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Gummy dietary supplements for children – helpful or harmful?

Suplementy diety w postaci żelek – pomocne czy szkodliwe?

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Abstract

Introduction and objective: The optimal way to provide children with nutrients is through a balanced diet. However, this remains a challenge for many parents; therefore, they decide for dietary supplements intended for children. The aim of the article was to analyse the composition of available supplements for children in the form of gummies in terms of their content of additives, such as sweeteners, gelling agents, flavourings, and colourants. **Materials and methods:** 103 dietary supplements for children in the form of gummies available in the Polish market in 2022 were included in the analysis. The selection was made based on the manufacturer's declarations on the packaging. **Results:** Colourants of synthetic origin included carmine and carminic acid (8/103; 7%), cochineal (5/103; 4.85%) and Brilliant Blue FCF (2/103; 1.94%). The acidity regulator in all analysed supplements was citric acid. Coconut oil (27/103; 26.21%), palm oil (9/103; 8.73%), sunflower oil (9/103; 8.73%), and rapeseed oil (5/103; 4.85%) were used as emulsifiers. That majority of products used simple carbohydrates as sweeteners, in the form of glucose syrup (52.43%), sugar (56.31%), and glucose (4.85%). **Conclusions:** Analysis of the declared composition of dietary supplements for children in the form of gummies indicates a high content of simple carbohydrates, sweeteners, and artificial colourants. There is a need to develop and implement precise guidelines for the composition of dietary supplements for children.

Keywords: dietary supplements, harmful substances, artificial colourants, simple carbohydrates, children

Streszczenie

Wprowadzenie i cel: Optymalnym sposobem dostarczania dzieciom składników odżywczych jest zrównoważona dieta. Dla wielu rodziców pozostaje to jednak wyzwaniem, dlatego decydują się na suplementy diety przeznaczone dla dzieci. Taka dieta optymalizuje wzrost i rozwój dziecka, podczas gdy złe nawyki żywieniowe mogą negatywnie wpłynąć na krótko-

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i długoterminowe wyniki zdrowotne, a także na osiągnięcia akademickie. Celem artykułu była analiza składu dostępnych suplementów dla dzieci w postaci żelek pod względem zawartości w nich składników dodatkowych, takich jak słodziki, substancje żelujące, aromaty i barwniki. **Materiał i metody:** Do analizy włączono 103 suplementy diety dla dzieci w postaci żelek dostępne na polskim rynku w 2022 roku. Wyboru dokonano na podstawie deklaracji producentów zamieszczonych na opakowaniach. Kryteria włączenia dla suplementów diety obejmowały rejestrację produktu jako suplementu diety i deklarację producenta, że jest on przeznaczony dla dzieci. **Wyniki:** Barwniki pochodzenia syntetycznego obejmowały karmin i kwas karminowy (8/103; 7%), koszenilę (5/103; 4,85%) i błękit brylantowy FCF (2/103; 1,94%). Środkiem zakwaszającym we wszystkich analizowanych suplementach był kwas cytrynowy. Jako emulgatory stosowano oleje: kokosowy (27/103; 26,21%), palmowy (9/103; 8,73%), słonecznikowy (9/103; 8,73%) i rzepakowy (5/103; 4,85%). W większości produktów jako słodzika używano węglowodanów prostych w postaci syropu glukozowego (52,43%), cukru (56,31%) i glukozy (4,85%). **Wnioski:** W analizie deklarowanego składu suplementów diety dla dzieci w postaci żelek wykazano wysoką zawartość węglowodanów prostych, słodzików i sztucznych barwników. Konieczne jest opracowanie i wprowadzenie dokładnych wytycznych dotyczących składu suplementów diety dla dzieci.

Słowa kluczowe: suplementy diety, substancje szkodliwe, sztuczne barwniki, cukry proste, dzieci

INTRODUCTION

The best way to provide children with the nutrients they need to stay healthy is through a balanced diet that includes plenty of fruit and vegetables, adequate amounts of protein, fibre and carbohydrates, and limited processed sugar. Such a diet optimises a child's growth and development, while poor eating habits can negatively affect short- and long-term health outcomes, as well as academic performance.

Dietary supplements are products designed to increase the intake of vitamins and minerals consumed as part of a regular diet. Some supplements contain a single vitamin or mineral, while others are complex preparations; other popular supplements include probiotics, and omega-3 fatty acids.

Giving supplements to children can be difficult due to their large size and choking hazard, as well as unpleasant taste or texture. New preparations such as gummies introduced in recent years have made intake more acceptable. Gummies are even considered the most suitable dosage form for dysphagia patients[1]. In addition, these products have become more attractive, branded with colourful cartoon characters and increasingly bought by customers.

In Poland, dietary supplements have the legal status of food products, so they do not receive the same evaluation and pre-market review as medicines. The Food and Nutrition Safety Act both defines the rules of marketing and provides the very definition of a dietary supplement as a product intended to supplement the normal diet, being a concentrated source of vitamins, minerals or other substances beneficial to health. The Act allows supplements to be available in form of capsules, tablets, drops, sachets with powder, ampoules with liquid, bottles with droppers, and in other similar forms, and indicates that dietary supplements should be consumed in small measured quantities[2]. As dietary supplements in Poland can be marketed without tests confirming the effectiveness and quality, the number of dietary supplements introduced in different forms to the pharmaceutic market has increased significantly in the past years. Recent reports show that as many as three-quarters of Polish citizens use dietary supplements with vitamins and microelements at least once a year. Similar figures are reported for children. Recent research conducted in Poland, involving 507 legal guardians of the youngest children (up to 3 years of age), revealed that 79% of all children received dietary supplements[3,4]. In turn, in the American population, over 33% of children take vitamins, whereas 45% of Canadian children aged 1–8 years receive dietary supplements[5–7]. Similarly, approximately one-third of children in study conducted in Turkey in 2024 use dietary supplements[8].

In addition to the lack of legal regulations governing the introduction and distribution of dietary supplements in Poland, a recent report by the Polish Economic Institute highlights the lack of public awareness of supplements and limited supervision over them[9]. The technology for the production of specific supplements requires the inclusion of many additives in the process, such as sweeteners, preservatives, colourings, acidity regulators, flavourings, gelling agents, and emulsifiers. Unfortunately, some of these can have a significant negative impact on children's health[10,11]. Lack of supervision over the production and content of over-the-counter supplements can easily become a reason for the consumption of inadequate doses, with an overdose risk; the same concern applies to additives[12–14]. Most research conducted so far has focused on the analysis of supplements for their vitamin or micronutrient content, without paying much attention to additives.

The aim of the review was to analyse the available supplements for children in the form of gummies and their composition in terms of additives such as sweeteners, gelling agents, flavourings, and colourings.

MATERIALS AND METHODS

A total of 103 dietary supplements for children in the form of gummies, available in the Polish market in 2022, were included in the analysis. The inclusion criteria for the dietary supplements were as follows: registration of the product

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as a dietary supplement and the declaration of the manufacturer about children being the dedicated group of consumers. The components compared across the available supplements included sweeteners, such as glucose syrup, saccharose, glucose, maltodextrins, steviol glycosides, erythritol, corn syrup (glucose-fructose syrup); sugar alcohols – sorbitol, mannitol, xylitol, maltitol, synthetic intense sweeteners – acesulfame K, sucralose; colourings of natural, synthetic or semi-synthetic origin; flavourings of natural, synthetic or unspecified origin; gelling agents – gelatin, pectin, starch, gellan gum, and acacia gum. The analysis was based on the list of ingredients declared by the manufacturer for each product.

Statistical analysis

Statistical analysis was performed using Statistica 13 (StatSoft Inc.). To handle missing data, complete case analysis (listwise deletion) was applied. Normality of the data distribution was tested with the Shapiro–Wilk test. Mann–Whitney *U* and Student's *t* tests were used for quantitative data comparison, as required. The two-sided Fisher's exact test or the chi-square test were used for categorical and binary data comparison as appropriate. Biserial correlation was carried out for comparison between continuous and dichotomous variables, and a p value of <0.05 was considered statistically significant.

Ethical considerations

This study was conducted in accordance with the ethical standards stipulated in the 1964 Declaration of Helsinki and its later amendments. The study received approval by Poznan University of Medical Sciences Medical Bioethics Committee (reference number: KB-284/23). This manuscript presents a part of a larger research project that did not involve active participants; however, participants included in the full study had given their informed consent.

RESULTS

The general characteristics and composition of the analysed dietary supplements for children in the form of gummies are presented in Tabs. 1 and 2.

Most of the analysed supplements contained substances of natural origin, such as colourants (67/103; 65.05%). Colourants of synthetic origin included carmine and carminic acid (8/103; 7%), cochineal (5/103; 4.85%) and Brilliant Blue FCF (2/103; 1.94%). The analysis of flavouring substances revealed that the majority (63.11%) were of natural origin. However, in every fourth product, the origin of the flavourings was not specified. The acidity regulator used in all the gummies was citric acid. Coconut oil (27/103; 26.21%), palm oil (9/103; 8.73%), sunflower oil (9/103; 8.73%), and rapeseed oil (5/103; 4.85%) were used as emulsifiers. Most products contained added sugar as a sweetener in the form of glucose syrup (52.43%), sugar (56.31%), and glucose (4.85%). They also contained synthetic intense sweeteners, such as sucralose and acesulfame K.

Type of supplement/effect	Number of supplements (N = 103)	%
Vitamin and mineral supplements		
Multivitamin	54	52.43
Vitamin C	6	5.83
Vitamin D	8	7.77
Omega-3	8	7.77
DHA	3	2.91
Magnesium	1	0.97
Supplements with a declared organ-specific effect		
Throat	1	0.97
Supplements with declared systemic effects		
Focus	1	0.97
Immunity	15	14.56
Probiotic	5	4.85
Energising	1	0.97

Tab. 1. Types of available dietary supplements in the form of gummies

Ingredient	Quantity (N = 103)	%
Sweeteners		
Glucose syrup	54	52.43
Saccharose	58	56.31
Glucose	5	4.85
Maltodextrins	13	12.62
Steviol glycosides	7	6.80
Erythritol	8	7.77
Corn syrup (glucose-fructose syrup)	1	0.97
Sugar alcohols		
Sorbitol	28	27.18
Mannitol	3	2.91
Xylitol	3	2.91
Maltitol	2	1.94
Synthetic intense sweeteners		
Acesulfame K	1	0.97
Sucralose	6	5.83
Colouring substances		
Natural origin	67	65.05
Synthetic or semi-synthetic origin	19	18.45
Flavouring substances		
Natural origin	65	63.11
Synthetic origin	3	2.91
Unknown origin	26	25.24
Gelling agents		
Gelatin	58	56.31
Pectin	38	36.89
Starch	4	3.88
Gellan gum	2	1.94
Acacia gum	1	0.97

Tab. 2. Composition of dietary supplements in the form of gummies

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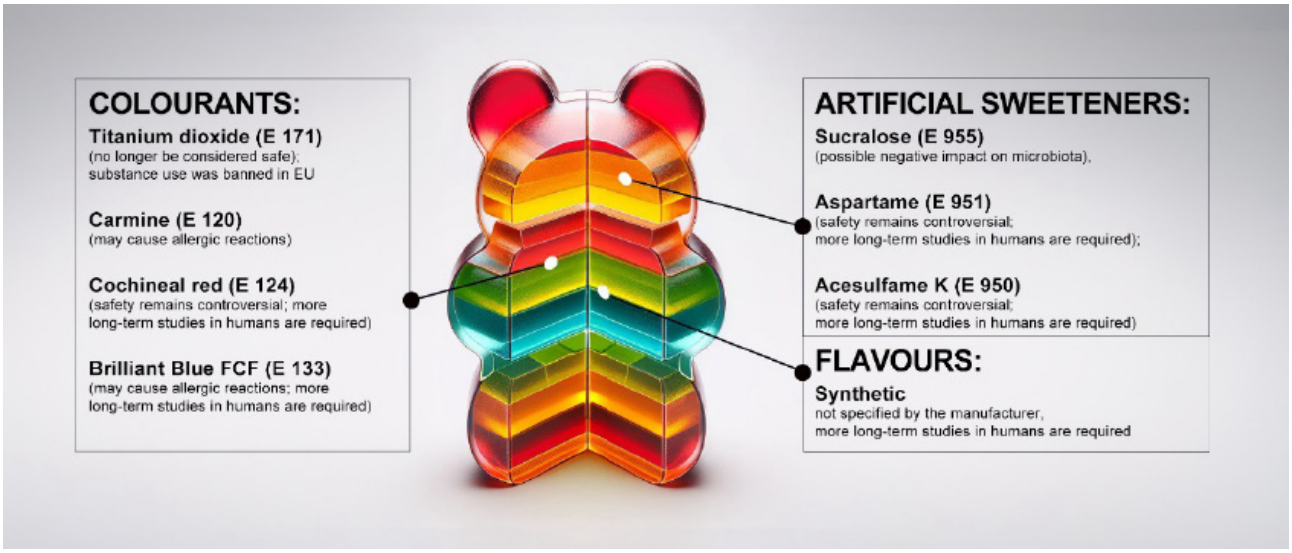

Fig. 1. Content of colourings, sweeteners and flavourings in analysed dietary supplements for children (author: Paweł Jaskólski)

Fig. 1 presents the components present in gummy dietary supplements for children.

DISCUSSION

Children's nutrition has an important impact on their further development, not only physiological, but also psychological. Sweeteners and colourants contained in dietary supplements for children have been shown to have a significant impact on their health and can potentially negatively modulate the functioning of organs and tissues in the developing body. This is particularly relevant in the context of this study.

General harmful effects of sugar and sweetener consumption

International dietary recommendations generally and consistently indicate that the intake of simple carbohydrates should be reduced[15]. High sugar consumption is common among both young children and adolescents, and is a major factor for the development of dental caries[16]. Scientific evidence supports a strong causal link between sugar consumption and the increased risk of obesity and metabolic disorders due to higher caloric intake[17]. Consumption of simple carbohydrates affects the satiety centre in the hypothalamus, inducing hunger and greater energy intake, which may exceed actual caloric requirements. Additionally, the rapid intestinal absorption of simple carbohydrates causes an insulin surge that initiates a cascade of changes in the secretion of appetite-regulating hormones and inflammatory biomarkers which may contribute to an increased risk of type 2 diabetes and cardiovascular disease in children[18]. A diet overloaded with simple carbohydrates can also affect the cognitive and behavioural abilities of children and adolescents. Behavioural patterns induced by excessive consumption of simple carbohydrates observed in rats are similar to those seen in drug-addicted rats, due to concurrent neurochemical changes in the dopamine, acetylcholine, and opioid concentrations[19].

Sweeteners can be several hundred to several thousand times sweeter than sucrose, so they are consumed as sugar substitutes. Although non-nutritive sweeteners are considered safe and well-tolerated, their effects on glucose tolerance, changes in the composition of the gut microbiota, and activation of sweet taste receptors are controversial.

The reported analysis found that one of the gummy supplements for children contained acesulfame K used as a sweetener, with research showing that it can be responsible for hyperactivity, kidney and liver dysfunction, respiratory problems, vision alteration, and headaches. Studies on animals that received acesulfame K revealed that it induced development of breast, lung and haematological tumours[20]. However, acesulfame K was classified by the Food and Drug Administration as a generally safe substance[21].

Harmful effects of sweeteners on the intestinal microbiota

The negative influence of sweetener consumption on the gut microbiota has been the subject of numerous studies[22]. On the one hand, the use of sweeteners leads to a reduction in the glycaemic load of the diet; on the other hand, studies indicate a link between the consumption of non-nutritive artificial sweeteners and an increased risk of developing glucose intolerance, primarily by negatively modulating the diversity of intestinal microbiota. Suez et al. analysed a dietary intake of 180 mg/dL of saccharin (about 20% of the acceptable daily intake for adults) and 102 mg of sucralose over two weeks in a group of individuals aged 18–70 and found significant negative effects on microbiome diversity and an increase in glycaemic response[22]. However, these

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observations were not confirmed in another study involving a daily intake of 800 mg of saccharin over a comparable observation period[23]. It is worth noting that these discrepancies in the results are likely due to different study protocols and varying baseline parameters among study groups, such as baseline microbiome composition, dietary habits, and variations in baseline blood metabolome profiles. Studies in animal models, particularly with use of saccharin, indicate its adverse effects on microbiota composition and highlight similarities in metabolic pathways leading to glucose intolerance in humans. Bian et al. concluded that sucralose consumption at levels corresponding to the human acceptable daily intake may increase the risk of developing tissue inflammation by disrupting gut microbiota function, as supported by elevated pro-inflammatory gene expression in the livers of sucralose-treated mice[24].

Effects of colourants on children's health and development

The use of colourants is also controversial. They are used to enhance product appeal and help preserve the original colour that may be lost during processing. Some colourants are extracted from plant or animal sources, but the most commonly used food dyes are synthetic organic compounds. The most frequently used food azo dyes include Tartrazine (E102), Sunset Yellow FCF (E110), Carmoisine (E122), Amaranth (E123), Allura Red AC (E129), Brilliant Blue FCF (E133), and Brown HT (E155)[25,26]. Food colouring has been tested by regulatory agencies responsible for consumer safety. However, the safety of these substances remains controversial; they have been associated with adverse effects, especially due to the reduction and cleavage of the azo bond. Consumption of FD&C dyes has been associated with neurobehavioral issues in some children[10].

Brilliant Blue FCF (E133), a blue-green synthetic colourant, is not recommended for individuals with irritable bowel syndrome and other gastrointestinal conditions. Like most food additives, it can cause allergic reactions and is potentially carcinogenic[27]. Rats exposed to Brilliant Blue for 90 days at a dosage of 1.2 mg bw/day developed neutrophilia and lymphopaenia. Another study suggests a genotoxic effect of Brilliant Blue FCF on *Allium cepa* root meristematic cells[28].

The quantity of colourant used in commercial products is proprietary, making it difficult to assess dietary intake and determine exposure levels in children. Nearly one in five dietary supplements tested (18.45%) contained synthetic or semi-synthetic dyes in their declared composition. Cochineal, also known as E120, is extracted from an insect that feeds on Mexican cacti. According to Commission Regulation (EC) No. 2018/1472 of 28 September 2018, carminic acid must have a minimum purity of 90%, and the content of carminic acid in chelates must not be less than 50%[29]. While classified as a colourant of natural origin, it may also contain proteinaceous material derived from insects, which may be responsible for shortness of breath, as well as allergic and anaphylactic reactions in users and consumers of products containing this pigment[30]. Although the amounts of carmine added to foods and beverages are strictly controlled, their use can exceed permitted levels. Therefore, monitoring the levels of this carmine pigment in widely consumed products is essential[31]. Moreover, it should be taken into account that most foods containing this colourant are consumed by children, who have a lower body weight, a higher metabolic rate, and a lower capacity for detoxification; this age group is therefore more likely to exceed toxic doses.

Titanium dioxide (TiO_2) is an inorganic chemical compound that occurs in nature in the form of several minerals, such as rutile, anatase, and brookite. TiO_2 is also synthetically produced and used across various industries, including paints, varnishes, paper, textiles, ceramics, electronics, solar energy, and biomedicine. Due to its unique properties, TiO_2 is widely used as a food colourant that gives products a white colour and lustre. It is also present in cosmetics, medicines, and dietary supplements, where it serves as a colourant, bleaching agent, sun protection agent, and a substance that improves product stability and durability[32].

TiO_2 has been approved by the U.S. Food and Drug Administration (FDA) as a safe food additive since 1966, being considered biologically inactive and not absorbed by the body. TiO_2 is also recognised as safe by other regulatory agencies worldwide, such as the European Food Safety Authority, the World Health Organization, the Organisation for Economic Co-operation and Development, and others. However, in recent years, a wealth of new scientific evidence has emerged that raises concerns regarding the safety of TiO_2 and highlights its potential risks to human and environmental health. In particular, TiO_2 may contain nanoparticles that may exhibit completely different properties and effects compared to larger TiO_2 particles. TiO_2 nanoparticles can be inhaled, swallowed, or absorbed through the skin, penetrating cell membranes into various tissues and organs, where they can induce oxidative stress, inflammation, DNA damage, and genetic mutations. TiO_2 nanoparticles may also disrupt the intestinal microbiome, immune system, and metabolic function. Additionally, these nanoparticles are capable of crossing the blood-brain barrier and inducing apoptosis in human hippocampal neurons[33,34]. Moreover, TiO_2 nanoparticles have been identified as potentially carcinogenic, teratogenic, and toxic to aquatic organisms[32,34,35].

As a result, many non-governmental organisations, including the Environmental Working Group, Center for Food Safety, Consumer Reports, and others, have called on the FDA to revoke the approval of TiO_2 as a safe food additive and to require food manufacturers to disclose the presence of TiO_2 on product labels. These organisations argue that TiO_2 has no nutritional or functional benefit in food and is added solely for aesthetic purposes. Furthermore, they are urging the FDA to conduct new, independent, and

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rigorous studies on the health and environmental effects of TiO_2, while advising consumers to avoid products containing it and instead choose natural and organic alternatives.
Contamination of colourants with heavy metals is a significant concern for child development. The findings of this study are biologically plausible. Researchers at the U.S. Environmental Protection Agency have previously demonstrated that mercury (Hg) accumulates in the endocrine system and that Hg is directly cytotoxic to endocrine tissues. It has also been reported that mercury can cause changes in hormone levels, affecting sex hormones and up- or down-regulating enzymes within the steroidogenesis pathway[36].
In a similar survey conducted by Kumar et al., the presence of additives such as colourants, sweeteners, and other excipients (flavourings, preservatives, stabilisers, and fillers) were analysed in 41 chewable/liquid multivitamin and mineral supplements. Sucrose was present in 63% of the preparations, followed by lactose (29%), glycerine (22%), and sorbitol (17%); however, on average, each product contained two sweeteners. The most commonly used colourant was FD&C Yellow (Sunset Yellow), present in 46% of the preparations, followed by FD&C Red #40 in 29%; moreover, in 34% of the products, no colourant was identified by the manufacturers[37].
This does not imply that manufacturers should abandon the use of excipients entirely. Without them, it would not be possible to formulate certain medicines into suitable medicinal products. For others, the removal of excipients would shorten shelf life and render production uneconomical or too costly for consumers. While excipients are important, some may cause harm. Therefore, it is essential to minimise exposure and use them only when there are clear requirements.
Interesting experiments were conducted by Pandey and Kejriwal; their study aimed to identify and select natural vegan components for developing gummy prototypes to produce gummies with a variety of bioactive and sensory properties. This work sheds light on potential opportunities in the production of new safer supplements for children[38].
The analysis highlights the important issue of regulation and supervision of dietary supplements for the young. A key finding of the study is that there are no specific guidelines for dietary supplements intended for children, which calls into question their safety and effectiveness. In Poland, as in many other countries, dietary supplements are regulated in a way that does not always reflect their specific characteristics, especially when it comes to products made for children. While foods for infants and young children are subject to strict ingredient and labelling standards, dietary supplements, including those in gummy form, often escape such detailed scrutiny. This leads to a situation where products may contain undesirable or harmful substances without proper labelling, making it harder for parents to make informed choices.
When comparing the situation in Poland with other countries, significant differences emerge in the approach to the regulation of dietary supplements for children. For example, in the United States, the FDA requires dietary supplement manufacturers to follow Good Manufacturing Practices, which are designed to ensure product safety and quality. However, even there, supplements are not subjected to the same rigorous testing and regulation as medicines. In European Union countries, despite a shared legal framework for dietary supplements, there are still differences in implementation and enforcement at the national level. This can lead to situations where a product available in one member country may not meet the standards of another.
Some countries, such as Norway and Canada, apply stricter regulations to dietary supplements for children, emphasising detailed verification of composition and restrictions on the use of certain substances. This kind of approach promotes greater safety and health protection for young consumers.

LIMITATIONS OF STUDY

The main limitation of this study is that the analysis of supplements was restricted to gummy dietary supplements for children available in Poland. Additionally, the analysis was based solely on the content declared by the manufacturer, without biochemical verification of the supplements' composition.

CONCLUSIONS

In conclusion, the analysis of the declared composition of children's dietary supplements in the form of gummies reveals regulatory gaps and inconsistencies in the oversight of the safety of these products. Dietary supplements for children should contain only essential ingredients, and their composition must not raise any health concerns for consumers. The safety of dietary supplements is questionable, which results from insufficient market surveillance, low entry requirements for new formulations, and the lack of minimum safety regulations. When compared with other countries, there is an evident need to develop and implement stricter and more uniform guidelines that take into account the specific requirements of children's dietary supplements and provide adequate protection across all markets.

Conflict of interests
The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the content of this publication and/or claim authorship rights to this publication.

Author contribution
Original concept of study: PM, ED. Collection, recording and/or compilation of data: PM, ED, EB. Analysis and interpretation of data: PM, BCh. Writing of manuscript: PM, ED, UR, JP, MDB, MM, JK, JS, EB, BCh, AS, RV, AMRW. Critical review of manuscript: AM, GJ, AMRW. Final approval of manuscript: PM, MW, AMRW.

Informed consent statement
Informed consent was obtained from all subjects involved in the study.

Data availability statement
All data are available from dr Piotr Merks (piotrmerks@googlemail.com).

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