Journal of Agricultural Technology 2010 Vol. 6(4): 747-759
Available online http://www.ijat-rmutto.com
ISSN 1686-9141

The study on polymers permeability for foodstuffs packaging by some serious species of stored pest insects and phosphine gas

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Allahvaisi, S., Pourmirza, A.A. and Safaralizade, M.H. (2010). The study on polymers permeability for foodstuffs packaging by some serious species of stored pest insects and phosphine gas. Journal of Agricultural Technology 6(4): 747-759.

The polymer could inhibit insect penetration was determined and fumigated with phosphine (PH3) that carried out to prevent the infestation in storages. The ability of penetration and the percentage of contamination was investigated by eleven important stored product pest insects using four conventional flexible polymers (polyethylene, cellophane and polypropylene) at two thickness (16.5 and 29 µm), which are used for packing of agricultural products. Permeability of these polymeric pouches was tested for insect pests in two conditions viz, in the presence and absence of food. Polypropylene was the best for packaging that tested for permeability to fumigants. Infested foodstuffs with developmental stages of the most serious test pests (*Plodia interpunctella*) were placed inside these packages and then placed in air-tight tanks. The permeability of the packaging polymer to PH_3 was evaluated by calculating percentage insect mortality after fumigation in the tanks with aluminum phosphide tablets, which emit PH_3 when exposed to air. There was a significant difference ($p \leq 0.05$) in the penetration of used polymers by insects. Polyethylene packages with thickness of 16.5 µm were the worst polymer as its employing led to complete infestation of the products. The results showed that the polypropylene polymer was the best permeability to fumigants and could be used for stored foodstuffs packagings with thickness of 29 µm.

Key words: penetration, polymer, thickness, stored-pests, packaging, phosphine gas

Introduction

Storage is a usual method to maintain products for long times. This is carried out in sacks to control stored-product pests. These sacks are made of different materials such as sheeted polymers which are used for packaging the agricultural products in order to prevention of entrance of pests. Consumer-size food packages vary considerably in their resistance to insects. Some times the contamination was created by entrance of one infested package. When neglected,

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such an infestation will serve as a source of infestation for other commodities in the storage area. Fumigation is a common method to control pests of packaged products in storage. Phosphine is the most frequently used fumigant because of its simple application. To control the insect pests by phosphine, the plastic sheeting should be permeable to gases as the gas penetrates from the air-space beneath the tarps into the bags containing the stored product. Polymers with various thicknesses have different permeability to fumigants. Some researches in this field is present (Hall, 1970; Stout, 1983; Appert, 1987; Iqbal, 1993; Valentini, 1997; ACIAR, 1989). An imperfect fumigation increases the risk of development of resistance by the insects. The polymer thickness and manner of placing packages in storage should be corrected to prevent serious damage in 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 that should achieve two main objectives; a suitable polymer would prevent insects outside the bags from entering them and also allow the fumigant gas to enter the bags to ruin the probable contamination in them. If the use a suitable disinfestations method before packing we will prevent cross-infestation during the storage period. However it must aware of the abilities of different insect species to penetrate the bags. Little information is available on developmental stages behavior of insects at the time of feeding and inflicting loss to foodstuffs. Insect pests can gain access to packaged foods either by entering through existing holes (invaders) or by boring through packaging materials (penetrators) (Highland, 1984). The ability of insect life stages to penetration packaging polymers varies with emphasis is given to those life stages and polymer types (Bowditch, 1997). Recently, some research to have exposed test different polymers to penetration of insects in one thickness (Cline, 1978; Bowditch, 1997) but, none has been done to study effect of polymer's thickness on disinfestations. The project was to investigate these properties on permeability of common flexible packaging polymers with different thickness to stored pest insects and phosphine gas.

Materials and methods

The used polymers

In this study, the permeability of four kinds of transparent and flexible polymers was prepared against stored-insect pests and phosphine gas as the same polymers for foodstuffs packaging, including: Polyethylene (PE), Polypropylene (PP), Polyvinylchloride (PVC) and Cellophane. These polymers were prepared in two thicknesses of 16.5 µm and 29 µm. some important properties of these polymers was shown in Table 1 (Odian, 2004). These flexible packaging polymers were cut into 15×22-cm pieces with the aid of a template and after that cutting of these polymeric sheets. The 8×10-cm pouches were prepared by the sealed polymeric pieces the aid of a press plastic machine for packaging 15 g foodstuffs similar of wheat grains, flour and nuts. These pouches were completely without any pores.

Table 1. Some properties of used different polymers for packaging foodstuffs.

Properties		Polyethylene	Polypropylene	Polyvinyl chloride	Cellophane
Max. heat tolerance(°C)		82-93	132-149	66-93	90-140
Min. heat tolerance(°C)		-57	-18	-46 to -29	-77
Sun light resistance		moderate to	moderate	good	good
Gas transmission (mm/100 cm2 in 24h and 25°C)	O_2	500	160	8-160	122-480
	N_2	180	20	1-70	33-90
	CO_2	2700	540	20-1900	2220
H2O Absorption %		<0.01	<0.05	0	<0.03
H2O Vapor transmission (g/100 cm2 in 24h & 37.8°C & R.H. 90%)		1-1.5	0.25	4-10	0.2-1

The tested insects

The insects used in these tests were obtained from cultures maintained in laboratory. Two developmental stages (larvae and adult) of the following insect species were used: *Tribolium castaneum* Herbst (Col.), *Sitophilus granarius* L., *Oryzaephilus surinamensis* L. (Col.), *Rhyzopertha dominica* F. (Col.), *Callosobruchus maculates* F. (Col.), *Trogoderme grararium* Ev. (Col.), *Lasioderme serricorne* F. (Col.), *Sitotroga crealella* Olivieri (Lep.), *Batrachedra amydraula* Meyr. (Lep.), *Plodia interpunctella* Hub. (Lep.) and *Ephestia kuehniella* Zeller (Lep.). Tested larvae were first and last instar active larvae. The direct observation of larvae's molting number was determined the different ages of larvae. The adult insects selected from the same as age group from the viewpoint of physiological (cohort) was used.

The test insect penetration

The tested insects were divided into two states (without and with food) to study on packaging polymers. In first state, the insects with none food during test released around the pouches which were contained foodstuffs. This experiment was determined various species on abilities of stored-product insects in different life stages for penetration. In second state, the insects with very little foodstuffs were placed inside packages in order to determine of dispersion ability of the species in stores and contaminated creation on other packages. The prepared packages were without any pores and each one of them with one thickness placed in a ca. 150 cc container vertically. The 20-tested insects (larvae or adult insect) in two mentioned states for examination a thickness of each polymer was applied as the work of Bowditch (1997). Each container was capped with a filter fine lace-mesh lid to confine the potential escape and to keep out foreign objects. Then, the containers incubated at 27±1°C, 65±5% RH and a 12L: 12D h cycle. Each treatment replicated 5 times. The packages were extracted from the jars and examined for penetrations daily on the basis life cycle of species of insect and suffering ability due to the lack of food. The last recorded penetration was for larvae *T. granarium* at 97 days. When a puncture created on or one insect observed inside packaging, it would be as begin of penetration and data recorded. Some packages were removed from the results from following marks: (1) the insects could escape through their small gaps where edges of the packages was not sealed completely, (2) insects were died before entrance them, (3) the last age larvae that pupated on package before finishing of trail period and (4) the first age larvae were entried to next ages. Insect's penetrations in 0.5 cm of bottom or top of packages were more than their number in middle.

The test Co_2 gas penetration

For this stage, the pouches with size 40×50-m from used polymers was prepared. These bags were filled with Co2 gas and placed in laboratory conditions (25± 1 C, 55 ± 5% .H.). The existence balance gas after 24 hours was measured and therefore determinated the average of percentage polymers permeability to fumigant. Each treatment was replicated 10 times.

The test phosphine penetration

Egg stage: After determining the best polymer for packaging that would be resulted both properties (permeable to gas and not insect pests), in this stage little infested foodstuffs with 2-3 day-old eggs of *P. interpunctella* was placed into mentioned polymer and then the openings of the bags were sealed with a hand iron. The packages containing were placed at the center of air-tight tanks with a volume of 31 m3 per tank. Inside each tank, placed 10 packages. These tests carried out in the tanks empty space. One bag of each thickness was 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 1g/m3 for closed spaces) the doses from 3 g tablet of Phostoxin in each tank was used. A Phostoxin tablet of 3 g emits 1g phosphine resulting in 1g phosphine per tank. The laboratory temperature was 20ºC. After 72 hours, the tanks were opened and the packages were removed from the tanks. The treatment and control bags of eggs were placed in an incubator (29 ± 1ºC, 75 ± 5% R.H.) for 10 days. This is a sufficient period to allow for hatching of the eggs. The dead and hatched eggs were then counted under a stereomicroscope. The number of dead eggs in both the experiment and control units was counted with regard to the percentage mortality.

Larva stage: The experimental procedure for larvae was similar to that of the egg stage. For this stage, 5 g foodstuff heavily infested with larvae was placed into each polymer package in cylindrical container. After 72 hours fumigation the containers were removed and then the packagings containing were inspected by stereomicroscope and the percentage mortality was registered.

Adult stage: The process was similar to the previous stages. In each packaging containing 2 to 3 day-old adults were released. After 72 hours fumigation the packages were removed from the tanks and after aeration the live and dead insects were counted.

Statistical analysis

In these tests, each thickness of each polymer was as one treatment. Statistical analysis of data carried out with MSTATC and EXCEL software and Randomized Complete Block Design (RCBD) and the means were compared with Duncan's Multiple Range Test. T-test. The pest mortalities against phosphine fumigant would be computed by probit program in SPSS10 software.

Results

The test insect penetration

The average of the penetration percentage of species of insects without food or with food on various packaging polymers was indicated in Table 2 and

3. The penetration percentage of insect's life stage was different as last age larvae penetration was more than first age larvae. Struggles of adults and larvae of insects for the most penetration in the least struggled times was observed. Analysis of variance showed significant differences (*P* ≤0.05) between the polymers for being permeability to pests. From four kinds of used polymers, polypropylene was the least permeability against pest insects as some pests did not able to penetrate this polymer and if penetration was occurring, it was very low. There was a significant difference between permeability of thickness of 16.5 and 29 µm and consequently, contamination rates of products inside the polymers with thickness of 29 µm were less than 16.5 µm (*P* ≤0.05). More of species of insect's penetration occurred in 16.5 µm thickness of polymers at less than 48 hours but permeability of polymers with 29 µm thickness was slowly occurred. These results showed permeability percentage of some packaging polymers against insects is related to bilateral effects of both type and thickness. All tested insects without any food were penetrated more than with food. The penetration percentage of one of the tested pest insects without food in two thicknesses of packaging polymers in difference times and ages was shown in Fig. 1.

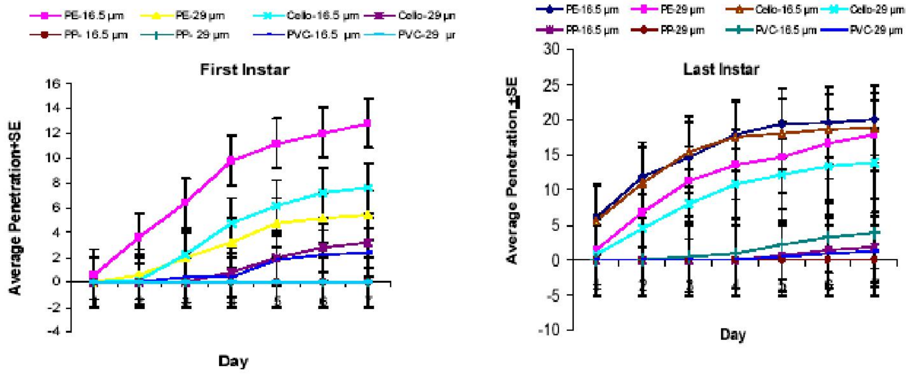


Fig. 1. Number of first and last instars larvae of *S. cerealella* that penetrated to the tested polymeric pouches with 2 thick in lack of food conditions during 7-d period (PE=polyethylene, PP=polypropylene and Cello=cellophane).

It was found that penetration percentage at first days is very quick but whatever number of the insects into packages would be increased and insect penetration percentage decreased. It was interested that number of insects after the maximum penetration dwindled in next days and some exited from the packages for the reason of crowded. Larvae and adult insects created holes with various diameters which were of 0.2 mm until 1.6 mm. The holes were usually characterized by excess frass and webbing from larvae for pupating and moving and also by fragmented pieces of polymer around the holes. Those last age larvae that do not able to penetrate and changed to pupa on packages. Hungriness was one of the factors that caused changing of the larvae to pupa would be faster than common time. Larvae of some species such as *O. surinamensis* were not able to penetrate the polymers while their adults did. In case of some other species such as *L. serricorne,* the larvae were penetrated than adults. The adult insects were very active such as *T. castaneum*, observed that adult was more penetrated than larvae. Larvae of insects such as *T. granarium* were very active and adults did not indicate any penetration. Adults and larvae of all species showed a much greater inclination to penetrate when released without food on polymer packages. According to results, the penetration ability of insects was various based on species and life stage of insects and kind of polymer and its thickness. Therefore, polypropylene with 29 µm thickness showed lower permeability.

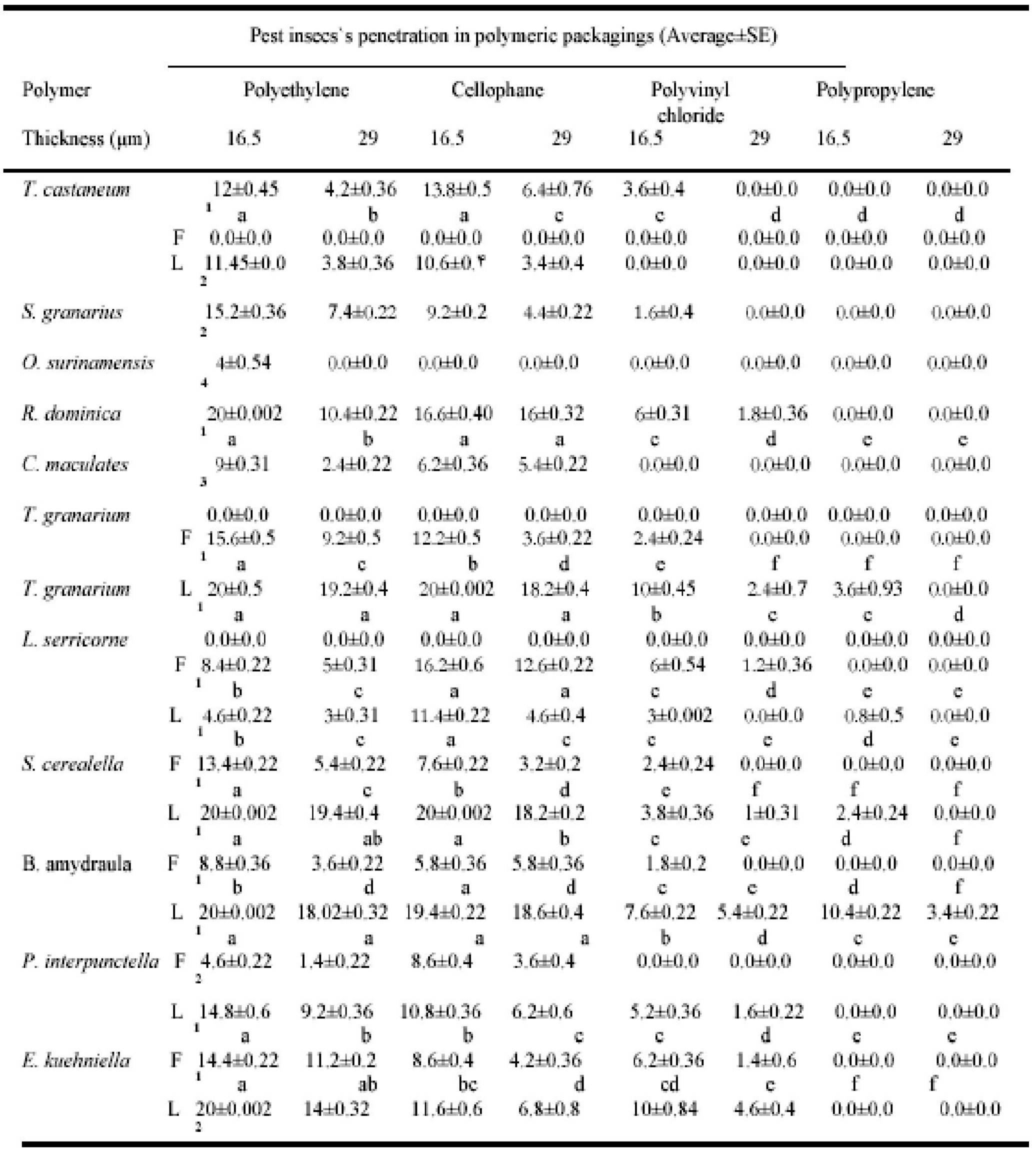
The test Co$_2$ gas penetration

Analysis of variance showed significant differences ($P<0.05$) between the polymers. Classification of mean percentage permeability located the 29 µm polyvinyl chloride in group f and the other polymers had permeability well. Polyvinyl chloride is showing a lower permeability to CO_2 gas than the other polymers (Table 4). These results confirm that 16.5 and 29µm polypropylene with placing in group c and e respectively have suitable permeability to the gas.

The test phosphine penetration

Comparison of mean percentage mortalities of the developmental stages of the tested pest was shown in the Table 5. These LC50 and LC95 determinate the fumigant doses in the storages of maintaining foodstuffs packagings.

Table 2. Average permeability percentage of different polymers to major stored-product insects in state of without food.



		Pest insecs's penetration in polymeric packagings (Average±SE)							
Polymer		Polyethylene		Cellophane		Polyvinyl chloride		Polypropylene	
Thickness (μm)		16.5	29	16.5	29	16.5	29	16.5	29
T. castaneum		12±0.45	4.2±0.36	13.8±0.5	6.4±0.76	3.6±0.4	0.0±0.0	0.0±0.0	0.0±0.0
	1	a	b	a	c	c	d	d	d
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	11.45±0.0	3.8±0.36	10.6±0.۴	3.4±0.4	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	2								
S. granarius		15.2±0.36	7.4±0.22	9.2±0.2	4.4±0.22	1.6±0.4	0.0±0.0	0.0±0.0	0.0±0.0
	2								
O. surinamensis		4±0.54	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	4								
R. dominica		20±0.002	10.4±0.22	16.6±0.40	16±0.32	6±0.31	1.8±0.36	0.0±0.0	0.0±0.0
	1	a	b	a	a	c	d	e	e
C. maculates		9±0.31	2.4±0.22	6.2±0.36	5.4±0.22	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	3								
T. granarium		0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	F	15.6±0.5	9.2±0.5	12.2±0.5	3.6±0.22	2.4±0.24	0.0±0.0	0.0±0.0	0.0±0.0
	1	a	c	b	d	e	f	f	f
T. granarium	L	20±0.5	19.2±0.4	20±0.002	18.2±0.4	10±0.45	2.4±0.7	3.6±0.93	0.0±0.0
	1	a	a	a	a	b	c	c	d
L. serricorne		0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	F	8.4±0.22	5±0.31	16.2±0.6	12.6±0.22	6±0.54	1.2±0.36	0.0±0.0	0.0±0.0
	1	b	c	a	a	c	d	e	e
	L	4.6±0.22	3±0.31	11.4±0.22	4.6±0.4	3±0.002	0.0±0.0	0.8±0.5	0.0±0.0
	1	b	c	a	c	c	e	d	e
S. cerealella	F	13.4±0.22	5.4±0.22	7.6±0.22	3.2±0.2	2.4±0.24	0.0±0.0	0.0±0.0	0.0±0.0
	1	a	c	b	d	e	f	f	f
	L	20±0.002	19.4±0.4	20±0.002	18.2±0.2	3.8±0.36	1±0.31	2.4±0.24	0.0±0.0
	1	a	ab	a	b	c	e	d	f
B. amydraula	F	8.8±0.36	3.6±0.22	5.8±0.36	5.8±0.36	1.8±0.2	0.0±0.0	0.0±0.0	0.0±0.0
	1	b	d	a	d	c	e	d	f
	L	20±0.002	18.02±0.32	19.4±0.22	18.6±0.4	7.6±0.22	5.4±0.22	10.4±0.22	3.4±0.22
	1	a	a	a	a	b	d	c	e
P. interpunctella	F	4.6±0.22	1.4±0.22	8.6±0.4	3.6±0.4	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	2								
	L	14.8±0.6	9.2±0.36	10.8±0.36	6.2±0.6	5.2±0.36	1.6±0.22	0.0±0.0	0.0±0.0
	1	a	b	b	c	c	d	e	e
E. kuehniella	F	14.4±0.22	11.2±0.2	8.6±0.4	4.2±0.36	6.2±0.36	1.4±0.6	0.0±0.0	0.0±0.0
	1	a	ab	bc	d	cd	e	f	f
	L	20±0.002	14±0.32	11.6±0.6	6.8±0.8	10±0.84	4.6±0.4	0.0±0.0	0.0±0.0
	2								

(1: Being Bilateral Effect and Duncan's Multiple Range Test Grouping , 2: Disbilateral Effect of Polymer and Thickness, F : First Instar Larvae, L: Last Instar Larvae, 3: Being Bilateral Effect , 4: T-value)

Table 3. Average permeability percentage of different polymers to major stored-product insects in state of without food.

		Pest insecs's penetration in polymeric packagings (Average±SE)							
Polymer		Polyethylene		Cellophane		Polyvinyl chloride		Polypropylene	
Thickness (μm)		16.5	29	16.5	29	16.5	29	16.5	29
T. castaneum		12.6±0.4 [2]	3.2±0.36	13.4±0.49	4.4±0.49	2.2±0.67	0.0±0.0	0.0±0.0	0.0±0.0
	F	0.0±0.0 [2]	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	6.2±0.36 [2]	0.0±0.0	5.4±1.34	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
S. granarius		12±0.31 [3]	5±0.31	7.6±0.18	3.2±0.18	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
O. surinamensis		3.8±0.35 [4]	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
R. dominica		16.8±0.2 [1] a	7.2±0.2 d	13.2±0.4 b	8.2±0.2 c	3.6±0.4 d	0.0±0.0 e	0.0±0.0 f	0.0±0.0 f
C. maculates		7.2±0.2 [2]	2.4±0.22	10.2±0.2	4.6±0.22	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
T. granarium		0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	F	7±0.31 [2]	3±0.31	4.8±0.2	1.6±0.22	1.2±0.36	0.0±0.0	0.0±0.0	0.0±0.0
T. granarium	L	14.2±0.5 [1] ab	8±0.45 bc	19.4±0.2 ab	13.2±0.22 a	9.6±0.4 c	1.4±0.6 e	2.6±0.7 d	0.0±0.0 f
L. serricorne		1.4±0.85 [3]	0.0±0.0	3.8±1.61	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	6±0.45 [2]	2.8±0.2	7.8±0.36	3.4±0.22	1±0.63	0.0±0.0	0.0±0.0	0.0±0.0
S. cerealella	F	7±0.45 [2]	2±0.32	12.2±0.2	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	20±0.2 [2]	13.2±0.2	11.2±0.5	7±0.31	4.8±0.37	0.0±0.0	1.4±0.6	0.0±0.0
B. amydraula	F	3.2±0.4 [3]	0.0±0.0	1±0.32	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	20±0.002 [1] a	18.02±0.32 a	19.4±0.22 a	18.6±0.4 a	14±0.31 a	5.8±0.36 b	13.4±0.22 a	3.4±0.22 b
P. interpunctella	F	8.4±0.22 [2]	3.2±0.18	11.2±0.36	4.8±0.18	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	14.8±0.18 [1] a	7.2±0.18 c	9.6±0.22 b	4.6±0.22 d	5±0.32 d	0.0±0.0 e	0.0±0.0 e	0.0±0.0 e
E. kuehniella	F	9.6±0.4 [2]	3.8±0.36	9.4±0.5	3.6±0.4	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	L	19.8±0.18 [1] a	12.8±0.5 b	10.8±0.6 bc	7.8±0.6 c	7.2±0.7 c	1±0.63 d	0.0±0.0 e	0.0±0.0 e

(1: Being Bilateral Effect and Duncan's Multiple Range Test Grouping , 2: Disbilateral Effect of Polymer and Thickness, F : First Instar Larvae, L: Last Instar Larvae, 3: Being Bilateral Effect , 4: T-value)

Table 4. The tested polymers to mean permeability the polymers to CO_2 gas.

CO_2 gas insecs`s penetration in polymeric packagings (Average±SE)								
Polymer	Polyethylene		Cellophane		Polyvinyl chloride		Polypropylene	
Thickness (μm)	16.5	29	16.5	29	16.5	29	16.5	29
	1.3±0.013 a	0.44±0.004 b	1.28±0.01 a	0.443±0.005 c	0.4±0.012 d	0.23±0.004 f	0.73±0.004 c	0.32±0.007 e

Table 5. The probit analysis of *P. interpunctella* mortalities into PP packagings against phosphine gas.

Developmental Stage	**LC_{50} (mg/lit)**	**LC_{95} (mg/lit)**	$\chi2$	***P***	**Slope (a)**	**Intercept (b)**
Adult	3.95 (2.9-5.1)	149.35 (96.63-261.7)	6.215	0.2	1.043	4.4
Larvae	8.75 (6.45-11.6)	848.12 (476.1-1794.4)	3.3	0.35	0.83	4.22
Egg	23.1 (17.2-30.97)	2042.82 (1076.5-4763.7)	2.34	0.504	0.845	3.85

Discussion

The results of this study should be viewed from three aspects, (1) the use of different polymers for packaging as stored pests unable penetrate on them, (2) the use of polymers as gas-proof covers to fumigate goods in stacks or bulk, (3) the use of polymer films as liners of packagings to enable in-bag fumigation and minimize cross infestation. This subject would prevent spreading the contamination in stores and could help to foodstuffs sanitation and should be effective for the consumer's healthy. Based on the mentioned results penetration of different species of insects were at various times, completely. Of all tested species, Larvae of *B. amydraula* had most penetration in packages in the least time. Insects of *O. surinamensis* in two states (with and without food) had the least penetration in the packages. Some larvae had no penetration at all to the polymers. Last age larvae penetrated generally in a shorter time than first age larvae and in some cases. It observed the first age larvae that unable to penetration began molting very quickly. This molting was for increasing head capsule width, probably which caused mouth fragments would be larger and thus penetration would be easier penetrated because in the some cases this molting observed at head capsule only, e.g. larvae of *P. interpunctella*. This molting insect without food was viewed much more than with food. In this test, the insects of without food had more penetrated on polymers that resulted similar to Cline (1978). The increasing in first, remaining constant and subsequently decreasing the slope at insect penetration last days (after maximum penetration) proved that insects attempted to penetrate new food packages and their high activity was for availability to more food sources. Whereas these sources would be limited, they the life period lost for feeding. Foodstuffs packaging with polypropylene polymers could provide the conditions and only by suitable packaging the stored pest insects would be without food and would become extinct. The polymers permeability used including polyethylene, polypropylene, polyvinyl chloride and Cellophane to tested insects showed significantly differences. The least penetration was carried out by insects (adult or larvae) in polypropylene polymers with 29 μm thickness. Entirely, permeability the polymers with 29 μm thickness took place at later times. The results was agreed with findings of previous of Cline (1978) that believed penetration of large larvae and adult insect of many species of stored pests to polymers of polyethylene and cellophane with thickness of less than 29 μm is possible. Proctor and Ashman (1972) suggested using of polyethylene layers with thickness of more than 65 μm in plastic bags and unsuitable using of bags with thickness of less than 40 μm. Highland and Wilson (1981) believed 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 ages larvae of *E. cautella* Walker and *P. interpunctella* (Hübner), and *T. 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 and Serrano (1990) reported that *Prostephanus truncates* can penetrate 30-300 μm polyethylene films. Despite ability of some insects to penetrate both thicknesses of one polymer, it was considered that they could not penetrate other polymer kind with lower thickness. Therefore, it is one of the important results in this study that in insect's penetration what has principle role is following: first polymer kind and subsequently its thickness. On one part, fumigation of different products is frequently carried out under nylon covers where it is important for the polymer to be gas-permeability and transmit enough concentration of the fumigant inside. The results showed that among the different tested polymers and their thicknesses was significant difference with regard to co2 permeability. In the used polymers, all of four polymers were permeable to gas, especially in the 16.5 μm thicknesses. The 29 μm polyvinyl Chloride had lowest permeability to co2 gas and the 16.5 μm cellophone and polyethylene had the most. Hall (1970) and Stout (1983) considered that plastic sheeting (polyethylene and polyvinyl chloride) less than 0.1 mm thick is permeable to phosphine. Appert (1987) claimed that opaque polyethylene or polypropylene with 300 μm thickness in plastic packages is suitable for conserving fumigated grain seeds, polyethylene films of 150-200µm thickness were suitable for fumigation. Iqbal (1993) showed that polyethylene sheetings with 200µm thickness were suitable to retain sufficient concentration of phosphine to kill Tribolium confusum. Valentini *et al*. (1997) reported that polyethylene and polyvinyl chloride 210µm thick prevents phosphine exchange. Also according to findings of Aciar (1989), 200 µm films of polyvinyl chloride and polyethylene had a low permeability to methyl bromide. Therefore, 29µm thick polyvinylchloride could be covered on different products which need to fumigation frequently and could retain enough concentration of the fumigant inside. The probit analysis of the pest mortalities showed that the 29µm polypropylene had high permeability to phosphine.

According to the results a polymer cover of 29 µm thickness was the most suitable one for packagings Such covers would reduce the danger of cross-infestation and on the one hand, it was permeable to stored gases e.g. phosphine for ruining the contaminations into stored products. It is revealed that polypropylene liners with 29µm thickness were suitable for packaging foodstuffs to allow the fumigant to enter the packages (because of their high permeability to phosphine and co2) and also to prevent insect pests from entering the packages, thus protecting the products from recontamination. Such a change would undoubtedly reduce the use of chemical pesticides, the storages food maintaining and therefore, the results to reduce economic losses associated with infestation and minimize injury to company image as a manufacture of high quality foodstuffs.

Acknowledgments

We gratefully acknowledge the standard office in Western Azerbaijan and Toxicology and Entomology laboratory in Urmia University and the contributions of H. Salimi zand and P. Najafi in groups of physic and polymer chemistry.

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(Received 14 December 2009; accepted 20 August 2010)