A Review of Computational Methods for the Design of Innovative Drying Systems for the Prevention of Postharvest Aflatoxin Contamination of Maize in Kenya

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Introduction

- Maize is a staple food in Kenya with a percapita consumption of 98 kilograms
- Aflatoxin contamination of maize is a recurrent problem
- They are produced by the fungi Aspergillus flavus and Aspergillus parasiticus and are carcinogenic .
- Aflatoxin risk is enhanced during growth by prolonged moisture and nutrient stress conditions and also by exposure to high humidity and temperature in the harvest/post harvest period
- Timely and adequate drying is critical for the minimization of food spoilage.

Prediction of the maize drying is sometimes based on published empirical data. The objective of this study was to compare the documented numerical models of low temperature drying of maize and determine the nature and the significance of the variability when cross - border / experiment model applicability is assumed.

Materials and methods

Experimental data for the drying characteristics of shelled and fully exposed maize ears (Table 1 and Table 2) was compiled

The selected drying models

- represented research on original maize samples
- reported sufficient accuracy in reproducing the drying dynamics of the studied samples in their stated range of application.

Drying and moisture diffusivity curves for shelled maize and fully exposed ears (with a specific surface of 784 and 92 m²/m³ respectively) were reproduced in the range 35 - 60 °C.

Table 1 Empirical data comparisons for shelled maize drying

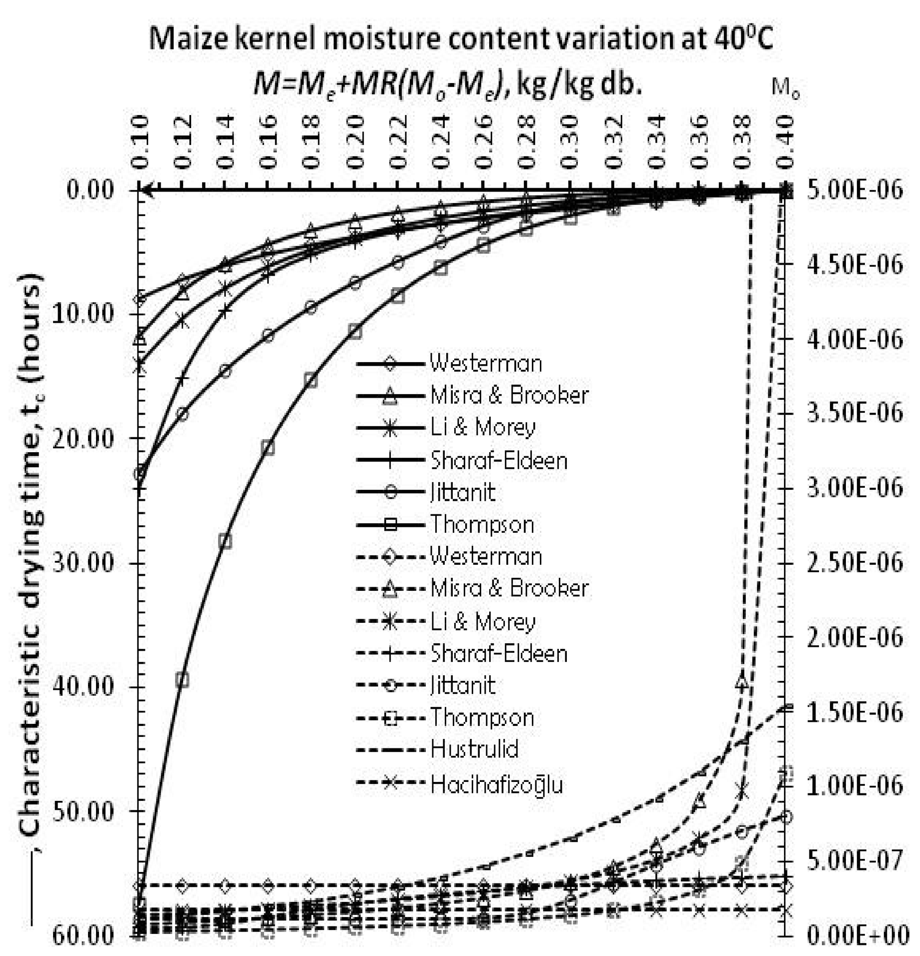
Model	Experiments [Accuracy]	Curve fitted parameters and range of application
1. Lewis (Newton) $MR = exp(-kt)$	Westerman et al., 1973	$\varphi = 1$, $k = exp(13.328 - 0.0115rh - 8255.9(492 + 1.8T)^{-1})\ h^{-1}$ $23.5 \leq T \leq 56.9$ °C, $10 \leq rh \leq 60\%$
2. Page $MR = exp(-kt^n)$	Misra & Brooker, 1980 [R^2=0.967]	$k = exp(-7.1735 + 1.2793ln(1.8T + 32) + 0.1378v)\ h^{-n}$ $n = 0.0811ln(rh) + 0.78M_o$ $2.2 \leq T \leq 71.1$°C , $3 \leq rh \leq 83\%$ $0.025 \leq v \leq 2.33$ [m/s], $0.18 \leq M \leq 0.6$ kg/kg, db
	Li & Morey, 1984 [R^2=0.975]	$k = 0.01091 + (2.767 \times 10^{-6})T^2 + (7.286 \times 10^{-6})TM_o\ min^{-n}$ $n = 0.5375 + (1.141 \times 10^{-5})M_o^2 + (5.183 \times 10^{-5})T^2$ $27 \leq T \leq 116$ °C, $0.23 \leq M \leq 0.36$ kg/kg db
3. Two term exponential $MR(t) = \varphi_1 exp(-k_1 t) + \varphi_2 exp(-k_2 t)$	Sharaf-Eldeen, 1979	$\varphi_1 = 0.6567$ and $\varphi_2 = 1 - \varphi_1$ $k_1 = 236.6exp[(0.00021T_{abs} - 0.0574)M_o - 2108.5/T_{abs}]\ h^{-1}$ $k_2 = 0.0981k_1$ $35 \leq T \leq 75$ °C, $0.03 \leq M \leq 0.39$ [kg/kg, db] $2 \leq rh \leq 13.4$], v=2.65 m/s
	Jittanit, 2007 [R^2=0.971]	$\varphi_1 = 0.73106$ and $\varphi_2 = 0.22499$ $k_1 = 281.287exp[-3863.87/T_{abs}]\ min^{-1}$ $k_2 = 25.027k_1$, $40 \leq T \leq 80$ °C, $2.8 \leq v \leq 3.0$ m/s, $0.25 \leq M_o \leq 0.33$ kg/kg db
4. Thompson $t = \tau_1 ln(MR) + \tau_2[ln(MR)]^2$	Thompson et al., 1968	$\tau_1 = -1.862 + 0.00488(1.8T + 32)$ [h] $\tau_2 = 427.4exp[-0.033(1.8T + 32)]$ [h] $50 \leq T \leq 150$ °C, $0.136 \leq M \leq 0.49$ kg/kg, db $0.1 \leq v \leq 0.3$ m/s
5. Analytical $\frac{dM}{dt} = \frac{1}{r^2}\frac{\partial}{\partial r}\left\{r^2 D \frac{\partial M}{\partial r}\right\}$	Hacıhafızoğlu et al., 2009	$D = 0.00415exp\left(-\frac{3157.6}{T_{abs}}\right)$ m²/h $40 \leq T \leq 70$ °C, $0.136 \leq M_o \leq 0.25$ kg/kg, db $v = 2$ m/s, $9 \leq rh \leq 24$ %, $r_s = 0.004$m
	Chu and Hustrulid, 1968	$D = 1.5314exp[(0.00045T_{abs} - 0.05485)M - 2513/T_{abs}]$ m²/h $50 \leq T \leq 70$ °C, $10 \leq M \leq 36\%$ kg/kg, db $r_s = 0.0035$m, $11 \leq rh \leq 70$ %,

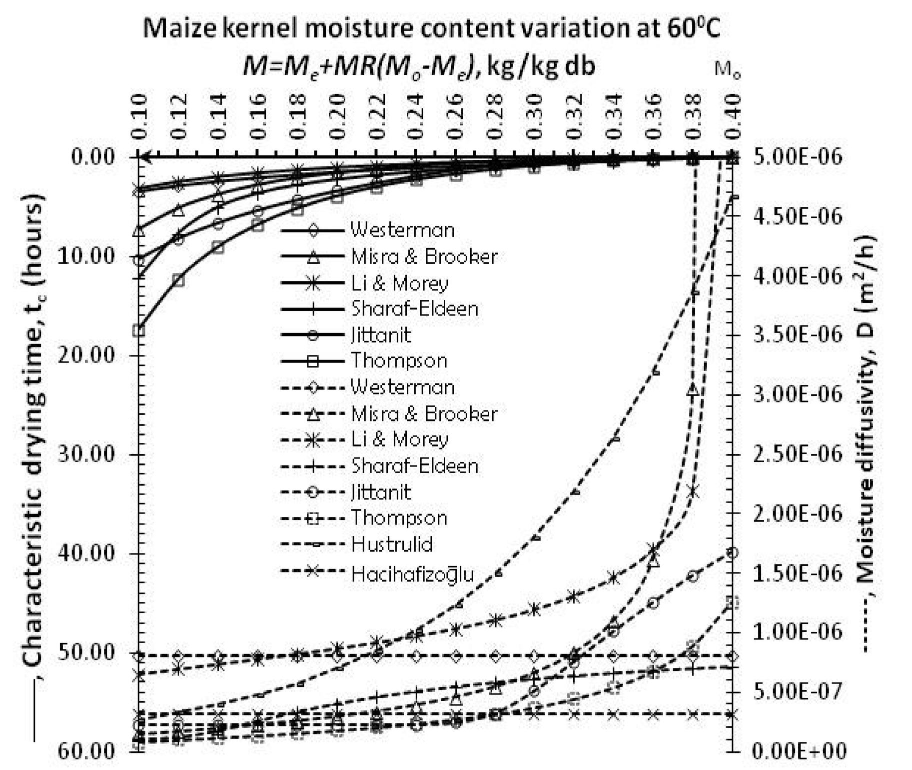
Table 2 Empirical data comparisons for drying of fully exposed maize ears

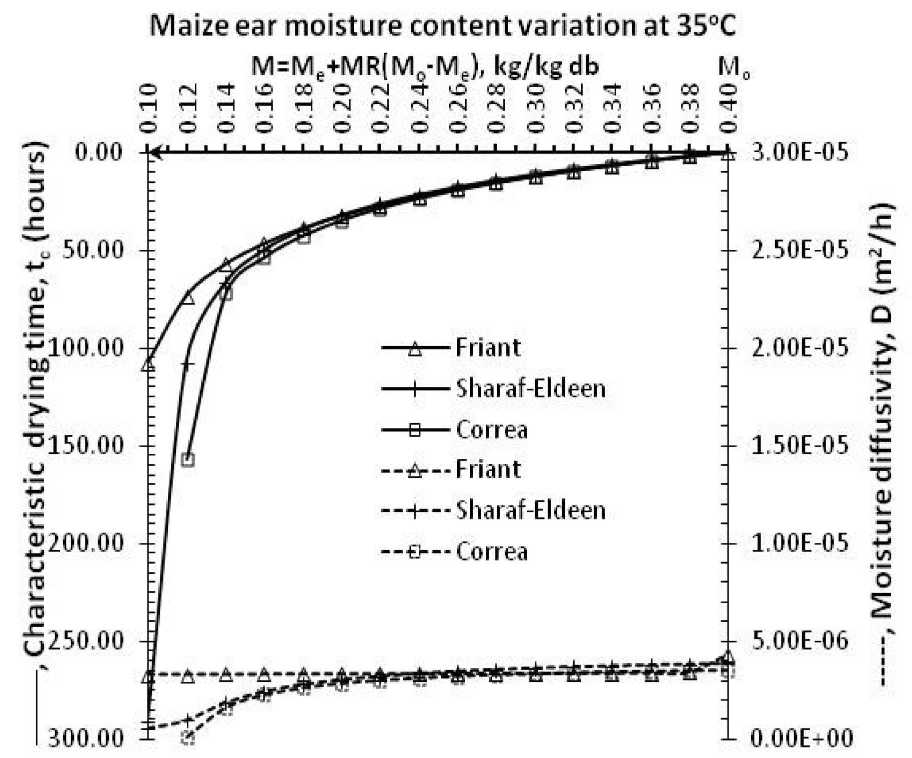
Model	Experiments [Accuracy]	Curve fitted parameters and range of application
1. Page $MR = exp(-kt^n)$	Friant et al., 2004 [R^2=0.98]	$k = exp[-28.66 + (0.2744T_{abs} - 86)M_o + 7947.8/T_{abs}]\ h^{-n}$ $n = 0.9915$ $35 \leq T \leq 45$ °C, $8 \leq rh \leq 15$ % $v = 0.3$ m/s, $0.136 \leq M_o \leq 0.52$ kg/kg, db
2. Two term exponential $MR(t) = \varphi_1 exp(-k_1 t) + \varphi_2 exp(-k_2 t)$	Sharaf-Eldeen et al. , 1980 [R^2=0.98]	$\varphi_1 = 0.8459$ and $\varphi_2 = 1 - \varphi_1$ $k_1 = 902exp[(0.000195T_{abs} - 0.0975)M_o - 2619/T_{abs}]\ h^{-1}$ $k_2 = 0.1278k_1$ $35 \leq T \leq 75$ °C, $0.03 \leq M \leq 0.41$ kg/kg db $2 \leq rh \leq 13.4$ %, $0.609 \leq v \leq 2.65$ m/s
3. Logarithmic $MR(t) = \varphi_1 exp(-kt) + \varphi_2$	Corrêa et al., 2011 [R^2=0.99]	$\varphi_1 = 0.011102T + 0.51609802$ $k = exp[-4.6292 - 17644.8/(RT_{abs})]\ s^{-1}$ $\varphi_2 = -0.010848587 + 0.47428181$ $45 \leq T \leq 65$°C, $0.12 \leq M \leq 0.45$ kg/kg, db

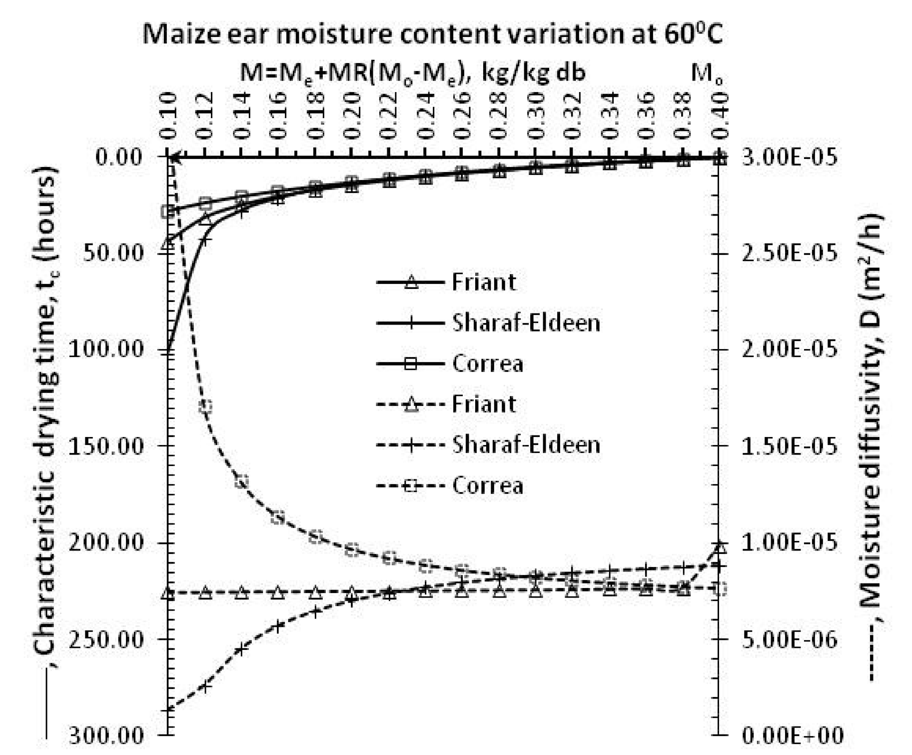
Results

The graphical representations of the obtained model comparisons are as shown below.









Key findings

- Significant differences in the water activity representations were observed.
- An accurate drying time prediction is not always indicative of precise drying process dynamics as determined by the variable product diffusivity.
- Standardisation of equipment and procedures for rapid on-site profiling of product drying is important for the design and optimisation of safe drying and storage systems.

Selected references

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