Calibration of wireless moisture content probes for varying levels of rice dockage and moisture content

Kaushik Luthra1, Soraya Shafiekhani2, Griffiths G. Atungulu2* and Sammy Sadaka1,3

1Department of Biological & Agricultural Engineering, University of Arkansas, Fayetteville, AR
2Department of Food Science, University of Arkansas, Fayetteville, AR
3Division of Agriculture-University of Arkansas, Little Rock, AR

ABSTRACT

Rice drying and storage is a field of immense importance to Arkansas farmers. Arkansas produces almost half the U.S. rice each year. After harvest, 20% of the US rice is dried and stored on farm. The farmers wait for the time to maximize the profit for their produce. Therefore it is important to dry rice to 12.5% moisture content (w.b.) for safe storage and maximum shelf life. Past studies stressed on monitoring the drying process to achieve the desired rice quality and maximize the profit. Many engineering tools have emerged like temperature/humidity cables, mobile applications to determine the air flow rate, environmental parameters for the drying air and drying time to help farmers save money. However, not many tools are available that determines the accurate moisture content with ease of operation and low cost. This study uses one such wireless moisture content probes, its accuracy and precision for moisture content measurement is checked and calibrated using the standard oven method. The study showed that the probes are highly precise and have high accuracy, however, a calibration equation developed should be used to reduce the variance in the measurements. Thus, these probes can prove to be a handy grain monitoring tool for farmers due to low initial and maintenance cost, ease of operations and precise and accurate measurements.

INTRODUCTION

• Rice – most important cereal in the world and the staple of more than half the world’s population (Aritch, 2015).
• US is the fourth largest exporter of rice and Arkansas produces approximately 47% of US rice (USDA, 2016).
• Rice is dried after harvest to reduce the moisture level required for safe storage.
• Post-harvest quality control is possible if rice moisture content and temperature is monitored in storage bins continuously (Asfeli et al., 2015).
• Manual monitoring was replaced by temperature/humidity cables, later are expensive, have complex maintenance and hinders stirring mechanism in bins.
• Moisture content probes-wireless monitoring, portable, cheap ($600/bins), easy operation and maintenance, and runs on battery-solar energy.
• Any sensor used for monitoring of rice should report accurate and precise moisture content.
• Past studies have reported that rice is harvested at a wide range of initial moisture content ranging 14-26% with safe storage level of 12.5-13% wet basis.
• In rice drying and storage bins, dockage varies but remain less than 8% of total bin capacity.

OBJECTIVES

• To test the accuracy and precision of the probes for a practical range of rough rice initial moisture content and dockage levels as found in drying and storage bins.
• To find the calibration equation for the probes based on the standard values of moisture content.

MATERIALS AND METHODS

PROBE CONSTRUCTION

• Probes (Deacon Technologies, LLC.) consist of a temperature and humidity sensor; measure moisture content of grain. The sensors are shielded in 5/8" diameter aluminum pipe. The probe is 3 ft. and 5 in long, has a hexagonal base which provides solid base to mount battery powered electronic circuit (fig. 1-A & B).
• The sensors are placed inside the tapered tip at the other end from the flat hexagonal base (fig. 1-C).

• The sensors are connected from the circuit at the base through the wires, the aluminum duct prevents dust and other foreign materials.

RESULTS

• There was no effect of dockage to rough rice ratio on moisture content measurement (p = 0.5389), the dockage in the rough rice did not affect the moisture content measurement by the probes.
• There was no overall difference in probes used for the experiments (p = 0.4820), no interactions with desired moisture content and dockage to rough rice ratio.
• The probes were highly precise for a practical range of moisture content and dockage to rough rice ratio.
• Probes can be considered interchangeable in rice monitoring as there is no difference in the data measured using different probes.

RICE AND DOCKAGE PROCUREMENT

• Jupiter medium-grain rice was harvested from a farm in Northeast Arkansas.
• Harvested rice was cleaned with a dockage tester.
• Following, the cleaned rice was gently dried in the conditioned environment (80°F, 56% relative humidity) to dry rice to 12.5 % (w.b.).
• Dried rice was dehulled to prepare rice hulls used as dockage.
• Rough rice and dockage were either re-wetted using a spray bottle with the amount of water calculated using the initial and desired moisture content or dried to attain the desired moisture content.

EXPERIMENTAL DESIGN & PROCEDURE

Table 1. Experimental design.

<table>
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<tr>
<th>Exp No.</th>
<th>Initial moisture content (w.b.)</th>
<th>Dockage to rough rice ratio</th>
<th>Bulk Density (lbs/cu ft)</th>
<th>Replication/probe number</th>
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Figure 2. Experimental setup to measure the moisture content of rough rice samples using probes.

Figure 1. Moisture content probe visual description (A) Probe length wise in an upright down position (B) hexagonal base with the circuit mounted (C) temperature and moisture sensors located at the tip.

ACCURACY OF PROBES AND CALIBRATION

• The experimental value reported by the probes needs to be corrected to minimize the error through the calibration process.
• Moisture content measured by the probes was compared to the standard value as determined by ASAE Standard S552.2.
• The calibration line was plotted between the experimental/measured moisture content and the standard values (fig. 3).

Figure 3. Calibration line fitted between the experimental and standard moisture content (w.b.).

• The coefficient of determination (R2) value is 0.979 which means a good line of fit for the prediction of true moisture content.
• Strong positive correlation between the experimental and the standard value (r = 0.998), therefore the probes are highly accurate.
• However, it is advisable to use calibration equation for better accuracy.

True moisture content = 1.228*Measured moisture content -3.386

• The equation coefficients are statistically significant at 95% level of significance.
• The standard error with the slope (1.228) is ±0.02 and with the intercept (-3.386) is ±0.34.
• Thus, the calibration equation is dependable due to small standard error for equation coefficients, R2 close to 1, and a small p-value (<0.0001).

CONCLUSIONS

• The primary objective was to check the accuracy and precision of the probes.
• Medium grain rough rice samples were used for the study.
• Rice hulls was used as dockage to vary dockage to rough rice ratio (0.1, 1.1, 1.6, and 1.9), thus to check the effect of dockage on moisture content readings reported by the probes.
• The range of moisture content for the samples varied from 13 to 25 % (wet basis).
• Three probes were tested as three replicates to check the precision.
• Calibration was done using measured moisture content from the probes and the standard moisture content values (ASAE, S352.2).
• Anova analysis suggests that there is no effect of varying dockage on moisture content of rough rice.
• There was no statistical difference in the probes for moisture content measurement, thus the probes are highly precise.
• The strong correlation between measured and standard moisture content (r = 0.989) suggested good accuracy of the probes.
• The calibration equation was determined, which gives true moisture content based on measured reading, thus reducing error.
• In future, the probes can be checked for accuracy and precision for a wider range of moisture content and for different rice cultivars.

REFERENCES

• ASAE S552.2 (2008). “Moisture measurement - Ungrain and seeds,” American Society of Agricultural and Biological Engineers, St. Joseph, MI, USA.

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CONTACT

Griffiths G. Atungulu, Assistant Professor, Dept. of Food Science, University of Arkansas, Fayetteville, AR.
Email: atungulu@uark.edu Phone: 479-575-6643