

Understanding Microwave Heating and Calorimetry

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This paper describes experiments that were done to compare how efficiently water, vinegar, and olive oil absorb energy in a microwave oven and explains the results.

Microwave ovens quickly heat food, but have you ever wondered why some foods heat up faster than others? Microwave radiation tends to rapidly heat substances with a large dielectric constant. Small, polar molecules have a larger dielectric constant than larger, less polar molecules. Polar molecules have a positively charged end and a negatively charged end. Examples of polar molecules are water (H_2O) and acetic acid (CH_3COOH). Nonpolar molecules do not have a positive and negative end. Hydrocarbons (C_xH_y) are examples of nonpolar molecules¹.

Microwave ovens produce an electric field with a frequency of $2,450 \times 10^6$ oscillations per second. Polar molecules try to line themselves up with the electrical field. The molecules do not have time to line up one way before they have to try to line up the other way. The resulting friction of the molecules in motion causes the sample to heat up. Under the same conditions, molecules with the highest dielectric constant are expected to absorb the most energy².

For this paper I examined the chemical structure of water, the acid in vinegar (vinegar is 5% acetic acid and 95% water), and the primary fatty acids in olive oil³ (oleic and linoleic acid with a small amount of linolenic acid). It can be seen that water, which is small and polar, should have a large dielectric constant, and efficiently absorb microwave energy. Vinegar, which contains the larger acetic acid molecule, is slightly less efficient at absorbing microwave energy than distilled water. The fatty acids in olive oil are large and significantly less polar, so olive oil has a smaller dielectric constant and absorbs microwave energy much less efficiently.

Equal volumes of water, vinegar, and olive oil at room temperature were heated for one minute in the microwave. As expected, the water heated up the most (68C temperature increase), the vinegar heated up nearly as much (65C temperature increase), and the olive oil heated up much less (31C temperature increase).

References

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