A Non-gravimetric Approach to Tracing Changes in Water Activity During Convective Cobed Maize Drying

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INTRODUCTION

Maize (*Zea mays* L) plays a great role in ensuring food security in Kenya. It is also significant for its starch and oil, which are used in adhesives, medicines, soaps, cosmetics and several other products. Climate change, however, is putting a strain on its production and preservation. Yield losses, associated with inadequate drying and subsequent aflatoxin contamination, are on the rise and natural (sun) drying is no longer an attractive option. Early harvesting has been recommended as a preventive strategy against the opportunistic agents of spoilage and waste, but it requires provision of forced drying facilities customised to handle maize on the cob. Importing finished technology helps, but only a little and the development of home-grown capacity to design and fabricate drying solutions is the way to go.

The traditional drying experiment is gravimetric, i.e. drying is described mainly in terms of weight change. For products with long – term drying, the weighing process is tedious and prone to error even when automated systems are employed. A multi-dimensional approach, combining experimentation with computational methods, was adopted in this study to characterise drying of maize ears, with a focus not just on weight but also temperature and humidity (or water activity) of the product and its immediate environment.

METHODOLOGY: THE NON GRAVIMETRIC TECHNIQUE

The temperature of a wet ear inserted abruptly into a flowing stream of hot air increases in a piecewise constant manner, representing a series of equilibrium levels between the rate of convective heat gain and rate of evaporative heat loss.

$$H_{wv}\frac{dX}{dt} = ha(T_a - T) \approx ha(T_e - T) \quad \text{since as } t \to \infty, T_e \to T_a \qquad (1)$$

H_{wv} is the water latent heat of vaporisation, T is the variable ear temperature and T_e is the final or equilibrium ear temperature at $a_w=0$. For falling rate drying, the maximum condition occurs at the start of drying ($T = T_o$)

$$H_{wv}\left.\frac{dX}{dt}\right|_{max} = ha(T_a - T_o) \approx ha(T_e - T_o) \qquad (2)$$

Dividing the first two expressions and neglecting changes in the heat transfer coefficients, yields the following simplified expression for the variable drying rate:

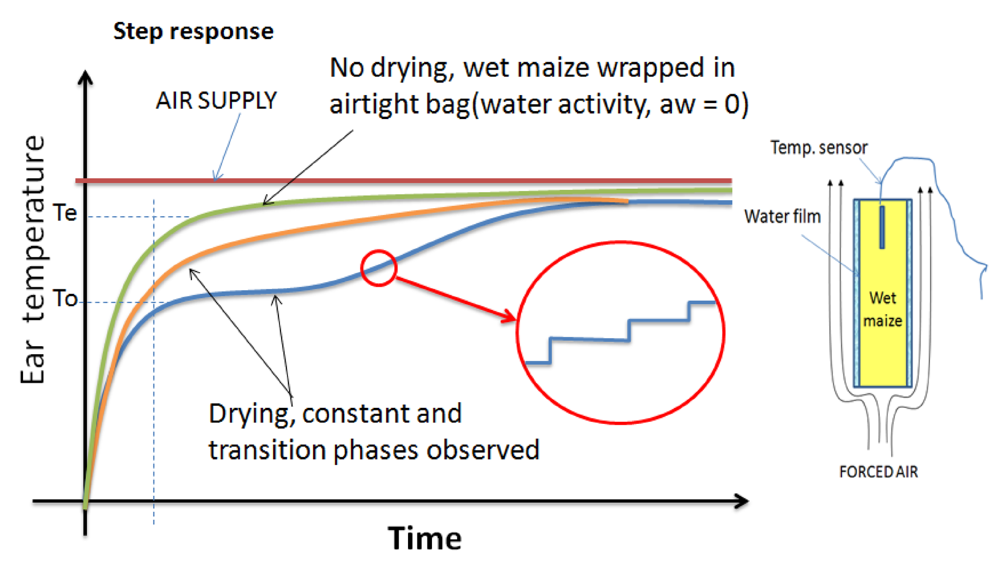
$$\frac{dX}{dt} = \left.\frac{dX}{dt}\right|_{max} \times \frac{T_e - T}{T_e - T_o} \qquad (3)$$

The drying rate is derived from the temperature curves. A spreadsheet is used to intergrate the drying rate between the known initial and final ear conditions using experimental temperature profiles. An optimal solution for the drying rate equation (3) is then sought using the Microsoft Excel Solver™ add-in.

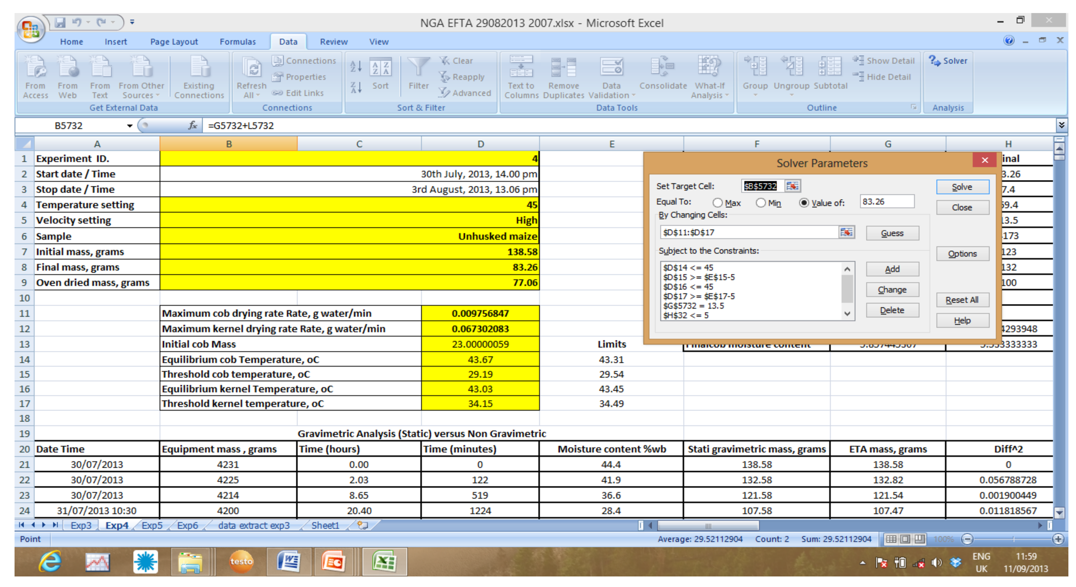
To validate the new approach, wet dehusked maize ears were halved and dried in a unique water activity profiler, at temperatures of 38° C, 45° C and 55° C, with air supply in the range 7– 14 m³/hour. Temperature readings from the ear center, ear surface and free stream were logged at intervals of 1 minute using a PicoLog TC-08, thermocouple recorder. Static weighing was carried out at intervals of approximately 12 hours.

Simultaneous drying of the kernels and cob was assumed and parallel evaluations made based on their respective temperature profiles, and a summation of the two independent outcomes done to give the ear drying rate. The solver was the applied to find an optimal solution that matches the model with actual experimental data collected at the start and end of the experiment, as well as the intermediate calibration points.

Influence of drying on temperature curves

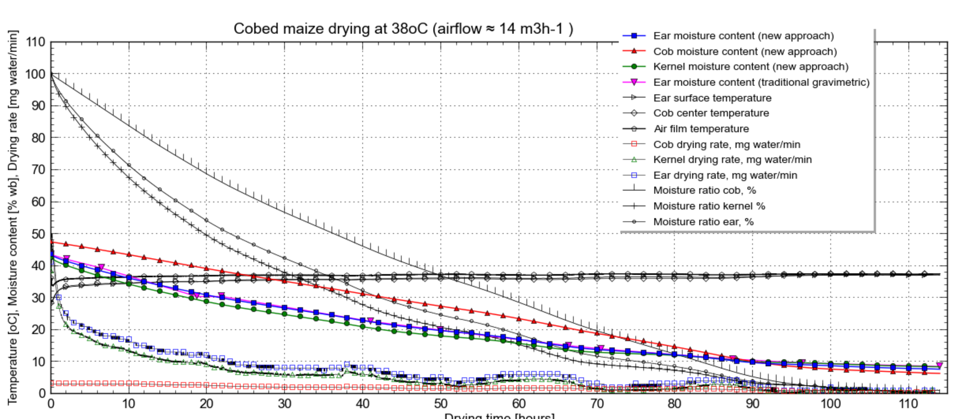


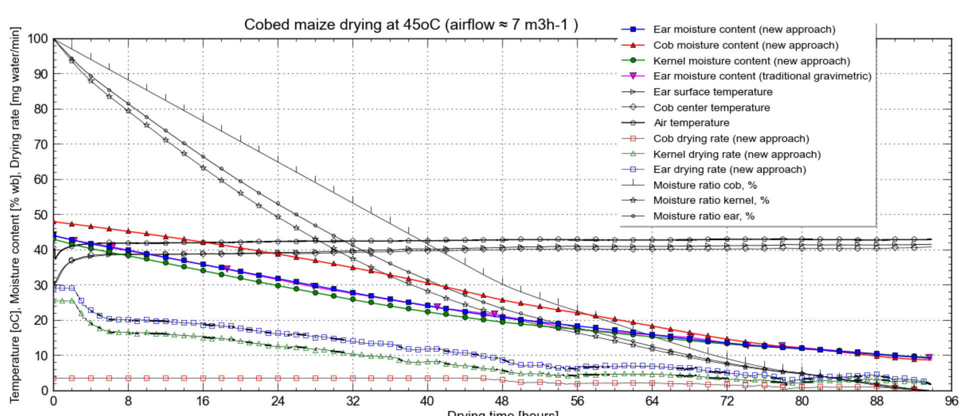
Microsoft Excel 2007 Solver™ interface

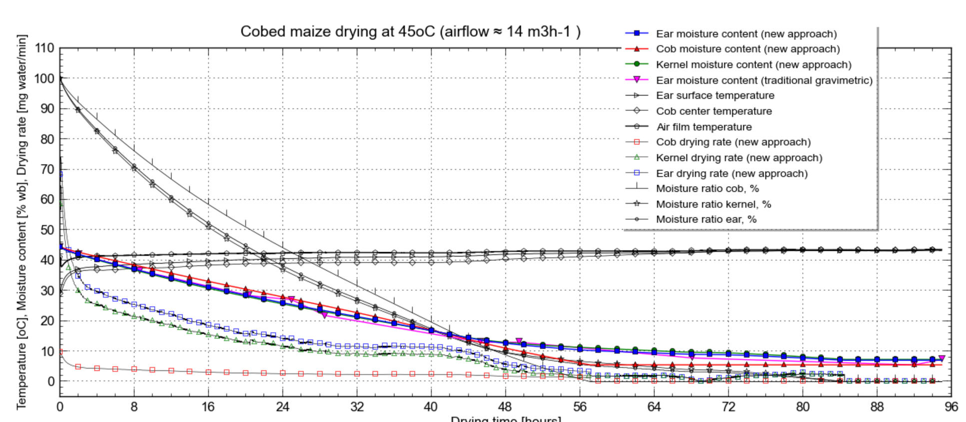


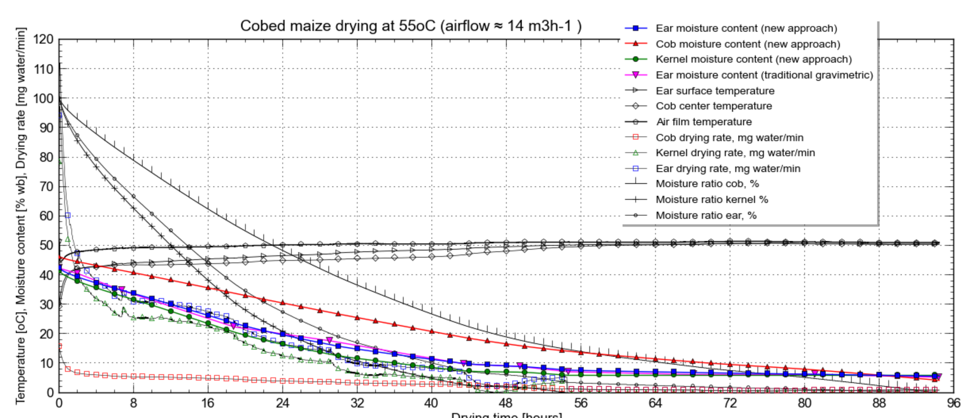
RESULTS AND DISCUSSION

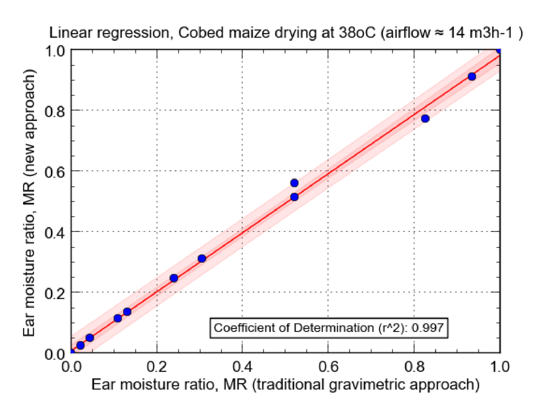
The results of the validation tests are summarised in the graphs that follow. Very good consistency was observed comparing the new approach with the traditional gravimetric drying curve analysis. As expected, drying with higher airflow and at higher temperature resulted in shorter drying times. The drying rate is relatively high only in the first 3 to 5 hours (consistent with the theory of free and bound water movement). Kernels were observed to dry at a faster rate than the cob. This uneven drying was more pronounced at 55ºC. The cob moisture content affects the thresh- ability of the ear. The results give good insight into the role of different variables on the drying process of maize ears.

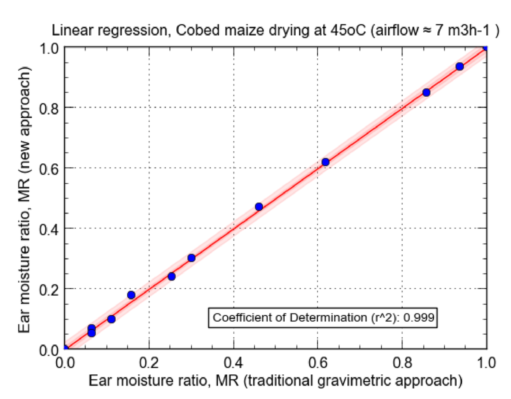


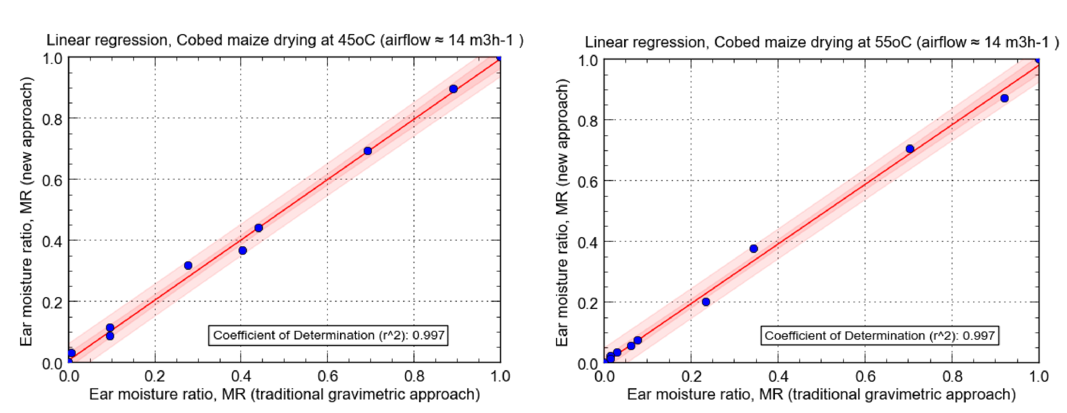












CONCLUSION

A novel way to characterise drying of maize ears has been developed. The new technique facilitates extraction of much more qualitative and quantitative information from the drying experiment and provides useful leads for further investigations into quality, energy use, remote sensing, process optimisation and control. It is an invaluable resource for technicians seeking to develop forced-air drying solutions for bulky products.

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