CHAPTER 5

EXPERIMENTAL WORK

In this chapter theory about microwave oven components and its operation has been described. The aim of this chapter is to explain the experiment did for cooking potatoes to ascertain the simulation results and eggs in the identified suitable power regions oven without explosions and its results.

5.1 INTRODUCTION

Microwave ovens are nowadays becoming a part of kitchen in most of the Indian homes because of their inherent abilities to process materials quickly, to heat uniformly and to control heating. Typical microwave oven components with food sample have been shown in Figure 5.1. Cavity of the oven have well-polished walls for good reflection and a carousel to provide uniform heating.
A microwave oven consists of:

- A high voltage power source, commonly a simple transformer
- An electronic power converter, which passes energy to the magnetron
- A cavity and magnetron, which converts high-voltage electric energy into microwave radiation
- A magnetron control circuit (usually with a microcontroller to set time and power)
- A waveguide (to control the direction of the microwaves towards the oven cavity)
- A cooking chamber
- A turn table or carousel
- A stirrer
- Food or load

**Figure 5.1 Typical Microwave Oven**
A door interlaced with metallic wires.

Domestic and institutional microwave ovens operate at the frequency of 2450 MHz. The lower microwave frequency ovens (915 MHz in the America or 896 MHz in the United Kingdom) are currently only used for industrial applications. The principal construction of a household microwave oven is shown in Figure 5.1. A typical oven requires about 4 KV to start current which is fed to the microwave generator, called a magnetron. A waveguide directs the generated microwaves either directly into the oven cavity or first into a feed box with a mode stirrer, which is a metallic fan blade that rotates within the feed box. The stirrer is used to reduce the effect of hot and cold spots through modifying the field pattern in the oven. Alternatively, a rotating turntable can be used.

To further reduce non-uniform heating, most ovens have a microwave transparent shelf, which elevates the food from the metal bottom (Buffler 1993, Ohlsson and Bengtsson 1974). The output power of the household microwave ovens is normally 600-1300 W, of which about 90% is absorbed into the food material and 10% is reflected back to magnetron. If the amount of food is smaller than 500g the reflected part may rise up to 40- 50%, especially in ovens with smaller cavities (Risman 1989).
(electromagnetic fields) have different polarizations and propagation directions and the polarity determines the amount of reflected and transmitted part of energy. For a TM (Transverse Magnetic field) polarized wave the reflection factor has a minimum at a high angle of incidence while for TE (Transverse Electric field) polarized the situation is vice versa. Certain TM modes cause much less overheating of horizontal food edges than TE modes and they are common in microwave ovens. They are also non-resonant, which means that they are not very sensitive to changes in the food dimensions.

Heating from below, called under-heating cannot be achieved by the cavity volume modes. These confined modes (under-heating modes) are of great importance for more uniform heating and smaller waste of energy by evaporation. Better heating of low permittivity foods, such as frozen products, may be obtained by raising them by a couple of centimetres, although this does not work well for high-permittivity foods. (Risman 1992, Risman 1994, Ohlsson and Bengtsson 2001).

There is considerable variation of electric field inside the microwave oven cavity. In general, more expensive ovens tend to have a well-designed stirrer or a turntable and more uniform field distribution, while low-cost ovens have more hot and cold spots (Buffler 1993). Analysis of field patterns in a microwave oven and their interaction with typical foods is very
Many methods have been proposed for determining both the oven field pattern and measuring the microwave power output. Oven field distribution has been determined by e.g. using layers of homogeneous food materials or model substances and measuring the temperature distribution after a certain heating time.

Model substances can visualise the temperature by changing colour, or temperature of the product surface can be monitored by IR imaging. Food geometry and composition affect the microwave power distribution, and therefore test loads should be similar when evaluating the heating performance for food products. (Ohlsson and Bengtsson 2001). The International Electrotechnical Commission (IEC) has worked with microwave oven performance testing and it has issued a standard including cooking, defrosting, and heating tests (IEC International Standard 60705, 1999).

It should be noticed that the determinations are carried out in room temperature ovens; within about one minute, the power delivered in the food may be reduced 20-35% due to magnetron and power supply heat-up after only a few minutes of operation. Also the voltage input affects the output power. The variation allowed at the power supply is ± 6% in the UK and this may change the power delivered into the food typically ± 10% but may be over 30% (James 1996 and Risman 2002).

5.2 EXPERIMENTATION OF MICROWAVE COOKING OF POTATOES AND IN-SHELL EGGS

The different processes of experimentation have been shown in Figures 5.7 to 5.13. Initially the microwave oven with turntable was considered for cooking an in-shell egg in a paper cup and it was placed at the
center of the oven cavity. The oven was operated at 600 watts power and expected that the egg would be cooked after 2 minutes. But after 90 seconds, a high sound like a cracker blast was heard and it was observed that the egg has exploded and splattered over the entire volume. This has been shown in Figure 5.10.

Fresh potatoes were procured from vegetable market has been refrigerated until their usage and then they are sliced into cubes of each side 2cm dimension. Prior to experiment the simulation results for eggs, the simulation results for potatoes have been experimented and found that potato sample placed at high power region reached 61°C and low power region reached 44°C. These regions (identified from the simulation) are well spaced at half wavelength of the waves in the oven (for 2.4GHz, >122mm). By operating the oven at different powers and timing, the level of cooking was measured. This experiment has been depicted through Figures 5.2 to 5.6 Potato placed in high power region was cooked well and the rest is left half cooked. The experiment confirmed that the identified simulation results are correct with the real oven and it is followed by the experiment for eggs.
Figure 5.2 Microwave oven used for experiment

Figure 5.3 Potato samples placed in high power and low power regions
Figure 5.4 Oven operation for 1 Minute at 300 Watts

Figure 5.5 Potato samples after heating for 1 Minute
The eggs were cracked carefully and the egg white (35g) and yolk (20g) were collected separately in beverage bottle caps. Egg white was homogenized by slowly stirring with a glass rod and deal with a single entity for the experiment and not as thin and thick albumen. All trials were made in triplicates. Egg white from an individual egg formed one replicate and egg yolk from an individual egg formed one replicate. Initially the albumen was filled in small cups (paper cups). These cups are placed at specific points estimated to have minimum energy from simulated results.

The spots where the albumin got cooked fast and started to splatter is noted as high energy points. The spots where the albumen got slowly cooked are marked as points of low energy. Next a full egg with shell is placed at the low energy point and the oven was operated at 40% power for 2 minutes. The egg was found well cooked and there was no explosion. Six number of whole in-shell eggs have been placed at estimated low power
regions and oven is operated at 40% of power for 2 minutes and the eggs were found well cooked without explosions.

Figure 5.7 Microwave oven with carousel (turn table)

Figure 5.8 Placing Egg to be cooked in a Paper Cup
Figure 5.9 Cooking Egg with Carousel

Figure 5.10 Exploded Egg pieces
Figure 5.11 Microwave Oven Without Carousel

Figure 5.12 Locating Eggs in Identified Low Power Regions
5.3 SUMMARY

The concept of non-uniformity has been used for cooking in-shell eggs without explosions. Nonuniformity in temperature inside the microwave oven was realized by avoiding turntable and mode stirrers and it was verified first for potato samples and then for in-shell eggs. The role of the turntable and mode stirrers is to provide uniform heating to the materials placed inside the oven, i.e. to avoid over browning at one particular spot. Low power regions inside the oven were identified by simulating the electromagnetic model of a domestic microwave oven by using the MATLAB PDE tool. Then sample eggs were placed in a domestic microwave oven in the identified regions as suitable for egg cooking and the oven was powered at 40% for 2 minutes. The samples were found well cooked without explosions.