Conditioning Research / National Strength & Conditioning Association 30: 2880-2891.

SCF (Commission of the European Communities: Scientific Committee for Food) (1981). Reports from the Scientific Committee for Food (11th series). Report of the Scientific Committee for food on extraction solvents (Opinion expressed 15 January 1981). 8 pp.

SCF (European Commission: Scientific Committee for Food) (1997). Opinion on Certain Additives for Use in Foods for Infants and Young Children in Good Health and in Foods for Special Medical Purposes for Infants and Young Children (expressed on 21 March 1997 and amended on 13 June 1997).

Scheadler C. M. (2010). glycerol hyperhydration and endurance running performance in the heat. College of Education and Human Ecology, The Ohio State University, Ohio

Schievink W. I., Dodick D. W., Mokri B., Silberstein S., Bousser M. G., Goadsby P. J. (2011). diagnostic criteria for headache due to spontaneous intracranial hypotension: a perspective. Headache: The Journal of Head and Face Pain 51: 1442-1444.

Sommer S., Nau R., Wieland E., Prange H. W. (1993). Pharmacokinetics of glycerol administered orally in healthy volunteers. Arzneimittelforschung 43: 744-747.

Stolzenberg H., Kahl H., Bergmann K. E. (2007). Körpermaße bei Kindern und Jugendlichen in Deutschland. Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz 50: 659-669.

Stoskuviene A., Siaudvytyte L., Januleviciene I., Vaitkus A., Simiene E., Bakstyte V., Ragauskas A., Antman G., Siesky B., Harris A. (2023). The Relationship between Intracranial Pressure and Visual Field Zones in Normal-Tension Glaucoma Patients. Diagnostics 13: 174.

Sun W. M., Houghton L. A., Read N. W., Grundy D. G., Johnson A. G. (1988). Effect of meal temperature on gastric emptying of liquids in man. Gut 29: 302-305.

van Rosendal S. P., Osborne M. A., Fassett R. G., Coombes J. S. (2010). Guidelines for glycerol use in hyperhydration and rehydration associated with exercise. Sports Medicine 40: 113-139.

VCF online (abgerufen November 2024). Volatile compounds in food 16.10. https://www.vcf-online.nl/VcfHome.cfm.

Wald S. L. and McLaurin R. L. (1982). Oral glycerol for the treatment of traumatic intracranial hypertension. Journal of Neurosurgery 56: 323-331.

**About the BfR**

The German Federal Institute for Risk Assessment (BfR) is a scientifically independent institution within the portfolio of the Federal Ministry of Food and Agriculture (BMEL) in Germany. The BfR advises the Federal Government and the States ('Laender') on questions of food, chemicals and product safety. The BfR conducts independent research on topics that are closely linked to its assessment tasks.

*This text version is a translation of the original German text which is the only legally binding version.*

**Legal notice**

Publisher:
**German Federal Institute for Risk Assessment**
Max-Dohrn-Straße 8-10
10589 Berlin, Germany
T +49 30 18412-0
F +49 30 18412-99099
bfr@bfr.bund.de
bfr.bund.de/en

Institution under public law
Represented by the president Professor Dr Dr Dr h. c. Andreas Hensel
Supervisory Authority: Federal Ministry of Food and Agriculture
VAT ID No. DE 165 893 448
Responsible according to the German Press Law: Dr Suzan Fiack



**BfR** | Identifying Risks –
Protecting Health