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Temperature measurement of trimmed chicken breast sample with and without turntable movement under MW conditions

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Introduction and objective

Microwaves are used in a number of industrial processes, including meat tempering, bacon cooking, potato chip drying, rubber vulcanization, and drying of pharmaceuticals. In a conventional gas or electric oven, an object is warmed gradually as heat penetrates from the outside in. Microwave energy, by contrast, is "cold," producing heat only when it is absorbed by a sample. And since microwaves easily penetrate materials (except metals), they can be directly and uniformly absorbed throughout the entire volume of an object, causing it to heat up evenly and rapidly.

A household microwave oven generates and accelerates electrons as microwave radiation at an approved ISM frequency of 2450 MHz. Upon transmission through food - a composite dielectric - placed in the oven, microwave radiation interacts with food constituents. The electrical energy of the radiation dissipates and heat is generated. The phenomenon is dependent on frequency, temperature, density, composition and viscosity. Heat is produced as a result of dipolar rotation and/or ionic conduction. The spatial domain of the MW-food material interaction is bounded by the wavelength of a 2450 MHz radiation or 12.24 cm. Whereas the dielectric properties of the food determine the transmission and dissipation of microwave energy as heat, transfer of heat throughout the food depends on the food's thermo-physical properties.

Temperature profiles in microwave heating depend on an energy penetration depth defined as the depth from the surface at which the remaining energy is some 37% of the energy at the surface (Von Hippel, 1954). Profiles also depend on the level of energy coupled from the electromagnetic field in a microwave cavity. These characteristics are related to electrical properties that depend largely on the moisture and salt contents of the product, and are quite sensitive to frequency and temperature. Provided the 'electrical thickness' of the food products is close to its penetration depth, time-temperature profiles in microwave heating are much more uniform than conventional heating, irrespective of the energy levels coupled from the heat source. One of the interesting features of microwave food processing is the ability to generate reverse temperature profiles, which give center temperatures that are higher than temperatures in regions nearer the surface. Such effects have been related to product shape, conductivity, size, and frequency and offer a potential, not only for combining microwave and conventional heating processes, but also for processes using more than one frequency as a means of obtaining more uniform temperature profiles (Mudgett, 1988). Despite the fact that there are number of sensing techniques to determine the temperature, the latter measurement in a microwave processing environment has always been a challenging task. New temperature sensors are designed and developed by companies (FISO Technologies Inc. – http://www.fiso.com) and industrial researchers. However, there is a continuous need to measure accurate temperature and pressure values during processing without any complicated tools or handling tasks.

The objective of this study included the measurement of temperature of chicken breast sample at 2450 MHz and 5 power levels and time intervals using the new Microwave Workstation™ and the OSR features of the FISO Technologies Inc. (Canada).

Materials and Methods

Fresh chicken meat sample (breast) (10x6x4 cm) was purchased from a local supermarket for temperature measurements. The OSR (optical slip ring) system developed by FISO Technologies (Canada) was used to measure the temperature. The Microwave Workstation™ allowed for the data collection and graphical features including the microwave configuration controls. 4 temperature sensors were used in this experimental study and the tips were placed in direct contact with the meat sample at random positions and depths. The turn-table of the microwave cavity was either included or removed off the base for static measurements. All tests were performed at 100% duty cycle. The power levels and the time of each run are indicated below.

Experimental plan

The following is the power and time range selected for this study:
1. 200 Watts for 1 min (with and without turntable movement)
2. 400 Watts for 45 sec (with and without turntable movement)
3. 600 Watts for 30 sec (with and without turntable movement)
4. 800 Watts for 20 sec (with and without turntable movement)
5. 1000 Watts for 15 sec (with and without turntable movement)

Results and Discussion

The temperature of the chicken breast sample was measured at 4 different locations and depths (randomly selected) using the FISO equipment and sensor technology. The results represent average values for 2 replicates. The main goal was to measure the temperature of a meat sample with and without turn-table movement at a selected power-time combinations. The table and graphs illustrate the results of the tests.

The normal cooking temperature range of the chicken meat is about 50-55^{o}C. As shown in Figures 1 and 2, obviously, the temperature did not rise as much as in the case where the turn-table movement was used. The initial temperatures were not identical for each test because the same sample was radiated after sufficient cooling of the sample. The difference in the initial and final values of the temperature gain can be tabulated and further study is necessary to test the sample at other Microwave conditions. Figure 1 and 2 describe the temperature and time variation at 200 Watts of MW power exposed for 1 minute. The predicted trend is shown beyond the set temperature point. (sample graphs are shown here, all other graphs and data can be obtained on request).

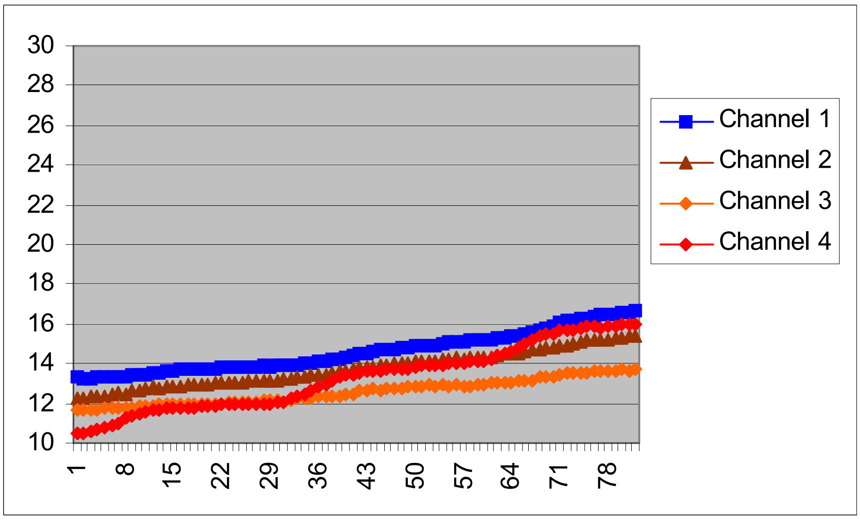

Figure 1 Temperature – time profile of chicken breast at 2450 MHz (200 Watts, 60 sec) with turn-table on.

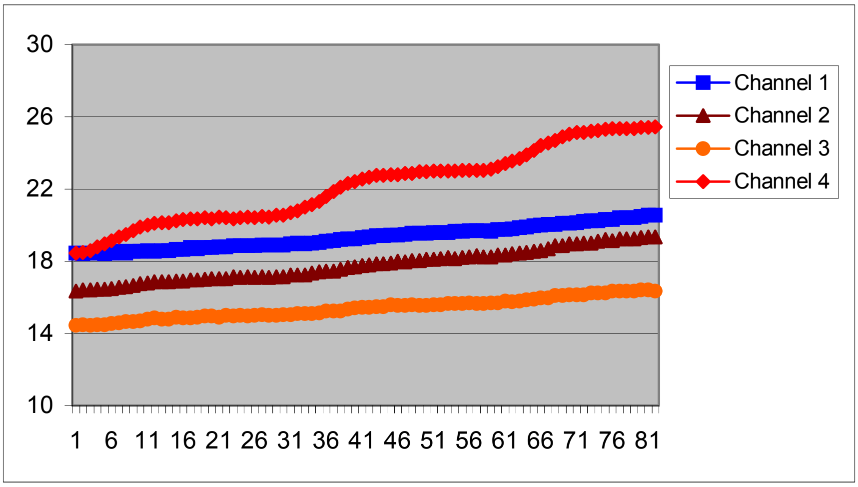

Figure 2 Temperature – time profile of chicken breast at 2450 MHz (200 Watts, 60 sec) without turn-table on.

References

Mudgett, R.E. 1988. Electromagnetic energy and food processing. Journal of Microwave Power and Electromagnetic Energy (IMPI) Vol. 23, No. 4.

Von Hippel, A.R. 1954. Dielectrics and Waves. MIT Press. Cambridge