JOURNAL OF
EMERGING INVESTIGATORS

Article

The effects of container materials on food microwave heat times

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SUMMARY

The purpose of this study was to determine which material of container heats food the fastest in the microwave: plastic, glass, or ceramic. By finding out this information, microwave cooking times could be shortened, which would reduce money spent on electricity bills since the microwave would be running for less time. To conduct this study, a set amount of water and Campbell's condensed tomato soup were heated in the microwave in a cup and a bowl of the various materials. After heating, the temperature change (°F) was measured and averaged for each container. We hypothesized that a plastic container would cause the food to heat the fastest because plastic is often not as thick as glass and ceramic. We observed that the ceramic cup and the glass bowl heated the fastest in their respective categories for both the water and tomato soup. Additionally, we also noted that bowls heated water and tomato soup faster than the cups. This implies that there are other factors that affect the heating times of food in the microwave, such as container surface area and mass. In conclusion, the data collected supports that there is a significant difference in cooking times between the different container materials that food is microwaved in.

INTRODUCTION

Although it is understood how microwaves work and the physics behind them, it is unclear as to which material heats food the fastest in the microwave. By finding out which material heats food the fastest in the microwave, cooking times could be drastically shortened. Many foods require a lengthy amount of time in the microwave, so the ability to shorten microwave cooking times by adjusting the food container's material could allow people to heat and enjoy their food quicker. Also, logically, with shorter microwave cooking times, less power would be used. Less power means lower electricity bills since microwaves would not be running for as long.

It is important to understand how microwaves, as well as their components, work before researching how different materials heat. A device in the microwave called a magnetron uses household electricity to generate microwaves, which are a type of electromagnetic wave. A filament at the center of the magnetron is heated by the electricity and boils off electrons that are then bent back towards the filament. This generates microwaves that are transmitted into the cooking chamber where they bounce around and hit the food. The microwaves hitting the food excite the water molecules within, causing them to start to move rapidly, generating friction and heating up the food. The microwaves are kept from leaking out of the cooking chamber by the metal mesh on the microwave door, which reflects the waves. Microwaves work by generating and transferring energy to the food that increases the motion of the water molecules, causing the food to heat up (1).

Food is almost always placed in a container while being heated in the microwave, but different materials have different compositions that could affect how fast they heat food. Microwave-safe materials are classified as such because microwaves can pass through the material. For example, metal is not safe to put in the microwave because it can conduct electricity since the electrons in metal are free to move around. This can cause the metal to spark and start a fire when heated in the microwave. Three microwave-safe materials are certain plastics, such as type 5 polypropylene, glass, and ceramic. However, not all plastics are microwave-safe. Some plastics are softer and thinner, which could cause them to leak chemicals into the food when heated. Plastic, glass, and ceramic are all insulators, which means that their electrons do not move as freely as in conductors. Since these materials are insulators, they cannot be heated by microwaves, but they can become hot because of the food cooking inside of them (2). Additionally, thermal conductivity is important to consider when using materials in the microwave. A material that has a high thermal conductivity heats up faster than a material with a low thermal conductivity. This partly explains why metals are not safe to use in the microwave since they have a very high thermal conductivity compared to other materials, which would result in metal heating up dangerously fast in the microwave (3). The different compositions of microwaveable materials are not well-studied, but it is important to investigate because it can affect how efficiently they heat food in the microwave.

Overall, microwaves work by increasing the motion of the molecules in food, and not all materials are microwave-safe due to the fact that certain materials don't allow electromagnetic microwaves to pass through them. It is important to find out what material heats food the fastest in the microwave because then cooking times could be drastically shortened for many foods. Additionally, the ability to shorten microwave cooking times by adjusting the material of container that food is microwaved in could allow people to heat their food quicker, use less power, and save money on their electricity bills. Here, we tested which material of container heats food the fastest in the microwave by putting a set amount of water and Campbell's condensed tomato soup in different material containers of the same general size and shape. We chose water and tomato soup because they are common liquids that people microwave. We then put these containers in the microwave for a set amount of time, and once they were done heating, we measured the temperature of the food to see which material of container caused it to heat the most. We hypothesized that a plastic container would cause the food to heat the fastest because plastic is usually a thinner material than glass and ceramic, so we thought it would heat up faster. We concluded that there is a statistically significant difference between the container's material and how fast it heats food. Specifically, the ceramic cup and the glass bowl were most effective at heating the water and tomato soup in their separate container categories. This information can be applied to what is already known about microwaves and the materials we tested to reduce microwave cooking times.

RESULTS

The average temperature changes of water and tomato soup were measured from each trial for each material and container after being microwaved for 30 seconds (**Table 1** and **Table 2**). In terms of material and container, the ceramic cup and the glass bowl were most effective at heating the water and tomato soup (**Figure 1** and **Figure 2**)

Table 1: Temperature Change of Water. Temperature change of 115g of water (°F) when microwaved for 30 seconds in plastic, glass, and ceramic containers (cup and bowl). The mean temperature change (°F) was measured for each condition (n = 20), with ± for standard deviations.

Containers	**Temperature Change of Water (°F)** Mean ± Standard Deviation
Plastic cup	35.7 ± 1.5
Glass cup	31.7 ± 1.2
Ceramic cup	36.7 ± 1.2
Plastic bowl	43.1 ± 1.4
Glass bowl	53.7 ± 1.2
Ceramic bowl	47.2 ± 1.4

We concluded that there is a significant difference between the temperature change of water (°F) after being heated in the microwave in plastic, glass, and ceramic cups and bowls ($p<0.05$) (**Table 3**). Also, there is a statistically significant difference between the plastic and glass cups, the glass and ceramic cups, the plastic and glass bowls, the plastic and ceramic bowls, and the glass and ceramic bowls ($p<0.05$) (**Table 4**). We concluded that there is a significant difference between the temperature change of tomato soup after being heated in the microwave in plastic, glass, and ceramic cups and bowls ($p<0.05$) (**Table 5**). Also, there is a statistically

Table 2: Temperature Change of Tomato Soup. Temperature change of 115g of Campbell's condensed tomato soup (°F) when microwaved for 30 seconds in plastic, glass, and ceramic containers (cup and bowl). The mean temperature change (°F) was measured for each condition (n = 20), with ± for standard deviations.

Containers	**Temperature Change of Tomato Soup (°F)** Mean ± Standard Deviation
Plastic cup	35.6 ± 0.9
Glass cup	34.5 ± 1.1
Ceramic cup	37.1 ± 1.4
Plastic bowl	46.3 ± 0.9
Glass bowl	56.6 ± 1.0
Ceramic bowl	47.4 ± 1.2

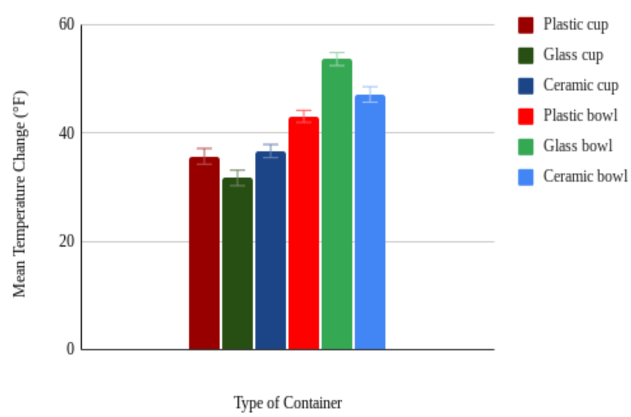

Figure 1: Comparison of the mean temperature change (°F) of water when microwaved in plastic, glass, and ceramic containers. Plastic, glass and ceramic containers (cup and bowl) were microwaved for 30 seconds with 115 g of water. The mean temperature change (°F) was measured for each condition (n = 20). Error bars represent standard deviation.

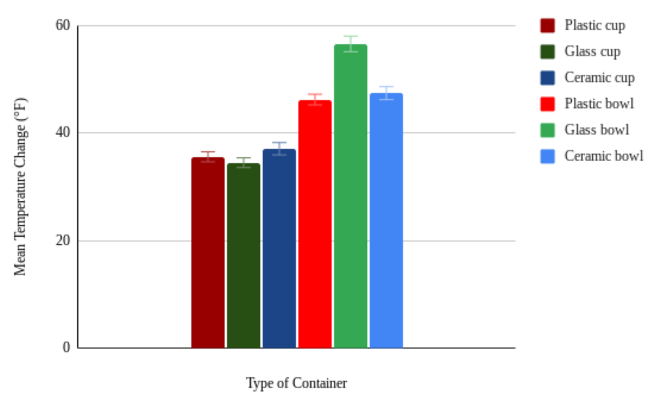

Figure 2: Comparison of the mean temperature change (°F) of Campbell's condensed tomato soup when microwaved in plastic, glass, and ceramic containers. Plastic, glass and ceramic containers (cup and bowl) were microwaved for 30 seconds with 115 g of tomato soup. The mean temperature change (°F) was measured for each condition (n = 20). Error bars represent standard deviation.

significant difference between the plastic and glass cups, the plastic and ceramic cups, the glass and ceramic cups, the plastic and glass bowls, the plastic and ceramic bowls, and the glass and ceramic bowls ($p<0.05$) (**Table 6**).

Table 3: Water Data - ANOVA. Values produced from a single-factor ANOVA using the data acquired from microwaving 115g of water for 30 seconds in plastic, glass and ceramic containers (cup and bowl). The mean temperature change (°F) was measured for each condition (n = 20).

Containers Tested	p-value
Plastic, glass, and ceramic cups and bowls	<0.0001

Table 4: Water Data - Tukey's Multiple Comparisons Test. Values produced from a Tukey's multiple comparisons test using the data acquired from microwaving 115g of water for 30 seconds in plastic, glass and ceramic containers (cup and bowl). The mean temperature change (°F) was measured for each condition (n = 20).

Comparisons Tested	p-value
Plastic cup vs. Glass cup	<0.0001
Plastic cup vs. Ceramic Cup	0.1679
Glass cup vs. Ceramic cup	<0.0001
Plastic bowl vs. Glass bowl	<0.0001
Plastic bowl vs. Ceramic bowl	<0.0001
Glass bowl vs. Ceramic bowl	<0.0001

Table 5: Tomato Soup Data - ANOVA. Values produced from a single-factor ANOVA using the data acquired from microwaving 115g of Campbell's condensed tomato soup for 30 seconds in plastic, glass and ceramic containers (cup and bowl). The mean temperature change (°F) was measured for each condition (n = 20).

Containers Tested	p-value
Plastic, glass, and ceramic cups and bowls	<0.0001

Table 6: Tomato Soup Data - Tukey's Multiple Comparisons Test. Values produced from a Tukey's multiple comparisons test using the data acquired from microwaving 115g of Campbell's condensed tomato soup for 30 seconds in plastic, glass and ceramic containers (cup and bowl). The mean temperature change (°F) was measured for each condition (n = 20).

Comparisons Tested	p-value
Plastic cup vs. Glass cup	0.0235
Plastic cup vs. Ceramic Cup	0.0005
Glass cup vs. Ceramic cup	<0.0001
Plastic bowl vs. Glass bowl	<0.0001
Plastic bowl vs. Ceramic bowl	0.0235
Glass bowl vs. Ceramic bowl	<0.0001

DISCUSSION

In a certain study, a new form of ceramic was composed that was supposed to heat food faster in the microwave and cause it to retain heat longer (3). This study found success with a form of ceramic, which connects to the results of this experiment since we found that the ceramic cup was the container that heated food the fastest out of all the cups. We concluded the hypothesis that plastic containers would heat food the fastest in the microwave was not correct because, based on this experiment, the ceramic cup heated food the fastest compared to the plastic and glass cups, and the glass bowl heated food the fastest compared to the plastic and ceramic bowls. We found that plastic did not heat food the fastest in either container type (**Figure 1** and **Figure 2**), suggesting that it is not the best material for microwaving food quickly. However, the results varied for cup versus bowl as to which material heated food the fastest. This emphasizes that the material of the container, along with its shape, greatly affects the effectiveness of heating the contents inside. We expected one material to heat food the fastest as a cup and a bowl, so it initially seemed illogical when the data did not support this thought. However, there are many factors that could contribute to why the material that heated the food the fastest differed between cup and bowl. For example, only one cup and one bowl of each material were used, but food could heat up faster in a certain glass bowl than in another depending on its specific attributes, such as its dimensions or weight. The mean temperature change of water and tomato soup (°F) between the cup and the bowl for each material varied greatly (**Table 1** and **Table 2**). A reason for this could be because bowls have a larger surface area than cups, which causes the food to be more spread out when heated; therefore, the food would heat faster in bowls.

A material that has a high thermal conductivity heats up faster than a material with a low thermal conductivity. Following the results in this experiment, ceramic and glass have a higher conductivity than plastic, which means that they would heat up faster in the microwave (4). As shown in the results of this experiment, there is not a clear answer as to what is the best material to microwave food in because there were varying results between cup and bowl. However, this experiment supports that heating food in bowls is faster than in cups since the average temperature changes (°F) in water and tomato soup after being microwaved were higher in bowls than in cups (**Table 1** and **Table 2**). This suggests that the shape of the container impacts how fast it heats food when microwaved. According to Panasonic, round or oval containers heat food more evenly, while square or rectangle containers do not (5). In addition to plastic not heating water the fastest in neither a cup nor a bowl, there are also other reasons as to why its use should be avoided in the microwave. Microwave-safe plastics still leach chemicals into the food being heated in them; even though it is lower than the FDA maximum amount allowed, safety is not guaranteed (6). Given these findings, future experiments should focus on how the container's shape and mass affect how fast it heats food in the microwave, since we found that these factors can affect how the material heats food as well.

The standard deviations for all of the containers were 1.5 or less, which is relatively low (**Table 1** and **Table 2**). However, more trials could be conducted to lower the standard deviations and produce more consistent results. Another factor that could have introduced error is that we only used one type of cup and bowl for each material, and they were not of the same mass. This could lead to inaccurate results because a certain cup or bowl cannot accurately represent a whole material category since shapes can vary widely. To fix the error in shapes and masses of containers, multiple versions of cups and bowls for each material could be used, or all of the containers could be of the same mass. To reduce the error that possibly occurred in the temperature measurements, a standard set of time could be set for how long the thermometer can display the temperature. This would help support the goal that the containers are all exposed to air for the same amount of time after microwaving before having the temperatures measured so that they all cool down the same amount.

The purpose of this experiment was to determine which material of container heats food the fastest in the microwave. By conducting this experiment, we did not confidently answer that specific question because of the varying results between the fastest heating material for cup versus bowl. However, we discovered that bowls heat food faster than cups. Our hypothesis that heating food in a plastic container in the microwave would make it heat the fastest was not supported in this experiment since the ceramic cup heated the food the fastest out of all the cups, and the glass bowl heated the food the fastest out of all the bowls. We expected the same material of cup and bowl to heat the food the fastest; however, this gave light to new questions about this topic, such as "How does the shape and mass of the container that food is microwaved in affect how fast it heats?" In conclusion, this experiment suggests that it is a combination of the container's material, surface area, shape, and mass that affects how fast it heats food in the microwave.

MATERIALS AND METHODS

One cup and one bowl of each material was gathered (plastic, glass, and ceramic). Information about the containers is as follows (masses were measured with a Smart Weigh scale): plastic cup (59 g, brand: N/A), plastic bowl (65 g, brand: Snapware), glass cup (231 g, brand: Ball), glass bowl (308 g, brand: N/A), ceramic cup (309 g, brand: Alice Tait), ceramic bowl (390 g, brand: Crate & Barrel). Room temperature water (115 g) was measured out into the plastic cup, and its initial temperature was recorded with a Habor digital thermometer. The containers containing water were placed into a Thermador MD24JS/01 950 W microwave for 30 seconds. This microwave has cavity dimensions of 7 1/8" x 17 5/16" x 16 9/16". Once the microwave was done, the containers were taken out of the microwave and the temperature of the water was recorded with a Habor digital thermometer. The initial temperature was subtracted from the after-heating temperature to get the change in temperature (°F), which was then recorded. These steps were repeated 19 more times for a total of 20 trials using each container. Then, the above procedure was repeated using 115 g of Campbell's condensed tomato soup instead of water for all the containers. The data from the water and tomato soup was analyzed using single-factor ANOVAs, conducted through XLMiner Analysis TookPak, and Tukey's multiple comparisons tests, both with an alpha of 0.05, to see the relationship between the material of container that food is microwaved in and how fast the food within it heats (the varying container sizes, shapes, and masses were considered as possible affecting factors).

ACKNOWLEDGEMENTS

I would like to thank my parents, peer editors, and Peter Pintz for helping me complete this research project.

Received: October 19, 2020
Accepted: February 18, 2021
Published: April 29, 2021

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