CFAES / Department of Food, Agricultural, and Biological Engineering / BSAL Lab

Evaluating Small-Scale Grain Dryer for Developing Countries

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INTRODUCTION

-Corn is the most important grain crop in sub-Saharan Africa and is subject to the highest losses [1]

-Inadequate drying and storage infrastructure in developing countries leads to post-harvest losses of over 40% (Figure 1) [2]

Fig 1. Traditional drying leaves grains vulnerable to weather, dust, and pests [4]

-Inadequate moisture removal is the main cause of microbial degradation and aflatoxin development during storage [1]

-Lack of technology and drying infrastructure for small-scale subsistence farming operations (80% of farmers in sub-Saharan Africa) [3]

OBJECTIVE

(1) Create and validate a thin-layer drying model for a grain dryer adapted from a 55-gallon drum

(2) Construct and experimentally evaluate the novel grain drying system to determine impacts on grain quality.

METHODS

Model Development

A time-step system of equations for deep-bed, thin layer drying was programmed in MATLAB based on [5]. The inputs required to determine drying time (Figure 2):

- Temperature of drying air
- Relative humidity of drying air
- Height of grain bed
- Mass flow rate of drying air
- Initial moisture content of grain
- Desired moisture content of grain

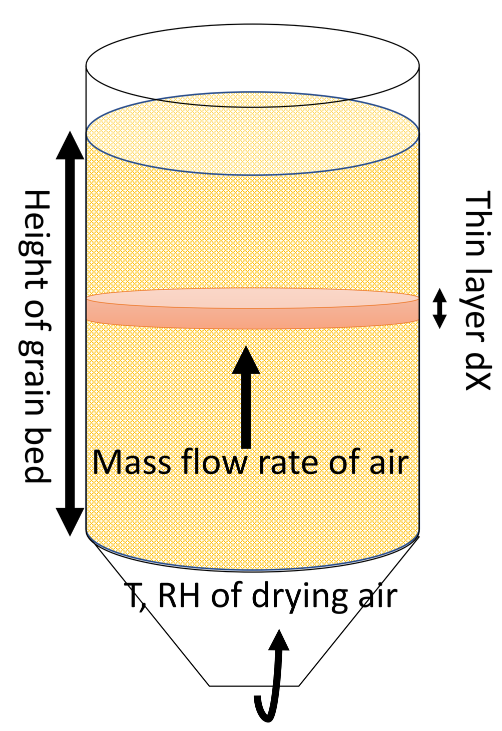

Fig 2. Thin-layer drying model inputs

Governing Equations [5]

Henderson's Equation: $M_e = \left(-\frac{\ln(1-RH)}{cT}\right)^{1/n}$

M_e = EMC; T= temp of drying air; c and n = Henderson's constants for material

Moisture content in layer: $M_1 = M_e + (M_0 - M_e)\exp(-k_0 \Delta\tau)$

Me = EMC, M_0 = beginning moisture content, k_0 = drying parameter, $\Delta\tau$ = time increment.

RESULTS

System Design

- Identified fan to provide volume flow recommended by [6] for deep-bed drying
- Used an Inkbird ITC-106V PID controller and 1875W-rated heating element
- PID temperature controller set to 40C.

Data Collection (Fig 4)

- Dent corn from OARDC research plot
- 3 replications of different dryers and ambient conditions (Table 1)
- Monitored moisture content at 3 depths (Fig 3)

Fig 3. Moisture content profile collected from center and 4 sides

Initial moisture content

↓

Ongoing data collection:

Monitor (every ½ hour)	Sample moisture content profiles (every 12 hours)
- drying air - exit air With HOBO MX1101, measure: - Temperature (T) - relative humidity (RH)	- T-test grain spear sampler & Agratronix MT-16 grain moisture tester

↓

Final moisture content

↓

Run & compare model using average T and RH

Fig 4. Overview of measurements

Table 1: Model and actual results

Trial	Initial MC (%)	Final MC (%)	Model time (h)	Actual time (h)	kWh to dry
1	17.01	11.91	15.00	21.50	10.6
2	18.70	12.04	17.33	26.50	13.1
3	17.08	11.16	17.83	30.00	14.8

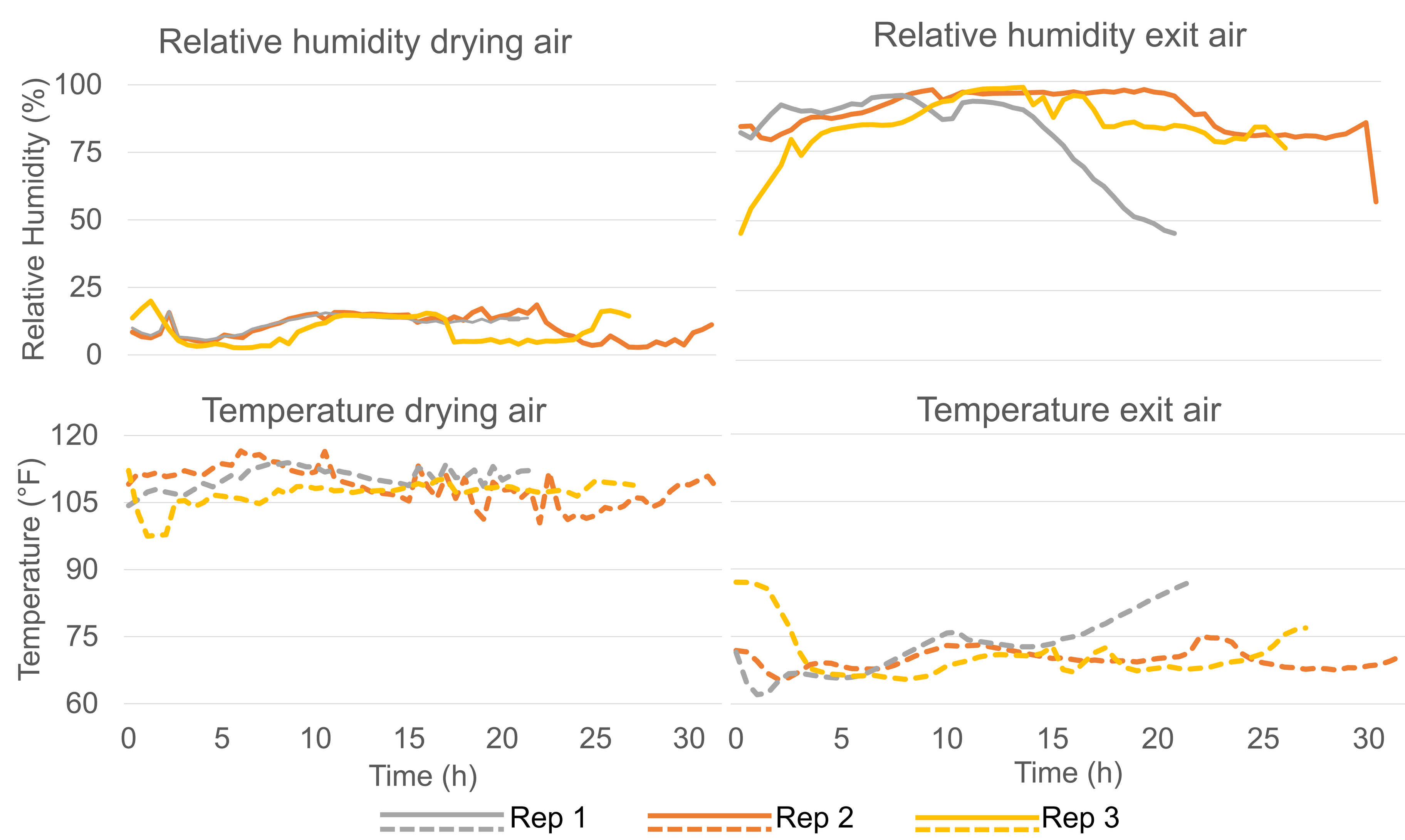

Fig 5. Temperature and relative humidity of drying and exit air throughout drying period

RESULTS

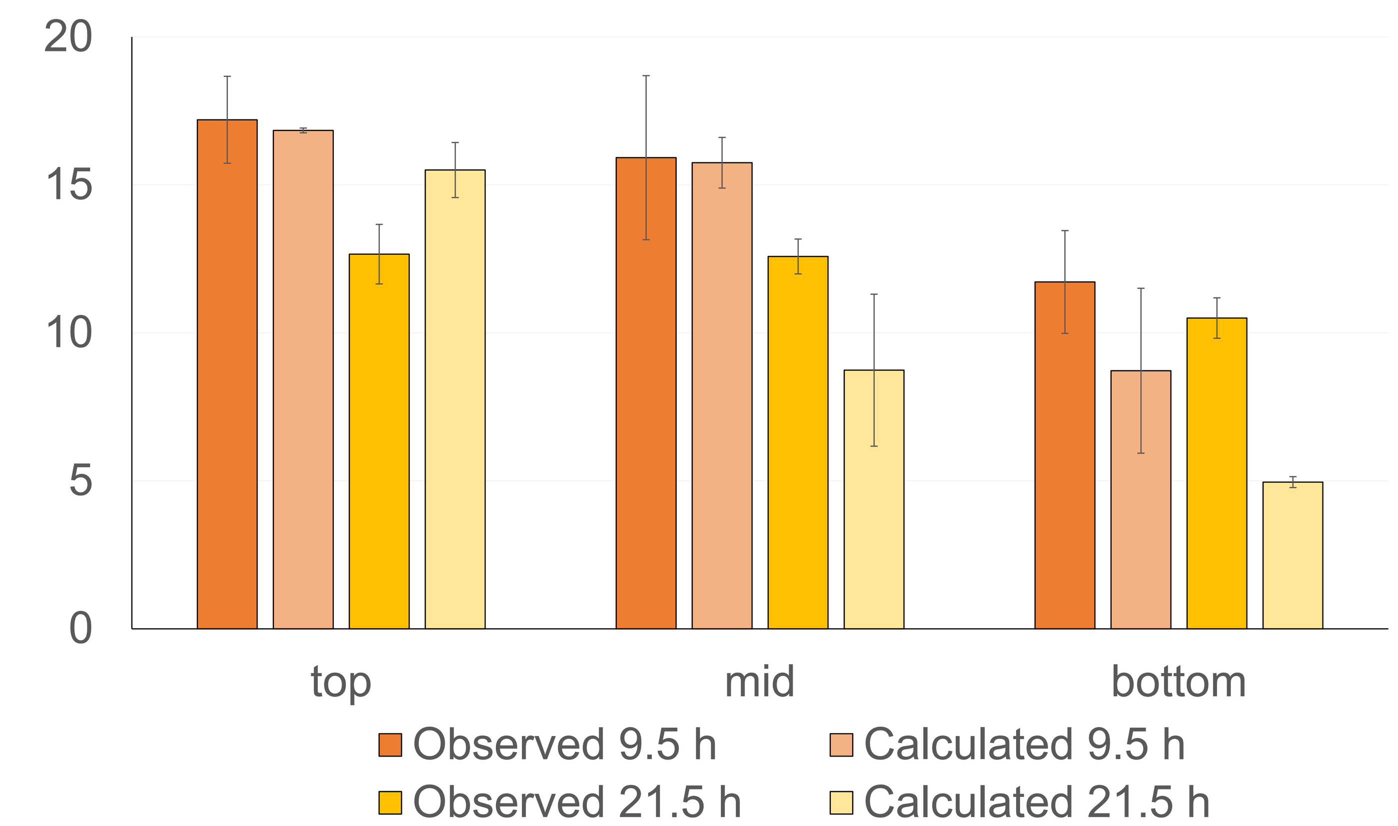

Fig 6. Moisture content profile of Rep 1 collected from center and 4 sides at 3 depths

DISCUSSION

- Diurnal temperature variation (16°F) of drying air may cause some discrepancy between modeled and actual time to dry (Figure 5). Model accuracy can be improved by using time-stepped observed temperature and relative humidity values.
- Prescence of fine in grains impacts drying and is not represented in the model constants.
- Moisture profiles reveal even drying throughout grain bed
- Energy requirement of <15 kWh for drying suggests possibility for small-scale renewable energy

FUTURE WORK

- Validate model using time-stepped observed temperature and relative humidity values (Figure 5)
- Survey renewable power options in sub-Saharan Africa for powering drying
- Evaluate an integrated storage and drying system that we have developed

REFERENCES

[1] Hodges, Buzby, & Bennett, 2011. Journal of Agricultural Science. 149(1)

[2] Gustavsson et al, 2011. FAO.

[3] Jones & Lowenberg-DeBoer, 2011. Purdue Press.

[4] Henderson, Perry, & Young, 1997. ASAE

[5] http://www.knowledgebank.irri.org/ericeproduction/VI.B.2_Sun_drying.htm

[6] Wilckle, 2018. NDSU Extension

ACKNOWLEDGEMENTS

Research support provided by state and federal funds appropriated to The Ohio State University, College of Food, Agricultural, and Environmental Sciences, Ohio Agricultural Research and Development Center; Research supported by OSU Sustainability Institute

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