Keto gums as dietary supplements

Market analysis and potential in the context of the ketogenic diet

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Abstract

The ketogenic diet is not only used in the therapeutic sector, but also in the context of trends in areas such as weight loss and competitive sports. A common challenge of the ketogenic diet is its practical implementation, which is why some countries prescribe exogenous ketone bodies to support the diet. Relatively new products such as keto gummy bears (keto gums) promise to make the ketogenic diet easier and also advertise benefits such as weight loss, boosting the immune system, promoting general health and detoxifying the body. Certain health claims are legally permissible, namely certain claims based on the addition of vitamins and minerals. However, many of the benefits these products claim to offer are neither scientifically proven nor permissible by law. In particular, there is no scientific basis for the supposed positive effects of keto gums as part of a ketogenic diet. This study analyzed the gummy sweets that claim to have a ketosis-promoting effect (keto gums) currently available on the German market. Their ingredients and advertising claims were assessed in terms of their potential effectiveness and usefulness in the context of ketogenic diets. Based on the currently available research, the products assessed here cannot be recommended as a useful supplement to the ketogenic diet.

Citation
Assmann M, Dapprich J, Albrecht I, Fischer T: Keto gums as dietary supplements. Market analysis and potential in the context of the ketogenic diet. Ernahrungs Umschau 2025; (72)7: 132–41.e40–2.

Open access
The English version of this article is available online: DOI: 10.4455/eu.2025.030

Peer review process
Manuscript (overview) submitted: 04 Nov 2024; revision accepted: 12 Feb 2025

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Introduction

The ketogenic diet is defined as a diet with a carbohydrate intake of ≤ 50 g per day, a moderate to slightly increased protein intake and a high fat intake [1–3]. This diet deviates significantly from the general dietary recommendations of the German Nutrition Society (DGE). These recommendations state that carbohydrates should be the most important macronutrient in terms of quantity and that fat intake should be moderate [4–6].

In traditional media, on social media, and in advertising, low-carb diets are often presented as ketogenic diets. Strictly speaking, ketogenic diets (◆ box) are low-carb, or even very low-carb, but not every low-carb diet is automatically ketogenic [3]. The goal of the ketogenic diet is to put the body into a state of physiological ketosis, in which the body uses ketone bodies as an energy source instead of glucose. This diet has been found to have promising results in certain clinical trials, particularly in the treatment of pharmacoresistant epilepsy and some rare congenital metabolic disorders such as glucose transporter 1 (GLUT1) deficiency and pyruvate dehydrogenase (PDH) deficiency [6].

Ketosis, which is the target metabolic state in the ketogenic diet, is induced by drastically

The ketogenic diet

As early as 500 BC, complete abstinence from food and liquids was being recommended as a treatment for epilepsy. Religious texts also mention fasting as a healing method. In 1911, French doctors Guillaume Guelpa and Auguste Marie documented the first systematic treatment of epilepsy patients using intermittent fasting and described its partially positive effects on the reduction of seizures [7]. Based on similar observations, in 1921, Dr. Russell Morse Wilder hypothesized that the positive effects of fasting were due to an increased concentration of ketone bodies in the blood. Wilder posited that this state of ketosis could also be induced by a high-fat, low-carbohydrate diet and maintained over a longer period of time. Due to his success applying this in clinical practice, Dr. Wilder has since been regarded as the founder of the ketogenic diet [8].

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reducing carbohydrate intake while simultaneously increasing fat intake. As the body's supply of glucose (its primary energy source) reduces, it begins to use more ketone bodies – especially β-hydroxybutyrate and acetoacetate – as an energy source. With a diet that is high in carbohydrates, these ketone bodies, which are continuously produced in the liver, only occur in minimal quantities [9]. When an adult has a daily carbohydrate intake of more than 40–50 g, no significant increase in ketone bodies in the blood is to be expected. In addition, for ketogenesis to occur, protein intake should be kept moderate, as excessive intake can promote gluconeogenesis from glucogenic amino acids and thus inhibit ketogenesis.

A high fat intake is therefore a crucial element of the ketogenic diet, as this is the basis for the production of ketone bodies [3].

Research into applications in diseases such as type 2 diabetes mellitus, cancer and migraines is on the rise, but the ketogenic diet is also increasingly being researched in the context of primary prevention. Initial studies suggest that the ketogenic diet could lead to a reduction in body weight and a reduction in body fat, particularly in overweight and obese people, possibly due to an appetite suppressant effect [10]. In addition, the ketogenic diet has been shown to have positive effects on weight, body composition, performance and muscle growth in some sports [11–13].

Regardless of the individual reasons for following a ketogenic diet, long-term adherence to it is often very challenging. Drastically reducing carbohydrate intake requires abstaining from a wide range of foods, all of which contain carbohydrates, including rice, pasta, bread and confectionery, and many types of fruit and vegetables. At the same time, the proportion of high-fat foods in the diet must be significantly increased. According to a recent review, the average diet adherence rates (= treatment compliance) for epilepsy are between 64% and 72% across all age groups, with considerable fluctuations being observed. In overweight and obese people with type 2 diabetes mellitus, even greater variations in diet adherence of between 9.5% and 98% have been observed [14]. This adherence depends on various factors, including age, duration of the diet, possible side effects and the specific form of the ketogenic diet [15].

In response to the challenges of adhering to the ketogenic diet, over the last few decades, the food supplement industry has developed various products to support the production of ketone bodies. As early as the 1980s, exogenous ketone bodies were brought to market in the form of ketone salts and esters. They were initially used in the sports sector and then later also for metabolic diseases. These products are designed to complement the ketogenic diet in promoting ketosis, and today they are often targeted toward the wellness market [16].

In the European Union (EU), such products are subject to the *Novel Food* Regulation and are currently not authorized, as their safety is not considered sufficiently proven [17].

Nevertheless, an increasing number of foods and dietary supplements that contain little or no exogenous ketone bodies and yet are advertised as having a ketosis-promoting effect are currently available on the market. For example, in 2023 the consumer advice center in Hesse, Germany (Verbraucherzentrale Hessen – VZ), reported on gummy sweets that claimed to be suitable for weight loss and claimed to promote ketosis. Disproportionate advertising claims such as "No diet or exercise" and before-and-after pictures of customers were used to appeal to potential buyers. The only ingredients these products generally contain besides a small amount of ketone bodies are sugar, water, vitamins, minerals and various plant extracts, for which there is as yet no scientific evidence to justify weight loss claims, according to the VZ. In addition, such advertising claims are prohibited under the Food Information to Consumers Regulation (FIC) (EU) No. 1169/2011 Art. 7 [18–20].

The following is an analysis of the gummy sweets that claim to have a ketosis-promoting effect (keto gums) currently available on the German market. The aim is to scientifically assess their ingredients and advertising claims in terms of their potential effectiveness and usefulness in the context of ketogenic diets.

Methods

The market research was conducted by searching for products with the keywords (originally in German, translated here) "keto wine gums", "keto gummy bears", "keto fruit gums", "keto gum(s)", "keto gummy" and "keto gummies" on Amazon.de [21], the online mail order company with the highest sales (in Germany). All products listed in Germany that could be classified as gummy sweets or chewing gum based on general public perceptions according to the Food Federation Germany (Lebensmittelverband Deutschland e. V.) [22] were inspected and documented. In addition, the two top-selling German drugstore chains, dm and Rossmann [23], were searched for relevant products by means of on-site visits. The data collection period was two weeks and it ended on April 22, 2024. To ensure accurate data entry, the search was carried out by two people independently of each other. The data analysis included both the information on the packaging and the information on the online store and cross-checks were carried out accordingly. The following information was recorded: product designation, product name,

manufacturer, flavor, quantity, price, recommended daily dosage, ingredients according to the manufacturer's specifications (macro and micronutrients as well as all additives and other ingredients), number and quality of reviews in the online store, as well as the advertising claims presented there. For the statistical calculation, descriptive statistical methods (mean value, median, standard deviation [SD], range) were used, via the programs Microsoft Excel 2019 and IBM SPSS Statistics 29.

Results

Products, flavors and presentation

The two-week market research process generated a total of 13,711 hits through the use of specific search terms. The number of hits displayed per search term ranged from 76 to 10,000 products (SD: 2056). In contrast, no relevant products were found in the searches of the drugstore chains. After excluding duplicates and products that did not meet the established definition, 33 products from 20 different manufacturers were included in the dataset. The majority of manufacturers (80%; percentages are rounded in this text) had only one product in their range, but one manufacturer sold nine different products. In addition, one manufacturer offered products under two different brand names. Most of the products were in the form of gummy sweets (93.9%), with the remaining products falling into the chewing gum category. The online store usually only offered one pack size per product. More than 80% of the products came from EU countries, although two products (6%) came from the UK and four products (12%) came from China. A total of eight different flavors were identified, ranging from classic flavors such as apple or mixed fruits to unusual flavors such as mango or lemongrass (◆ Figure 1). No different flavors or other variations were offered for the same product.

When reviewing the product designs, the use of gender-specific marketing was particularly striking. Manufacturers who sold more than one product marketed their different products (which had the same standard formulation) with a clear focus on a specific gender (male or female), selecting flavors (e.g., raspberry), colors (e.g., pink) or marketing strategies (e.g., photos, advertising claims of "weight loss") accordingly. On the Amazon rating system, which uses a scale from 1 to 5 stars (5 stars = highest possible rating), the products had a high level of customer satisfaction and popularity with an average of 3.71 ± 0.71 stars (n = 24; median: 3.8; min.–max.: 2.1–5) and 556 ± 2409 total ratings (n = 33; median: 32; min.–max.: 0–14076). Only verified purchases are taken into account in the Amazon rating system, unless the person providing the rating shares additional details in the form of text, images or videos [24].

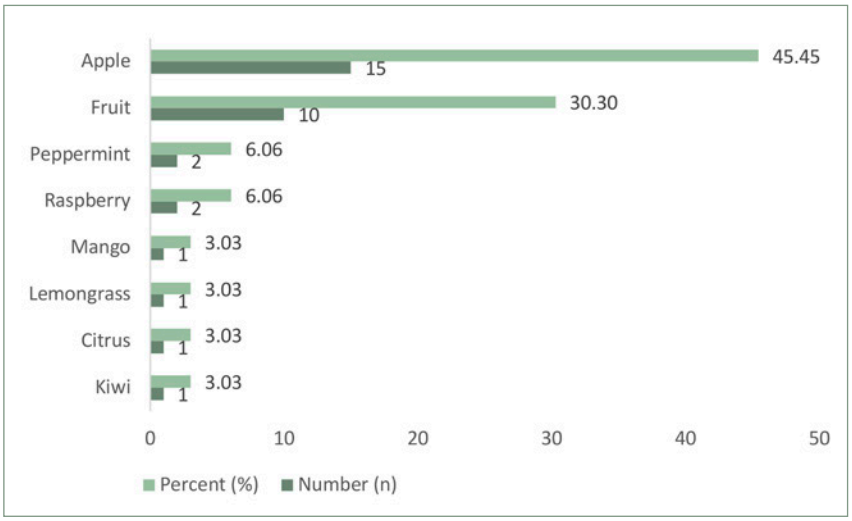

Fig. 1: **Number (n) of mentions and percentage (%) of each flavor of the keto gums examined (n = 33)**

Pack size and price

The average pack size of the products examined was 61 ± 15 pieces or 163.96 ± 47.24 g. The price per pack was €28.91 ± 12.23 (median: €29.38), which corresponds to €0.50 ± 0.20 (median: €0.54) per piece or €0.20 ± 0.09 per gram of the final product. The most expensive product cost €59 for a pack size of 60 pieces. The portion size recommended by the manufacturers varied between 1 and 3 pieces per day, which would result in an average daily cost of €0.99 ± €0.44. Two manufacturers gave the recommendation to take "as much as necessary" (◆ Table 1).

Composition of the products

The overall composition of the products as stated in the ingredients lists/manufacturer's descriptions proved to be heterogeneous (◆ Figure 2). 30% of the products contained medium-chain triglycerides (MCTs) derived from coconut oil. However, only one manufacturer advertised the MCT oils their product contained and provided the corresponding nutritional labeling for this, which indicated a content of 190 mg per recommended serving. One product's nutritional label additionally indicated 166 mg of raspberry ketones per serving. The recommended daily intake of the products provided an average of around 14.2 ± 7.8 kcal. An overview of macronutrient compositions can be found in ◆ Table 2.

All products contained different types of saccharides, sugar alcohols and sweeteners (◆ Figure 3). Sucrose and glucose (52%) were particularly common among the saccharides (55% in total) and maltitol (52%) was particularly common among the sugar alcohols. In addition, 39% (n = 5) of the products containing sugar alcohols were not correctly declared in

n = 33	Price (€)	Price per portion (€)	Pack size (g/pack)	Portion size (g/piece)	Portions per day (pieces)	Price per portion per day (€)
n (%)	33 (100)	32 (97)	28 (84.9)/ 32 (97)	27 (81.8)/ 33 (100)	32 (97)	30 (91)
Mean value	28.91	0.50	163.96/61	2.76	1.93	1.0
Median	29.38	0.54	171/60	3/1	2	1.2
SD	12.23	0.20	47.24/15	0.69/0	0.36	0.4
Min.–max.	4.37–59	0.16–0.98	50–270/34–120	1.1–4.5/1–1	1–3 or ∞	0.16–1.97

Table 1: **Characteristics of the keto gums examined (n = 33) with the number [n], percentage [%], mean, median, standard deviation [SD], minimum [min.] and maximum [max.]**
∞ = "as much as necessary"

n = 33	Energy (kcal)	Fat (g)	Protein (g)	Carbs (g)	of which, sugars (g)	of which, polyhydric alcohols (g)	Dietary fibre (g)
n (%)	11 (33.3)	7 (21.2)	7 (21.2)	10 (30.3)	10 (30.3)	4 (12.1)	4 (12.1)
Mean value [SD]	14.2 [7.9]	0.1 [7.9]	0.4 [0.7]	3.7 [1.9]	1.6 [1.5]	3.5 [2.6]	0.3 [0.3]

Table 2: **Energy content (kcal) and macronutrients (fat, protein, carbohydrates) in g per portion of the keto gums examined (n = 33) with the number [n], percentage [%], mean and standard deviation [SD]**
Carbs: carbohydrates

accordance with Annex III of the Food Information to Consumers Regulation (FIC) [25]. Various sweeteners such as acesulfame K and sucralose were only listed in two products. The other ingredients of the products were predominantly simple in composition, including flavorings, colorants, gelling agents, citric acid or other edible acids (◆ Figure 2). Correspondingly, these additives were the most frequently used in the products. Coating agents, predominantly carnauba wax, were used in 42% of the products and preservatives were used in 18%. Other ingredients typical of gummy sweets such as humectants, gum base or bovine gelatin, on the other hand, were rarely used, with a frequency of only 6–12%. The main ingredient was sweeteners (27.3%), followed by saccharides (24.2%) and L-arginine (24.2%).

In addition, 94% of the products contained L-arginine as a supplementary amino acid and added vitamins (◆ Table 3), minerals (◆ Table 4) or plant extracts ("botanicals") (◆ Table 5). Apple cider vinegar (52%) and ginger extract (39%) were the most frequently added supplementary ingredients. The average amount of apple cider vinegar per recommended daily dose was 601.67 ± 305.04 mg (n = 18) and for ginger extract it was 10 mg (n = 5). Among the added vitamins, B vitamins (◆ Table 3) such as vitamin B_6 (27%), folic acid (15%) and vitamin B_{12} (15%) were particularly common. All other ingredients, such as dietary fibre or phytochemicals, were included in a maximum of 3% of the products (◆ Figure 2).

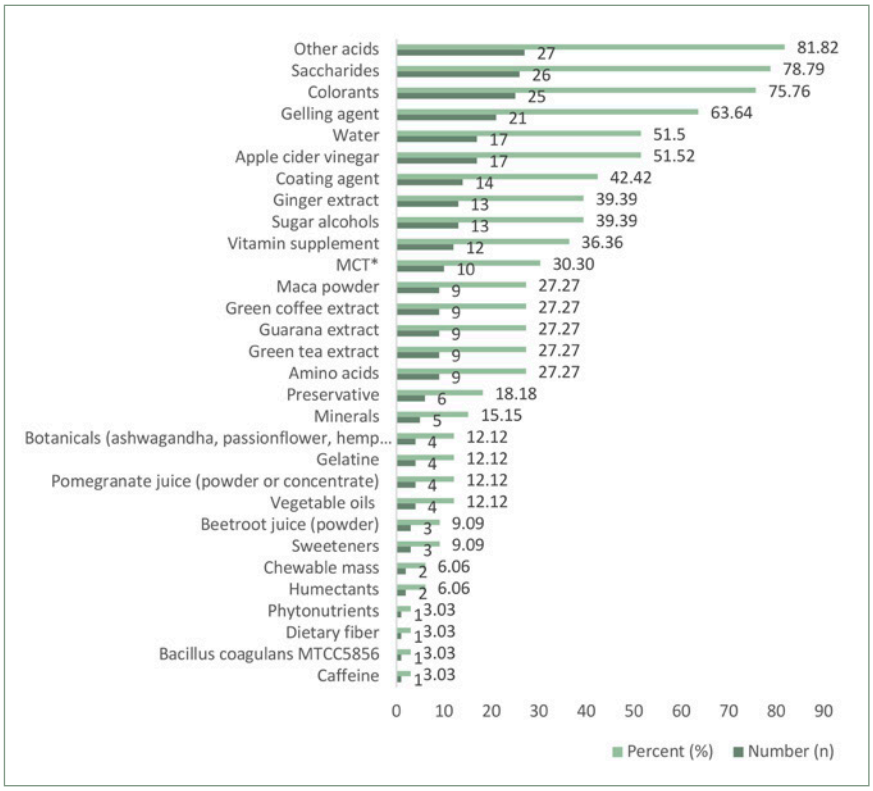

Fig. 2: **Presentation of the number (n) and percentage (%) of the ingredients included in the keto gums studied (n = 33)**
* MCT: medium-chain triglycerides

Manufacturers' advertising claims

Analysis of the manufacturers' primary advertising claims on the website revealed a clear focus. The focus of the advertising was on the immune system (64%), followed by improving athletic performance (46%), supported by statements (note: all translated from German

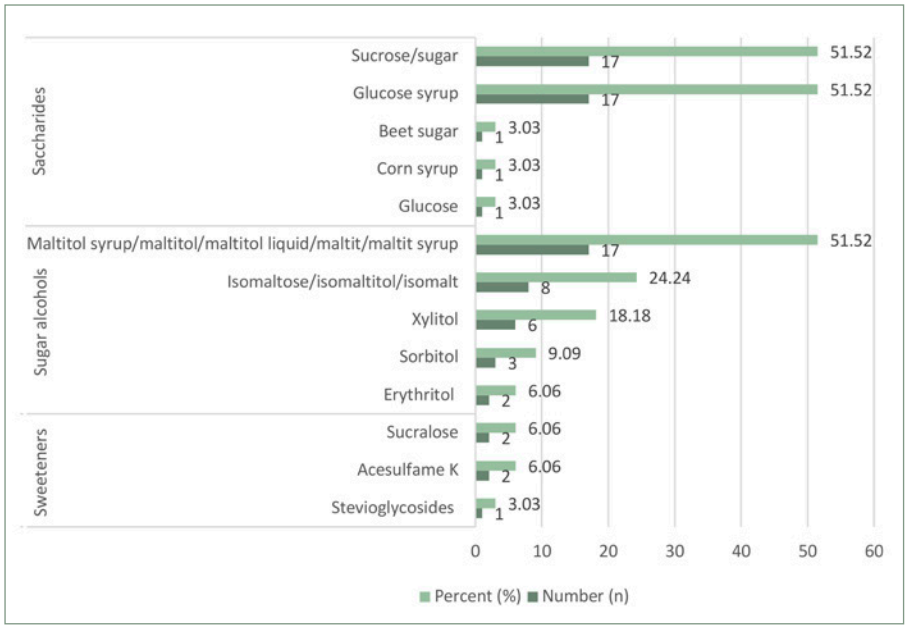

Fig. 3: **Presentation of the number (n) and percentage (%) of the various types of saccharides, sugar alcohols and sweeteners used in the keto gums studied (n = 33)**

here) such as "Our gummies help you achieve your athletic goals!" and "the ideal aid to help you feel more energetic during sports". In addition, it was often emphasized that the products support fat burning and weight loss, especially by controlling appetite (43%). Furthermore, 33% of the products referred to a performance-enhancing effect with statements (note: all translated from German here) such as "The ultimate motivation boost" or "Supports your concentration, mood and energy" (♦ Figure 4). The claims mainly related to the product as a whole and not to individual ingredients.

91% of the supplements had direct advertising claims about the ketogenic diet on the packaging or the website. These claims related to supporting a ketogenic diet (76%), helping with the process of returning to ketosis (9%), increasing blood ketone levels (3%) or achieving ketosis faster (3%). The remaining products (9%) simply had the word "keto" in the product name. Only 30% of the products displayed these advertising claims directly on the packaging. In some cases (30%), permitted health claims such as: "Vitamins B_6 and B_{12} contribute to normal energy metabolism," were used. In 18% of cases, no explanatory information about the advertising claims was found on the packaging. The remaining health-related claims were found in the product information provided on the online marketplace or on associated advertising images.

Two manufacturers stated that their product was suitable for all ages (with the exception of children) and all target groups, which would include pregnant and breastfeeding women. Five products were described as suitable for everyone, including children. One product was, according to the manufacturer, developed by experts (vegan nutritionists).

n = 33	Niacin (mg)	Vitamin B_6 (mg)	Biotin (µg)	Folic acid (µg)	Vitamin B_{12} (µg)	Vitamin C (mg)	Vitamin D_3 (µg)	Vitamin K (µg)
n (%)	2 (6.1)	10 (30.3)	1 (3.1)	6 (18.2)	6 (18.2)	3 (9.1)	1 (3.0)	1 (3.0)
Mean value	10.4	1.5	50	243.3	1.9	42.7	5	75
Median	10.4	1.4	–	220	1.9	40	–	–
SD	5.6	1.2	–	120.2	0.6	3.8	–	–
Min.–max.	4.8–16	0.5–5	–	100–400	1.2–2.5	40–48	–	–
German Nutrition Society / Austrian Nutrition Society reference values[a] (day)	♀: 13 ♂: 16	♀: 1.4 ♂: 1.6	40	300	4.0	♀: 95 ♂: 110	20	♀: 60 ♂: 70
German Federal Institute for Risk Assessment (BfR) recommendations for maximum doses of nutritional supplements	160[c] 4[d] 4.4[e]	3.5	–	200	25	250	20	80[f] 25[g]
***Tolerable Upper Intake Level* (UL)[b]**	900	12	–	1000	–	-	100	–

Table 3: **Overview of the vitamin supplements contained in the keto gums studied (n = 33) per recommended daily portion compared to the German Nutrition Society / Austrian Nutrition Society reference values, the German Federal Institute for Risk Assessment (BfR) recommendations for maximum doses and the tolerable upper intake level (UL)** together with the number [n], percentage [%], mean, median, standard deviation [SD], minimum [min.] and maximum [max.] (modified in accordance with [26–28])

[a] adults > 19 years, [b] adults > 17 years, [c] as nicotinamide, [d] as nicotinic acid, [e] as inositol hexanicotinate, [f] as vitamin K_1, [g] as vitamin K_2

Discussion

"Keto-friendly" and other advertising claims

The use of advertising claims such as "keto-friendly" and similar health claims raises considerable questions in the context of the current discourse about consumer information and compliance with legal regulations. According to the currently valid EU Regulations No. 432/2012, No. 1169/2011 and EC Regulation No. 1924/2006, health claims may only be used on products if they are expressly permitted in the regulations and the respective requirements are met [19, 20, 25, 29]. Despite this, analysis of the products found on the market shows that the majority of the claims used (◆ Figure 4) are not covered by these regulations and are therefore not legally permissible.

In particular, claims about suitability for a ketogenic diet or for general health promotion are frequently used, despite the fact that they are not currently covered by the Health Claims Regulation and are not included in the list of permitted claims [29]. In fact, the EU register of health claims currently only includes one ketosis-related health claim, which is about hunger reduction, and it categorizes this claim as non-authorized [30]. There are also other health claims made by these products that are not authorized, referring to ingredients such as apple cider vinegar, beet or probiotic bacteria *(Bacillus coagulans)*. These claims of health-promoting effects have not been recognized or explicitly rejected under current EU law [29]. Even when vitamins or minerals are added in sufficient quantities to justify the authorized health claims used, inadmissible statements are often made in connection with the entire product or with unspecified quantities. Therefore, it is often unclear which specific ingredients are responsible for the advertised positive effects. Consumers are also often lured in with additional claims such as "vegan", "natural" or "sustainable", which correspond to current food trends [31] but have no direct link to the advertised benefits. Other terms such as "developed by experts", "laboratory-tested" or "certified" often serve to give the appearance of scientific rigor, but are often not or not sufficiently substantiated on the manufacturers' product pages.

n = 33	Potassium (mg)	Zinc (mg)	Iodine (µg)	Chromium (µg)
n (%)	1 (3.0)	1 (3.0)	1 (3.0)	3 (9.1)
Mean value	0.1	9	50	50.7
Median	–	–	–	40
SD	–	–	–	36.7
Min.–max.	–	–	–	12–100
German Nutrition Society / Austrian Nutrition Society reference values[a] (day)	4000	♀: 7–0* ♂: 11–16*	200	30–100
German Federal Institute for Risk Assessment (BfR) recommendations for maximum doses of nutritional supplements	500	6.5	100	60
***Tolerable Upper Intake Level* (UL)[b]**	–	25	600	–

Table 4: **Overview of the mineral supplements contained in the keto gums studied (n = 33) per recommended daily portion compared to the German Nutrition Society / Austrian Nutrition Society reference values, the German Federal Institute for Risk Assessment (BfR) recommendations for maximum doses and the tolerable upper intake level (UL)** together with the number [n], percentage [%], mean, median, standard deviation [SD], minimum [min.] and maximum [max.] (modified in accordance with [26–28])
[a] adults > 19 years, [b] adults > 17 years, * depending on phytate intake

n = 33	n (%) with information about nutritional content	Mean value	Median	SD	Min.–max.
Apple cider vinegar (mg)	17 (51.5)	601.7	500	305.0	200–1000
Beet (mg)	2 (6.1)	80	–	40	40–120
Pomegranate juice powder (mg)	3 (9.1)	80	80	32.7	40–120
Ginger extract (mg)	5 (15.2)	10	10	0	–
Ashwagandha extract (mg)	1 (3.0)	60	–	–	–
Passionflower extract (mg)	1 (3.0)	51	–	–	–
Caffeine (mg)	1 (3.0)	200	–	–	–
Raspberry extract (mg)	1 (3.0)	500	–	–	–
Hemp leaf extract (mg)	1 (3.0)	9	–	–	–
Bacillus coagulans MTCC5856 (million strains)	1 (3.0)	1000	–	–	–

Table 5: **Number of plant extracts contained in the keto gums studied together with the nutritional content information (n = 33) per recommended daily serving, showing the number [n], percentage [%], mean, median, standard deviation [SD], minimum [min] and maximum [max].**

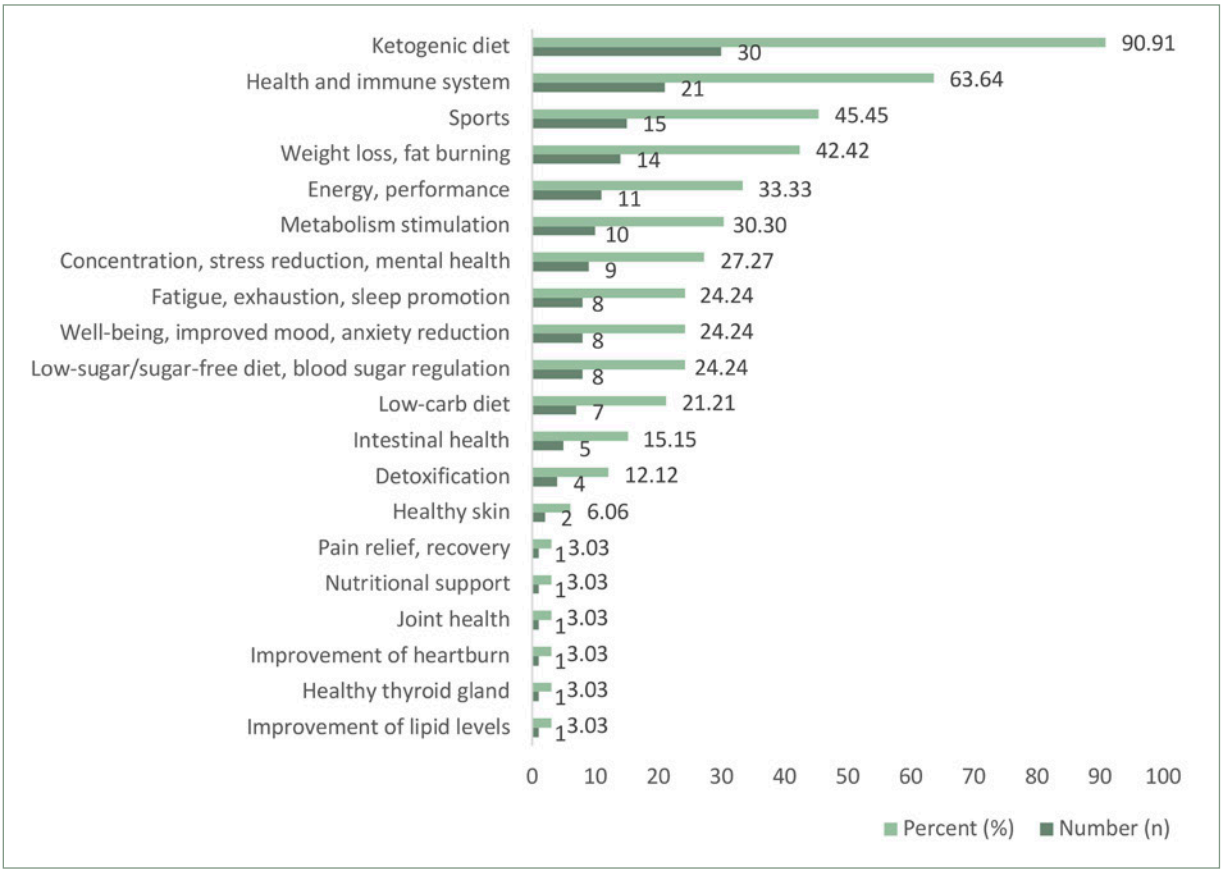

Fig. 4: **Presentation of the number (n) and percentage (%) of the advertising claims for the keto gums studied (n = 33)**

The high level of customer satisfaction reflected in the Amazon rating system projects a positive image to consumers and seems to guarantee effectiveness. Only verified purchases are taken into account in the Amazon rating system, unless the person providing the rating shares additional details in the form of text, images or videos [24]. Due to the large number of ratings, it was not possible for the authors to verify the extent to which these ratings may have been manipulated or falsified.

Saccharides, sugar alcohols and sweeteners

The ketogenic diet aims to minimize increases in blood glucose and the associated release of insulin in order to promote ketosis [32]. With this in mind, the use of saccharides in products advertised as "ketogenic" should be viewed critically, as they could impair the effectiveness of the diet.

Sugar alcohols are divided into three categories based on the number of saccharide units present in the molecule. While xylitol and sorbitol are derived from monosaccharides, maltitol belongs to the category of disaccharide sugar alcohols and isomalt to the category of polysaccharide sugar alcohol mixtures [33]. It is assumed that polyols trigger a low glycemic and insulinemic response due to their incomplete absorption in the small intestine. They have also been linked to an inhibition of lipogenesis and reduced insulin production [33, 34]. With a glycemic index (GI) of 0, erythritol has no influence on blood glucose levels, whereas maltitol (GI: 35) causes a moderate increase in plasma glucose [33]. Since maltitol was used in over 50% of the products analyzed that were advertised as "ketogenic", and since it affects blood sugar as previously described, the effectiveness of these products as part of a ketogenic diet is questionable.

In addition, ketogenic products also use sweeteners that do not directly interfere with ketogenesis [35]. The S1 guideline on ketogenic dietary therapies for the treatment of pharmacoresistant epilepsy and other diseases recommends sweeteners for sweetening, whereas sugar substitutes, with the exception of erythritol, must be calculated [36]. However, more recent studies suggest that sweeteners could influence glucose absorption in the intestine as well as insulin and incretin secretion. In addition, some studies have observed that sweeteners can alter the composition of the gut microbiota, which could in turn have a negative impact on blood glucose control [37, 38]. However, research in this area currently remains insufficient. In clinical practice, the use of sweeteners in foods designed for ketogenic diets, especially in foods for special medical purposes (FSMP), has not yet been found to have any clear disadvantages. Interestingly,

far fewer of these products include sweeteners (only around 6% of the products). This once again raises the question of the credibility of products advertised as "ketogenic".

Effects on ketosis

None of the ingredients contained in keto gum products have been specifically tested with regard to their ability to promote a ketogenic metabolic state. Despite this, the term "keto" was at least mentioned in each product, suggesting targeted marketing aimed at those following a ketogenic diet. A third of the products tested contained MCTs, which have been shown to support physiological ketosis when used in higher quantities. According to studies, around 10 g of MCT is required to produce a significant increase in ketone bodies in the blood [39, 40]. However, only one of the analyzed products explicitly stated the quantity of MCTs (190 mg/serving). This quantity corresponds to only approx. 2% of the quantity examined in the relevant studies, meaning that it cannot be assumed that its inclusion would have a relevant effect in this case. In the other products that included MCT, this was mostly included in the form of coconut oil and was further down in the ingredients list, which suggests a low dosage. This is of particular interest because MCT derived from coconut oil consists mainly of lauric acid (C12) [41], which has a significantly less ketogenic effect than caprylic acid (C8) and capric acid (C10) [42], meaning that hardly any effect can be expected. The ketogenic effect can also be severely limited by the simultaneous intake of carbohydrates [43].

In addition to MCT, one product contained raspberry ketone, promising faster and more sustainable ketosis. Raspberry ketone, a natural component of red raspberries, is mainly known as a flavoring agent in foods and cosmetics. However, it has no biochemical connection to the ketone bodies acetoacetate and β-hydroxybutyrate, which are produced during ketosis. Studies on raspberry ketone focus primarily on possible weight-reducing effects and potential effects on metabolic diseases. However, these studies are mainly based on animal studies and cell-based assays, and the results are contradictory [44, 45]. There is no evidence that raspberry ketone has a ketogenic effect. In addition, raspberry ketone is currently not covered by the Health Claims Regulation, which means that health claims regarding its effects are not permitted [29]. Furthermore, the potential toxicological effects of raspberry ketone have not yet been fully investigated and tachycardia has been reported in individual cases where individuals have consumed high doses [46, 47]. Therefore, according to the Rapid Alert System for Food and Feed (RASFF), raspberry ketone is currently classified as a non-authorized novel food in the EU [48]. Exogenous ketone bodies, which according to current studies can lead to a short to medium-term increase in ketone body concentrations in the blood, were not included in any of the products, which can be explained by the fact that there is no novel food approval for them in the EU [17]. In addition, larger quantities than could be provided by a single keto gum product would be required to achieve a measurable increase in ketone bodies in the blood [49–51]. To summarize, the use of terms such as "keto" in these products is a marketing strategy that is not supported by the use of scientifically proven ingredients or the quantities required for effectiveness.

L-arginine and plant extracts

Several keto gum products contained an almost identical combination of ingredients, including L-arginine and extracts of matcha or green tea, green coffee, ginger and guarana. The associated health claims were about improving athletic performance and maintaining a healthy lifestyle. The problem here is that none of the ingredients in the products are covered by the current Health Claims Regulation. Even for caffeine, which is present in matcha, green coffee and guarana, there is no authorized health claim [29, 52].

Setting aside the fact that the health claims are inadmissible under the Health Claims Regulation [52], a closer look at the individual ingredients shows that, once again, the scientific evidence does not support the advertising claims. For example, a meta-analysis shows that although L-arginine can potentially improve aerobic and anaerobic performance in sport, acute doses of 0.15 g L-arginine per kilogram of body weight are necessary for positive effects, and for long-term effects, a daily intake of 1.5–2 g is required for aerobic improvements and 10–12 g for anaerobic improvements, with these doses being taken over several weeks [53]. Another meta-analysis found that L-arginine (6–20 g/day) had no significant effect on oxidative stress markers or inflammation markers after physical activity [54]. As the keto gum products do not state how much L-arginine they contain and online research in international online stores indicates they contain a maximum quantity of only 100 mg per daily dose, the dosage can be assumed to be far below the amounts stated above.

The picture is similar for other ingredients such as maca, green coffee extract, guarana and matcha or green tea extract. Studies suggest that 2–2.5 g of maca per day could have positive effects on athletic performance [55, 56], while keto gum products only contain 80 mg of maca. Green coffee extract, which is often studied in association with increased metabolism and weight loss, has been found to have various significant effects in normocaloric comparison groups and at doses of 400 mg/day for eight weeks, e.g., weight loss of 0.5–1.7 kg compared to 0.1–0.4 kg in control groups [57–59]. In comparison to this, keto gum products only contain 5 mg of green coffee extract. The situation is similar with guarana, which was studied in trials at a dose of 500 mg per day showing poor results in terms of improving athletic performance,

while the keto gum products contain only 5 mg/day [60, 61]. For matcha or green tea extract, studies have shown that a daily intake of 3 g of matcha during a strength training program can lead to reduced subjective fatigue after exercise and to positive effects on fat burning [62, 63]. However, once again, the amount used in keto gum products is significantly lower – just 80 mg per day. It remains unclear whether the effects observed in studies are primarily attributable to the common component caffeine, as some of the studies also used decaffeinated variants or tested different amounts of caffeine [57–61]. Other specific ingredients besides caffeine, such as phenols (e.g., chlorogenic acid), flavonoids, saponins, tannins, L-theanine or epigallocatechin gallate (EGCG) could also play a role [58, 61–63]. EGCG is an example of an individual substance that could pose risks at higher doses. At doses above 800 mg per day, EGCG is known to increase the risk of liver damage, increased blood pressure, increased intraocular pressure and drug interactions [64, 65]. In the case of ginger, used as an extract or powder, there is also a clear discrepancy between the quantities used in studies (at least 1 g) and the dosage in the keto gum products (5 mg). While studies using 2 g of ginger powder per day showed significant effects on body mass index, body weight and waist and hip circumference in overweight people, this effect was not observed in other studies using comparable amounts [66, 67]. In contrast, the keto gum products only use ginger extract, which makes comparison even more difficult. In addition, in the cited studies, most of these ingredients were tested either alone or in combination with only one other active ingredient. There are no studies on the effectiveness of the mixtures of ingredients in the keto gum products as a whole, or on possible interactions.

Overall, it is clear that the advertising claims made by these products in relation to increased athletic performance and a healthy lifestyle are not supported by scientific evidence, nor are they supported by the quantities of active ingredients contained in the products. The available research on the undefined plant extracts used is also inadequate – as is so often the case.

Apple cider vinegar

Over 50% of the keto gum products analyzed contained apple cider vinegar or apple cider vinegar powder as an ingredient. Apple cider vinegar is often advertised on online marketplaces as having a variety of health-related benefits, such as natural body cleansing, pH control and detoxification. Other health claims include improved lipid levels, fasting blood glucose and heart health, relief from flatulence and support with weight regulation. Apple cider vinegar is therefore often marketed as the "perfect supplement" for the ketogenic diet. Since the ketogenic diet is an extremely low-carbohydrate diet that is often associated with weight loss, this could be an explanation for the marketing strategy [68, 69]. However, once again, these health claims are not covered by the Health Claims Regulation [29].

No studies on apple cider vinegar powder could be found at the time of writing. Existing studies are mostly based on the use of liquid apple cider vinegar. A study in people with type 2 diabetes mellitus showed that taking 30 mL of apple cider vinegar after a meal led to lower insulin secretion and a flattening of postprandial glucose peaks [70]. Apple cider vinegar's possible positive effect on weight loss was investigated in studies with a dosage of 5–30 mL/day. The effects of the interventions can be regarded as low to moderate over an intervention period of 12 weeks. No side effects from taking apple cider vinegar were reported in any of these studies [69, 71, 72]. One interesting historical insight is that doctors in France were prescribing apple cider vinegar for weight loss as early as the 18th century. There have been some cases of serious health problems, including death, in women who have consumed excessive amounts of apple cider vinegar. However, it is not possible to deduce from the available data whether this was due to the consumption of apple cider vinegar alone [73].

Irrespective of the very limited number of studies on apple cider vinegar, there are also considerable differences between the quantities used in studies and the doses in the keto gum products. Some keto gum products contain only 0.5–1 g of apple cider vinegar, which differs significantly from the 5–30 mL/day used in the studies. Other keto gum products contain 0.2–1 g of apple cider vinegar powder. However, this form of apple cider vinegar has not been investigated in the currently available studies, so it is not possible to directly extrapolate the study results to this dosage form [74]. In addition, it is not possible to calculate equivalents in the form of liquid apple cider vinegar due to a lack of specifications, meaning that no assessment of potential side effects can be made.

Limitations

This market analysis only examined products from the German online retailer Amazon.de over a two-week period from April 8 to April 22, 2024. No relevant products could be found in the top-selling German drugstore chains during this period. This approach could have led to underestimation of the products available on the market, as no other distribution channels (such as manufacturers' own websites or specialized platforms, for example in the sports sector) were taken into account. In addition, the dietary supplement market tends to change rapidly, and any changes that may have occurred before or after the survey period were not taken into account. However, due to the high market relevance of the Amazon online marketplace, it can be assumed that this study has provided a good overview of current market developments. With regard to the ingredients, the analysis was based on the information provided by the manufacturers and on the product packaging, which

means that it is possible that the information may be incomplete or incorrect. In addition, 6 of the 33 manufacturers stated a country of origin outside the EU, which means that German market perceptions may not apply in these cases, but were nevertheless included in the analysis. However, the use of the four eyes principle for data transfer ensured that the available information was transferred correctly and completely.

Conclusion

This analysis shows that the keto gum products available on the market largely fail to deliver on their health and dietetic claims. Although some of the health claims made are permitted (some claims about added vitamins and minerals), the primary marketing focus is on claims that have not yet been scientifically proven. This is because of the ingredients that are used as well as the insufficient quantities used. Particularly with regard to the intended ketogenic effect, it is clear that although many products have the term "keto" in their name or description, they cannot be expected to support ketosis. The addition of saccharides and certain sugar alcohols in some of the products may even counteract ketogenesis. Despite this discrepancy, the products are often expensive and are endorsed through many positive consumer reviews, which demonstrates the effectiveness of the associated marketing and raises questions about actual use by consumers. In conclusion, the term "keto" is primarily used for marketing purposes and does not mean that the products have any actual effect on a ketogenic diet.

Disclosures on conflicts of interest and the use of AI
IA and MA: Staff posts are financed by a grant from the Anton Schär Foundation for scientifically independent research. JD: Staff post is financed by a donation from Sanotact GmbH for scientifically independent research. TF received funding from the Anton Schär Foundation and a donation from Sanotact GmbH to finance staff positions for scientifically independent research. The authors declare that no AI software was used to create the manuscript.

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