Microwaveability of Steel and Aluminium Food Packaging

by Thomas Pfeiffer

Fraunhofer Institute for Process Engineering and Packaging, Freising, Germany,

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Introduction

Fraunhofer Institute for Process Engineering and Packaging performed an experimental study on microwaveability of different rigid food containers made from steel and aluminium. The study was funded by the following organisations:

Alcan Rhenalu, Biesheim, France
APEAL, the Association of European Producers of Steel for Packaging, Brussels, Belgium
Crown Food Europe, Paris, France
FGM, Fördergesellschaft Metallverpackungen, Düsseldorf, Germany
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The aim of the study was to look into the safety and performance of microwave heating food in rigid steel and aluminium containers.

This study also refers to some of the findings and experiments conducted in the study on "Microwaveability of Aluminium Foil Packages" carried out by Fraunhofer Institute for Process Engineering and Packaging in 2006 on behalf of the European Aluminium Foil Association (EAFA).

Heating experiments were performed with food packed in five metal containers of different dimensions and shape and with four different popular household microwave oven models .The tested metal containers were:

+ a round steel bowl (99 mm diameter x 35 mm height), used with 200 g filling,
+ a round steel bowl (127 mm diameter x 30 mm height), used with 250 g filling,
+ a square steel container (125 mm x 125 mm x 25 mm), used with 300 g filling,
+ a rectangular aluminium container (160 mm x 99 mm x 35 mm), used with 400 g filling,
+ a round steel container (153 mm diameter, 36 mm height), used with 425 g filling.

These containers were chosen because of their large open surface and shallow profile. This is considered as preferable for use in microwave ovens.

Comparison experiments were performed with plastic containers of similar shape and size, filled with the same quantity of test food. The plastic containers were made of C-PET and were specified for microwave heating.

Test fillings in heating experiments were tap water, egg batter, chili con carne and an infant meal (pasta with vegetables and small meat balls in sauce). All the test materials were liquid or semi-liquid and filled the containers completely from wall to wall.

Microwave nominal power ratings of the four ovens were 700 W, 800 W, 900 W and 1000 W. The oven constructions were of the standard household type with glass turntable and with the opening of the microwave wave-guide in the right side wall of the oven cavity. The volumes of the oven cavities were different. Also different were the constructions of the wave-guide that optimise power transfer from the magnetron into the oven cavity.

Only the microwave heating function of the ovens was used in the heating experiments though some ovens were equipped with infrared grill or hot air circulation. In all experiments, oven power setting was 100% and only the heating time was adjusted to achieve the heating goal. No attempts were made to optimise the heating regime beyond this simple scheme.

The performed experiments were:

+ measurement of heating efficiency with containers filled with tap water
+ visualisation of microwave heating patterns with partly solidified egg batter

+ measurement of heating performance and temperature distribution in containers filled with chilli con carne and infant meal by an array of thermocouples immediately after microwave heating.

In addition, the effects of misuse of metal containers in microwave ovens were analysed and the stability of the oven microwave power level during the experimental series was tested.

Test Results

Heating Safety

When the tested metal containers were employed in microwave ovens in standard food heating experiments, their use was safe. During about 1000 microwave heating experiments with metal containers, which also includes a previous study with other metal containers, not a single spark occurred nor was a potentially risky situation observed.

For safe use of metal containers in microwave ovens the following procedures need to be applied:

+ A metal lid of the container must be removed completely prior to microwave heating.
+ As with containers of other materials, only full containers must be put into the microwave oven.
+ Only one metal container must be heated at a time.
+ Place the metal container in the centre of the glass turntable. An insulating air gap of at least 2.5 centimetres between metal container and oven walls or oven floor should be maintained. For ovens without glass turntable, the container must be placed on a ceramic dish.

In experiments focusing on misuse conditions, where a metal to metal contact was enforced, sparks of different strength occurred. The sparks produced marks in the containers and the oven walls. However, no technical defect of an oven was observed. An air gap of 2 mm between container and oven wall seems sufficient to suppress sparks in all tested situations. Heating instructions for consumers should include an ample safety margin and recommend an air gap of at least 2.5 centimetres.

In normal practice, the raised rim of the oven turntables and the additional use of a plastic dome cover to prevent product splattering make it practically impossible to bring the metal containers unintentionally into contact with floor or walls of the oven cavity.

Heating efficiency and heating times

Microwave heating efficiency is lower in metal containers compared to similar sized plastic containers i.e. for the same heating effect in metal containers, a longer heating time is needed. This has been observed in previous studies and can be derived from the basic fact that in the case of metal containers access of microwave energy to the food is only possible from the open surface side while with plastic containers access is possible from all sides. The actually required heating time for food in metal containers depends on oven power rating and power adjustment, container shape and size, food load, and on oven construction.

For some tested metal containers, the time to heat food to serving temperature was twice as long as for the same food portion in an equivalent plastic container. This resulted e.g. in a time of 3.5 minutes to heat a 250 g portion from a temperature of 10°C to an end temperature of 75°C in an oven with 900 W microwave power. For the smallest metal container with a 99 mm diameter, the heating time was about three times as long as for a similar plastic container. With larger metal containers, a better heating efficiency can be achieved and less heating time difference to similar plastic containers is observed.

Heating patterns and temperature distribution

Heating experiments with egg batter as well as experiments with multiple temperature measurements in heated chili con carne and infant meal showed heating patterns with large differences between maximum temperature (hot spot) and minimum temperature (cold spot). These patterns were observed in plastic as well as in metal trays. They could not be avoided or evened-out by moving the container with the turntable, since they are a characteristic of microwave heating. The actual pattern form or temperature distribution depended on container material, container geometry, food, and oven construction.

Generally, there was less temperature variation and better heating uniformity in the tested metal containers than in equivalent plastic containers, if the food was heated to serving temperature of 75°C.

In the case of chili con carne in metal containers, the difference between measured hot spot and cold spot temperatures was between 20°C and 40°C, depending on container geometry and oven type. In similar plastic containers, a temperature difference between 40°C and 60°C was measured. It is evident that the longer heating times needed to warm up food in metal containers help temperature equilibration by internal heat transfer.

The heating pattern in metal containers showed in most instances high temperatures near the centre and low temperatures near the wall and at the bottom edge. In plastic containers, the highest temperatures were in general measured near the walls and in particular at the bottom edge. The centre region of the plastic container remained cooler in most cases.

Stability of oven performance

Long-term use of microwave ovens leads to normal wear and degradation of power output. It has been suggested that operation of microwave ovens with metal containers may lead to increased degradation and shorter magnetron lifetime beyond normal household wear or may even damage the ovens. To observe changes of power output of the used four microwave ovens during the experimental work, the effective microwave power output of the ovens was tested before and after the series of heating experiments.

After more than 400 heating experiments per oven including 250 experiments with metal containers of different size and misuse experiments with empty containers, we did not observe a rapid decrease of oven power or any oven failure.

Conclusions

+ Microwave heating of food in steel and aluminium containers of a wide open form is safe when following the recommended operating instructions.
+ No functional oven damage or unusual degradation of microwave power has been observed.
+ Microwave heating times for food in metal containers are longer than for food in similar plastic containers. The difference decreases for larger containers. Therefore, it is recommended to use shallow metal containers with a large opening surface.
+ Temperature distribution was generally more uniform in the tested metal containers than in the plastic containers.