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S. Banooni [a], S. M. Hosseinalipour [a], A. S. Mujumdar [b], E. Taheran [a], M. Bahiraei [a] & P. Taherkhani [a]

[a] Department of Mechanical Engineering, Iran University of Science and Technology, Tehran, Iran

[b] Department of Mechanical Engineering, National University of Singapore, Singapore

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Baking of Flat Bread in an Impingement Oven: An Experimental Study of Heat Transfer and Quality Aspects

S. Banooni,[1] S. M. Hosseinalipour,[1] A. S. Mujumdar,[2] E. Taheran,[1] M. Bahiraei,[1] and P. Taherkhani[1]

[1]*Department of Mechanical Engineering, Iran University of Science and Technology, Tehran, Iran*
[2]*Department of Mechanical Engineering, National University of Singapore, Singapore*

A new impingement oven was designed and tested for its thermal and quality performance for baking of thin flat bread. The test facility was instrumented to monitor and record during the baking process. Bread temperature and weight loss were recorded on-line during baking at oven temperatures of 150, 175, 200, 225, and 250°C and 1, 2.5, 5, 7.5, and 10 m/s jet velocities, respectively. Image processing was used for monitoring the bread volume and surface color changes during baking. Better baking conditions were obtained with the impingement oven in comparison with the conventional direct fired ovens. Experiments showed that a higher jet velocity can be used for flat bread baking at lower oven temperatures and yield shorter baking times for the same quality product. For very thin breads (such as the Iranian breads), results show that conduction heat transfer from the bottom surface of the tray must also be considered along with the convective heat transfer from the jets in selection of optimal operating parameters. It is noted that desirable baking conditions, e.g., good browning, uniform color, high volume increase, etc., can be achieved in a well-designed and operated impingement oven in shorter baking times compared to the conventional ovens.

Keywords Baking; Browning; Color; Flat bread; Image processing; Impinging jets

INTRODUCTION

About a third of world population consumes various types of flat breads. They are typically baked in traditional ovens but there is little knowledge about the cooking conditions and oven performance, which makes their design and operation empirical and not necessarily optimal in terms of energy consumption and quality of the baked products.

Air jet impingement units are used in various industrial processes for efficient heat and mass transfer operations such as in textile and paper drying, electronics cooling, metal annealing, glass tempering, etc., because of the high heat and mass transfer rates attainable with such convection designs. Mujumdar[1] has given a concise but comprehensive summary of impingement drying.

These systems have found many applications in industrial food processing in the last two decades. Li et al.[2] compared large impingement ovens and the combination of impingement and microwaves and found large differences to industrial hot air ovens. Walker et al.[3] and Henke et al.[4] in general describe impingement ovens. Considerable reduction in process times and improvement in product quality can be obtained using this technique.[5–7]

As the underlying physicochemical principles governing the system to be modeled are not clearly understood as yet, an empirical approach appears more suited for this investigation. For cooking in ovens, Wahlby et al.[7] noted that the rate of evaporation, bread temperature, and thickness are the most important process parameters.

Lostie et al.[8] carried out a complete experimental study (internal and surface temperatures, weight loss, and volume expansion are continuously measured) of sponge cake baking including measurement of cake height with a CCD camera. By relating them to other product characterization, their results allow assignment of heat and mass transfer mechanisms to batter zone and baking period. Chevallier et al.[9] have performed the same type of experimental study in order to relate these variables to internal chemical modifications of biscuits. Sommier et al.[10] developed an instrumented pilot-scale oven for the study of French bread baking. They used those parameters besides internal pressure and ambient humidity to apply standard condition for their experiments. All these works show that some techniques are available to measure and follow the most significant variables of dough state during baking, but they are scarcely put all together. These parameters in addition to the bread surface color are examined in this work.

In this study, an experimental impinging jet oven equipped with an on-line data acquisition system was

Correspondence: A. S. Mujumdar, Department of Mechanical Engineering, National University of Singapore, Engineering Drive 1, Singapore, 117567; E-mail: mpeasm@nus.edu.sg