Brief Report

Occurrence of Aspartame (E951) in a German National Survey of Foods and Beverages 2000-2022: Trends and Insights

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Occurrence of Aspartame (E951) in a German National Survey of Foods and Beverages 2000–2022: Trends and Insights

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Abstract: This study aimed to investigate the occurrence of the artificial sweetener aspartame (E951) in a wide range of foods and beverages sampled by food control authorities in Germany between 2000 and 2022. The dataset was obtained through the Consumer Information Act. The results showed that aspartame was present in a wide range of product groups tested, most commonly in powdered drink bases (84%) and flavored milk drinks (78%). In the solid food groups, the highest mean aspartame content was found in chewing gum (1543 mg/kg, n=241), followed by sports foods (1453 mg/kg, n=125), fiber supplements (1248 mg/kg, n=11), powdered drink bases (1068 mg/kg, n=162), and candies (437 mg/kg, n=339). Liquid products generally had the highest aspartame content in diet soft drinks (91 mg/l, n=2021), followed by regular soft drinks (59 mg/l, n= 574), flavored milk drinks (48 mg/kg, n=207), and mixed beer drinks (24 mg/l, n=40). These results suggest that aspartame is widely used in foods and beverages in Germany and that certain product groups contain higher concentrations of the sweetener than others. However, the levels of aspartame found were generally within the legal limits set by the European Union. These findings provide the first comprehensive overview of aspartame in the German food market and may be particularly useful in informing the forthcoming working groups of the WHO International Agency for Research on Cancer (IARC) and the WHO/FAO Joint Expert Committee on Food Additives (JECFA), which are in the process of evaluating the human health hazards and risks associated with the consumption of aspartame.

Keywords: aspartame; sweeteners; food additives; food control; German national survey; food safety; risk assessment

1. Introduction

Aspartame (E951, CAS# 22839-47-0) is a widely used artificial sweetener in low-calorie beverages, prepared foods, and tabletop sweeteners that is approved for use in over 90 countries, and concerns about its safety and potential health risks have led to calls for further information and research. In 1981, the WHO/FAO Joint Expert Committee on Food Additives (JECFA) evaluated its health effects as part of a programme to assess the risks of food additives and chemicals [1]. However, the WHO International Agency for Research on Cancer (IARC) *Monographs* programme, which identifies potential carcinogenic hazards, has not evaluated aspartame to date. According to a recent IARC priorities advisory group report [2,3], epidemiologic studies have generally not demonstrated an association between aspartame intake and cancer risk. However, a prospective study on hematologic malignancies found a positive association for multiple myeloma and non-Hodgkin lymphoma in men [4]. Also, a case-control study of exocrine pancreatic adenocarcinoma found a positive association with low-calorie soft drink consumption in men [5], and another case-control study showed a positive association of regular use of artificial sweeteners with urinary tract tumors [6]. More recently, a large cohort study of 102,865 French adults showed that aspartame intake was

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associated with increased breast and obesity-related cancer risks [4]. Concerns have also been raised by a few studies in experimental animals showing dose-related increased risks of certain cancers at exposure levels previously considered safe for human consumption [5]. Mechanistic studies relevant to the key characteristics of carcinogens have also been conducted (e.g. [6–8]). For these reasons, the IARC priorities advisory group recommended aspartame as a high priority for evaluation [2,3]. In addition to IARC, JECFA has also recommended aspartame as a high-priority substance for re-evaluation [9].

According to the proposals, both the *IARC Monographs* programme and the JECFA will conduct complementary evaluations in 2023: IARC will investigate whether aspartame has any potential carcinogenic effects (hazard identification), while JECFA will update its risk assessment by reviewing the acceptable daily intake and dietary exposure assessment of aspartame [10]. The sequence of these evaluations will allow for a comprehensive evaluation of the health effects of aspartame consumption based on the most recent available evidence.

Both IARC and JECFA have published calls for data [10,11] that include data relevant to the dietary exposure assessment, such as the level of use of the additive in foods. To properly characterize the exposure of the general population and specific subgroups to aspartame, detailed data on its content in a variety of food groups are needed. However, although aspartame is one of the most widely used artificial sweeteners, there is a paucity of data in the scientific literature on its occurrence in various foods other than artificially sweetened beverages. To provide the agencies with such data from Germany to inform their exposure assessments, this article examines the results of a recent request for information on aspartame, providing a summary of the data and an analysis of their implications.

2. Materials and Methods

2.1. Data Request under the Consumer Information Act

The samples in this dataset were collected and analyzed between 2000 and 2022 by official food control laboratories in Germany as part of the governmental food control using validated and externally accredited methods according to ISO/IEC 17025 [12]. The methodology for sample selection in the study is a combination of convenience sampling and systematic testing such as annual food monitoring projects. Samples were collected using a risk-based sampling approach, which means that samples are not selected at random, but rather based on a perceived risk of contamination or non-compliance [13]. Samples were collected from a variety of sources, including retailers, importers and manufacturers, which may introduce some bias into the results, such as the focus of food control on the "bottleneck", i.e., primarily at the manufacturer or importer. The data did not include information on consumption patterns of the products, which limits the ability to estimate actual exposure levels.

The data were then collected and consolidated by the German Federal Office of Consumer Protection and Food Safety (BVL) in March 2023 and published on the website FragDenStaat.de in response to a consumer request from the last author (D.W.L.) [14]. The consumer request is based on the Consumer Information Act, which requires food control authorities to provide consumers with information on food, feed, consumer products, and cosmetics. The obligation to provide information includes, for example, unauthorized deviations from requirements, and measures and decisions taken in connection with the deviations, hazards, and risks to health and safety posed by products, monitoring activities, and measures for consumer protection [15].

The original consumer request, including the complete dataset, can be accessed via the internet portal FragDenStaat.de of the non-profit association Open Knowledge Foundation Deutschland e.V. (Berlin, Germany) [14].

2.2. Data Description and Analysis Methods

The available data include information such as the year and type of shop where the sample was collected, the country of origin, the product group and matrix of the sample, the aspartame content,

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the analytical methods, and the limit of detection (LOD) and the limit of quantification (LOQ) of the method used. In total, this dataset contained 53116 analytical results for aspartame in different food products. The dataset included separate tables with qualitative data (n=720) and quantitative data (n=52396). In this study, only the quantitative data were further evaluated.

The analytical methods used to determine the aspartame content in the major food groups were primarily test methods according to the official collection of paragraph 64 of the German Food, Commodities and Feed Code (Lebensmittel-, Bedarfsgegenstände- und Futtermittelgesetzbuch) for food control authorities and testing institutions. This ensures consistent quality of testing and comparability of results [16]. Generally, the high-performance liquid chromatography (HPLC) method BVL L 00.00-28 is used, which is an adoption of the standard DIN EN 12856 with identical wording [17]. Some laboratories have used other validated and accredited methods, based on HPLC coupled with different detectors, or based on nuclear magnetic resonance (NMR) spectroscopy (e.g., [18]). The method used for each analytical result is indicated in the raw data Excel table called "Anlage 5" of the dataset [14].

2.3. Data Analysis and Selection of Food Items for Inclusion: Regrouping and Prioritizing Foods

The analysis of the dataset presented in this study, including all statistical calculations, was performed using Microsoft Excel version 2016 (Microsoft, Redmond, WA, USA).

During the evaluation of the data, it quickly became apparent that most of the samples (73%) were negative for aspartame, i.e., the food was analyzed but aspartame was not detected. This finding can be explained by the fact that multiparameter methods, which analyze several sweeteners with the same assay, are commonly used for food control. This means that aspartame could have been measured even if the original intention was to measure another sweetener. Therefore, it is important to note that the dataset is heavily biased toward foods that were suspected of containing aspartame or other compounds that were measured with the same assay. This means that the sample of foods in Germany is not representative, and that the mean values should be interpreted with caution.

The original BVL grouping of the raw data was less informative (see the Excel table called "Anlage 7" of the original dataset [14]) because only subgroups of the major food groups appeared to contain aspartame. For example, in the dairy category, aspartame was found only in certain subgroups such as ready-to-drink buttermilk beverages. It was decided to re-analyze the data and categorize them into more meaningful groups using the standardized FoodEx2 food classification and description system of the European Food Safety Authority (EFSA) [19]. Only food groups in which at least 20 samples were analyzed and at least 40% of the samples were found to contain aspartame were retained in the analysis.

3. Results

Nine major food groups were included in this analysis based on minimum detection frequency and number of samples. In relation to the total values provided, this represents a percentage of 11% that were finally included in this study (5703 samples). Samples that did not belong to the selected food groups were not included in the assessment of aspartame occurrence.

Food items were grouped according to their respective product groups (flavored milk drinks, soft drinks, diet soft drinks, mixed beer drinks, candies, chewing gum, powdered drink bases, sports foods and fiber supplements). The product groups and the corresponding individual products included in each product group are listed in Table A1 in the appendix A. Table 1 shows these food groups with the calculated percentage of positive samples.

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Table 1. Overview of the different product groups analyzed for the presence of aspartame.

Product Group	Total number ofFrequency of aspartame-positive samples	samples [%]
Diet soft drinks	2783	72.7
Soft drinks	1167	49.2
Candies	603	56.2
Chewing gum	312	77.2
Sports foods (with protein and amino acids)	297	42.1
Flavored milk drinks	268	78.0
Powdered drink bases	195	83.6
Mixed beer drinks	58	69.0
Fiber supplements	20	55.0

Most of the samples were collected from German retailers. Additionally, samples were collected from German kiosks, restaurants, grocery stores, drugstores, canteens, breweries, butchers, bakeries, fitness centers, and all other food outlets or directly from importers. The main country of origin of the samples was Germany (79%). A high number of samples had no information on the country of origin (9.5%). If known, the most common other countries were Poland (1.0%), the Netherlands (0.8%), France (0.4%), Turkey (0.4%), Denmark (0.3%), China (0.2%), Belgium (0.2%), and the United Kingdom (0.2%) (Supplementary Materials, Table S1).

The main descriptive statistical parameters, including mean, standard deviation, median, maximum, and 95th percentiles, were calculated from the positive samples and are presented in Table 2 (Supplementary Materials, Table S2). The highest mean levels of aspartame were found in sports foods and chewing gum. The data also showed that the levels of aspartame varied widely within food categories, with some products containing much higher levels than others.

Finally, the data were re-evaluated against the EU maximum levels. Generally, the levels of aspartame found were within the legal limits. Apart from the isolated outliers, there were only two exceedances (diet soft drinks: 970 mg/l, 636 mg/l) which were not excluded. In addition, the isolated outliers (see footnotes in Table 2) were considered to be data entry errors due to their technologically unlikely high levels.

Table 2. Aspartame content in various product groups analyzed 2000 to 2022.

Product Group	Number of Quantifiable Samples	Unit	Mean	Median	Maximum	Standard deviation	95th Percentile	EU maximum level [20]
Chewing gum	241	mg/kg	1543	1369	4617	1042	3649	2500[d] 5500[e]
Sports foods (with protein and amino acids)	125	mg/kg	1453	1030	6615	1461	5002	2000[f] 5000[f,g]
Fiber supplements	11	mg/kg	1248	1276	1469	175	1460	2000[f] 5000[f,g]
Powdered drink bases[a]	162	mg/kg	1068	1133	4861	672	1600	600[h]
Candies	339	mg/kg	473	440	3096	332	890	2000[i] 6000[j]
Diet soft drinks	2021	mg/l	91	60	970	101	335	600
Soft drinks[b]	574	mg/l	59	34	531	74	203	600
Flavored milk drinks[c]	207	mg/kg	48	47	90	17	79	1000
Mixed beer drinks	40	mg/l	24	26	55	15	42	600

[a] excluding one data outlier (above 20000 mg/kg); [b] excluding three data outliers (above 20000 mg/kg); [c] excluding two data outliers (above 900 mg/kg); [d] with added sugars or polyols [e] with no added sugars; [f] maximum levels refer to products ready for consumption, prepared according to the manufacturer's instructions [g] in chewable

form; [h] maximum level for flavored drinks in liquid form (the maximum levels refer to the finished products prepared according to the instructions for use provided by the manufacturer and not to the powder bases); [i] confectionery, energy-reduced or with no added sugars; [j] breath-freshening micro-sweets, with no added sugars.

4. Discussion

According to market data published by the German Federal Institute for Risk Assessment, between 2015 and 2018, 989 foods and 1055 beverages with added non-nutritive sweeteners (NNS) were launched in Germany, of which 16% contained aspartame [21]. Despite this widespread use, a lack of occurrence and exposure data in Germany was noted. The last major European assessment by EFSA in 2013 [22] did not include data from Germany.

The only comprehensive study on aspartame exposure in Germany was published by Bär and Biermann in 1992 [23]. In this study, the occurrence data of aspartame in different food and beverage products were evaluated by different methods. First, the researchers collected data from food manufacturers by requesting information on the sweetener content of their products. Second, package labels were examined to determine the presence and amount of aspartame. Finally, chemical analysis was used in cases where information was not readily available. These multiple complementary approaches provided a comprehensive understanding of the prevalence of aspartame in the marketplace and allowed for a comprehensive exposure assessment when the data were combined with food frequency questionnaires, but the authors did not publish the occurrence data, so that no comparison with this survey is possible. Currently, quantitative labeling of aspartame is not required, so only the qualitative presence of the compound is indicated in the ingredient list. Therefore, it is not possible to assess quantitative occurrence by evaluating package labels.

Some data from previous surveys have been published, mostly in government reports. As part of the German National Surveillance Plan 2006, fruit, vegetable, and mushroom products were analyzed for additives. Aspartame was not detected in any of the 237 samples analyzed [24]. According to the German National Surveillance Plan 2007, the occurrence of aspartame was determined in different types of beverages. Of the 170 samples of fruit juice drink samples analyzed, 29 contained aspartame at levels ranging from 11 to 381 mg/kg, with a mean of 85 mg/kg. Of the 51 nectar samples tested, only one was positive for aspartame at 0.1 mg/kg. In other types of beverages, 21 of 124 samples were positive for aspartame, with levels ranging from 18 to 444 mg/kg and an average of 115 mg/kg. None of the samples tested in any category exceeded the legal limit [25]. According to the German National Surveillance Plan 2008, sweeteners in confectionery without added sugar (including hard and soft candies and confectionery for diabetics) were analyzed. Of a total of 353 samples, 185 were found to contain aspartame. The mean amount of aspartame was 404 mg/kg, with a maximum of 1203 mg/kg. The 90th percentile value was 774 mg/kg. The maximum limit for aspartame of 1000 mg/kg was exceeded in one sample, which was an unfilled hard candy [26]. During the German National Food Monitoring 2015, mineral waters, including raw waters, were analyzed for selected sweeteners. Aspartame was not detected in any of the 19 samples [27].

Van Vliet et al. reported aspartame analyses of seven soft drinks from Germany. Aspartame was detected in five samples with a mean of 119 mg/l (range 53–330 mg/l) [28]. Maes et al. detected aspartame in two brands of diet coke at 138 and 149 mg/l [18].

Recently, the German Federal Institute for Risk Assessment (BfR) published data from an analytical survey of 92 energy-reduced or sugar-free non-alcoholic beverages. For energy-reduced beverages, the study found that of three aspartame-positive samples, the average level of aspartame was 20 mg/kg, with a range of 0.05–45 mg/kg. For sugar-free non-alcoholic beverages, the study found 64 positive samples and found that the average level of aspartame was 75 mg/kg, with a range of 11–492 mg/kg [29].

The results of this study confirm that aspartame is widely used in foods in Germany and that some individuals may be consuming high levels of the sweetener through certain products. Given the wide variation in aspartame content in foods and beverages, the survey data in this study are in reasonable agreement with the results of the previous studies. However, this study is based on a much larger number of samples and should therefore provide more stable statistics. The data analysis

showed no obvious time trends or changes in content (Appendix 1, Figure A1), even when compared to previous literature. However, a statistical evaluation and time trend analysis was not possible due to the lack of data from several years depending on the product group.

The survey of the occurrence of aspartame in Germany based on official food controls has some limitations. The data may not be representative of the general population's consumption of foods containing aspartame, because the sampling was a combination of systematic and convenience sampling and a threshold of at least 20 samples was applied in this analysis. However, the sample size is comparatively large, which may indicate that representativeness was achieved for the food groups containing aspartame. This means that the data may still be suitable for exposure analysis of consumers of food groups containing aspartame, even if they are not fully representative of the general population. Despite the large sample size, it is important to consider that there may be other factors that influence aspartame consumption, such as individual preferences and purchasing habits, including regular consumption of a product containing aspartame. Therefore, the data should be interpreted with caution and further research, such as combining occurrence data with dietary survey data, may be needed to fully understand the extent of aspartame consumption in the population. Second, the samples were collected only in Germany and may not be representative of other countries or regions. Studies reporting the occurrence of aspartame in foods and beverages in other countries are mainly from Europe and focus primarily on beverages. Comprehensive data on the occurrence of aspartame are available from only four European countries [22].

Given this lack of comprehensive data, the main purpose of obtaining the data through the Consumer Information Act was to make the German data on aspartame publicly available so that the conditions of the IARC preamble are met, which require that the data be made publicly available to meet transparency requirements and to provide protection against preliminary or non-peer-reviewed information [30]. It is hoped that the data can now be used in the work of the IARC and JECFA working groups. Because this study is the first to provide significant data on food groups such as dietary fiber supplements, certain dairy products, and powders used to make beverages, it is considered critical to providing a comprehensive understanding of aspartame exposure, despite the limitations noted above.

5. Conclusions

These data on the occurrence and levels of aspartame in various foods in Germany provide new and updated information on the use of aspartame in the food industry that may help researchers better understand its prevalence and potential health effects. Based on the data provided, it appears that aspartame is present at varying levels in a wide variety of foods. In terms of the levels of aspartame detected, the data show that the highest concentrations were found in sports foods and chewing gum. However, the levels of aspartame found were generally within the legal limits set by the European Union.

Overall, the data suggest that aspartame is a commonly used sweetener in a wide variety of foods and that consumers concerned about their intake of this additive should carefully read the labels of the foods they consume. However, based on the levels found in this dataset, it does not appear that there is cause for alarm in terms of exceeding the intake levels that are currently considered safe [22].

Nevertheless, these new data can contribute to a better understanding of the presence and levels of aspartame in different foods and help ensure the safety and health of consumers, especially when considering the cumulative exposure from different food groups, such as sports foods and some dietary supplements, which may have been underestimated.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Table S1: Evaluation of product origin, Table S2: Evaluation of qualitative and quantitative data.

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R.W., E.S., M.K., and A.K.K.; visualization, S.,S., K.G.; supervision, D.W.L. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Publicly available datasets were analyzed in this study. These data can be found here: https://fragdenstaat.de/en/request/aspartam/ (accessed on 28 March 2023). The data were provided by the German authority Federal Office of Consumer Protection and Food Safety (BVL) in the area of food safety and consumer protection, survey on aspartame, 2000-2022. The own derivative calculations presented in this study are available in the Supplementary Materials.

Disclaimer: Where authors are identified as personnel of the International Agency for Research on Cancer/World Health Organization, the authors alone are responsible for the views expressed in this article and they do not necessarily represent the decisions, policy, or views of the International Agency for Research on Cancer/World Health Organization.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Product subgroups included in the product groups.

Product group	Product subgroups contained in the product group
Flavored milk drinks	Whey with other added food
	Whey blend products from whey with fruit/fruit preparation
	Buttermilk products with fruit preparation
	Soft drink with added dairy products
Soft drinks	Apple juice beverage
	Orange juice beverage
	Orange lemonade
	Citrus lemonade
	Cola lemonade
	Bitter Lemon
	Tonic-Water
	Effervescent cold drink with flavor (raspberry, cherry, woodruff, citrus)
Diet soft drinks	Fruit juice reduced in calorific value
	Lemonade reduced in calorific value
	Cola lemonade reduced in calorific value
	Lemonade containing quinine and/or containing bitter substances, reduced in calorific value
	Bitter Lemon reduced in calorific value
	Effervescent cold drink reduced in calorific value
	Energy drink reduced in calorific value
	Non-alcoholic drinks for diabetics excl. fruit nectar
Mixed beer drinks	Full beer without wheat beer with clear lemonade (1:1) "Alsterwasser"
	Beer with sugars

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Candies	Hard caramel unfilled
	Hard caramel unfilled reduced in calorific value
	Pressings
Chewing gum	Chewing gum
	Chewing gum coated
Powdered drink bases	Tea extract with lemon extracts or lemon flavoring
	Other Tea extracts
	Beverage powder with tea extract
Sports foods (with protein and amino acids)	Food for intense muscular effort, especially for athletes
	Protein concentrate incl. proteins/protein hydrolysates/amino acid mixture
	Dietary supplements containing carnitine
Fiber supplements	Fiber concentrates

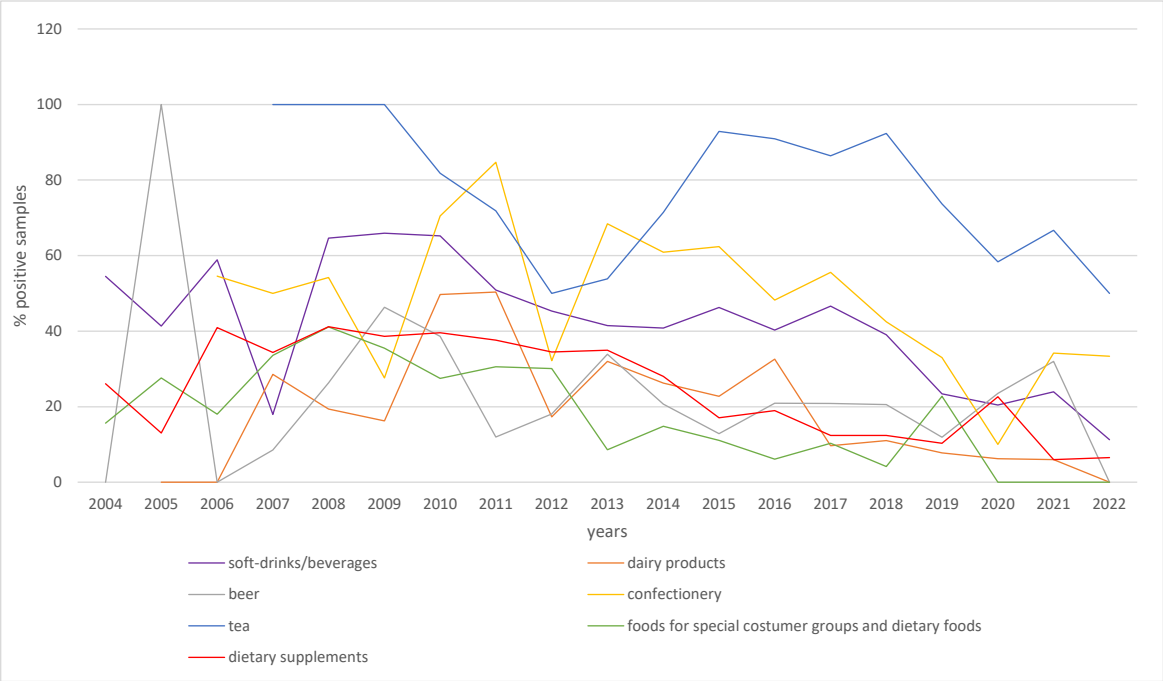

Figure A1. Samples with detectable levels of aspartame in the major food groups analyzed between 2004 and 2022.

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