NC-213 PROGRESS REPORT FOR 2023

Title
Engineering Properties to Characterize Performance of Hermetic Storage Bag Technology

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Research Updates/Outputs
The beneficial impacts of hermetic storage bag technology on food security are well established in numerous published articles and proven by the increasing adoption of smallholder farmers in Sub-Saharan Africa and Asia. Though the demand for hermetic storage bags continues to grow, more research is needed to address existing and emerging challenges to improve and expand the supply chain of this storage technology, ensuring the continued success of hermetic storage bags in reducing grain damage and loss, preserving grain quality, and increasing profit of farmers. The research goals of this project focused on the engineering properties to characterize the performance of hermetic storage bag technology.

Deliverables and updates of studies continued in 2023

1. Characterization of Engineering Properties of Hermetic Storage Bag Technology for Standards Development – Progress continued on developing an international engineering standard, i.e., ASABE Project X657 (*Measurement and Rating of Hermetic Storage Bags – Specifications of Gas Barrier Liners)*. Maier (chair) and Ignacio (co-chair) lead the development committee for the standard project and have been facilitating monthly meetings since July 2021. The committee is drafting a document following ASABE standard development protocols and proactive coordination with the Kenya Bureau of Standards and Eastern African Grain Council. Virtual meetings are held monthly with continued active participation of committee members, including several technology suppliers. A draft standard document is anticipated to be ready by early 2024.

2. Life Cycle Assessment and Techno-Economic Analysis – This study aimed to estimate the environmental and economic impacts of hermetic storage bags as the basis for the sustainable adoption of the technology. The life cycle assessment (LCA) of six commercially available hermetic bags (AgroZ®, GrainPro, Storezo, ZeroFly®, Elite, and PICS™) from cradle-to-grave was evaluated and compared using the Sustainable Minds LCA software. The gas barrier liners were analyzed for structure and polymer composition using Confocal microscopy and Raman spectroscopy. Results showed that bag manufacturing has the highest environmental impact contribution, 84.6% to 90.8%. The carbon footprint contribution for the total service delivered of one hermetic bag ranged from 1.1 to 1.7 kg CO_2 eq. The economic benefits of using hermetic bags were calculated and compared with traditional storage bag methods. Results found that using hermetic bags exhibited the highest profit and

storage loss reduction when used for three years. A TEA dashboard is being finalized and will be available online in early 2024.

3. Performance Analysis of Biological Oxygen Scrubber used in Hermetic Storage Bag Technology – A storage experiment was conducted to quantify the effectiveness of hermetic bag storage technology in achieving and maintaining a low-oxygen environment. Two commercial bag products (AgroZ® and PICS™) were used to store maize with two initial insect infestations for 45 days. After populations were established, a biological (caged maize weevil, *S. zeamais*) and a chemical (O2frepak®, USA) oxygen scrubber were added for 105 days to evaluate efficacy in reducing oxygen content to lethal levels while maintaining grain quality. After 150 days of storage, hermetic bag liners were tested for gas barrier and mechanical properties following ASTM standard methods. Results indicate that storing maize at < 14% MC w.b. in both types of hermetic bags with 2 *S. zeamais*/kg grain initial infestation achieved oxygen concentration below 5% and 8-10% in 105 days after the biological oxygen scrubber and chemical oxygen scrubber were added, respectively. The study found that there were significant (p-value< 0.05) reductions in barrier (OTR, WVTR) and mechanical (elongation, tear strength, penetration resistance, impact failure weight) properties of the two gas barrier liner types after 150 days of storage treatment. A manuscript is being prepared for submission to a peer review journal.

4. Prediction of Oxygen Depletion in Hermetic Storage Bags – The study developed a model that predicts oxygen depletion in hermetic storage bags as a function of insect and grain kernel respiration and liner OTR. Simulation results confirmed that insect respiration dominates oxygen depletion in maize stored at safe storage moisture contents of 13-14%, while grain respiration is negligible. Bags with low OTR liners reduced oxygen below 5% to asphyxiate adult insects in maize (13-15% MC w.b.) 2 to 14 days faster than bags with high OTR liners at low initial infestation levels (2 adult *S. zeamais*/kg) stored at 27-33°C. Moreover, high initial insect infestation (10 adult *S. zeamais*/kg) reduced oxygen levels inside bags in less than 30 days, regardless of the OTR value of a gas barrier liner. A manuscript is being prepared for submission to a peer review journal. A dashboard predicting the performance of the hermetic bag storage technology is being finalized and will be available online in early 2024.

5. Analytic Hierarchy Process (AHP) to Rank Commercially Available Hermetic Storage Bag Liners – A study used engineering properties, economic benefits, and environmental impacts from previous studies to rank six commercially available hermetic bag liners using AHP. The analysis ranked the Storezo bag highest among the six hermetic bags, having a global priority value of 0.19 because of its high-performance values for barrier and mechanical properties and low carbon footprint. The Elite bag ranked lowest because of its low-performance values for OTR, dart impact failure weight, and tear strength performance. A manuscript is being prepared for submission to a peer review journal.

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Faculty, REPS, Administrative Staff Development Program (FRASDP), University of the Philippines (UP), Los Banos, The Philippines.

Deliverables

Publications

- Ignacio, M.C.C.D. 2023. Ensuring Performance of Hermetic Bag Storage Technology for Food Security and Resource Sustainability. Unpublished Ph.D. dissertation, Iowa State University, Ames, Iowa.
- Ignacio, M.C.C.D., Maier, D.E. and Vorst, K.L. (2023). Engineering properties of commercially available hermetic storage bag liners. *Journal of the ASABE* 66(3), pp. 601-615. https://doi.org/10.13031/ja.15366
- Ignacio, M.C.C.D., Rosentrater, K.A., and Maier, D.E. (2023). Estimating environmental and economic impacts of hermetic bag storage technology. *Sustainability* 15(20), 14850; https://doi.org/10.3390/su152014850