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Purdue Improved Crop Storage (PICS) bags for safe storage of groundnuts

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Groundnut seeds are prone to quality deterioration and damage due to improper storage. Hermetic storage of pods offers a novel, sustainable and ecologically safe alternative over traditional methods. In this paper, we demonstrate the efficacy of triple-layer “Purdue Improved Crop Storage (PICS)” bags, (that comprises of two inner high density polyethylene bags and one outer woven polypropylene bag), for protecting pods from quality deterioration, damage by bruchids (*Caryedon serratus*) and aflatoxin contamination (*Aspergillus flavus*). Custom made triple-layer bags were used and pods (of cv ICGV 91114) were placed @ 2 kg/bag. Over four months of storage under ambient conditions, triple-layer bags supported retention of seed weight, germinability and oil content significantly better than cloth bags. Further, under both natural and artificial infestations with *A. flavus*, seed aflatoxins levels were lower in PICS bags compared to cloth bags. Toxin accumulation in PICS bags deliberately infested with bruchids and *A. flavus* was less compared to cloth bags under similar conditions. Bruchid damage to pods was less in PICS bags versus cloth bags in all cases. Our results suggest the superiority of triple-layer PICS bags over cloth bags in protecting seed viability, seed weight and oil content while safeguarding the groundnuts from bruchids and retarding toxin accumulation.

1. Introduction

Post-harvest food losses during storage are substantial and have various causes (Kitinoja and Gorny, 1999; Musa, 1984; Tindall and Proctor, 1980). Losses in stored cereals, pulses and oilseeds depend on the crop, the storage conditions and the type of post-harvest processing. Groundnut (*Arachis hypogaea* L.) is an important cash crop, rich in oil, protein and energy value. Sizeable post-harvest losses have been reported in groundnut, particularly during storage (IITA, 2000). Molds, pests, flavor changes, and rancidity are the major negative factors that affect groundnuts during storage. Physical deterioration of pods/seeds such as shrinkage and weight loss, are also common.

Groundnuts are semi-perishables and can be stored for long periods if pod/kernel moisture, temperature and relative humidity are optimized. Any deviations from optimum conditions of storage result in losses either during storage or at milling. For bulk storage of unshelled groundnuts at farmers' level up to one year, optimal conditions are 7.5% kernel moisture, a temperature of 10 deg C and a relative humidity (RH) of 65% (Pattee and Young, 1982). In general, major storage problems for groundnut include suboptimal weather and infestation by insects, rodents and toxigenic molds. The groundnut bruchid, *Caryedon serratus* (Olivier) is the primary storage pest of unshelled groundnuts in many parts of Asia, and throughout West and Central Africa (Delobel, 1995; Singal and Toky, 1990; Okeke, 1986; Misari, 1975; Davey, 1958). Pod damage by bruchids of up to 83% has been reported under ambient conditions for unprotected groundnuts following 8–13 months of storage (Dick, 1987; Okeke, 1986; Conway, 1974). For confectionary varieties that are harvested early and dried for prolonged periods under field conditions, the bruchid poses an even greater threat when the pods are kept in the open for longer durations (Conway, 1983). Bruchids can greatly reduce germinability of seeds and the quality of oil produced from them and are considered an economically important pest of stored groundnut in India (Wightman et al., 1987). On the other hand, mold growth on pods in storage is associated with high moisture content of the groundnuts. Storage molds in groundnut result in reduced levels of germination, decreased weight, kernel discoloration, and chemical and nutritional changes in addition to mycotoxin contamination (Sauer et al.,

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1992). Coupled with this, the quality of fats in the groundnuts is reduced, thereby leading to a lower quality of commodity and market value (Pomeranz, 1992). Aflatoxin contamination in food stuffs due to *Aspergillus flavus* and *Aspergillus parasiticus* is severe in developing countries where handling and storage technologies are less than needed (Bulaong and Dharmaputra, 2002).

Current farmer practice is to use jute (gunny) and woven polypropylene bags for groundnut storage (Bulaong and Dharmaputra, 2002). Storage of groundnuts in pod form in jute bags is associated with bruchid infestation and mold growth, especially with *A. flavus*. Jute bags are highly porous and can easily absorb moisture, and so foster the rapid growth and multiplication of these aflatoxigenic molds. While polypropylene bags are non-absorptive, they tend to trap heat inside (Kennedy and Devereau, 1994). On the other hand, storage of food grains in polyethylene (PE) bags has several advantages. For example, storing wet corn for two weeks in PE bags either singly or in combination with polypropylene inhibited fungal growth and aflatoxin production (Siriacha et al., 1990). Groundnut seeds stored in PE bags retained germination for longer periods (up to 7 months) compared to jute bags (Reddy et al., 1992). Hermetic storage offers a new alternative to traditional storage of grains and pods, and is a sustainable practice. Hermetic storage works on the principle of creating airtight conditions in which oxygen levels are lowered through insect, fungal and seed respiration (Quezada et al., 2006). In the present study, we explored the use of triple layer "Purdue Improved Crop Storage (PICS)" bags, evaluating their performance and safety for short-term groundnut pod storage. These hermetic triple-layer bags consist of three bags, one inside the other, made up of an outer woven polypropylene layer for strength, and two inner bags composed of 80 micron thick high density polyethylene. They have been used with success for storing several crops including cowpea, maize, Bambara groundnut and others (Hell et al., 2010; Murdock et al., 2003; Murdock, unpublished). Our hypothesis was that the controlled atmospheric conditions that prevail in triple layer bags will delay insect infestation, reduce kernel damage, weight loss, mold growth, and rancidity while maintaining germinability. Our results suggest that PICS bags can provide a sustainable and ecologically safe approach to preserve groundnut pods at the farmers' household level.

2. Materials and methods

2.1. Storage bags and description

Triple-layer hermetic "Purdue Improved Crop Storage" (PICS) bags were used in the present study. Triple-layer bags were originally developed under the Bean/Cowpea Collaborative Research Support Program (CRSP) project in the late 1980s through funding from USAID (Murdock et al., 2003). These bags consist of two inner layers of 80 micron thick high density polyethylene bags surrounded by a third layer of woven nylon bag for strength. These bags are produced in 50 kg and 100 kg capacity sizes (Baributsa et al., 2010). For our experiments, we used reduced size bags created by cutting the original PICS bags and heat sealing them to form units that held 2 kg of groundnuts. PICS bags were obtained from Purdue University, USA but were originally produced by Lela Agro, Kano, Nigeria.

The non-airtight muslin cloth bags were procured from the local market and held 2 kg of groundnut pods. These cloth bags served as controls for comparison with triple-layer bags. Cloth bags were selected since they work on the same principle as that of jute/gunny bags in permitting air exchange with the surrounding environment. Triple-layer bags were carefully inspected for holes and sealing imperfections, to ensure that only good quality bags were used (Vales et al., 2014).

2.2. Groundnut pods

Pods of variety ICGV 91114 (released as "Anantha Jyothi" in Andhra Pradesh; "Devi" in Odisha of India) were used. Important characters of the variety are: it has predominantly 2-seeded pods (with occasional 3-or 1-seeded) with slight ridges, slight reticulation, slight beak and constriction. It has an average shelling turnover of 75% and the seeds are tan-colored. The average seed oil and protein contents are 48% and 27%, respectively.

2.3. Insect culture and maintenance

Groundnut bruchid (*C. serratus* Olivier) culture was obtained from a state agriculture university (Acharya NG Ranga Agricultural University, Hyderabad, Andhra Pradesh, India). The population was allowed to multiply under laboratory conditions at ICRISAT. Cultures were established by dispensing 200 g of unshelled groundnut into a plastic container fitted with a mesh lid. Each container was then infested with a few adult *C. serratus*. A total of ten containers were set up and all incubated at laboratory temperature that fluctuated between 26 and 30 °C and 60–75% RH. After 7 days, the original adult weevils were sieved off from the pods and the groundnuts were kept for about 10 weeks to collect emerging adults. Emergence was checked daily and new adults were kept in separate containers containing groundnut pods (Ekesi et al., 2001).

2.4. Aspergillus flavus inoculum

A highly virulent, toxigenic isolate of *A. flavus* (AF11-4) was obtained from the culture collection of the Groundnut Pathology Laboratory at ICRISAT, Patancheru, India. The isolate was originally isolated from freshly harvested groundnut pods at ICRISAT. The culture was maintained on potato dextrose agar (PDA) slants at ambient temperature. Inoculum of AF 11-4 was produced on PDA by transferring 3 mm core plugs aseptically on to PDA petri-dishes. Dishes were sealed with parafilm and incubated at room temperatures. Two weeks later, *A. flavus* cultures profusely sporulated on PDA and conidia were harvested in sterile distilled water (SDW) and adjusted to a concentration of 5×10^5 CFU ml^{-1}.

2.5. Experimental design and procedure

The experiment was conducted at ICRISAT, Patancheru (Andhra Pradesh, India) in a storage room at ambient temperature. The experiment consisted of six treatments with three replications. The treatments were: 1) Triple-layer bags with pods infested with *A. flavus*; 2) Cloth bags with pods infested with *A. flavus*; 3) Triple-layer bags with pods infested with *A. flavus* + Bruchids; 4) Cloth bags with pods infested with *A. flavus* + Bruchids; 5) Triple-layer bags with pods alone; and 6) Cloth bags with pods alone (resembling farmers' practice of storing in jute bags). Two kg of pods (kernel moisture of 8%) were added uniformly to the test bags. Pods were fumigated using standard procedures to prevent any field contamination from getting carried over to the experimental site. *A. flavus* inoculum (@ 3 ml) was spray inoculated onto pods in treatments wherever applicable prior to placing them in bags. Approximately 200 g of bruchid-infested pods were added to the selected treatments, ensuring approximately ten pairs of adult bruchids were added to the pods. The bruchid infested pods were gently and uniformly mixed with the remaining pods before heat sealing the two inner layers independently. Storage was for four months. Altogether, there were 18 bags in the experiment, and the