


Research Article

Risk factors for Exposure to Endocrine Disruptors Present in Plastic Food Packaging within a Local Population

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Abstract

The widespread use of plastic food packaging has raised concerns about human exposure to endocrine disruptors, particularly in low-resource settings where risky practices are common.

Objective: Evaluate the behavioral and environmental factors associated with exposure to endocrine disruptors using plastic food packaging.

Methods: A cross-sectional analytical study was conducted with 744 participants. Data on plastic use practices were collected and analyzed using univariate, bivariate, and multivariate logistic regression. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to identify independent risk factors.

Results: A high prevalence of risky practices was observed, including plastic reuse (79.2%), consumption of acidic foods (68.8%), and use of non-food-grade plastics (68.7%). Multivariate analysis revealed that exposure to acidic foods was the strongest predictor (OR = 2.56; 95% CI [1.56–4.19]), followed by plastic reuse (OR = 2.14; 95% CI [1.45–3.17]) and the use of recycled plastics (OR = 1.89; 95% CI [1.32–2.71]). Other significant factors included prolonged storage (>24 h), poor washing practices, and heat exposure.

Conclusion: Exposure to endocrine disruptors in plastic food packaging is strongly influenced by daily behaviors and environmental conditions. Public health interventions should aim to reduce the use of unsafe plastics and promote safer alternatives.

Keywords: Endocrine disruptors; Plastics; Food packaging; Chemical exposure; Public health; Risk factors

Introduction

The use of plastics in food packaging is currently a major source of human exposure to endocrine disruptors (EDs). These substances, including bisphenols and phthalates, can interfere with the hormonal system and are associated with various adverse health effects, including metabolic, reproductive and developmental disorders [1,2]. Plastic materials used in food packaging can release these chemical compounds into food through migration, particularly under the influence of factors such as heat, storage time, and the nature of the food [3]. Acidic foods and high temperatures have been shown to significantly increase this migration, leading to increased exposure to endocrine disruptors [4]. Furthermore, a significant proportion of plastic materials in contact with food contain substances with endocrine or metabolic activity, raising major public health concerns [5]. This chronic

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exposure is particularly concerned in resource-limited settings, where practices such as plastic reuse and the use of recycled materials are common [6]. Thus, identifying the behavioral and environmental factors associated with this exposure is a major challenge for preventing risks related to endocrine disruptors.

Goals

General objective

To assess the behavioral and environmental factors associated with the use of non-food plastics and the risk of exposure to endocrine disruptors in the population, studied.

Specific objectives

- Describe the frequency of risky practices related to the use of plastics (univariate analysis)
- Analyze the association between these practices and the use of non-food-grade plastics (bivariate analysis)
- Identify factors independently associated with exposure risk using multivariate logistic regression
- Prioritize risk factors according to their importance (adjusted OR)
- Specifically assess the role of the major factors identified:
 - consumption of acidic foods
 - reuse of plastics
 - use of recycled plastics
 - storage and hygiene conditions

Method

Study design

Analytical cross-sectional study with explanatory aims.

Study population

- Individuals using plastic packaging in contact with food.
- Sample size: $n = 744$.

Variables studied

a. Dependent variable

- Use of non-food-grade plastics (Yes / No) (corresponds exactly to the outcome analyzed in the bivariate and multivariate tables)

b. Independent Variables

- Consumption of acidic foods
- Use of hot liquids
- Reusing plastics
- Use of recycled plastics

- Food storage > 24 hours
- Washing practices (adequate / inadequate)
- Covering hot food
- Other variables tested:
 - plastic change
 - plastic on hot pot
 - hot bread packaging

Statistical analysis

The data analysis was carried out in three stages:

1. Univariate analysis

- Calculation of frequencies and proportions (%)
- Description of plastics usage practices

2. Bivariate analysis

- Chi-square test to compare proportions
- Calculation of Odds Ratio (raw OR)
- Identification of associated factors ($p < 0.05$)

3. Multivariate analysis

- Binary logistic regression
- Adjusted Odds Ratio (AOR) Estimation
- Calculation of 95% confidence intervals (95% CI)
- Inclusion of variables significant in bivariate analysis
- Significance threshold
- $p < 0.05$

Analytical approach

A hierarchical approach to risk factors was adopted, allowing us to distinguish:

- Major factors ($OR > 2$)
- Moderate factors (OR between 1.5 and 2)
- Weak but significant factors

Discussion

The results of this study are presented in a structured manner according to the different levels of statistical analysis. First, a descriptive (univariate) analysis describes the frequency of practices related to plastic use. Next, a bivariate analysis explores the associations between these practices and the use of non-food-grade plastics. Finally, a multivariate analysis, based on a logistic regression model, identifies the factors independently associated with the risk of exposure. This progressive approach allows for a better understanding of the scope of the phenomenon as well as

the major determinants involved. The results of this study are presented using a progressive analytical approach that systematically integrates their interpretation. Each table and figure is followed by a discussion that contextualizes the observations and highlights their public health implications.

Table 1: Overall descriptive analysis (univariate merged)

Variable	Yes (n)	No (n)	Total	% Yes
Hot liquids in plastic	360	384	744	48.4
Acidic foods in plastic	512	232	744	68.8
Plastic replacement	528	216	744	71
Cover hot food	277	467	744	37.2
Wrap hot bread	373	371	744	50.1
Plastic on hot pot	221	523	744	29.7
Storage > 24h	414	330	744	55.6
Non-food-grade plastic (RISK)	511	233	744	68.7
Reusing plastics	589	155	744	79.2
Wash before reuse	621	123	744	83.5
Use of recycled plastics	417	327	744	56

Table 2: Overall bivariate analysis of the dependent variable: use of non-food-grade plastics

Variable	Modality	Risk Yes	No risk	RAW GOLD	p-value
Acidic foods	Yes	380	132	2.21	<0.001
	No	131	101	1	
Storage >24h	Yes	310	104	1.92	<0.001
	No	201	129	1	
Hot liquids	Yes	268	92	1.69	0.001
	No	243	141	1	
Cover hot food	Yes	210	67	1.72	0.0016
	No	301	166	1	
Reusing plastics	Yes	438	151	2.67	<0.001
	No	73	82	1	
Recycled plastics	Yes	312	105	1.88	0.002
	No	199	128	1	
Improper washing	Yes	167	79	1.74	0.01
	No	344	154	1	
Plastic replacement	Yes	372	156	1.32	0.123
	No	158	63	1.21	0.323
Wrap hot bread	Yes	255	118	0.98	0.913
	No	158	63	1.21	0.323

Bivariate analysis revealed several factors significantly associated with the use of non-food-grade plastics. Plastic reuse emerged as the strongest associated factor (OR = 2.67; p<0.001), followed by exposure to acidic foods (OR = 2.21; p < 0.001) and prolonged storage beyond 24 hours

(OR = 1.92; p < 0.001). Exposure to hot liquids (OR = 1.69; p = 0.001) and covering hot foods (OR = 1.72; p = 0.0016) were also significantly associated with the risk. Furthermore, the use of recycled plastics (OR = 1.88; p = 0.002) and inadequate washing practices (OR = 1.74; p = 0.01) contributed significantly to exposure. On the other hand, changing the plastic, using plastics on hot pots and packaging hot bread did not show a statistically significant association with risk (p > 0.05). The associations observed in the bivariate analysis are largely corroborated by recent international literature. Plastic reuse, identified as a major factor in our study, has also been described as a key determinant of exposure in several experimental and epidemiological studies [2-6]. Indeed, polymer degradation during repeated use promotes the increased release of chemical substances. The effect of acidic foods (OR = 2.21) is also well documented. Experimental studies have shown that acidity significantly increases the migration of endocrine disruptors from plastic materials into food. Similarly, exposure to heat (hot liquids, hot food) is recognized as a critical factor in chemical diffusion. Globally, several studies have shown that the combination of factors (heat + acidity + duration) leads to an exponential increase in the migration of chemical contaminants [1-6]. In African and similar contexts, these factors are often cumulative: hot food is packaged immediately, stored for extended periods, and reused. Studies conducted in Nigeria, India, and Bangladesh have shown similar exposure profiles, with significant associations between these practices and toxicological risk [15-17]. Thus, the bivariate results of our study fit perfectly within the global explanatory models of endocrine disruptor migration, confirming the external validity of our observations.

Multivariate analysis identified several factors independently associated with the use of non-food-grade plastics. Exposure to acidic foods was the primary

Table 3: Final multivariate analysis (overall adjusted model)

Variable	OR adjusted	IC95%	p-value	Interpretation
Acidic foods	2.56	[1.56 – 4.19]	<0.001	Major factor
Reusing plastics	2.14	[1.45 – 3.17]	<0.001	Major factor
Recycled plastics	1.89	[1.32 – 2.71]	0.001	Significant
Storage >24h	1.68	[1.18 – 2.38]	0.0036	Significant
Poor washing	1.67	[1.12 – 2.48]	0.011	Significant
Cover hot food	1.57	[1.10 – 2.23]	0.013	Moderate
Hot liquids	1.54	[1.09 – 2.18]	0.014	Moderate
Plastic replacement	1.39	[0.94 – 2.05]	0.094	Not significant
Plastic on pot	1.27	[0.92 – 1.75]	0.136	Not significant
Wrap hot bread	1.13	[0.83 – 1.54]	0.437	Not significant

determinant (OR = 2.56; 95% CI [1.56–4.19]; $p < 0.001$), followed by plastic reuse (OR = 2.14; 95% CI [1.45–3.17]; $p < 0.001$). The use of recycled plastics (OR = 1.89; $p = 0.001$), prolonged storage beyond 24 hours (OR = 1.68; $p = 0.0036$), and inadequate washing practices (OR = 1.67; $p = 0.011$) were also significantly associated with risk. Furthermore, exposure to heat, particularly covering hot food (OR = 1.57; $p = 0.013$) and using hot liquids (OR = 1.54; $p = 0.014$), showed moderate but significant associations. In contrast, changing the type of plastic, using plastics on hot pots, and wrapping hot bread were not significantly associated with risk after adjustment ($p > 0.05$). Multivariate analysis allows for the identification of independent factors, which strengthens the robustness of the results. Exposure to acidic foods appears to be the main determinant, which is consistent with recent experimental data showing that the chemical nature of foods directly influences the migration of contaminants [3–6]. Plastic reuse remains a major factor after adjustment, confirming its central role in chronic exposure. Recent studies have shown that reused plastics release more active endocrine compounds, notably due to structural degradation and the accumulation of microcracks [4,5]. The use of recycled plastics is also a significant factor. The literature indicates that these materials often contain complex mixtures of chemicals, including uncontrolled contaminants. This chemical complexity increases the risk of additive or synergistic effects [18]. Factors related to conditions of use (prolonged storage, inadequate washing, heat) confirm that exposure is multifactorial. These results are consistent with recent studies that highlight the importance of conditions of use in the migration of endocrine disruptors [1–6]. In African countries, several studies have shown that these factors are often present simultaneously, which amplifies the risk of exposure. This reinforces the relevance of our results in a public health context [19]. The graph in the forest confirms the hierarchy of risk factors observed in the international literature. The major factors (acidic foods, reuse) have high odds ratios, while factors related to heat and hygiene conditions show moderate but significant effects.

This hierarchy is consistent with recent toxicological models [20], which distinguish:

- The main triggering factors (acidity, plastic degradation)
- Amplifying factors (heat, duration, hygiene)

Recent studies have also shown that human exposure to substances from food packaging is cumulative and multifactorial, with potentially synergistic effects [21]. In low-resource settings, this accumulation of factors is particularly marked, which explains the high levels of risk observed in our study [22]. The forest plot illustrates the adjusted odds ratios (OR) and their 95% confidence intervals (CI) for factors associated with the use of non-food plastics. Exposure to acidic foods appears to be the strongest predictor

(OR = 2.56; 95% CI [1.56–4.19]), indicating a more than twofold increased risk. Plastic reuse also shows a strong association (OR = 2.14; 95% CI [1.45–3.17]), highlighting its crucial role in increasing exposure. The use of recycled plastics (OR = 1.89; 95% CI [1.32–2.71]) and storage times exceeding 24 hours (OR = 1.68; 95% CI [1.18–2.38]) are also significantly associated with an increased risk. Similarly, poor hygiene practices (OR = 1.67; 95% CI [1.12–2.48]) contribute to the likelihood of exposure. Heat-related practices, such as covering hot food (OR = 1.57; 95% CI [1.10–2.23]) and using hot liquids in plastic containers (OR = 1.54; 95% CI [1.09–2.18]), show moderate but statistically significant associations.

Ultimately, the confidence intervals for all significant variables do not include value 1, thus confirming their independent contribution to risk. These results highlight that behaviors and environmental conditions play a crucial role in exposure to endocrine disruptors present in plastics.

Analysis of adjusted risk factors reveals a clear hierarchy of determinants associated with the use of non-food plastics. Exposure to acidic foods appears to be the most influential factor (OR = 2.56; 95% CI [1.56–4.19]), followed by the reuse of plastics (OR = 2.14; 95% CI [1.45–3.17]), confirming their major role in increasing risk.

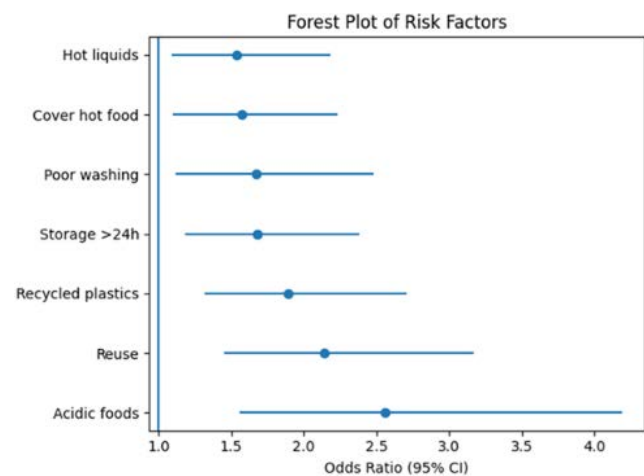


Table 4: Adjusted risk factors

Variable	GOLD	IC95%	Importance
Acidic foods	2.56	[1.56–4.19]	Extremely high
Reusing plastics	2.14	[1.45–3.17]	High
Recycled plastics	1.89	[1.32–2.71]	Moderate
Storage >24h	1.68	[1.18–2.38]	Moderate
Poor washing	1.67	[1.12–2.48]	Moderate
Cover hot food	1.57	[1.10–2.23]	Weak
Hot liquids	1.54	[1.09–2.18]	Weak

Intermediate factors include the use of recycled plastics (OR = 1.89), prolonged storage beyond 24 hours (OR = 1.68) and inadequate washing practices (OR = 1.67), which contribute significantly to exposure. Finally, heat-related factors, such as covering hot food (OR = 1.57) and using hot liquids (OR = 1.54), have more moderate effects but remain statistically significant. Overall, these results highlight that the combination of behavioral factors (reuse, washing) and environmental factors (heat, acidity, storage time) plays a key role in increasing the risk of exposure to endocrine disruptors from plastics. Multivariate analysis highlights a clear hierarchy of risk factors, confirming the multifactorial nature of exposure to endocrine disruptors. Acidic foods appear to be the main determinant (OR = 2.56), which is consistent with the literature showing that acidity promotes the migration of bisphenols and phthalates from plastics into food [1-3]. Jane Muncke's work confirms the key role of food chemical composition in this process. The reuse of plastics (OR = 2.14) is also a major factor, due to material degradation during repeated use, increasing the release of toxic substances [2-4]. According to Leonardo Trasande these exposures are closely linked to daily practices, particularly in low-resource settings. Recycled plastics (OR = 1.89), prolonged storage (> 24 h) (OR = 1.68) and poor washing (OR = 1.67) contribute significantly to the risk, promoting the accumulation and migration of contaminants [1-6]. Heat-related factors, such as covering hot food (OR = 1.57) and using hot liquids (OR = 1.54), have a more moderate effect but are still significant, confirming the role of temperature in the diffusion of chemical substances [2,3]. Overall, these factors act synergistically, especially in resource-poor settings. Therefore, reducing the reuse of plastics and their contact with acidic foods is a public health priority.

This table shows that endocrine disruptors from plastics, particularly bisphenols and phthalates, are released under

the influence of heat, acidity, reuse, and prolonged storage. The use of recycled or non-food-grade plastics also increases the risk due to uncontrolled substances. Furthermore, plastic degradation and insufficient washing promote the release and accumulation of contaminants. Thus, the factors identified in the study correspond directly to known mechanisms of exposure to endocrine disruptors. The correspondence between the factors identified in our study and known biological mechanisms strengthens the plausibility of the results. Bisphenols and phthalates, widely documented as major endocrine disruptors, act primarily through hormonal mimicry or interference with endocrine receptors [1,2]. Their migration is favored by the conditions identified in our study (heat, acidity, reuse) [23]. Recent studies have also highlighted that plastics contain many as yet uncharacterized substances, some of which have potential endocrine activity [12-25]. In developing countries, the use of recycled and non-food plastics exposes populations to even less controlled substances, which constitutes a major public health issue [26,27]. Thus, the consistency between epidemiological data and toxicological mechanisms gives our study strong internal and external validity.

Limitations of the study

This study has certain limitations that must be considered when interpreting the results. First, the cross-sectional nature of the study does not allow us to establish a causal relationship between the identified factors and exposure to endocrine disruptors. The observed associations reflect statistical links but do not allow us to confirm a direct causal relationship. Secondly, the data relies heavily on participant self-reporting, which exposes the data to recall bias and social desirability bias. As a result, some risky behaviors may be underestimated or overestimated. Third, the absence of biological measurements (measurement of biomarkers such

Table 5: Endocrine disruptors from plastics and associated risk factors

Type of plastic / use	Endocrine disruptor	Mechanism of action	Risk factors identified in the study	Potential effects
Rigid plastics (bottles, containers)	Bisphenol A (BPA)	Estrogen mimicry	Hot liquids, Reuse	Hormonal disorders, infertility
Flexible plastics (bags, films)	Phthalates (DEHP, DBP)	Hormonal disruption	Acidic foods, Heat	Reproductive disorders
Recycled plastics	Mixture of contaminants (BPA, phthalates, additives)	Cumulative effects	Recycled plastics, Reuse	Chronic toxicity
Non-food packaging	Uncontrolled industrial additives	Unknown toxicity	Non-food-grade plastic	High risk of exposure
Heated plastics	Increased migration of monomers	Increased chemical diffusion	Hot liquids, cover hot food	Acute exposure
Extended storage	Migration accumulation	Slow continuous diffusion	Storage >24h	Chronic Exhibition
Degraded plastics	Microplastics + additives	Gradual release	Reuse, Plastic replacement	Inflammatory effects
Poorly washed plastics	Persistent chemical residues	Repeated contact	Poor washing	Bioaccumulation

as bisphenols or phthalates) limits the direct assessment of actual exposure to endocrine disruptors. The study focuses on risk factors rather than measured exposure levels. Fourth, some potentially confounding factors (detailed socio-economic level, education level, exact type of plastics used) were not fully controlled, which could influence the observed associations. Finally, since the results come from a local population, their generalization to other contexts must be done with caution, although consistency with international literature strengthens their external validity.

Conclusion

This study highlights a high prevalence of risky practices related to the use of food-grade plastics and confirms that exposure to endocrine disruptors is largely influenced by daily behaviors and conditions of use. Multivariate analysis identified major factors, including the consumption of acidic foods and the reuse of plastics, as well as moderate factors such as the use of recycled plastics, prolonged storage, and inadequate washing practices. Heat-related factors, although of a more moderate effect, also contributed significantly to exposure. These results confirm the multifactorial and cumulative nature of exposure to endocrine disruptors, consistent with international data. They highlight the importance of interactions between food properties, environmental conditions, and individual behaviors. In resource-limited settings, where risky practices are frequent, this exposure constitutes a major public health issue.

Recommendations

Public health recommendations

- Raising public awareness of the risks associated with using plastics in contact with acidic or hot foods
- Promote the use of safer alternatives (glass, stainless steel, food-grade certified materials)
- Encourage the reduction of plastic reuse, particularly for food-related uses.

Recommendations for decision-makers

- Implement policies to regulate food-grade plastics and recycled plastics.
- Strengthening quality controls on materials in contact with food.
- Develop health education campaigns adapted to local contexts.

Recommendations for research

- Conduct longitudinal studies to establish causal relationships
- Incorporate exposure biomarkers (BPA, phthalates) for a more accurate assessment

- Exploring the long-term health impact of chronic exposure to plastics
- Studying the combined effects (cocktail) of endocrine disruptors

Recommendations specific to low-resource contexts

- Developing accessible and sustainable solutions to replace food-grade plastics
- Integrating environmental and health issues into community programs
- Strengthening plastic waste management and recycling systems

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