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Moisture Determination of Agricultural Crop (*Capsicum annum*) by Microwave Energy

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The dipole rotation and ionic polarisation mechanisms that govern microwave heating were examined in relation to determination of moisture content in visco-elastic material. Samples of pepper were dried by heating in a microwave oven for time duration 5,10,20 and 30 min at different microwave power 350W, 500W and 650W respectively. The moisture content of the samples was determined for specific time and microwave power. The results were compared with standard measurement. Moisture content measurement accuracy in the microwave oven was affected by drying time and microwave power.

Key words: Microwave, Dipole rotation, Radiation, Moisture.

Introduction

Microwave energy derived from electromagnetic radiation in the frequency range between 3 MHz and 30,000 GHz (Bouraoui *et al* 1993). Presently; microwaves are widely used for telephone network, radio and television systems as well as other communication applications. Microwave techniques are also now being introduced in extremely fast computer operations (Cottingham and Greenwood, 1991). Just like any other form of energy, microwave energy is also used for heating. Thermal effects produced by microwave energy have been used for crop drying and food processing (Yousif *et al* 1999; McGee *et al* 1999). Industrial manufacturers needs have spurred substantial research on the use of microwave in food processing (Fitzgerald 1999). This has stimulated the interest in using microwave energy in processing pepper (*Capsicum annum*) an agricultural crop that is grown and widely eaten in Nigeria. Previous attempts to preserve the crop by solar drying (Nwagho, 1989) had limitations due to the oxidation and physical changes in structure, colour and sensory quantities of dried products. The microwave drying technique is considered appropriate for crop drying since it has been successfully used in dehydrating cranberry (Yongsawatdigual and Gunasekran 1996) carrot (Lin *et al* 1998). Microwave dried foods were also reported to have physical sensory qualities and retention of key constituents than their air-dried counterparts (Yousif *et al* 1999). The objective of this study was to use microwave oven to determine the moisture content of *Capsicum annum*. The result of microwave aquametry experiments were compared with results obtained by determining moisture content according conventional method specified in American standard for testing and materials (ASTM) 2000. It is hoped that microwave energy might be considered in tackling the issue of preservation of Agricultural products in developing countries.

Materials and Methods

Mechanisms of microwave heating. The main methods of heat transfer during microwave heating include conduction, convection and radiation. When a material is exposed to microwave radiation, heat is transferred to the surface of the material by radiation and convective currents while the dominant means of heat transfer within the material is conduction. Thus food items less than 25mm thick are cooked rapidly by microwaves while thicker food materials rely mainly on conductive heat transfer mechanisms similar to what obtains during conventional cooking (Buffer, 1993). Heat from the microwaved layer is conducted into areas that the microwaves are unable to penetrate (Gupta 1983). Dielectric losses, which cause heat generation, are proportional to $\in r''$, the imaginary part of the dielectric constant. The power dissipated in a certain volume V of the material is given by

$$Pd = \tfrac{1}{2} \in w_o \int_v \in r'' |E|^2 dv \qquad \text{..................(1)}$$

$$Pd = 27.8 * 10^{-12} f \int_v \in r'' |E|^2 dv \qquad \text{.........(2)}$$

Where f = frequency in Hz, E = amplitude of electric field in V/m

$\in r'' = [\in r' - \delta \in r'']$ = relative permittivity of the material

Pd = Power dissipated in watts.

The power dissipated in the material determines the temperature rise at any point according to the relation

$$\delta T / \delta t = 0.23\, Pd / c\rho \qquad \text{.............. (3)}$$

Where 'c' is the specific heat capacity of material in calories per gram and ρ is the density of material (g/cm^3). Integrating equation 3 we obtain an expression for the temperature T

$$T = 0.23\, Pd / c\rho(t) \quad \ldots\ldots(4)$$

From the power dissipated in equation (1) we see that the dissipated power is proportional to the frequency, so that the higher the frequency, the more the power dissipated, and consequently from equation (4) the higher the temperature.

An additional advantage of microwave heating results from behaviour of $\in r''$ as a function of frequency. Most of the food products contain free water and the dipolar dispersion in water occurs at microwave frequency. For free water at 25°C, $\in r''$ is 0.36 at 10MHz, but increases to 12 at 3GHz. This shows that the increase of dissipated power at microwave frequency can be substantial (Buffer, 1993).

Fresh samples of *Capsicum annum* (pepper) were randomly collected and used for microwave aquametry experiments. The collected samples were further divided into 12 subsamples and 7 specimens were randomly selected from each subsample for the test. The initial weight of the specimens were determined before the specimen were dried in the microwave oven and after the drying process at the different microwave power and time duration. Tests were conducted at microwave power of 350, 500 and 650W at time duration of 5, 10, 20 and 30 min. The rate of moisture lost at each microwave power level and time were recorded and used in calculating percentage moisture content. Moisture content of some samples of pepper were also determined by using the conventional laboratory oven in accordance with the ASTM (2000). Samples selected for moisture content (MC) determination were weighed (Ww) and dried in the oven at 103± 2°C for 24 hr. There after the weight of ovendried samples (Wo) were determined and % moisture content was calculated as:

$$\%MC = (Ww - Wo) / Wo \times 100$$

where %MC = percentage moisture content

Ww = Initial weight of sample

Wo = Final weight of sample

The results of moisture contents determined by using the microwave oven and conventional laboratory oven were compared.

Results and Discussion

The average moisture loss (%) of the samples at different microwave power and time are presented in Table 1. The high rate of dehydation was recorded agreed with the report of (Yousif *et al* 1999) that thermal effects produced by microwave energy is suitable for fast drying of food crop. Figure 1 shows how the moisture loss (%) varies with time (min) for specific microwave power while the changes in moisture loss at different microwave powers are illustrated in Fig 2. The dipole rotation and the ionic polarization mechanisms that is responsible for the temperature,T in equation 4 is seen to depend on the specific heat and density, ρ of the material being examined, power (Pd) as well as the time (t). Charring was observed for time duration longer than 30min at microwave power of 500W and also at time duration longer than 10 min at microwave power of 650 W. This similar to the observations that heat generated at high microwave power is substantial and could change the colour and sensory qualities of food materials if it is not controlled (Bubber 1993). It is obvious that the longer the sample is retained at a particular microwave power, the higher the quantity of water evaporated from the sample as shown in Fig 1. This agree with the report of Bouraoui *et al* (1993) for the determination of moisture contents of food with microwave drying technique. The moisture content lost due to microwave drying varied from 27.86 to

Table 1

Average moisture loss at different microwave power and time

Sample power (W)	Applied time (min)	Moisture loss(%)
350	5	27.86
350	10	47.70
350	20	63.60
350	30	80.50
500	5	34.36
500	10	59.24
500	20	79.80
500	30	82.74
650	5	56.74
650	10	82.79

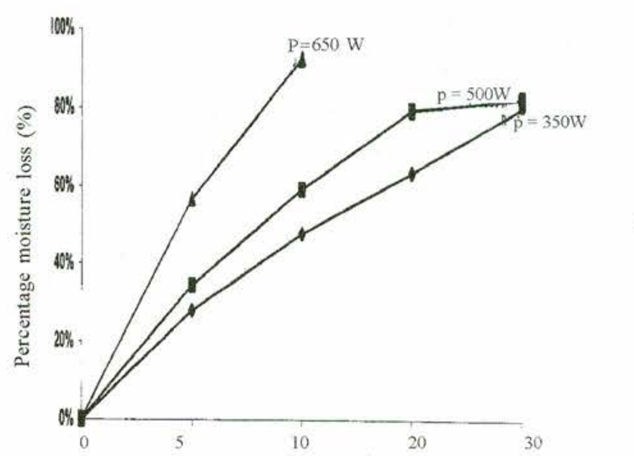

Fig 1. Time as a function of percentage moisture loss at specific power pd.

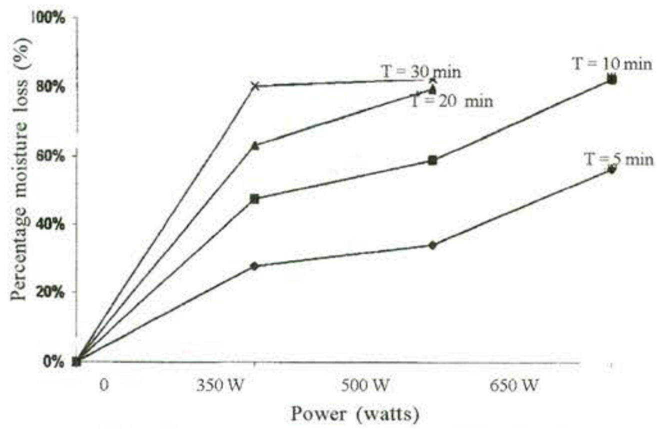

Fig 2. Power as function of percentage moisure loss at specific time (t)

82.74% (wet basis). The average moisture content value of 82.05±1.5% was obtained for samples of *Capsicum cumannum* subjected to ASTM 2000 oven drying method. The value is not significantly different (at $P < 0.05$) from values obtained in the microwave oven tests; 82.74% at 500W for 30min and 82.79% at 650W for 10min. This suggests that the moisture content of *Capsicum cumannum* could be rapidly determined by exposing the crop to microwave field at 500W for 30 min or 650W for 10 min. The results agree with the report that microwave oven gives rapid drying process that could be used in evaluating moisture content of food crops.

Conclusion

It has been concluded that the microwave drying method when properly calibrated can be sufficiently accurate to be used for routine determination of moisture content of many agricultural crops grown in Nigeria. In application such as quality control the advantage of rapid results that the method offers outweighs the limitations due to difficulties of calibration. Duration is the dominant parameter to be calibrated but attention must be paid to several other factors such as power level, sample mass, container size and shape. These factors affect the rate of temperature rise inside the sample and moisture removal from the product. Consequently, uneven drying, over-drying or charring of product may result from poor selection of parameter combination.

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