

2000 MAFMA Final Report

Note: The original final report consisted of two large volumes composed by Xue, J., Lefort, G., and Walker, C.E. This version has been condensed for the website.

Project Title: **Bakery Oven Humidity Measurement & Control**

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Academic

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Objectives:

1. To observe the effect of baking products on the humidity levels inside convection ovens.
2. To study the influence of oven humidity level during baking on a finished product such as bread, cake, and cookie
3. Study the heat transfer characteristics of an electrically heated air jet impingement tunnel oven, to observe how humidity changes in the baking chamber, and the effect of the humidity change on finished products.

Product analyses include volume, weight after baking, crust color, crumb texture, firmness, and moisture content. The preliminary testing of cake, bread, and cookies to find the optimum conditions for convection ovens such as baking time and temperature was done following a Response Surface Analysis (RSM) experimental design.

Conclusions

1. Characteristics of The Empty Oven

- a. Temperature is uniform and cycles around the set point in the both ovens. Airflow rate does not change the temperature but it affects the temperature fluctuation rate. In the **direct** fired oven, the temperature was not significantly different between the baking chamber and the exhaust, but in the indirect oven, the exhaust stack temperature did cycle rapidly with wide swings.
- b. Airflow is turbulent and the air velocity patterns are similar in both ovens.
- c. Heat transfer coefficient values increase with air velocity but not with temperature.
- d. Different oven loadings affect the humidity levels inside the baking chamber. The temperature and fan speed affect water evaporation rates but do not change much in the empty indirect fired oven. Humidity is affected by temperature and airflow in the direct-fired oven because the combustion products enter the baking chamber.

2. Humidity Affects The Finished Baked Products

- a. Humidity soon stabilizes in the direct-fired but rises in indirect fired ovens during baking
- b. The humidity level rises in the baking chamber with increased loading. High humidity makes the finished products surface color lighter, increases their specific volume and

spread ratio, and reduces texture firmness and water loss from the products.

- c. The humidity cycles inside the baking chamber as the burner cut on and off in the direct fired oven, but it tends to increase with more loading in the indirect fired oven rather than cycling. An exhaust damper could be used to control this.

3. Air-jet Impingement Tunnel Oven

- a. In the air-jet impingement tunnel oven, the airflow is turbulent; air velocity is higher at shorter distances between the top finger and the target.
- b. The heat transfer coefficient increases with air velocity but not with the temperature and humidity
- c. Humidity gradually increases with increasing loads in the baking chambers during baking but temperature drop off slightly when humidity rises from the higher loading.
- d. Finished product volumes increase, crust color lightens and moisture increases at high humidity.

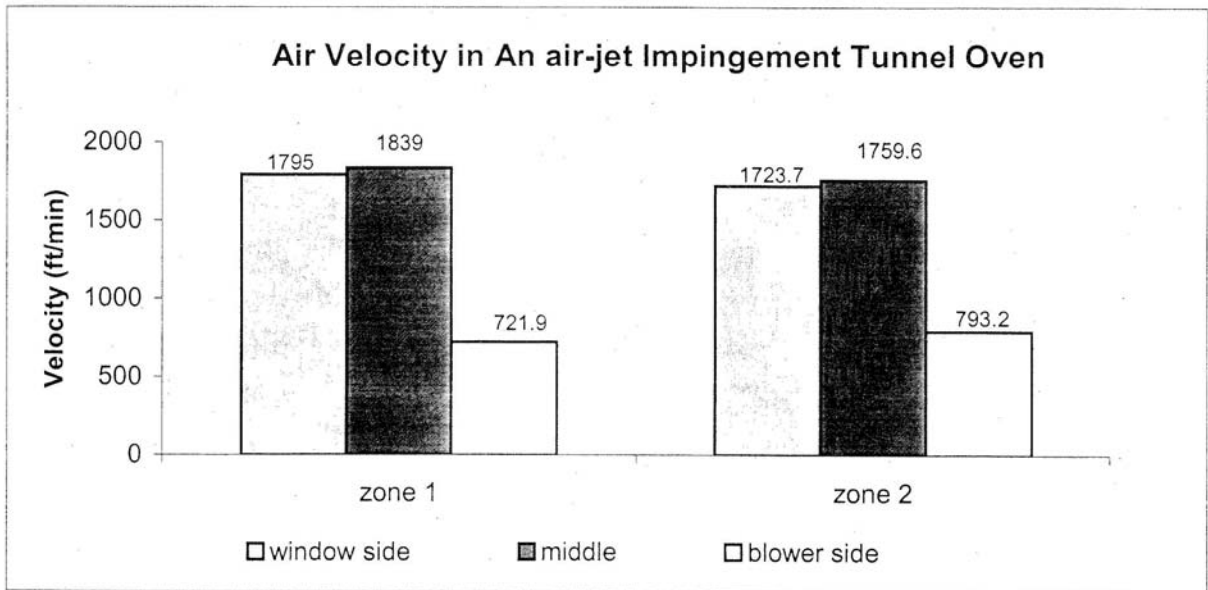


Fig 7. Average air velocity at pan height from the top finger at different positions in the air-jet impingement tunnel oven.

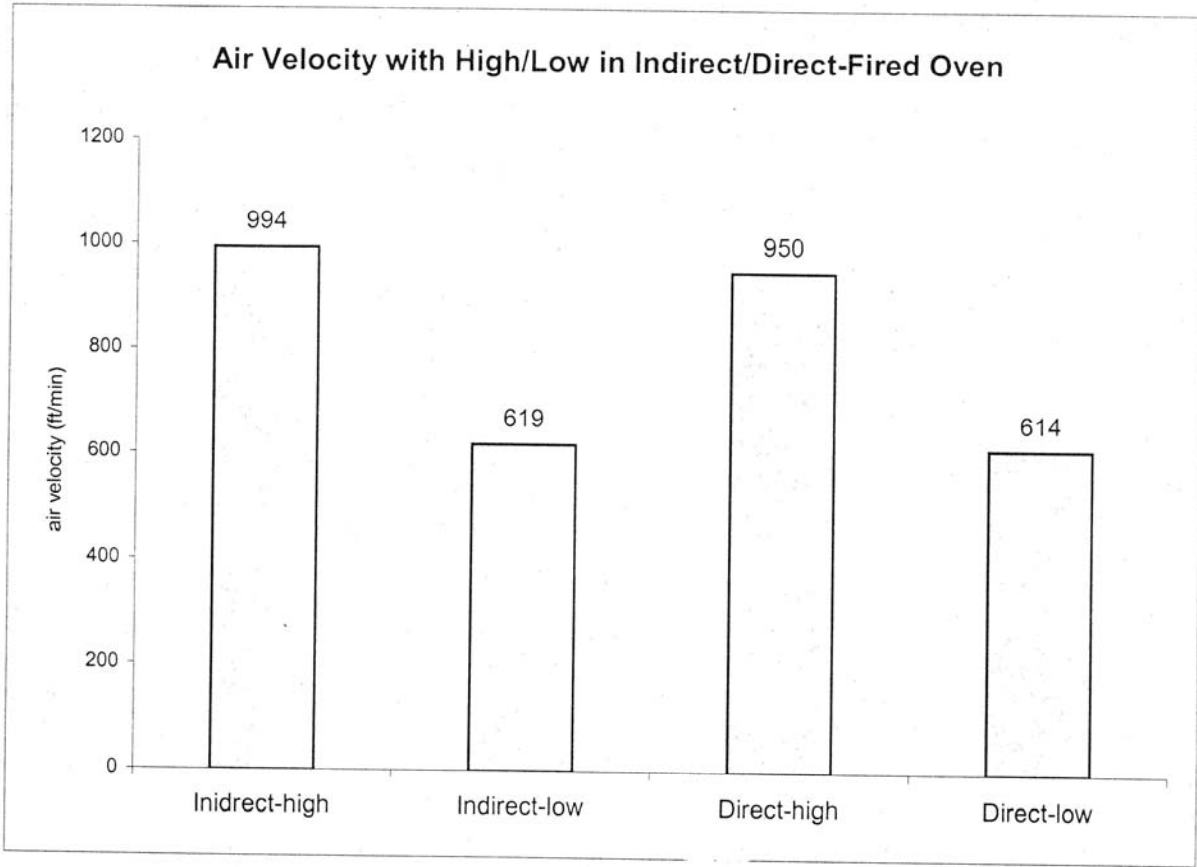


Fig 9. Comparison of average air velocity in both ovens (averaged for each fan speed at 27 points in each oven)

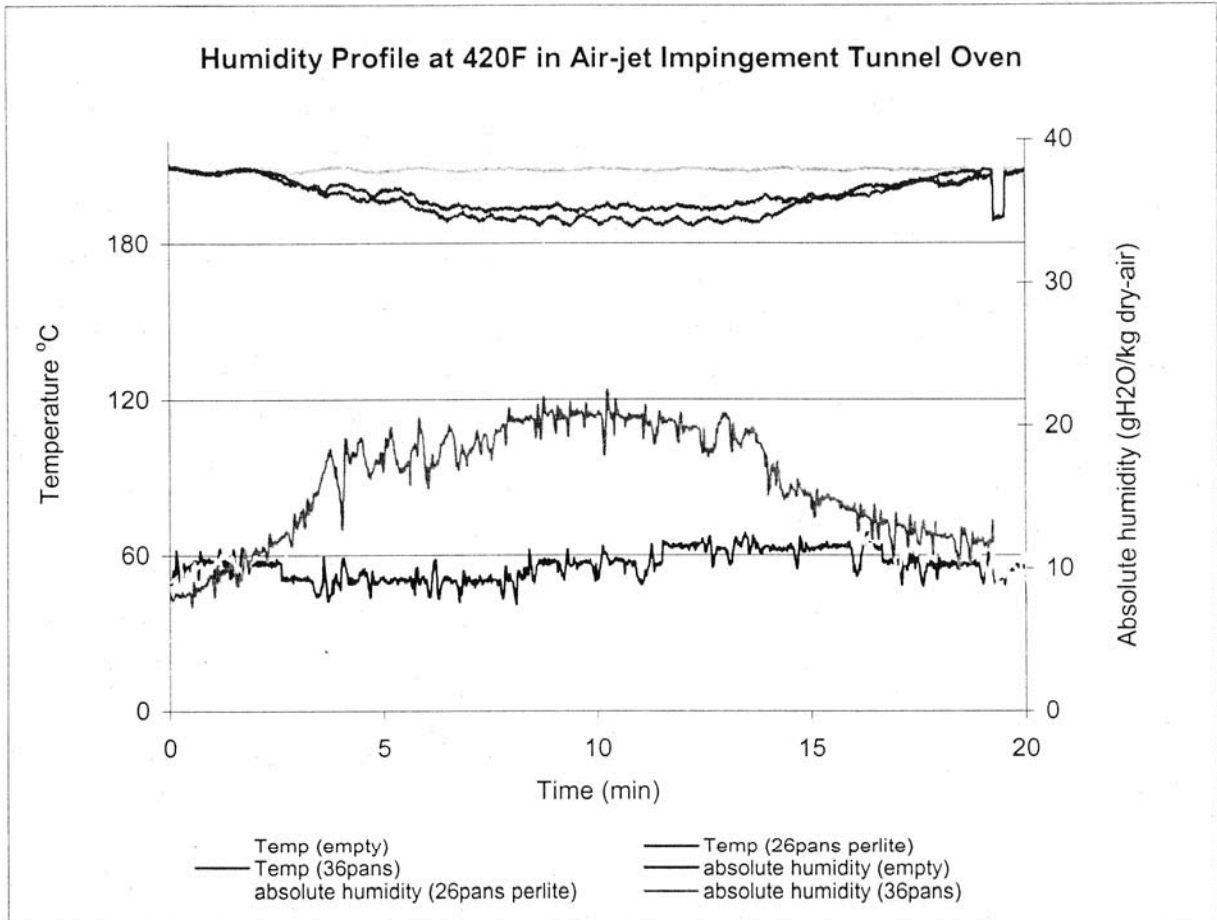


Fig 9 Humidity profiles in empty oven vs. different number of perlite dummy loads at 420°F.

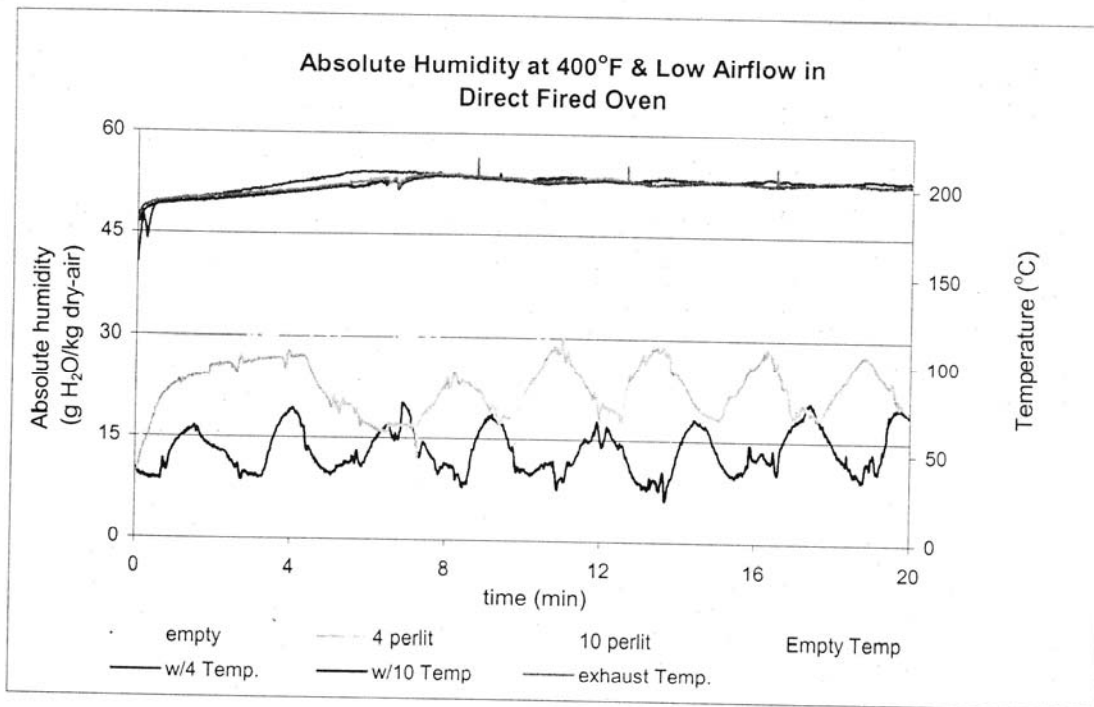


Fig12 Humidity profile at 400°F & low airflow with different number of perlite dummy loads in direct fired oven

Publications resulting from the research

Xue, J. and C.E. Walker. 2003. Humidity change and its effects on baking in an electrically heated air jet impingement oven. *Food Research International* 36: 561-569.

Xue, J., G. Lefort, and C.E. Walker. 2004. Effects of oven humidity on foods baked in gas convection ovens. *Journal of Food Processing Preservation* 28: 179-200.