

Determination of temperature of plastics materials and articles during microwave heating and conventional oven heating

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1 Introduction

Council Directive 93/8/EEC states that migration tests for plastics materials and articles are to be carried out, selecting times and temperatures specified in the Directive which correspond most closely to, but are not less than, the normal or foreseeable conditions of contact for the plastics materials or articles. The Directive also states that for materials and articles intended for use in microwave ovens, migration testing shall use a conventional oven and appropriate time and temperature conditions selected from the Table of the Directive. Temperatures generated during microwave heating and cooking cannot be predicted readily for complex food matrices.

The method described here can be used to measure the temperature of plastics materials and articles at the food-plastic interface during microwave heating and thereby enable selection of the appropriate test temperature for migration testing.

2 Scope

This method describes how to measure the temperature reached by plastics materials and articles during microwave heating. It is applicable to all plastics materials and articles for which the food(s) with which they will come into contact under normal or foreseeable conditions of use is/are known for example for prepackaged foods with on-pack heating instructions and for plastics materials and articles to be used for preparing foods in the home or for use in commercial food preparation.

3 Principle

Plastics materials and articles containing foods of the type which they will contact under normal or foreseeable conditions of use, are heated in a microwave oven. The temperature of the plastic is measured at the interface with the food using a fibre-optic thermometer. The temperatures measured are used to select an appropriate temperature for migration testing.

4 Reagents

4.1 Distilled water or water of equivalent quality

5 Apparatus

5.1 Polythene beaker 140 mm \pm 20 mm diameter of minimum capacity 1000 ml.

5.2 Expanded polystyrene foam pad to fit under plastic container (5.1) and at least 8 mm thick.

5.3 Calibrated thermocouple or thermometer capable of measuring over the range -10°C to 30°C to a precision of \pm 0.1°C.

5.4 Plastic tube or rod for stirring

5.5 Thermostatically controlled incubator capable of maintaining a set temperature of 10°C \pm 0.5°C.

5.6 Calibrated fibre-optic thermometer capable of measuring over a range of -20°C to 200°C.

5.7 Microwave oven, with output in the range of 600W to 1000W.

6 Samples

A minimum of three test materials or articles are required for temperature measurements. The number required is dependent on the number of fibre-optic probes of the fibre-optic thermometer. For thermometers with one probe, a minimum of twelve test materials or articles are required. For thermometers with 12 probes, a minimum of three test materials or articles are required.

Test materials or articles should contain food of the same, or similar, nature and of the same or similar mass, as will be heated in the material or article under normal or foreseeable conditions of use.

Materials or articles, containing food, which are to be heated from frozen should be stored at -20°C. Those containing food which is to be heated from a chilled state should be stored at 5°C and for not longer than 3 days.

7 Procedure

WARNING: Food heated in microwave ovens can bubble and splatter. Use caution when handling hot foods. Do not use metal thermocouples in microwave ovens unless special precautions are taken.

7.1 Determination of power output of microwave oven.

The power output of the microwave oven (5.7) to be used for the temperature tests is determined by measuring the time taken to raise the temperature of 1000 g of water by $10^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

For turntable ovens, disable the turntable. This can be done by removing the glass tray or by removing the rotating mechanism. Place the polystyrene pad (5.2) at the geometric centre of the base of the oven (non-turntable type) or at the centre of the disabled turntable mechanism. Bring distilled water to a constant temperature of $10^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ using an incubator (5.5). Transfer $1000 \text{ g} \pm 5 \text{ g}$ distilled water (4.1) to the polyethylene container (5.1). Stir using the plastic tube or rod (5.4) and measure the temperature of the water using a suitable calibrated device (e.g. a thermometer or a thermocouple (5.3)). Place the container with water on the centre of the polystyrene pad and microwave on full power until the temperature of the water has risen by $10^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Quickly stir the water and measure the temperature. Determine the change in temperature of the water. Repeat the test twice more.

NOTE: Some pre-experimentation may be necessary to determine the time required to raise the water temperature by $10 \pm 2^{\circ}\text{C}$. An approximate guide is between 50-80 seconds.

If foods will be heated under a setting other than full power under normal or foreseeable conditions of use, then the power output of the test oven at these power settings should be determined. The above procedure should be followed but using the appropriate power setting.

Calculate the power output of the microwave oven using the following equation:

$$P = M_w \times 4.187 \times \frac{T}{t} \quad \text{W}$$

where:

- P = microwave power output (W)
- M_w = mass of water heated (g)
- T = Mean of actual temperature rise ($^{\circ}\text{C}$) (which must be in the range $10 \pm 2^{\circ}\text{C}$)
- t = time taken to achieve rise (s).

7.2 Temperature measurement

7.2.1 Calculation of heating time

The total energy input to the sample for the temperature measurement should be the same as that which would occur under normal or foreseeable conditions of use. Heating times are typically given for standard wattage ovens. It may be necessary to adjust the heating time to allow for differences between the standard wattage oven and the power output of the microwave oven used for temperature measurement. This is done as follows:

$$t_t = \frac{t_r \times W_s}{W_t} \quad \text{min}$$

where:

- t_t = heating time for temperature measurement (min)
 t_r = heating time (min) under normal or foreseeable conditions of use for oven of standard wattage e.g. from microwave heating instructions on prepackaged food item
 W_s = standard wattage oven (W) for which t_r is given or implied
 W_t = test oven wattage (W)

7.2.2 Determining temperature

Plastics materials or articles should be tested containing food of the same or of similar type with which they will come into contact in normal or foreseeable conditions of use.

Place the plastic material or article to be tested containing food at the geometric centre of the base of the oven (non-turntable type) or at the centre of the disabled turntable mechanism. Insert the fibre-optic probe(s) between the plastic material or article and the food ensuring that the tip of each probe is in contact with the plastic material or article and the food.

With the microwave oven at the recommended power setting (7.1 and 7.2.1), heat for the time determined in Section 7.2.1. For plastics materials and articles heated for > 3 min, record the temperature reading of each probe every 15 s. For materials heated for > 1.5 to ≤ 3 min, record the temperature reading of each probe every 10s. For materials heated for ≤ 1.5 min, record the temperature reading every 5 s.

Temperatures should be measured over the heating period at a minimum of 12 positions on at least 3 packs, starting with a new pack for each heating. Positions for probe placement are shown in Figure 2.

NOTE: If the pack has a covering of plastic film which is to be left in position during normal or foreseeable conditions of microwave heating, the film should be pierced to allow insertion of the probes. If the film is to be removed for heating then the pack should be heated with no film in place.

The probe placement positions shown in Fig. 1 may need to be modified, depending on the shape of the container and/or the nature of the food. For foods which are very inhomogeneous in nature e.g. foods consisting of distinct portions of sliced meat, potatoes and vegetables, the probe positions shown may not be most appropriate i.e. there may be contact with the packaging but not with the food. More suitable probe positions should be selected to ensure that the temperature at the packaging/food interface is measured. For these types of foods additional temperature measurements may need to be made to ensure that the temperature of the pack in contact with each food component is measured, with a minimum of two measurements made for each food component.

If the material or article will be heated under a power setting of less than full power under normal or foreseeable conditions of use, then this power setting is the one which should be used for the temperature measurements. Where sequential periods of heating with different power settings will be made under normal or foreseeable conditions of use then these periods shall be followed for temperature measurement, using the time(s) as determined in Section 7.2.1.

8. Determination of temperature for migration testing

Construct temperature profiles, plotting heating time (min, x axis) against temperature (°C, y axis)

Figure 1: Example of temperature profile

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Examine the data visually and discard any series of measurements which indicate that the probe has not maintained good contact with the package and the food. Loss of contact is typically shown by a sudden and marked declination of the curve.

NOTE: If the number of suitable measurements remaining falls below 12 then it may be necessary to make more temperature measurements.

Calculate the mean and standard deviation of all non-discarded temperature measurements for the final 25% of the heating time.

The temperature for migration testing is calculated as follows:

$$t_m = \bar{x} \pm SD \quad (^\circ\text{C})$$

where:

t_m = temperature for migration testing (°C)

\bar{x} = mean of non-discarded temperature measurements for final 25% of heating time

SD = standard deviation of the mean

9 TEST REPORT

The test report shall contain the following:

name of laboratory

name of person responsible for analysis

date of report

date of test

a reference to this method

sample details, such as:

description of plastic material or article tested

description of food

origin and denotation of the sample

date and method of obtaining the test sample

storage conditions

heating time (min) in normal or foreseeable condition of use in oven of standard wattage (W)

power output of oven used for temperature measurements (W)

heating time used for temperature measurements

result expressed in degrees celsius (°C)

reasons for modifications introduced into the test method, if any