H.employer, as are Oklahoma State University, Ft. Valley State University, and the University of Kentucky.

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Low-Cost Instrument to Measure Equilibrium Moisture Content of Bagged and Bulked Grain

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DOI 10.5073/jka.2018.463.009

Introduction

Storage of grain in bags is common in Africa, Asia, and many other less developed countries. Because of this an *in situ* grain bag probing method is well-suited for moisture content (MC) measurement. A low- cost meter was developed under a USAID project to reduce post-harvest loss (PHL)(Fig 1). The meter, referred to as the PHL meter, measures the MC of maize and other grains based on relative humidity (RH) and temperature (T) measurements obtained by a small digital sensor located in the tip of a tubular probe that can be inserted into bags of grain or other grain bulks (Armstrong et al., 2017). Measurements are used in equilibrium moisture content (EMC) equations programmed into the meter to predict MC. A handheld reader connected to the probe provides a user interface.

Keywords. Equilibrium moisture content, Grain storage, Maize, Moisture content, Moisture meter, Post-harvest

The PHL moisture meter was evaluated based on laboratory studies in the U.S. and field studies in Ghana. Meter readings from field studies were compared to two commercial meters, a John Deere Chek-Plus-SW08120 grain moisture tester and a DICKEY-john GAC®2100 Agri meter. The John Deere portable moisture meter is a low cost meter by developed country standards (~US$250, 2016 price); the GAC 2100 benchtop moisture meter is an approved moisture tester by the U.S. Grain Inspection, Packers and Stockyards Administration (GIPSA) and has been a highly regarded and used electronic meter. Laboratory studies indicated that the PHL moisture meter may require up to six minutes to take a measurement due to the time required by the probe tip and sensor to equilibrate to grain conditions. Methods to reduce the measurement time by measuring temporal equilibration rates were developed. These can be programmed into the reader to shorten measurement time for many conditions. The accuracy of the PHL moisture meter was comparable to the GAC 2100 moisture meter for maize below 15% MC_{wb}. Average differences showed a positive offset of 0.45% for the PHL meter relative to the GAC 2100. The PHL meter provided an effective tool to probe bulk grain and bags.

A second generation (2G) PHL meter, Fig 2, has been developed with an emphasis on reducing manufacturing cost, improving the user interface, and increasing battery life. The 2G device also incorporates Bluetooth technology which can potentially reduce the cost further by eliminating the user screen.

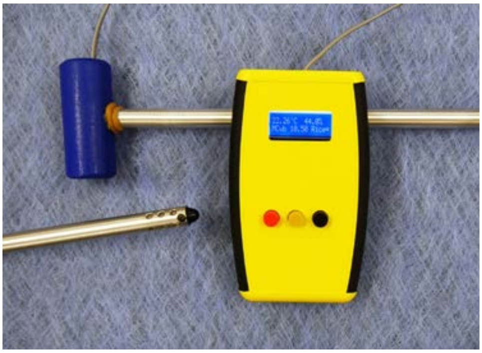

Fig. 1 PHL moisture meter based on measuring equilibrium moisture content.

Figure 2. Second generation PHL moisture meter

To expand the scope of the PHL meter, two crops, sesame and chickpea, were studied and included into the meter software by developing EMC equations specific to these crops. Both of these crops are important crops for Ethiopia as both are major exports providing small farmers and the country much revenue. There is a lack of information on fundamental equilibrium moisture content (EMC) relationships for these products which would help facilitate better monitoring and storage. For this reason EMC adsorption and desorption prediction models based on temperature (T) and relative humidity (RH) were developed for the modified Chung-Pfost and modified Henderson models for kabuli chickpea (KC), black sesame (BS), and white sesame (WS) seeds. Samples for adsorption and desorption tests were conditioned to various moisture content (MC) levels for EMC tests. Samples of approximately 500 g were placed in multiple sealed enclosures equipped with T and RH sensors, placed in an environmental chamber, and exposed to three temperatures (15, 25, and 35°C). For KC samples, the MC_{db}% ranges used for model development were 11.6-19.5% and 8.9-16.9% for adsorption and desorption, respectively; for BS, the range was 5.0-8.7% and 4.3-6.9%, respectively, and for WS, 4.2-8.7% and 3.5-7.6%, respectively. Nonlinear regression was used to determine model coefficients for the modified Henderson and modified Chung-Pfost equations. Prediction statistics for KC adsorption and desorption models yielded a SEE of 0.53 and 0.68% MC_{db}, respectively; for BS, SEE was 0.23 and 0.13%, respectively; and for WS, SEE was 0.28 and 0.25%, respectively. Model coefficients were incorporated into the PHL moisture meter.

EMC equation development for additional crops is needed which may include pulses, other grains and processed food products that span harvesting, drying, storage, conditioning, and processing operations.

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Stored Grain Protection: cases studies in Portugal

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DOI 10.5073/jka.2018.463.010

Abstract

Considering the edibility of insects' species associated with storage ecosystem, chemical control methods can be easily replaced by environmental and economically sustainable alternatives.

Use of biogenerated atmospheres is an inexpensive method that tolerates insect presence. In Portugal, during one year, hermetic bags were used to store paddy under 65-75-85% relative humidity (RH) and 14-17-24ºC temperatures. Brown rice infested with *Sitophilus zeamais* adults was placed inside the hermetic bags.

Biogenerated atmosphere was naturally produced inside the hermetic bag, at 85% RH, with low O_2 and high CO_2 contents, showing that *S. zeamais* can survive but has no progeny at 14º-17ºC, or attained 100% mortality before producing progeny at 24ºC. The most abundant fungi isolated were *Alternaria alternata* and *Epicoccum nigrum*. The results showed the importance of the RH on changes in atmospheric gas content of paddy, due to biological agents' activity.

Analysing the edibility of insects species associated with stored grain, preliminary studies were carried out to evaluate the nutritional value of immatures stages of *Tribolium castaneum*. Larvae of *T. castaneum* had a content of 21.4% protein, 9.1% lipids, 8.8% fiber, and a relevant content of eight essential amino acids and also manganese and copper. The edibility of insects must be consider given their high nutritional value, low emissions of Green House Gases (GHGs), low requirements for land, and by reducing and mitigating the need for chemical control.

Keywords: insect edibility, paddy, hermetic storage, biogenerated atmosphere, *Tribolium castaneum*, *Sitophilus zeamais*

1. Introduction

Rice in Portugal and in Europe in general is a seasonal crop. Among pest species of stored rice, *Tribolium castaneum* (Herbst, 1797) is common but *Sitophilus zeamais* Motschulsky, 1855 is considered the key pest. The most common practice to control insects of stored grain is the use of fumigants to prevent and suppress insect development. The development of resistance of these two insect species to fumigants has decades of history (Champ and Dyte, 1977), and consumer concern over the use of pesticides in food oblige the research for alternative methods of insect control in order to get food product free of pesticide residues. Also, insect protein can be a good alternative to livestock production because it is more efficient feed/food conversion, lower greenhouse gas and ammonia production, less land area needed, and has potential to be grown on organic byproducts (Huis et al., 2013). Concerning producing benzoquinone-containing defensive secretions by *T. castaneum*, IARC (International Agency for Research on Cancer) officially states that no epidemiological data are available on the carcinogenicity of 1,4-benzoquinone, which consequently is not classifiable as to its carcinogenicity to humans (IARC and WHO, 1999).