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DEVELOPING BIOSENSORS TO MONITOR TEMPERATURE IN A MICROWAVE FIELD

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Abstract

Heat distribution in a microwave oven is always a problem due to hot and cold spots, excessive heating at product edges and corners. When we are baking bread in a microwave,the bread will appear crispy and brown. If crispiness and browning is desired, combination mode is can be used to overcome the problem. The combination mode composed of three modes, microwave, halogen lamp and airflow. We are investigetting to combine them or use them individually. The Combination Microwave has been developed to control heat and mass transfer by using forced airflow. However there is loss of weight. The exterior layer of the product will have brownness problem. As the halogen lamp heating gives surface heating and microwave cook the bread faster, we can combine them to geta better result varied softness and hardness. Therefore if we could control the heat distribution inside the microwave by deploying the temperature sensors,to decrese weight loss and by using halogen lamp in combination can increse the brownness of bread.

Introduction

Cooking in a microwave (MW) is routine for most of the people in Europe and North America. Cooking in a MW is faster than any other traditional method, but there were some issues like texture, color, high moisture loss. When Microwave combination oven came to the market, some of the issues have been resolved. But still for some of the cooking processes, quality is not comparable with the traditional oven. For speed cooking, microwave power is needed and at the same time we need crispiness and brownness. Infrared lamps are complimentary to microwave oven. When it combines both microwave and infrared and the airflow, we can increase the uniformity of heating and at the same time it increases the speed of heating (Datta, Greedipalli & Almeida, 2005). Combination of MW and halogen lamp heating is new to the food industry. Halogen lamp heating is near to the infrared heating which gives heat just like traditional oven to enhance the quality of cooking. Bread baked in combinational oven can be compared with bread baked in conventional (traditional) oven. But still physical and olfactory properties are not exactly same as the traditional oven. Only when MW oven is used, volume and weight of the product is decreased. In case of MW-halogen lamp combination oven (combi-oven) some of the problem is solved. In this study, physical properties like texture, color (brownness), moisture loss and temperature variation has been observed. If we could find out how the temperature changes with different combinations of power level, then we can model the temperature profile of the cooking process which probably addresses the part of the problem.

Microwave heating

Microwave is a source of energy used for heating from early 1940s.People started using it after Percy Spencer patented it in 1950. The frequency range of microwave falls in between 300 MHz up to 30 GHz. But for the purposes, 915MHz and 2450MHz is allowed in North America. Application of microwave technique is widely used in food and chemical engineering. This is also used in different applications like polymer industries and medicine science. It is used in food industry for cooking, baking, drying, pasteurization, heating and reheating.

Heating food in microwave involves two mechanisms, dielectric and ionic. Water is responsible fore dielectric heating. Due to dipolar nature of water molecules follow the electric field associated with electromagnetic radiation as it oscillates at a very high frequency. In such an oscillation, water molecules produce heat due to friction of molecules. The migration of ions in the food generates heat under oscillating electric field. Under the influence of electrical field, the positive and negative ions attracted towards opposite pole which results in a multiple collision. In a result of this collision and breaking of hydrogen bonds produce heat. This ionic has conduction greatly affects the dielectric properties and decreases penetration depth.

Advantages of microwave cooking

Microwave does the volumetric and non-uniform heating. But it has some advantages over conventional oven. Microwave heating is faster than the usual convectional heating. It almost cooks five times faster than conventional. Heat distribution is more uniform than the conventional oven (Datta, A.K and R.C. Anantheswaran, 2001). It heats more on wet areas than dry areas. It has the got precise process control.

Disadvantages of microwave cooking

Non-uniformity and volumetric heating of microwave depend on the food and oven characteristics. Non uniformity arises due to electromagnetic field patterns of microwave. When

electromagnetic energy penetrates, it heats up the food material and part of it goes further. The distribution of heat is uneven between different layers of food. Surface intensity is not sufficient for Maillard reaction. Microwave baked products give firm texture and high moisture loss (Keskin, S. O., Sumnu, G. and Sahin, S., 2004).

Microwave- Halogen combination oven baking

This is a new technology where microwave combined with halogen lamp give a better cooking experience. With this technology we can cook, bake, toast and gill the food product. It has got higher throughput per linear foot of oven length. It gives more uniform heating than and conventional and microwave oven. It reduces surface moisture build up and increases surface temperature and hence helps Maillard reaction. Halogen lamp is an infrared source of energy provides near infrared radiation. In microwave baking, Maillard reaction does not occur due to low and limited time heating unlike conventional oven. But here in combinational oven, with the help of halogen lamps we can get that effect. It can reduce the conventional baking time of bread by 75% (Keskin, S. O., Sumnu, G. and Sahin, S., 2004).

Figure 1. GE Advantium™ oven (model SCA2000)

Materials and methods

The Microwave Advantium™ oven has Microwave power as well as halogen lamp heating with three halogen lamps, two placed on the top of the oven, and one from the bottom. There is a fan circulates the air when halogen lamp is on to uniformly distribute the heat. There are 10 different power levels for from 0-10. If M=5 means 50 % of time Microwave power will be on at full power. Maximum power of the microwave is 950 W. This gives near infrared heating which provides near infrared radiation and its electromagnetic spectrum is nearer to visible light.
Infrared (IR) radiation is the part of the sun's electromagnetic spectrum that is predominantly responsible for the heating effect of the sun (Ranjan et al., 2002). The penetration depth of infrared radiation is poor, so it does only surface heating. This infrared source gives the

temperature about 500-3000 ^{0}C. The heat transfer through the body is through convection or conduction.(Supulveda and Barbosa-Canovas, 2003).

Dough preparation

Bread flour (Robinhood all purpose flour) containing 27% wet gluten, 13.5% moisture and 0.65 % of ash was used. Water absorption capacity was determined by water hydration capacity method (AACC 88-04). The composition of bread was on weight basis. 100% flour, 8% sugar, 6% milk powder, 2% salt, 3% vegetable shortening, 3% yeast and 65% water. Dough containing 100 grams of flour is prepared by using standard method. All the dry ingredients are mixed including dry instant yeast. Shortening and water added later and put in a dough making machine also used as is without melting it. The Bosch dough making machine is used to make the dough. Each time 100gm is mixed and put into the incubation chamber which maintains 30 Celsius and 85 % humidity. The dough was made by same proofing time for all samples of 100gm and put in the combination oven one at a time. Total proofing time is 105 minutes. After dough has been prepared, it was kept for 70 minutes. Then it was taken out and punched. After 35 minutes again it was punched and make into two pieces each of 50gm and put in the pan finally for proofing.

Baking of Bread

There are three different conditions has been used for bread baking. Microwave, halogen lamp and combination of both MW and IR have been used. Each of two combinations with three power level makes six types. Bread was prepared by using combination oven (Advantium® oven General Electric Company Model SCA2000). This oven cooks food by combining the microwave and halogen lamp and airflow. For better circulation of air, a turn table is placed in the bottom of the microwave. Both the halogen lamp can work together or work individually in different power levels. Microwave, upper and lower halogen lamps can work from 0 to 10 power levels. The bread samples are baked at Microwave power level 10(M=10) with no halogen lamp heating (U=L=0); at no MW power(M=0) with 10 level halogen lamp(U=L=10) ;at MW power level 5 and Halogen power level 5 (M=5,U=L=5); at MW power level 5 with no halogen lamp heating(U=L=0); at no MW power(M=0)with 5 level of halogen lamp heating (U=L=5); at no MW power(M=0) with 10 level of halogen lamp heating(U=L=10).

Bread analysis

Weight loss measurement is done by continuously putting sample in microwave and weighing in 15 seconds interval of time. At the beginning, weight is taken before putting into microwave. Then after every 15 seconds weight was taken till there is no significant change in weight or the bread started burning. In case of high MW power, it was not possible to take weight after 3minutes.

Temperature measurement

FISO UMI4 (Universal Multi-channel Instrument, 4 channel, FISO Technologies, Inc, Quebec, Canada) was used with fiber optics probes for data acquisition. A signal mixture was used to convert analog to digital signal and feed into the laptop through Labview software for data acquisition. The fiber optics probes are placed at different points to get the data in real time.

Brownness test

The bread samples are measured for crust color by using Minolta Colorimeter (CR-10, Japan) Hunter Lab Color Scale L*,a*,b*. Each of three reading was taken from different positions of bread samples and mean value was calculated. By using the formula $\Delta E = [(L^*-L_0)^2 + (a^* - a_0)^2 + (b^*-b_0)^2]$ where L_0, a_0 and b_0 used as reference point.

Results and discussion

Weight loss of the bread in Microwave-combination oven is totally different from the weight loss in conventional oven. The variation of weight loss gives a linear trend.(Sahin, Sumnu & Zincirkiran, 2002).In Microwave only cooking, moisture loss is very fast and more than halogen lamp cooking(Fig.1). In case of Halogen lamp power, weight loss is very slow, and cooking process is also very slow. In the same time, microwave power gives more heat, so baking time will be less.

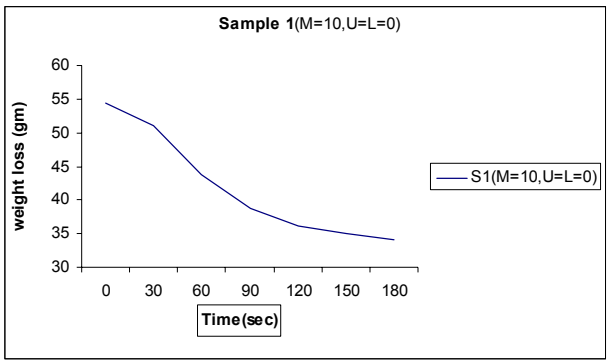

Figure 2. Weight loss of bread at M=10 use of MW-power

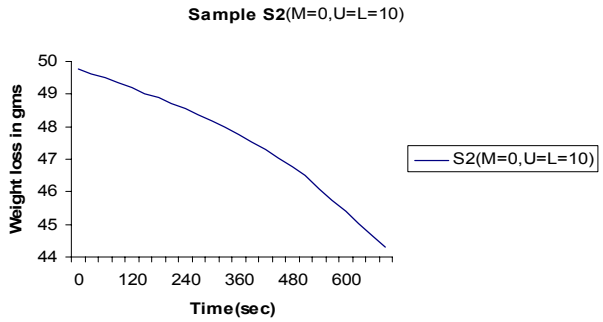

Figure 3. Weight loss of bread at U=L=10 use of Halogen lamp

But in case of microwave and Halogen lamp power heating occurs slowly, but weight loss is higher.(Keskin, S. O., Sumnu, G. & Sahin, S., 2004).. Microwave with power level 5, has slow weight loss than microwave and halogen with same 5 power level. Microwave power plays a dominant role in the microwave combination oven.

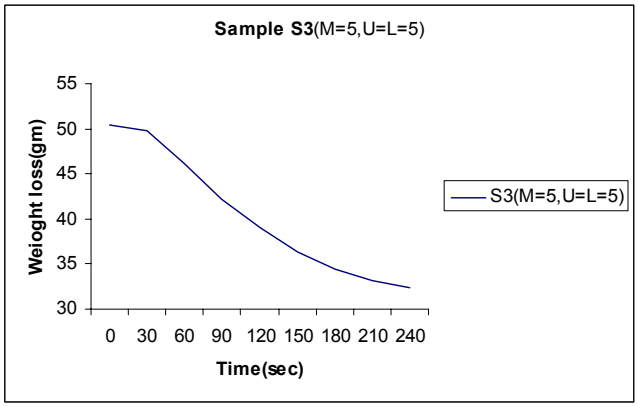

Figure 4. Weight loss of bread at M=5 and U=L=5

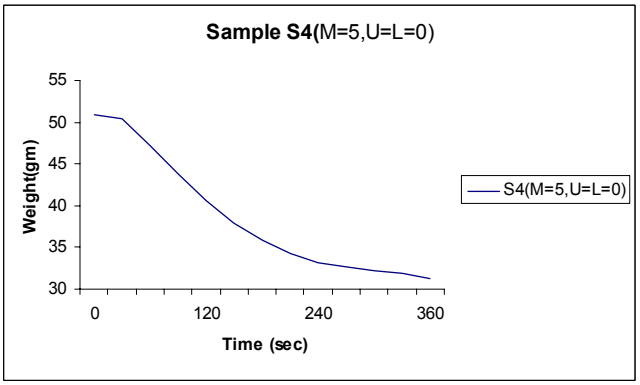

Figure 5. Weight loss of bread at M=5 and U=L=0 power level

Fig. 6 gives a comparison of weight loss in different power levels. It shows that, there is slow weight loss when halogen lamp power is used. When microwave power is used, weight loss is very fast. The abrupt termination of graph shows that, bread can not be cooked after that time, because after that there will be no moisture loss anymore and hence it can burn. It is time consuming, if bread is baked by using only halogen power although weight loss is quite low.

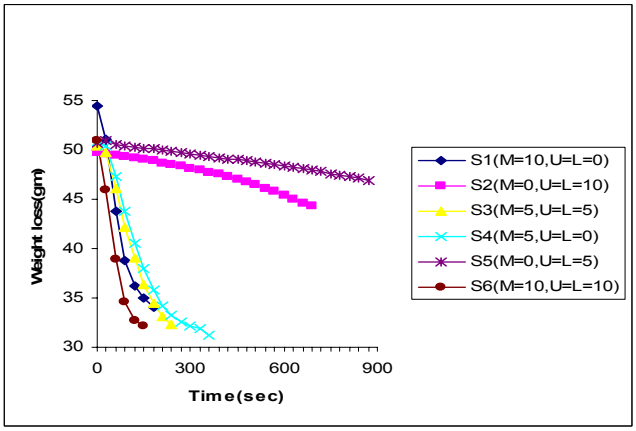

Figure 6. A comparison of weight loss of different combinations of MW-Halogen Lamp power

Figure 7. shows there is an increase in temperature at M=5, U=L=5 power level. The initial temperature was 36 degree ^{0}C and after 70 seconds it reaches 120 ^{0} C. In Fig.7, after 60 seconds it reaches the peak temp. Microwave gives a quick rise in temperature, which leads to high moisture loss.

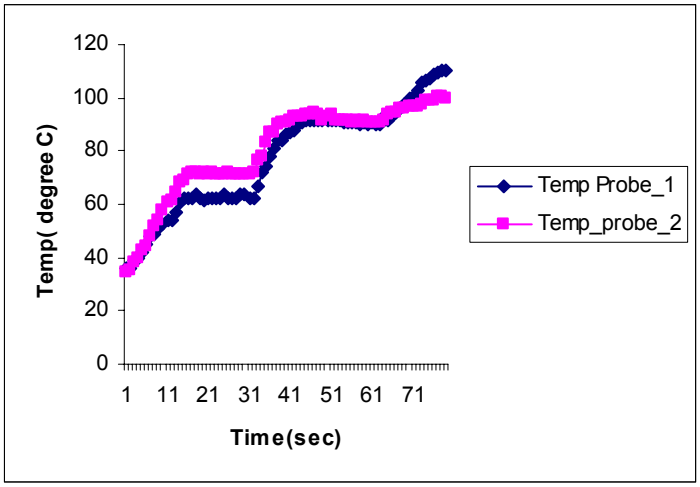

Figure 7. Temperature change inside the bread at M=5 and U=L=5

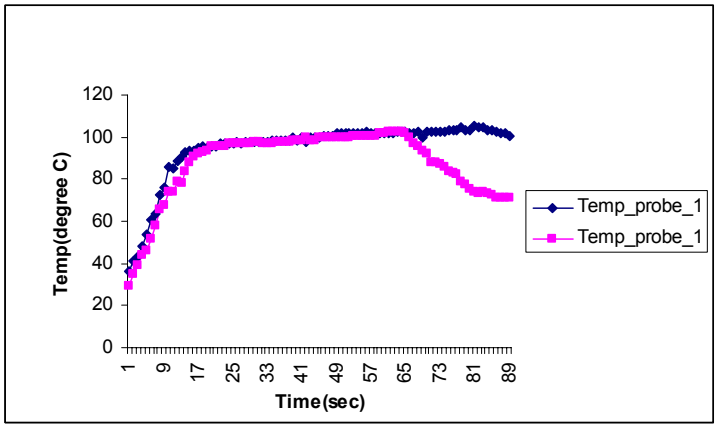

Figure 8. Temperature change inside the bread at M=10 & U=L=0

As shown in Fig. 8 and 9, ΔE value of bread increases if halogen power is used. If bread is placed for a longer period of time in microwave power, color changes occur due to burning of the bread. But in case of halogen power, if it is used with the combination of microwave, cooking process is faster as well as the brownness of the bread.

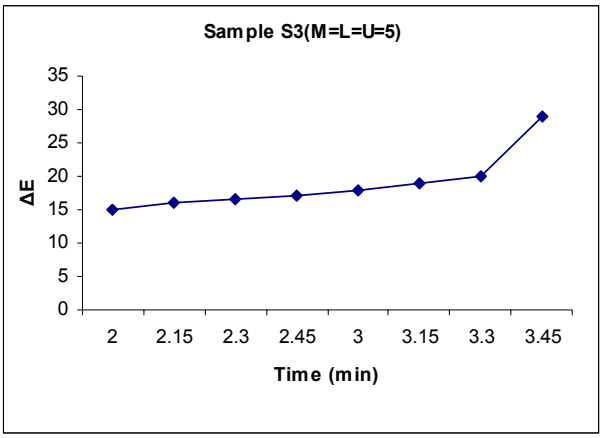

Figure 9.Change of color (ΔE value) of bread at M=U=L=5

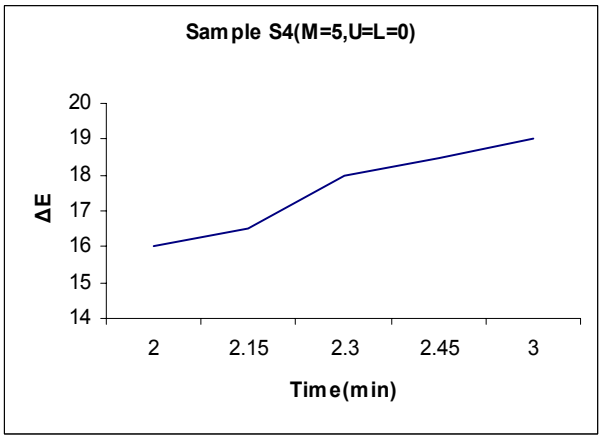

Figure 10.Change of color (ΔE value) of bread at M=5, U=L=0

In figure 11 shows that brownness occurs at different time bread baked at different power levels.

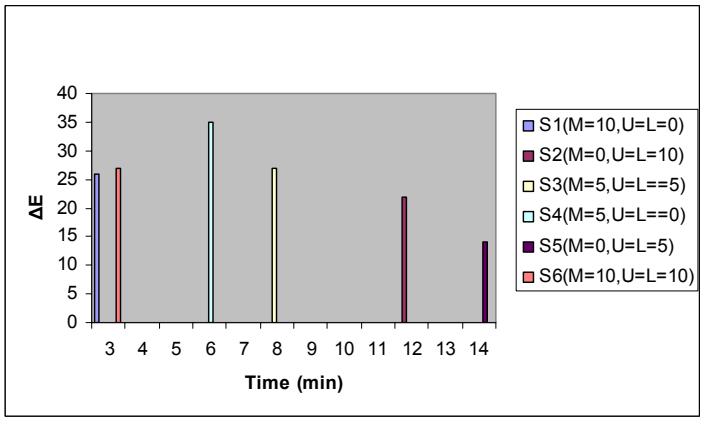

Figure 11. Color change in bread (ΔE) in different power levels which occurs at different interval of time

Conclusion and future work

If microwave and halogen power used in combination can give better result. Using only microwave cannot suitable for baking of bread. By analyzing the temperature profile to regulate power, so that there will be less moisture loss and can bake the bread better. As the weight loss is not faster in case of microwave and halogen lamp power level at 5 , optimum power level can be found out.

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References

Datta, A.K and R.C. Anantheswaran. 2001. *Handbook of microwave technology for food applications*. Marcel Dekker,Inc, New York.

Datta, A. K**.** , S.S.G. Geedipalli and M. Almeida. 2005. Microwave combination heating. *Food Technology.* 59(1):36-40.

Effect of pH upon Browning http://food.oregonstate.edu/color/maillard/factors_a.html (2006/03/06)

Govindarajan, S., D.S. Jayas, N.D.G. White, J. Paliwal. 2005. Dielectric properties measurement of bulk wheat samples using reflection and transmission techniques. *Department of Biosystems Engineering, University of Manitoba, CSAE/SCGR Meeting.*

Fernicola, V.C., R. Galleano. 2005. A multi-channel optical fiber thermometer. *Measurement* 37:1-8.

Keskin, S. O., Sumnu, G. and Sahin, S., 2004. Bread baking in halogen lamp–microwave combination oven. Food Research International, 37(5): 489-495.

Maillard Reaction http://www.landfood.ubc.ca/courses/fnh/410/colour/3_82.htm (2006/03/05)

Microwave combination ovens the route to profit.http://www.bsb.org.uk/conf%201995-96/paper_394.html. (2006/01/30).

Ozmutlu, O., G. Sumnu, and S. Sahin. 2001a. Assessment of proofing of bread dough in the microwave oven. *European Food Research and Technology,* 212(4): 487-490.

Ranjan, R., Irudayaraj, J., and Jun, S., 2002. Simulation of infrared drying process. *Drying Technology*, 20(2): 363-379.

Sahin, S, G. Sumnu, D. Zincirkiran. 2002. Effect of Susceptor, coating and conventional browning applications on color and crust formation during microwave baking. *Journal of Microwave power and Electromagnetic Energy 37: 223-236.*

Sepulveda, D.R. and G.V. Barbosa-Canovas. 2003. Heat transfer in food products. In: Transport phenomena in food processing (edited by J.W. Chanes, J.F. Velez-Ruiz, G.V. Barbosa-Canovas). *Food Preservation Technology Series.* Pp.42.

Sumnu, G. , S, Sahin, M. Sevimli. 2005. Microwave, Infrared and infrared-microwave combination baking of cakes. *Journal of Food Engineering* 71:150-155.