NON UNIFORMITY OF SURFACE TEMPERATURES AFTER MICROWAVE HEATING OF POULTRY MEAT

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Introduction

The number of incidences of food poisoning associated with poultry are increasing throughout the world. Morgan *et al.* [1996] has calculated that the amount of heat required to inactivate the enzymes in bacteria are 15 million times less than that required to cause lasting organoleptic changes to the surface of foods. Microwave heating is one potential method of achieving rapid surface temperature rises. Teotia and Miller [1975] found that 600 and 120 s of microwave exposure was required to destroy *Salmonella seftenberg* 775W on broiler carcasses and turkey drumsticks, respectively. Cunningham and Albright [1977] reported a stepwise reduction in total bacteria as microwave heating times for chicken pieces and skin were increased from 15 to 30 s. Cunningham [1978, 1980] used 915 or 2450 MHz microwaves to pasteurise the surface of chicken meat and concluded that consumers could extend the shelf life of meat by exposing it to 15-20 s microwave treatment before refrigerated storage and that there was commercial potential in minimal microwave processing. Variability in industrial [Burfoot *et al.*, 1996] and domestic [Russell *et al.*, 1996] microwave heating has however, always been a major concern of the microwave industry. The purposes of this study was to determine the variability of surface temperature after microwave heating and investigate methods of reducing the variability.

Materials and Methods

A domestic microwave oven [Sharp Inverter Model R-10R50, Japan], with a measured IEC power output value of 1191±15 W [IEC, 1988],was used to heat whole chilled chicken carcasses (wt 1063 g to 1820 g) and chicken breast portions (wt 126 to 189 g). Fibre Optic Probes (FOPs) [FT1110B, Takaoka Electric MFG Co. Ltd, Japan] were used to monitor temperature changes during microwave heating and a digital surface probe after heating. The range of samples and conditions used in the preliminary trials are shown in Table 1. In some trials a photograph of the surface temperature distribution was taken after heating using an Infra Red (IR) camera, and in some the breast and back of the carcass was sprayed with water at 40°C immediately prior to heating or the wing, lower leg and vent areas on one side were covered with squares of aluminium foil (12x12, 10x10 and 6x6 cm, respectively) prior to heating.

Results

In trial 1 the highest temperatures was measured on the vent, wing and lower leg areas and the lowest on the upper leg, upper back and breast. There were substantial differences of up to 30°C between final temperatures at the same position on different replicates. All samples showed signs of partial cooking especially on the vent, wing and lower leg areas. Spraying with 40°C warm water produced little change in the heating pattern. Temperatures of 20 to 25°C were measured on the upper back and 90 to 95°C on the vent, wings and lower legs. When the carcasses were placed breast down in the oven, the vent, wing, lower leg and lower back parts of the carcasses reached high average temperatures, 88, 97, 90 and 96°C, respectively. However, the average temperature on the upper leg (48°C) and on the breast muscle (29°C) were far below that required to destroy pathogens.

Heating for a longer time at reduced power, 5 minutes at 500 W, slightly reduced the maximum temperatures measured on the carcass. However, the temperature variations on the parts could not be eliminated. The temperature on the hottest areas, vent and wing, was around 91°C whereas the average temperature on the coldest parts, breast and upper back was 36 and 33°C, respectively. A further extension in the heating period to 10 minutes at 200 W reduced the average temperature of the hottest areas, the vent and wing. These were reduced by approximately 20°C, from 91 to 71-72°C without substantially changing the average temperature measured on the coolest areas, breast and upper back with average temperature of 38°C and 30°C, respectively. Thermal imaging after 500 W for 6 minutes showed a temperature range from 40°C on the breast to 90°C on the extremities. Shielding the extremities of the carcass, the wing, leg and vent areas, with aluminium foil reduced the rate of heating and resulted in average final temperatures of 52, 44 and 62°C respectively. The temperatures measured on the shielded positions were approximately 40°C lower than on unshielded controls. Thermal imaging revealed temperatures below 55°C on shielded areas and breast temperatures of 50-70°C. However, the abdominal cavity was 80 to 85°C and signs of cooking were apparent around the abdominal cavity and places close to the neck and wings. After 30 s the average temperature at the edge, middle top and middle bottom surfaces of chicken breasts were 72°C (Std Dev 16°C), 28°C (SD 7°C) and 26°C (SD 6°C). The edges of the samples showed evidence of partial cooking. Thermal imaging showed temperatures of 80°C around the edges and 25°C at the centre of the top and bottom surfaces

Discussion

The results were not unexpected since many factors have been shown to affect the rate of microwave energy absorption in a microwave oven. These include the chemical composition of the load e.g. fat, carbohydrate and moisture content, the size and shape of the load, its position in the oven, the electric properties of the load, the power and frequency of the microwave oven etc. [George & Burnett, 1991]. To further complicate matters the temperature rise resulting from the microwave energy absorption will also depend on the thermal properties of the load at the point of interest. Studies on the microwave heating of cooked products with defined shapes [Swain *et al.*, 1993], relatively homogeneous foods i.e. mashed potato in regular packs [Burfoot *et al.*, 1990], and homogeneous food substitutes [Russell *et al.*, 1996] have all reported substantial variability in final temperature between and within replicates.

Since a poultry carcass is an irregular shaped non-homogeneous body with position and temperature dependent thermal properties wide differences in surface temperatures after microwave heating are to be expected. As would be expected the highest temperatures after heating tended to be on the surface of the thin extremities, i.e. the wings and lower legs which would be exposed to microwave radiation from a number of directions. High temperatures were also measured on the vent area which is also an exposed position. In addition the chemical composition of the vent area was found to have a higher fat (43.8%, SD 4.39%) and lower water (48%, SD 1.145%) content than the main part of the carcass. This combination would result in a lower specific heat requirement and consequently the energy absorbed would produce a higher temperature rise than in the breast or thigh areas.

Changing the position of the carcass in the oven, shielding its extremities, and using lower power for longer times resulted in partial cooking accompanied by temperatures too low to eliminate pathogens. It was thought that spraying the sections of the carcass that remained coldest with warm water prior to heating could even out the temperature difference. The thin layer of water preferentially absorbing the microwave energy and consequently increasing the rate of temperature rise at the surface. However, the method had no appreciable affect on the temperature distribution. Substituting chicken breast portions for whole carcasses did not result in a more even temperature distribution. Substantial cooking occurred on the edges of the portions, while at the centre of the upper and lower surfaces temperatures as low as 25°C were measured.

Conclusion

These experiments show that heating poultry carcasses or portions at full power in a domestic oven results in: 1) considerable variability, up to 30°C, in final surface temperatures at defined positions on replicate carcasses, 2) an average temperature difference of up to 61°C between different points on the carcass. Conditions could not therefore be found that could guarantee substantial reductions in surface pathogens without causing substantial protein denaturation (cooking) of the chicken carcass.

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Table

Table 1. Conditions used in trials.

No	Product	Weight range (g)	No replicates	Power	Time
1	Carcass breast up	1292-1800	7	Max.	3 mins
2	Carcass breast down	1130-1829	4	Max.	3 mins
3	Carcass breast up	1063-1240	4	500W	5 mins
4	Carcass breast up	1093-1408	3	200W	10 mins
5	Carcass breast up foil wrap	1075-1350	4	Max.	3 mins
6	Breast portions	126-189	4	Max.	0.5 min