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ORIGINAL ARTICLE

Bisphenol A Levels and Public Health Risk Assessment of Canned Animal-Derived Foods in Türkiye

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ABSTRACT

Bisphenol A (BPA) is a compound used in food contact materials that has gained importance due to its endocrine-disrupting effects. In this study, BPA levels were determined by high-performance liquid chromatography-fluorescence detector (HPLC-FLD) method in a total of 56 canned food samples (33 tuna - Group I; 13 other fish - Group II; 10 meat-chicken-turkey - Group III) belonging to 23 different companies purchased from supermarkets and online sales platforms across Türkiye. Consumer exposure and potential public health risk were also evaluated. Mean BPA levels were determined as 12.44±2.34 µg/kg (<LOD-51.94), 15.50±10.08 µg/kg (<LOQ-130.51) and 11.23±6.62 µg/kg (0.54-69.61) in Group I, II and III, respectively. There was no statistically significant difference between the groups and plain and oil- or sauce-packed ($p>0.05$). Sex-specific estimated daily intake values ranged from 0.0033-0.0052 µg/kg body weight/day and exceeded the current tolerable daily intake in all groups. In conclusion, it has been determined that BPA is commonly found in the canned foods examined and that exposure from these products should be considered for public health reasons.

Keywords: Bisphenol A, canned food, estimated daily intake, HPLC-FLD, public health

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Introduction

Changing consumer lifestyles have increased the demand for convenient foods, and canned foods have become an important component of modern diets because of their extended shelf life and ease of consumption (Fellows, 2022). While fish meat has an important place in a healthy diet thanks to its high-quality protein content, essential amino acids and n-3 polyunsaturated fatty acids, chicken and turkey meat are widely preferred due to their high biological value protein content and low-fat content (Nousheen et al., 2025; Petracci & Cavani, 2011). Fish are highly susceptible to microbial spoilage and lipid oxidation owing to their biochemical composition (Tavares et al., 2021). Therefore, canning has become one of the most widely used preservation methods for ensuring microbiological safety and extending shelf life (Ghaly et al., 2010).

Bisphenol A (BPA; 2,2-bis(4-hydroxyphenyl) propane) is an industrial chemical widely used in the production of polycarbonate plastics and epoxy resins used for the interior surface coatings of food cans. Due to its lipophilic nature (log P=3.32), it tends to migrate from food contact materials to food, and this process is affected by contact time, temperature, packaging material, and the properties of the food matrix (Manzoor et al., 2022; Putra et al., 2025). Although human exposure to BPA may occur through oral, dermal and inhalation routes, the main source of exposure is food and food contact packaging materials. Canned foods, especially due to epoxy resin-coated metal cans, are among the important sources of dietary BPA exposure (Aral and Burtaçgiray, 2026). Endocrine disrupting effects of BPA; it has been associated with reproductive disorders, obesity, type 2 diabetes, cardiovascular diseases and immune system disorders, and it is reported that most of the total BPA exposure in the general population is due to diet (Bansal et al., 2018; Bemrah et al., 2014; Ekici et al., 2024; Gorecki et al., 2017; Maffini et al., 2006; Stanojević and Sollner Dolenc, 2025; Vandenberg et al., 2007). In line with the increasing scientific evidence on the negative effects of BPA on human health, risk assessment approaches and legal regulations have been significantly updated. The European Food Safety Authority (EFSA) set the tolerable daily intake value as 0.2 ng/kg body weight/day in 2023 (EFSA, 2023), while the European Commission banned the use of BPA and other hazardous bisphenols in certain food contact materials with Regulation (EU) 2024/3190 published in 2024 (European Commission, 2024). In contrast, the specific migration limit for BPA in Türkiye continues to be applied at 0.6 mg/kg (Ministry of Agriculture and Forestry, 2024).

In this study, it was aimed to determine BPA levels in canned fish, meat, chicken and turkey products obtained from markets and online sales platforms in Türkiye by high performance liquid chromatography (HPLC) method, and to evaluate consumer exposure and potential public health risk by calculating estimated daily intake (EDI) values.

Materials and Methods

Samples

A total of 56 canned food samples used in the study were obtained from supermarkets and online sales platforms operating in Türkiye between September 2020 and March 2021. The samples are classified into three main groups according to their content characteristics. These groups included canned tuna (Group I, n=33), other canned fish [sardines, mackerel, and mixed fish products] (Group II, n=13), and canned meat, chicken, and turkey (Group III, n=10). The samples were composed of products belonging to a total of 23 different companies, and products with different formulations and packaging features belonging to the same company were also included in the evaluation.

Each group was also examined according to the product composition under two subcategories: plain (containing only water or brine) and oil- or sauce-packed (containing vegetable oil, tomato sauce, or various spice mixtures). Before the analysis, all samples, bombing, deformation, rusting or expired products were excluded from the scope of the study.

Chemicals and reagents

The BPA standard used in the study (≥99% purity; Sigma-Aldrich, Germany) and HPLC purity acetonitrile, ethanol, acetone, chloroform and sodium hydroxide (Merck, Germany). Ultrapure water was obtained from the Millipore Direct-Q system. The stock standard solution was prepared in methanol at a level of 1,000 µg/mL and maintained at -20°C for the duration of the study. Finisterre C18 SPE cartridges (200 mg/6 mL; Technochroma, Spain) were used for solid-phase extraction.

Sample preparation and solid-phase extraction

The extraction process was carried out by adapting the method optimized for the cheese matrix by Kürekci et al. (2021) to the canned food matrix. After opening the can, the solid and liquid phase were homogenized, extracted in an ultrasonic bath for 5 min with a mixture of 5 mL ethanol-ultrapure water (1:1, v/v) and 1 g of the homogeneous sample. The mixture was centrifuged at 5,000 rpm for 40 minutes, the resulting supernatant was filtered through Whatman No. 4 filter paper and its volume was completed to 100 mL with ultrapure water. The pH of the extract was adjusted to 6-7 using 1 N NaOH.

The prepared extract was passed through a solid-phase extraction (SPE) cartridge preconditioned with 4 mL of acetone and 4 mL of ultrapure water at a flow rate of approximately 2 mL/min. The cartridge was washed with 4 mL of ultrapure water, then dried under a nitrogen stream for 5 min, then eluted with 2 mL of acetone containing 7.1% (v/v) chloroform. The resulting eluate was centrifuged at 6,000 rpm for 5 min, then the solvent was completely removed under a nitrogen stream in a 50°C water bath. The dry residue was resolubilized in 1 mL of mobile phase and injected into the HPLC system.

HPLC conditions

The analyses were carried out at Mustafa Kemal University Technology and R&D Application and Research Center using the Shimadzu LC-20AD HPLC system (Shimadzu, Japan) equipped with a fluorescence detector (RF-20A). Separation was achieved by the mobile phase of ultrapure water-acetonitrile (55:45, v/v) in isocratic flow, on a C18 reversed-phase analytical column (250 × 4.6 mm; 5 µm particle diameter). The flow rate is set at 1.0 mL/min, the column temperature is set at 30°C, and the injection volume is set at 20 µL. BPA was observed at wavelengths of excitation 227 nm and emission at wavelengths of 313 nm. Before each analysis, the system was conditioned with at least 30 minutes of mobile phase for baseline stability; 20 minutes of washing was applied after each analysis.

Method validation

The parameters of linearity, trueness (recovery), precision (repeatability and reproducibility), lower limits of detection and determination (LOD/LOQ) and extended measurement uncertainty parameters of the method were evaluated in accordance with the criteria specified in the European Commission Decision 2002/657/EC (European Commission 2002). The calibration curve was constructed at five concentration points (0.5; 1.0; 2.5; 5.0, and 10.0 ng/g) in the range of 0.5-10.0 ng/g, and the linearity coefficient $R^2 \geq 0.9987$ was obtained. LOD and LOQ values were calculated as 0.16 µg/kg and 0.53 µg/kg, respectively; mean recovery was determined in the range of 85-110%, and intraday and interday relative standard deviation (RSD) ≤ was determined at 15%.

Estimated daily exposure (EDI) and risk characterization

The amount of BPA that individuals will be exposed to with the consumption of canned foods was calculated with the following formula recommended by Adeyi and Babalola (2019) and adapted to Turkish data:

$$EDI\ (\mu g/kg\ body\ weight/day) = (C \times IR) / BW$$

In this formula, C represents the average BPA concentration (µg/kg) determined in canned food; IR represents the amount of daily consumption (g/day); (300 g) Turkish Dietary Guidelines (TÜBER, 2015); BW, on the other hand, averages body weight (kg) (male 78.4 kg; female 68.8 kg (TÜİK, 2019).

The calculated EDI values were compared separately with the current TDI (0.2 ng/kg/day) levels determined in the EFSA (2023) assessment and expressed with the formula Risk Quotient (%TDI)=(EDI ⁄ TDI) × 100. In cases where values below the detection limit (<LOD) and between detection and determination limits (LOD <x<LOQ) constitute less than 60% of the data, the approach applied by Barboza et al. (2020) was based on the recommendation of the World Health Organization: <LOD results were entered as LOD/2 (0.08 µg/kg), and results between LOD-LOQ were entered as LOQ/2 (0.265 µg/kg).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). All samples were analysed in duplicate, and the mean values obtained from the two analytical replicates were used for statistical analysis. Data are presented as mean±standard error (SE), median, and range. Group comparisons were performed using one-way ANOVA with Duncan's multiple comparison test or the independent samples t-test, as appropriate. Statistical significance was set at $p<0.05$.

Ethical approval

Ethical approval was not required for this study, as the research was conducted exclusively using commercially available canned food samples and did not involve human participants or experimental animals.

Results

Method validation

The validation parameters of the SPE-HPLC-FLD method used for the determination of BPA were determined according to the values specified in commission decision no: 2002/657/EC. Method; High linear relationship in the concentration range of 0.5-10.0 ng/g (R^2=0.9987), low detection and determination limits (LOD=0.16 µg/kg; LOQ=0.53 µg/kg).

Detection frequency and general distribution of BPA

Of the 56 canned samples analyzed, BPA levels were below the detection limit (LOD) in only one (1.79%) and between LOD and LOQ in another (1.79%). In the remaining 54 samples (96.42%), BPA concentrations exceeded the LOQ. The distribution of BPA concentrations according to the LOD/LOQ categories is presented in Table 1.

Table 1. Distribution of BPA concentrations according to the LOD/LOQ categories by canning group

Group	n	<LOD (<0.16 µg/kg) n (%)	LOD-LOQ (0.16-0.53 µg/kg) n (%)	LOQ-4 µg/kg n (%)	>4 µg/kg n (%)
Group I	33	1 (3.03)	0 (0.00)	11 (33.33)	21 (63.64)
Group II	13	0 (0.00)	1 (7.69)	7 (53.85)	5 (38.46)
Grup III	10	0 (0.00)	0 (0.00)	4 (40.00)	6 (60.00)

LOD: Limit of Detection (0,16 µg/kg); LOQ: Limit of Quantification (0,53 µg/kg). n: Number of instances

BPA levels by canned groups

Descriptive statistics on BPA levels determined in canned food groups are presented in Table 2. The difference between the groups was not statistically significant when evaluated by one-way analysis of variance (ANOVA) (F=0.127; P=0.881).

Table 2. BPA levels detected in canned food groups (µg/kg)

Group	n	Average±SE	Minimum- Maximum	P†
Group I	33	12.44±2.34	<LOD - 51.94	0.881
Group II	13	15.50±10.08	<LOQ - 130.51	-
Group III	10	11.23±6.62	0.54 - 69.61	-
Total	56	13.06±4.35	<LOD - 130.51	

SE: Standard error. † One-way ANOVA + Duncan multiple comparison test; P >0.05. n: Number of instances
BPA: Bisphenol A

BPA levels by product type

Descriptive statistics and comparison results regarding BPA levels in plain and oil- or sauce-packed canned food products are presented in Table 3. Among all the samples examined, the highest BPA concentration was determined in a can of sardines (130.51 µg/kg) belonging to the oil- or sauce-packed subgroup of Group II. There was no statistically significant difference in any of the within-group comparisons (p>0.05). Similarly, when all samples were evaluated together, product type did not have a statistically significant effect on BPA levels (p=0.351).

Table 3. Descriptive statistics and comparison results of BPA levels by product type in canned groups (µg/kg)

Group	Subgroup	n	Minimum(µg/kg)	Maximum (µg/kg)	Average±SE (µg/kg)	t	P
Group I	Plain	18	0.85	51.94	11.86±3.66	-0.269	0.790
	Oil-or sauce packed	15	0.08	34.39	13.14±2.80		
Group II	Plain	7	1.22	9.10	3.53±1.07	-1.322	0.213
	Oil-or sauce packed	6	0.27	130.51	29.46±21.32		
Group III	Plain	7	0.54	69.61	14.43±9.37	0.717	0.494
	Oil-or sauce packed	3	1.29	5.60	3.78±1.29		
Total	Plain	32	0.54	69.61	10.60±2.90	-0.933	0.351
	Oil-or sauce packed	24	0.08	130.51	16.05±5.54		

SE: Standard error. t: Independent samples t-test statistic; P: Significance level. n: Number of instances, BPA: Bisphenol A

Estimated daily exposure (EDI) and risk characterization

Gender-specific estimated daily intake (edi) values calculated using the average bpa levels determined in canned foods, the recommended consumption amounts in tüber 2015 and the average body weight values of the türkiye health survey (tüik, 2019) are presented in Table 4. the calculated edi values exceeded the efsa 2023 tolerable daily intake value in all groups and genders.

Table 4. Comparison with gender-specific Daily BPA exposure (EDI) and EFSA 2023 TDI values

Group	Sex	EDI (µg/kg body weight/day)	Fold exceedance of the 2023 (0.2 ng/kg/body weight/day)
Group I	Male	0.0037	× 18.5
Group I	Female	0.0042	× 21.0
Group II	Male	0.0046	× 23.0
Group II	Female	0.0052	× 26.0
Group III	Male	0.0033	× 16.5
Group III	Female	0.0038	× 19.0

TDI_{2023} exceedance factor=(EDI × 1000) / 0,2.
BPA: Bisphenol A

Discussion

In our study, BPA was detected in the majority (96.42%) of 56 canned food samples offered for sale in Türkiye; The average levels were determined as 12.44 µg/kg in canned tuna, 15.50 µg/kg in other fish cans and 11.23 µg/kg in meat-chicken-turkey cans.

Er and Sarımehmetoğlu (2011) reported BPA levels in the range of 80-1,120 µg/kg in tuna cans, and Sungur et al. (2014) reported BPA levels in the range of 21.86-1,858.71 µg/kg in different canned foods. Similarly, the maximum BPA level of 102 µg/kg reported by Toptancı (2023) in ready-to-eat foods offered for sale in Türkiye was found to be close to the maximum value of 130.51 µg/kg determined in Group II samples in this study. When these findings are evaluated together, it can be said that the BPA levels determined in our study are generally consistent with the values reported in Türkiye in recent years but may vary significantly between products and show that BPA continues to be widely found in canned foods. Differences in BPA concentrations among studies may be attributed to variations in processing and storage conditions. Tokat et al. (2018) reported that sterilization was the major factor influencing BPA migration, with storage temperature and duration further increasing BPA levels.

Gorecki et al. (2017) found that BPA levels of canned fish and meat products in France were 0.93 µg/kg and 0.42 µg/kg, respectively, which were lower than the average values reported in our study. Podlipna and Cichna-Markl (2007) reported that BPA levels in solid samples in canned tuna, mackerel and sardines in Austria were 2-4 ng/g in canned mackerel, the highest BPA level was 59 ng/g in canned tuna, and Sajiki et al. (2007) reported that they detected BPA in the range of 0.8-23 ng/g in 48 canned fish in Japan. The data of this study are similar to our results. Adeyi and Babalola (2019) detected 12.7±7.7 ng/g BPA in canned beef, 4.42±1.5 ng/g in canned chicken meat, and 11.2±11 ng/g in canned fish in their study conducted with the GC-MS method in Nigeria, which is similar to the average BPA levels obtained especially for Group I (12.44 µg/kg) and Group III (11.23 µg/kg). Cao et al. (2021) detected BPA levels of 77 µg/kg and 47 µg/kg in canned meat and seafood in China, respectively, and these values were found to be above the average concentrations determined in our study. On the other hand, Lin et al. (2022) determined the EDI value for canned seafood at the level of 11.69 ng/kg body weight/day, which is higher than the EDI value in the range of 3.7-5.2 ng/kg body weight/day determined for Groups I and II in our study. It is thought that this may be due not only to differences in BPA concentrations in the products, but also to the higher per capita consumption of seafood in China compared to Türkiye. In addition, the differences observed between the studies; It is reported that it may be due to differences in the product groups examined, sampling strategy, analytical method, structure of the packaging material, storage conditions and consumption habits.

One of the most notable findings of the study

is that all calculated EDI values exceeded the current TDI value set by EFSA in 2023. This result reveals that BPA exposure in all product groups examined exceeds current health-based reference values and therefore should be handled within the framework of the current risk assessment approach.

Conclusion

The findings provide up-to-date data on BPA levels in canned foods in Türkiye, providing a scientific basis for future monitoring studies and research evaluating multiple bisphenol exposures. The use of probabilistic risk assessment approaches in future studies will contribute to a more realistic representation of consumer exposure. In addition, considering the total exposure of BPA, which can come from different sources, it is important to increase controls and inspections in packaging materials that come into contact with food, to expand migration tests, to regularly update the legislation in line with current scientific developments, and to support research on alternative packaging materials.

Conflict of Interest

The authors stated that they did not have anyreal, potential or perceived conflict of interest.

Ethical Approval

Ethical approval was not required for this study, as the research was conducted exclusively using commercially available canned food samples and did not involve human participants or experimental animals.

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Similarity Rate

We declare that the similarity rate of the article is 8% as stated in the report uploaded to the system.

Author Contributions

Motivation / Concept: B.A., S.P.Ö., Design: B.A., S.P.Ö., Control/Supervision: B.A., S.P.Ö., Data Collection and / or Processing: B.A., S.P.Ö., Analysis and / or Interpretation: B.A., S.P.Ö., Literature Review: B.A., S.P.Ö., Writing the Article: B.A., S.P.Ö., Critical Review: B.A., S.P.Ö.

AI Usage Information

No artificial intelligence was used.

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