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AN EVALUATION OF THE PERMEABILITY TO PHOSPHINE THROUGH DIFFERENT POLYMERS USED FOR THE BAG STORAGE OF GRAIN

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ABSTRACT

Today, storage of agricultural products, and their infestation by stored-product pests poses an outstanding problem after harvesting. Whether storage is in bulk or in sacks a usual method to control stored-product pests is by fumigation with phosphine (PH_3).

Different materials such as sheeted polymers are used for packaging of agricultural products and the permeability of these polymers to PH_3 can affect results of fumigation. In this study aimed at evaluating bag storage where permeability to PH_3 is desirable, bags made from transparent and flexible polymers including: polypropylene of 50 and 100μm thickness, polyethylene of 75,125 and 150μm thickness, and polyvenylchloride (PVC) of 80,150 and 250μm thickness were filled with wheat. Kernels infested by the Angoumois grain moth (*Sitotroga cerealella* Ol.) were placed inside the packages manufactured from the above-mentioned polymers. The bags were then placed in air-tight tanks. The permeabilities of the polymers to PH_3 were evaluated by calculating percentage insect mortality after fumigation in the tanks with aluminum phosphide tablets, that emit PH_3 when exposed to air.

The results showed that the best polymer for use as a liner for jute bags, is polypropylene of 100μm thickness at the most.

INTRODUCTION

Fumigation is a common method to control pests of packaged products in storage. Frequently products are packed in jute bags or plastic bags. Since penetration of the fumigant into the bags is a critical factor it is evident that fumigations under tarps or plastic sheeting should take into account the properties of the packaging materials. Phosphine is the most frequently used fumigant, because of its simple application. To control the insect pests by phosphine, the gas must penetrate from the air-space beneath the tarps into the bags containing the stored product. An imperfect fumigation increases the risk of development of resistance by the insects. Packaging of agricultural products such as wheat, barley, and pulses in jute bags allows the insect pests to move freely into and out of the bags and results in dispersal of the infestation. The fumigation of products packed in woven polypropylene bags in an inappropriate manner can cause serious damage to the products. Furthermore, by incomplete fumigation, quarantine insect pests can easily enter countries within packaged products. In certain cases such as dried fruit, which are packed in plastic bags, entrance of fumigant into the bags is critical in controlling stored-product insect pests that originate in the field. Whether products are grains or dried fruit, by packaging them within a film of suitable polymer we should achieve two main objectives; a suitable polymer will allow the fumigant gas to enter the bags and will also prevent insects outside the bags from entering them. If we use a suitable disinfestation method before packing we will prevent cross-infestation during the storage period. However we must be aware of the abilities of different insect species to penetrate the bags.

In stores where products are kept in jute bags, infestation is probable even if the products have not been infested at the start of storage due to the ease of penetration of stored-product insects into these bags. The use of a polymer liner inside the jute bags will greatly reduce this possibility. The common polymers for packaging of food-stuffs are polypropylene, polyethylene, and polyvinyl chloride (PVC). Table 1 shows important properties of these polymers.

Researchers in this field have many recommendations: Hall (1970) and Stout (1983) consider that that plastic sheeting (polyethylene and polyvinyl chloride) less than 0.1 mm thick is permeable to phosphine. They propose that to preserve grain in bags with a polyethylene liner, one phostoxin pellet (0.6 gr.) should be inserted into each bag. Appert (1987) claims that opaque polyethylene or polypropylene 300 μm plastic bags are suitable for conserving fumigated grain seeds. He believes that polyethylene films of 150-200μm thickness are suitable for fumigation. Iqbal (1993) showed that polyethylene 200μm sheeting is suitable to retain sufficient concentration of posphine to kill *Tribolium confusum*. Valentini *et al.* (1997) reported that polyethylene and polyvinyl chloride 210μm thick prevents phosphine exchange. Also according to ACIAR (1989) 200 μm films of polyvinyl chloride and polyethylene have a low permeability to methyl bromide. Research into the penetrating powers of stored-product insects through bags shows that *Prostephanus truncatus* is able to penetrate polyethylene 30-300μm thick and *Sitophilus oryzae* is able to penetrate polyethylene 30 μm thick in 50 days (Fleurat-Lessard, 1990). Another research shows that polyethylene film less than 40μm thick is penetrated by insects and recommends the use of polyethylene films thicker than 65μm for packaging stored products (Proctor and Ashman, 1972).

MATERIALS AND METHODS

The polymers used

In this study we compared three kinds of transparent and flexible polymers: polyethylene of three different thicknesses - 75, 125 and 150μm-, polypropylene of two different thicknesses- 50 and 100μm-, and polyvinyl chloride of three different thicknesses- 80, 150 and 250 μm. We prepared 40 cm x 60 cm bags for packing 10 kg wheat. We used 48 bags (each thickness of each polymer replicated 5 times accompanied by a non-treated control bag).. Test insects consisted of eggs, larvae and adults of *Sitotroga cerealella* Ol. (Lep.; Gelechidae) as stored pests. We placed insects of each developmental stage separately inside each bag.

TABLE 1

Some properties of different polymers used for packaging of food stuffs

Properties		Polyethylene	Polypropylene	Polyvinyl Chloride
Max. heat tolerance(°C)		82-93	132-149	66-93
Min. heat tolerance(°C)		-57	-18	-46 to -29
Sun light resistance		moderate to good	moderate	good
Gas transmission	O_2	500	160	8-160
(mm/100 cm^2 in 24h	N_2	180	20	1-70
and 25°C)	CO_2	2700	540	20-1900
H_2O Absorption %		<0.01	<0.05	0
H_2O Vapor transmission (g/100 cm^2 in 24h & 37.8°C & R.H. 90%)		1-1.5	0.25	4-10

The test insects

Egg stage: For this stage cylindrical plexiglas containers (6 cm diameter, 5 cm long) were prepared, with a detachable lid and 1.5 cm diameter holes in the lid and base. To permit entry of air fine lace-mesh was glued over the lid and base of the containers. The containers containing 2-3 day-old eggs were placed at the center of the wheat bags, and then the openings of the bags were sealed with a hand iron. For fumigation of the bags two air-tight tanks were used with a volume of 0.7 m^3 per tank. Inside each tank we placed 20 bags. The 8 remaining bags (one for each thickness) were kept under normal environmental conditions without fumigation. The bags of different thicknesses were placed inside the tanks in random order. According to FAO recommendations (Phostoxin® at 1.5g/m^3) we placed a 3g tablet of Phostoxin in each tank. A Phostoxin tablet of 3g emits 1g phosphine resulting in 1g phosphine per tank. The laboratory temperature was 20 ºC. After 72 hours the tanks were opened and the containers were removed from the bags. We held the experimental and control containers of eggs in an incubator (29 ± 1 ºC, 75 ± 5% r.h.) for 10 days According to Sedlacek *et al*., (2001). this is a sufficient period to allow for hatching of the eggs. The dead and hatched eggs were then counted under a stereomicroscope. We counted the number of dead eggs in both the experimental and control units and calculated the corrected percentage mortality upon which we carried out our statistical analysis.

Larva stage: The experimental procedure for larvae was similar to that of the egg stage. For this stage 40 g wheat heavily infested with larvae were placed into each cylindrical container. After 72 hours fumigation the containers were removed and 100 grains were chosen randomly from each container. The chosen grains of wheat were inspected by stereomicroscope and the percentage mortality was registered.

Adult stage: The process was similar to the previous stages. In each container 25 2 to 3 day-old adults were released. After 72 hours fumigation the containers were removed from the bags and after aeration the live and dead insects were counted. Mortality in the control container was used to correct the percentage mortality of the fumigated adults according to Abbott's equation.

Statistical analysis was carried out based on Randomized Complete Design (RCD) and the means were compared with Duncan's means test.

RESULTS

Egg stage

Analysis of variance showed significant differences (P<0.01) between the polymers. Classification of mean percentage mortalities located the 250μm polyvinyl chloride in group B and the other polymers in group A with the 250μm polyvinyl chloride showing a lower permeability to phosphine than the other polymers (Table 2).

TABLE 2

Duncan’s test grouping for tested polymers according to mean *S. cerealella* egg mortality in bags after fumigation

Polymers	**Means of mortality%**	**Groups**
Polyethylene - 75μm	100	A
Polyethylene- 125μm	100	A
Polyethylene- 150 μm	100	A
Polyvinyl chloride- 80 μm	100	A
Polyvinyl chloride- 150 μm	100	A
Polyvinyl chloride- 250 μm	94.28	B
Polypropylene- 50 μm	100	A
Polypropylene- 100 μm	100	A

Larval stage

Again, analysis of variance showed significant differences ($P<0.01$) between polymers. As shown in table 3 250μm polyvinyl chloride is located in group B and other the polymers in group A.

TABLE 3

Duncan's test grouping for tested polymers according to mean *S. cerealella* larval mortality in bags after fumigation

Polymers	Means of mortality%	Groups
Polyethylene - 75μm	100	A
Polyethylene- 125μm	100	A
Polyethylene- 150 μm	100	A
Polyvinyl chloride- 80 μm	100	A
Polyvinyl chloride- 150 μm	100	A
Polyvinyl chloride- 250 μm	89	B
Polypropylene- 50 μm	100	A
Polypropylene- 100 μm	100	A

Adult stage

Analysis of variance (Table 4) again showed that the 250 μm PVC was significantly different from the other polymers with regard to phosphine permeability.

TABLE 4

Duncan's test grouping for tested polymers according to mean *S. cerealella* adult mortality in bags after fumigation

Polymers	Means of mortality%	Groups
Polyethylene - 75μm	100	A
Polyethylene- 125μm	100	A
Polyethylene- 150 μm	100	A
Polyvinyl chloride- 80 μm	100	A
Polyvinyl chloride- 150 μm	100	A
Polyvinyl chloride- 250 μm	89	B
Polypropylene- 50 μm	100	A
Polypropylene- 100 μm	100	A

DISCUSSION

The results of this study should be viewed from two aspects: 1- the use of polymer films as inner liners of jute bags to enable in-bag fumigation and minimize cross-infestation; 2-the use of polymers as gas-proof covers to fumigate goods in stacks or bulk. Concerning the first case which was the main objective of this research, the results showed that among the different tested polymers including polyethylene, polypropylene, and polyvinyl chloride, there were no significant differences between them with regard to phosphine permeability. Phosphine penetrated through all the three polymers of less than 250μm thick. The results of this study are in agreement with findings of previous studies such as Hall and Stout, (1970) ,Appert (1987), Valentini *et al*. (1997), Iqbal (1993) and ACIAR (1989). However when these polymers are used as liners for jute bags, the ability of insects to penetrate the polymers takes on importance. Highland (1981) believes that in this case polypropylene has a higher resistance than polyethylene (with equal thickness). Bowditch (1997) undertook a study to evaluate the barrier qualities of 2 flexible transparent films of the same thickness against 1st- and 5th- instar larvae of *Ephestia cautel*la Walker and *Plodia interpunctella* (Hübner), and *Tribolium confusum* Jacquelin du Val adults. He found that the polypropylene film tested was resistant to penetration by 1st-instar larvae of *E. cautella*. Moreover Fleurat-Lessard (1990) reported that *Prostephanus truncates* is able to penetrate 30-300μm polyethylene films.

With regard to the second aspect: fumigation of different products is frequently carried out under nylon covers, where it is important for the polymer to be gas-proof and retain enough concentration of the fumigant inside. According to the results of this research and some other studies a polymer cover of 250μm thick is the most suitable one for this objective. Such covers also reduce the danger of cross-infestation. It is evident that polypropylene liners of less than 100μm thickness are suitable as inner liners of jute bags to allow the fumigant to enter the bags (because of their high permeability) and also to prevent insect pests from entering the bags, thus protecting the products from reinfestation. In contrast a suitable polymer for fumigation under cover is the 250μm thick polymer. More research needs to be undertaken in this area before reliable and comprehensive information can be provided to the food industry.

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