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A time-saving method for sealing Purdue Improved Crop Storage (PICS) bags

Kabita Kharel [a], Linda J. Mason [a], Scott B. Williams [b], Larry L. Murdock [a], Ibrahim B. Baoua [c], Dieudonne Baributsa [a, *]

[a] *Department of Entomology, Purdue University, West Lafayette, IN, USA*
[b] *Spensa Technologies, West Lafayette, IN, USA*
[c] *Université de Maradi, Maradi, Niger*

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A B S T R A C T

Purdue Improved Crop Storage (PICS) bags were designed to reduce grain storage losses on smallholder farms. The bag consists of three layers: two high-density polyethylene liners fitted inside a woven polypropylene bag. Recently, farmer groups, development relief programs, and government food security agencies have shown interest in PICS bags for large-scale use. PICS bags are conventionally closed by a twist-tie (TT) method, which involves twisting, folding, and tying the lip of each layer individually with a cord. This is not only time and labor intensive, but also may affect the integrity of the liners. We evaluated three new bag closure methods: i) inner liner rolled onto itself and middle liner fold-tied (IR), ii) both liners folded together and tied (FT), and iii) both liners folded and tied separately (FS), along with the conventional twist tie (TT) method. The time to close partially or fully filled 50 kg-capacity PICS bags filled with maize grain was assessed. Results showed that FT was the most time-saving method, reducing bag sealing time by >34% versus the usual TT method. The average internal oxygen levels reached <2% within a week in bags containing grain highly infested with *Sitophilus zeamais*, while it remained >5% levels for less-infested bags. In both cases, insect population growth was suppressed. Oxygen depletion rates among tying methods remained the same regardless of the closure method used. When large numbers of bags need to be closed, the time-saving FT method is a good alternative PICS sealing method over the conventional twist-tie approach.

1. Introduction

The Purdue Improved Crop Storage (PICS) program grew out of an earlier project funded by the USAID Bean/Cowpea Collaborative Research Support Program (CRSP) in 1987 to address post-harvest losses of cowpea grain on smallholder farms in West Africa. In 2007, the PICS triple-bagging technology was promoted in ten countries in West and Central Africa (Baributsa et al., 2010; Baoua et al., 2012). The PICS bag consists of two, high-density polyethylene liners fitted inside a third woven polypropylene bag. When the bag is filled with grain and sealed, metabolic activities of living organisms inside the bag deplete the available oxygen, and the oxygen reaches low levels (e.g., less than 5% by volume) within a few days (Murdock et al., 2012). The low oxygen levels suppress the development, reproduction, and the survival of insects and pathogens (Baoua et al., 2014; Tubbs et al., 2016). The PICS bags have been evaluated and shown to be effective for storage of a wide range of crops including rice, wheat, maize, sorghum, groundnut, sunflower seeds, pigeonpea, beans, and mungbean (Jones et al., 2011; Baoua et al., 2014; Baributsa, 2014; Baributsa et al., 2015; Martin et al., 2015).

The PICS technology was disseminated to smallholder farmers in West and Central Africa since 2007; and by 2012, nearly 50% of the cowpea-stored on-farm in that region was stored using PICS bags or other hermetic containers (Moussa et al., 2014). Presently, the PICS program is active in more than 25 countries in Africa and has expanded into several countries in Asia including Nepal, India, and Afghanistan (PICS newsletter, 2015). PICS technology was developed to address postharvest grain losses on smallholder farms, but overtime it has attracted the interest of large-scale users including farmers' groups, international development relief

* Corresponding author.
E-mail address: baributs@purdue.edu (D. Baributsa).

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programs, government food security agencies, and grain traders.

PICS bags used by small-scale farmers and filled with grain have conventionally been sealed-using the twist-tie method. This involves twisting the lip of each layer individually (approximately 15 inches of plastic lips remain on the top after filling 50 kg of grain into a 50 kg capacity bag), folding the lip over, and tying with a cord. While simple, the twist-tie method requires substantial effort and is time-consuming. If not done right, it may damage the inner plastic liners. The time and effort required for the twist-tie method are one of the constraints to adoption of PICS bags among potential larger-scale users, some of which may use thousands of bags. Hence, it would be useful to find a simpler and faster alternative to the conventional twist-tie closure. In the present study, we developed and evaluated alternative methods of closing PICS bag and evaluated them by (1) estimating the average time taken to close the bags, and (2) assessing the effect of each tying method on oxygen depletion rates and grain quality.

2. Materials and methods

2.1. Alternative bag closing methods

We developed three new methods of closing bags, each involved either folding without twisting or rolling the plastic liners. The closing methods were: 1) ***Inner liner Rolled (IR)*** - the inner plastic liner was rolled onto itself and the second liner folded and tied; 2) ***Folded together (FT)-*** both liners were folded together and tied; 3) ***Folded Separately (FS)***- both liners were folded and tied separately (Fig. 1). The three methods described above were compared with the conventional method of bags closure, 4) ***Twist-tied method (TT)***. In this conventional procedure currently recommended, both the inner and second plastic liners are twisted and tied separately. The twist-tie method may stress the plastic liners when the bag is used multiple times. In all of the above alternatives, the outer woven bags were twist-tied to provide firm support to the bagging system. Wear and tear on the woven bags is of less concern.

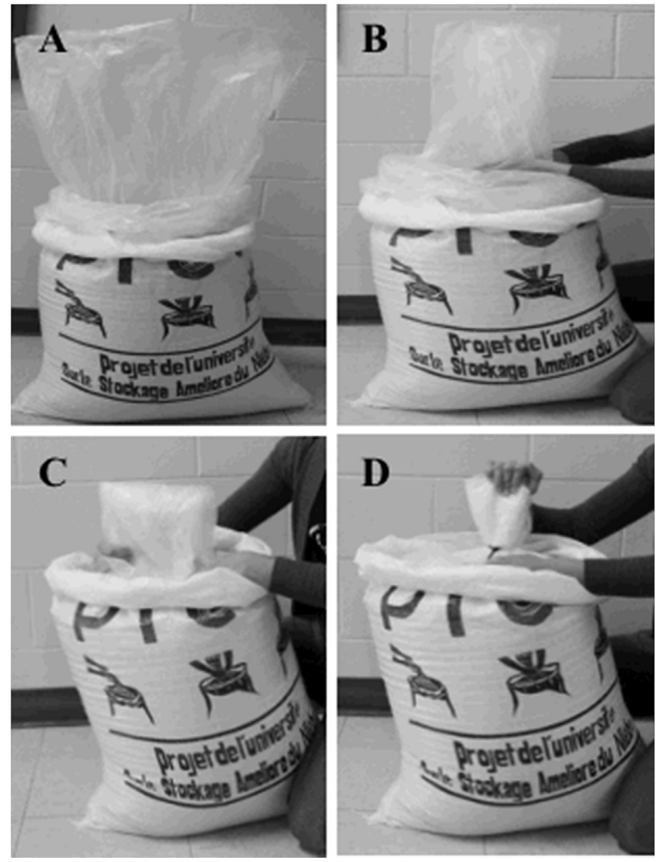

Fig. 1. Procedure for folding the liners of PICS bags: A = PICS bags with grain before sealing -inner liner, middle liner folded, and the external woven bag; B = Air is being pushed out of inner plastic liner; C = the inner liner is folded down to one-half; D = the inner liner is being tied with zip-tie.

2.2. Experimental details

Experiment 1: To determine the time taken to close bags utilizing different methods, we prepared 50 kg capacity PICS bags and filled them with 35 or 50 kg maize grain. The maize variety used in the experiment was yellow maize grain (Yellow Trucker's Favorite, Lot#502) purchased from the Wax Seed Co. (Armory, Alabama). The 35 or 50 kg filled bags represent real field bag usage where farmers partially or fully fill PICS bags. Two sets of eight people were selected to seal the 35 or 50 kg bags using the four methods (TT, IR, FT, FS). The two sets of people were selected in order to increase the number of scores as the skills and abilities might vary among people. The 35 and 50 kg bags were closed during separate weeks for better handling of the experiment. The order of sealing the bags using the four methods was randomized using a random sequence generator (Haahr, 2002). The 35 kg bags were sealed by the first group of eight people using four methods every day over six days ($N = 8*4*6 = 192$), while the 50 kg bags were closed by the second group of eight people using four methods every day over four days ($N = 8*4*4 = 128$). The time taken by each person to tie the bags was recorded for each sealing method.

Experiment 2: To assess the effect of the four sealing methods on the performance of the PICS bags, we monitored internal oxygen levels for 90 days (d) in the bags containing maize grain artificially infested with the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), one of the most important cosmopolitan pest of stored maize.

Preparation of infestation grain: Infested grain was prepared by rearing a population of *S. zeamais* in eight woven polypropylene bags filled with approximately 25 kg maize grain. Four bags were prepared by placing 15 mixed-sex *S. zeamais* adults in each bag to develop low-infested grain for a period of approximately three months. The remaining woven bags ($N = 4$) were infested with approximately 300 adult *S. zeamais* per bag to develop high-infested grain. Use of the infested grain ensured that all developmental stages of *S. zeamais* were present in the grain. On the first day of the experiment, six samples of 335 g each were taken from each of the four low-infested bags ($N = 4 \times 6 = 24$ samples). Similar samples were also drawn from the high-infested bags. The number of dead and live adults were counted as a measure of the baseline infestation for each group (Table 1).

Experiment setup: For the low-infestation study, twelve, 50 kg capacity PICS bags were filled with about 45 kg of clean maize grain that had been kept in a freezer (−18 °C) for at least 15 days to kill any field-related infestation and contamination. Then, approximately 5 kg of low-infested maize grain was mixed thoroughly in each bag and closed using either TT, IR, FT or FS method; with each treatment replicated three times. Similarly, for the high-infestation study, each bag received 5 kg high-infested maize grain and then closed using one of the four sealing methods. The low and high-infestation studies were initiated in separate weeks for data collection convenience. Uninfested controls were filled with 50 kg of clean maize grain and closed using the four methods. The bags were stored in Purdue University's insect quarantine room for three months. The temperature and percent relative humidity (r.h.) of the room during the experimental period (90 d) were recorded every