RAPID RESPONSE BRIEF

Chemical Migration in Microwave-heated Plastic Food Containers

A Brief Report and Inventory of Studies

KEY MESSAGE

This review found that there are no studies that directly evaluated the health effects of ingesting food reheated in the microwave using plastic food containers. The included studies evaluated the migration of toxic substances from plastic food containers when subjected to experimental microwave heating. These substances include: dibutyl phthalate (plasticizer), lead (heavy metal), formaldehyde (aldehyde), melamine (plasticizer), and substances with estrogenic activities. However, the amount observed in the studies were less than the maximum daily intake/tolerable daily intake recommended by the US Food and Drugs Administration or the European Food Safety Authority. Long-term longitudinal studies are needed to determine the harmful effects to health of microwave-heating of these containers.

CONTEXT

- Microwaves are electromagnetic waves that have various industrial uses (e.g., heating, broadcast and mobile communication, navigation, etc.)[1].
  - » One of its popular use is heating or reheating of food in microwave ovens. The shift in dietary consumption from traditionally-prepared meals to pre-packed and ready-to-eat meals[2] contributed to frequent use of microwave ovens. Usually, heating of food with microwave ovens makes use of microwave-safe containers that have food-grade contact surfaces and are not damaged by the heating conditions inside the microwave oven. Microwavable food containers can be made of glass, ceramic, or plastics. In terms of cost, microwave-safe plastic food containers are cheaper compared to glass or ceramic ones.
  - » The frequent use of plastic food containers in heating/reheating of food had been suspected to contribute to the increased risk of contracting diseases such as cancers. This is due to the suspicion that chemicals migrate from the container to the food[3].
- Microwavable food containers contain specific types of resin that make them stable under microwave energy. Use of containers not designed for microwave ovens can make it susceptible to the breakdown and migration (i.e., the transfer) of the chemicals to the food.
- The Republic Act 10611, or the “Strengthening of the Philippine Food Safety Regulatory System”, provides no specific standards or precautions regarding heating food in the microwave.
- Standards in food safety are set by the Department of Agriculture and the Department of Health, while its implementation in food businesses is the responsibility of the Local Government Unit.

INVENTORY OF STUDIES ON CHEMICAL MIGRATION IN MICROWAVE-HEATED PLASTIC FOOD CONTAINERS

Search strategy and Selection Criteria

Electronic databases such as PubMed/Medline, Cochrane Library, and Herdin were searched for studies investigating the harmful health effects of the use of non-microwavable food containers in reheating food in the microwave. The search strategy was constructed by combining search terms with appropriate Boolean operators in order to describe records including key words referring to microwave, reheating, heating, microwavable containers, microwave-safe food containers, non-microwave-safe food containers, health outcome, and health effects. The search was limited to English language with no limit on time period. Studies on plastic bottles were excluded.

Table 1. Results of the electronic database search

Search Terms	Number of hits	Number of articles based on abstract review	Number of articles included in the final review
“microwave-safe” OR “microwavable” OR “non-microwave-safe” OR “non-microwavable” OR “food container" OR “plastic container” OR plate* OR plastic* OR “plastic plates” AND reheat OR reheating OR heat OR heating OR leach OR leaching OR toxin OR toxins OR Melamine OR BPA OR “bisphenol-A” OR phthalates AND "microwave oven” OR microwave AND health OR “health outcome” OR disease	PubMed= 53 Cochrane= 26 HERDIN= 0	PubMed= 10 Cochrane= 0 HERDIN= 0	PubMed= 4

Studies

This is a summary of the results of 4 experimental studies showing descriptions of different chemicals that migrate from food containers to food when heated in microwave oven. Brief descriptions on the possible health effects of ingestion of these chemicals are also included. See Appendix I for the details of the results of the studies.

1. An experimental study in Thailand determined the effects of acidity, extraction time, and heat level on the migration of lead from pigmented microwavable plastic ware[5]:

- Exposure to lead is very toxic to humans. Acute lead poisoning can cause heart, blood circulation, and kidney problems, as well as liver failure, which may result in death. Chronic exposure is usually associated with anemia and kidney abnormalities.
- The findings of the study were the following:
  - » There was lead that migrated from the microwavable containers, with the amount increasing with length of exposure (minute) and pH level of the material in the container.
  - » The amount of lead extracted were all less than the maximum daily intake recommended by the Food and Drug Administration.

2. An experimental study in Brazil analyzed the migration of dibutyl phthalate (DBP) and benzyl butyl phthalate (BBP) to a food product placed in new and used plastic containers when these were subjected to different heating conditions[6].

- In humans, exposure to high doses of phthalates can affect hormone production which may interfere with sexual development and alter human sperm motility.
- The findings of the study were the following:
  - » Only DBP was detected to migrate from the containers. BBP was not detected to migrate from the containers.
  - » The concentration of DBP that migrated from the containers was below the limit recommended by the European Food Safety Authority. However, it had been found that continued use of the containers lead to increased amount of DBP migration.

3. An experimental study in Thailand compared the response of melamine formaldehyde (MF) tableware to different modes of heating[7].

- There are no direct studies on the health effects of melamine on human body. However, there was an influx of children with kidney stones in China following the melamine contamination of infant formula milk in 2008[8-11].
- The findings of the study were the following:
  - » Exposure to microwave oven for a cycle of 1 minute is associated with the most rapid increase in overall migration of melamine, exceeding the regulatory limit after 25 cycles. Similar results were found for the 2- and 3-minute cycles, with the number of cycles increasing to 29 and 67, respectively, before reaching the overall migration limit.
  - » Migration of formaldehyde did not reach the regulatory limit and was not detected in some samples.

4. An experimental study in the USA assessed chemicals with estrogenic activity (EA) leaching in bisphenol A (BPA)-free polycarbonate-replacement hard and clear, reusable, plastic products[12]:

- Exposure to high levels of chemical with EA can cause early menarche, reduced sperm counts and other altered functions of reproductive organs, obesity, and increased rates of some cancers.
- The findings of the study were the following:
  - » Most of the products tested had some amounts of chemicals with EA after exposure to microwave.
  - » Exposure to microwave might have reduced the release of chemicals with EA. Exposed products had lower amount of chemicals with EA in the assays compared to unexposed products.

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APPENDICES

Appendix I. Characteristics and findings of studies

<table>
<tr><td>Author, Year of publication</td><td>Inthorn et al., 2002</td></tr>
<tr><td>Study objective</td><td>To determine the effects of pH, extraction time, and heat level on the leaching of lead from pigmented microwaveable plastic ware.</td></tr>
<tr><td>Study design</td><td>Experimental study</td></tr>
<tr><td>Sample/specimen</td><td>Pigmented microwaveable plastic ware</td></tr>
<tr><td>Intervention, Comparator, and Study Conduct</td><td>• The effect of the following on the amount of lead that leaches from the containers were tested:
○ pH: 3.5, 4.5, and 6.5
○ Microwave heat level: 50°C to 53°C, 67°C to 69°C, and 75°C to 77°C
○ Time of exposure: 1, 3, and 5 minutes
• The lead levels were then extracted three times</td></tr>
<tr><td colspan="2">Outcomes: The mean amount of lead found (mean of 3 extractions) are the following:
<table>
<tr><th>Time of exposure</th><th>pH 3.5</th><th>pH 4.5</th><th>pH 6.5</th></tr>
<tr><td>1 minute</td><td>0.082</td><td>0.99</td><td>0.137</td></tr>
<tr><td>3 minutes</td><td>0.100</td><td>0.157</td><td>0.330</td></tr>
<tr><td>5 minutes</td><td>0.117</td><td>0.216</td><td>0.502</td></tr>
<tr><td colspan="4">Note: Maximum daily intake level (6uL/day) (FDA, 2017)</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Author, Year of publication</td><td>Moreira et al., 2013</td></tr>
<tr><td>Study objective</td><td>To do a quantitative analysis of the migration of dibutyl phthalate (DBP) and benzyl butyl phthalate (BBP) into a food product placed in plastic containers when these were subjected to different heating condition.</td></tr>
<tr><td>Study design</td><td>Experimental study</td></tr>
<tr><td>Sample/specimen</td><td>Polypropylene microwavable food containers (5 new and 5 exposed to long-term use of 1 year)</td></tr>
<tr><td>Intervention, Comparator, and Study Conduct</td><td>The containers filled with water were placed in a domestic microwave oven (700 W power) and were then heated at various powers (high, 700 W; medium, 350 W; and low, 210 W) and heating durations (1, 3, 5, and 7 mins for high and medium power and 10, 15, 20, and 30 mins for low power).</td></tr>
<tr><td colspan="2">Outcomes: Only DBP were detected in the containers. The concentrations found are the following:
<table>
<tr><th>Container type</th><th>DBP Amount</th></tr>
<tr><td>New containers</td><td><LOQ to 2.0 µg/L</td></tr>
<tr><td>Used containers</td><td><LOQ to 7.5 µg/L</td></tr>
</table>
Note: LOQ = level of quantification or the lowest amount detectable by the machine</td></tr>
</table>

<table>
<tr><td>Author, Year of publication</td><td>Poovarodom, 2014</td></tr>
<tr><td>Study objective</td><td>To understand and compare the response of MF to different modes of heating and ultimately to provide consumers with more precise instructions for use.</td></tr>
<tr><td>Study design</td><td>Experimental study</td></tr>
<tr><td>Sample/specimen</td><td>Melamine ware bowls</td></tr>
<tr><td>Intervention, Comparator, and Study Conduct</td><td>• Exposure to microwave oven (800W) for 1,2,3 and 5 mins.
• All of the specimens bowls contain a food stimulant, acetic acid 3% (w/v) at ambient temperature</td></tr>
<tr><td colspan="2">Outcomes:
• The effects of microwave heating on migration from melamine ware are the following:
<table>
<tr><th>Time of exposure to microwave heat</th><th>Number of cycles before reaching regulatory limit of 10mg/dm^2</th></tr>
<tr><td>1 minute</td><td>25 cycles</td></tr>
<tr><td>2 minutes</td><td>29 cycles</td></tr>
</table></td></tr>
</table>

3 minutes	67 cycles
5 minutes	37 cycles

- The migration of formaldehyde in all test scenarios was low. Results are the following:

Exposure	**Amount of migrated formaldehyde**
Microwave	<0.48 to 1.26 mg/kg
Control (no exposure)	1.55 to 4.61 mg/kg .

Note: Regulatory limit of formaldehyde is 15 mg/kg

Author, Year of publication	**Bittner et al., 2014**
Study objective	To assess the chemical with estrogenic activity (EA) leaching in bisphenol A (BPA)-free polycarbonate-replacement hard and clear, reusable, plastic products.
Study design	Experimental study
Sample/specimen	Fifty reusable polycarbonate-replacement products made from seven types of resins (i.e., acrylic, COC, COP, PES, PETG, PS, Tritan™)
Intervention, Comparator, and Study Conduct	• The containers were exposed to microwave, autoclave, and UV stress.

Exposure	**Protocol**
Microwave stress	1. 4x4 mm square pieces of plastic were placed into glass beakers in a 1200 W microwave oven set on “high” for two minutes, and then allowed to rest for 30 minutes. The cycle was repeated 10 time. 2. Placed in estrogen activity-free polypropylene tubes and then microwaved on “high” setting for three minutes with a resting time 30 minutes between stress. The cycle was repeated 5 times.
Autoclave stress	Products were enclosed in individually crimped packets of EA-free aluminum foil and placed in an autoclave at 134°C for 8 minutes.
UV stress	1. Long wavelength (315– 400 nm) UVA stresses that simulate many aspects of UV in sunlight: Samples were placed in a Q-Lab QUV unit containing UVA-340 nm bulbs to simulate exposure to moisture-free sunlight between 295 nm and 365 nm for 80 hours at 45– 50°C. 2. Short wavelength (100– 280 nm) UVC stresses that simulate many aspects of UV in germicidal sterilizers: Samples were placed on aluminum foil in a Labconco Biosafety hood about 24” from a germicidal fluorescent light (maximum intensity wavelength of 254 nm) for 24 hours.

- The products were placed in extraction solvent (saline or ethanol) before being run on MCF-7 or BG1Luc assays for detection of presence of estrogenic chemicals.

Outcomes:

- Overall 38/46 of the products exhibited significant ($p < 0.01$) EA for any stress
- Microwaved products had lower EA in the assays compared to unstressed products. This type of stress might have reduced the release of chemicals having EA.

Appendix II. Review Protocol

Selection Criteria and Limitation
Studies on factors affecting chemical migration/leaching from food containers used in heating food in the microwave. Studies on plastic bottles were not included. Studies on the health effects of the chemicals found to migrate from the plastic containers will not be explored due to time constraint.

Data Abstraction
A reviewer will extract the data from the included studies following the selection criteria. Extracted information for the final analysis of the included articles will be article title, author/s, year of publication, outcomes measured and results, and the conclusion.

Data Summarization and synthesis
The findings will be narratively synthesized in a table and an overall conclusion will be made based on all the studies included in the review.