Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic ISSN 1842-4309

Not. Bot. Hort. Agrobot. Cluj 37 (2) 2009, 218-222

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Packaging of Agricultural Products for Preventing Tobacco Beetles Contaminations

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Abstract

The problems related to insect contaminations on food consumables have created discontents among consumers. Pest insects can penetrate packaging by creating punctures and thereby get into food. Determining the most resistant packaging polymers against insect penetration, from storage until consumption is the target of this study. We evaluate the barrier qualities of four polymers (polyethylene, polypropylene, polyvinylchloride and cellophane) for two thicknesses of 16.5 and 29 µm against *Lasioderma serricorne* F. adults and larvae. These are the most important pest insects in tobacco, medicinal plants and flour storages. Each test had five replications. Means of penetration rates were compared by means of T-test and Duncan test ($P \leq 0.05$). Comparison of the means indicated a significant difference between insect penetrations. Cellophane with thickness of 16.5 µm had the most permeability to tested coleopteran insects as the foods stored into these packagings were completely contaminated, while foods in polypropylene packagings with 29 µm thickness were safe. The tested polymers rank generally from the easiest to most difficult permeability, are cellophane, polyethylene, polyvinylchloride and polypropylene, showing significantly that their thicknesses has a difference. Thus, research shows that the best packaging for the protection of agricultural products is accomplished by polypropylene packages with 29 µm thickness.

Keywords: penetration, packaging, polymer, tobacco beetles

Introduction

Various pests expose agriculture and food products to attack from storage until consumption by consumers. Insects are the most serious pests that can contaminate food products by penetrating them in warehouses. Despite modern food and other agricultural products storage and distribution systems, most packaged food products, with the exception of canned and frozen goods, are subject to attack and penetration by insects (Mullen and Highland, 1988). When a packaging containing one of insect life stages enters into storages (infested packaging), it could cause the prevalence of infestation. In addition to reducing food quantity, insects annihilate quality, too. By nourishing into the foods, they prepare the conditions for the attack by pathogen microorganisms, such as fungi and as such, the consumption of these foodstuffs could be followed by dangerous present day diseases e.g. cancer types. This matter is very clear in the case of the consumers. Therefore, different ways are designed for controlling tobacco pests. Today, several polymer types are currently used for foodstuff packaging. Some may offer virtually no resistance against insects while others may be extremely resistant (Highland, 1981). The ability of species to penetrate materials may vary between life stages (Cline, 1978). Therefore, the probability of contamination balance in products is forecasted as insect penetration diminishes according to the kind of the packaging and as such, by selecting the best materials for packaging. Most researches have been conducted in order to determine penetration abilities of various species of stored-product insects into packaged agricultural products, recently (Domenichini and Forti, 1975; Fletcher and Childs, 1976; Cline, 1978 ; Bowditch, 1997). Information of permeability polymers to stored pest insects in order to select the best for packaging is necessary. So, our study was carried out to prove how polymer and thicknesses could be effective in foodstuff safety.

Materials and methods

In this study, we compared permeability of four kinds of transparent and flexible polymers against stored-insect pests. These are the same current polymers for foodstuffs packaging, including Polyethylene (PE), Polypropylene (PP), Polyvinylchloride (PVC) and Cellophane. These polymers were prepared in two-thickness types of 16.5 µm and 29 µm. Tab. 1 shows some important properties of these polymers (Odian, 2004). These flexible packaging polymers were cut into 15×22^{-cm} pieces with the aid of a template and afterwards we prepared 8×10-cm pouches through the sealed polymeric pieces, with the aid of a press plastic machine for packaging 15^{-gr} foodstuff of flour. These packages were completely devoid of any pores.

The test insects (all obtained from laboratory cultures) were including adults of *Lasioderma serricorne* F. (Col.: Anobiidae) adults and first and last instar larvae. Via direct

Tab. 1. Some properties of different polymers used 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 good	moderate	good	good
Gas transmission (mm/100 cm^2 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
H_2O Absorption %		<0.01	<0.05	0	<0.03
H_2O Vapor transmission (g/100 cm^2 in 24h and 37.8°C and R.H. 90%)		1-1.5	0.25	4-10	0.2-1

observation of the number of larvae molting determine the different ages of larvae. Used adult insects were selected from the same age group, from the physiological (cohort) point of view, as well as for laying egg. First age larvae obtained by collecting the pest's eggs from the cultures and placing them into petri dishes at 25±1°C, 75±5% RH and a 12L: 12D h cycle. Then, first age larvae hatched and undergone testing. The last age larvae were obtained from laboratory culture directly. We tested these insects in two states (without and with food) studied on packaging polymers. In the first instance, the insects with no food during testing were released around foodstuff packages. Through this experiment, some abilities of stored-product insects to penetrate, were determined. Second, the insects with very little food were placed inside packages in order to determine the dispersion ability of the species in stores and contamination of 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. We applied 20 insects (larvae or adult insect) in the two mentioned states for examination, according to the thickness of each polymer (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 were incubated at 27±1°C, 65±5% RH and a 12L: 12D h cycle. The packages were extracted from the jars and examined for penetrations daily, based on the life cycle of insect species, which suffered due to the lack of food. The pests penetrated in from <4 days and finally most insect penetration occurred usually after 15 days. When a puncture was created or one insect was observed inside the packaging, it would be considered the beginning of penetration and data was recorded in accordance. Each hole was made by the insects in the packaging polymers was counted as penetration, but the only way to determine penetration percentage was counting the penetrated insects number of punctures. This is because sometimes several insects could penetrate from one break. When insect number reached the maximum, counting was stopped and no later penetration was considered. Sometimes, the insects were very active, entering and exiting in packages, so they came out after penetration into packages. In these cases, the highest penetration number showed the permeability percentage of used polymers, although this number in last day was lower. Some packages were removed from the results, namely the ones that had the following marks: (1) the insects could escape through their small gaps where edges of the packages were not sealed completely, (2) insects died before entering them, (3) the last age larvae that pupated in the package before finishing the trail period and (4) the first age larvae that evolved to the next ages. Insects' penetrations of 0.27 cm at bottom of packages were more than their number in the middle. In these tests, each thickness of each polymer was considered one treatment. In addition, each treatment replicated 5 times. Statistical analysis of data was carried out with MSTATC and EXCEL software and Randomized Complete Design (RCD) and the means were compared with Duncan's mean test and T-test.

Results and discussion

Tab. 2 and 3 indicate the average of penetration percentage of insect species, while they were without food or with food on various packaging polymers. In these tables, the penetration percentage of insect life stage is 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 times were observed. From four kinds of used polymers, polypropylene had the least permeability against pest insects, as many of the pests were not able to penetrate this polymer and if penetration occurred, 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 29-μm thickness, which was lower than 16.5 μm ($P \leq 0.05$). Most insect species penetration occurred in the case of 16.5 μm thickness of polymers for less than 48 hours, but the permeability of polymers with 29-μm thickness occurred slowly. The results show the permeability percentage of some packaging polymers against insects, which is consideraby related to both type and thickness bilateral effects. Fig.1 shows L. serricorne penetration percentage in the case of insects both with and without food

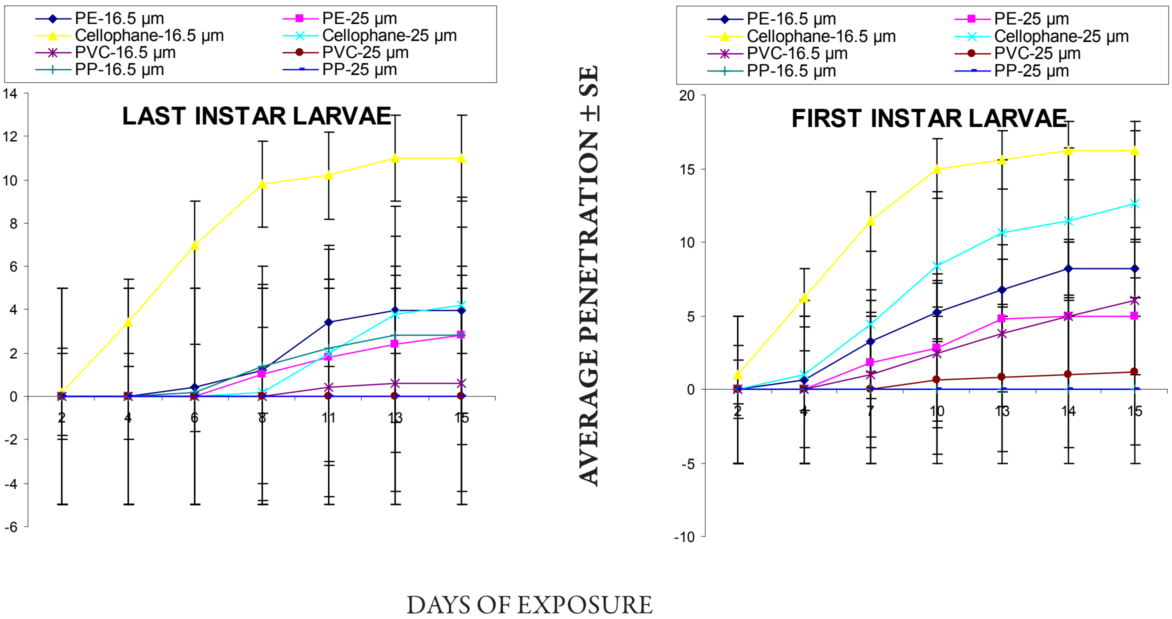

Fig. 1. Number of *L. serricorne* first and last larvae without food that penetrated tested polymeric packages during 15-d period (PE=polyethylene, PP=polypropylene and PVC=polyvinylchloride)

in two- thickness of packaging polymers and at different times of penetration. This figure shows Error Bars (=SE), namely if these different curves SE do not cut each other; the polymers related to these curves have significant differences from the permeability point of view and vice versa.

These curves reveal that the penetration percentage in the first days is very quick, but even if the number of the insects into packages would be higher, insect penetration percentage decreased. It was interesting that the number of insects after the maximum penetration dwindled in next days and some exited from the packages, as they were too numerous. Larvae and adult insects created holes with various diameters, of 0.09 mm until 1 mm. Sometimes a test revealed that although insects were of one age, but created holes of different sizes in packages. They 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 were not able to penetrate, became changed into pupa on packages. Hungriness was one of the factors that caused changing of the larvae to pupa and occurred sooner than common time. Some larvae were not able to penetrate none of the polymers while their adults could. In the case of tested species (*L. serricorne*), larvae penetration was higher than adults. Adults and larvae of the used species showed a much greater inclination for penetration when released without food on polymer packages. According to the results of this study, the penetration ability of insects was based on insect species and life stage and polymer type and its thickness.

Tab. 2. Average permeability percentage of different polymers to tobacco beetles in state of without food

		Pest insect's penetration in polymeric packaging (Average±SE)							
Polymer		Polyethylene		Cellophane		Polyvinyl chloride		Polypropylene	
Thickness (µm)		16.5	29	16.5	29	16.5	29	16.5	29
L. serricorne	A	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

([1]: Being Bilateral Effect and Duncan's Test Grouping, A: Adult, F: First Instar Larvae , L : Last Instar Larvae)

Tab. 3. Average permeability percentage of different polymers to major stored-product insects in state of with 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
L. serricorne	A	1.4±0.85	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
	1								
	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	2.8±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
	2								

([1] : Being Bilateral Effect, [2] : Disbilateral Effect of Polymer and Thickness, A : Adult, F : First Instar Larvae , L : Last Instar Larvae)

Conclusions

The results of this study should be viewed from the aspect of using the different polymers for packaging as stored pests are unable to penetrate them. This subject could help to sanitize foodstuffs and should be effective for consumer health, and thus it would prevent the spreading of contamination in stores. Based on the mentioned results, the penetration of different species of insects was, at various times, complete Low penetration of adult insects was observed in two states (with and without food). The last instar larvae had the highest package penetration. Some first instar larvae had no penetration at all. Last age larvae penetrated generally in a shorter time, than first age larvae. In these tests, it was observed that the first age larvae, which were unable to penetrate, began molting very quickly. This molting resulted in increasing head capsule width; probably which caused mouth fragments to be larger and thus penetration to be easier, because in some cases this molting was observed only at head capsule. This molting in the case of insects without food was viewed more than in the case of those with food. In this test, the insects without food managed easier penetration in polymers and this result agrees with Cline's study (1978). Also, at first constant and then subsequently decreasing, the slope of insect penetration in the last days (after maximum penetration) proves that insects always attempt to penetrate new food packages and their high activity is to access more food sources. Foodstuffs packaging with polypropylene polymers could provide the conditions and be the suitable packaging for stored pest insects without food to become extinct.

Permeability of used polymers including PE, PP, PVC and Cellophane for tested insects showed that there are significant differences between them. These polymers rank generally from easiest to most difficult to penetration, Cellophane, polyethylene, Polyvinylchloride and Polypropylene. Larvae in polypropylene polymers carried out the least penetration. Permeability of used polymers including polyethylene, polypropylene, polyvinyl chloride and Cellophane to tested insects showed that there are significant differences between them. The least penetration carried out by insects (adult or larvae) in polypropylene polymers with 29 μm thickness. Entirely, the permeability of polymers with 29 μm thickness takes place at later times. The results of this study agree with findings of previous studies, such as Cline (1978) that believed penetration of large larvae and adult insects of many species of stored pests to polyethylene and cellophane polymers with _ thickness of less than 29 μm is possible. Proctor and Ashman (1972) suggest using of polyethylene layers with _ thickness of more than 65 μm in plastic bags and the unsuitable use of bags with thickness of less than 40 μm. Highland and Wilson (1981) believe 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 (1990) reported that *Prostephanus truncates* can penetrate 30-300 μm polyethylene films. In the investigations, *L. serricorne* penetrated two thicknesses of PE, PVC and Cellophane, but were not able to penetrate 16.5 μm thickness of PP polymers, even. Therefore, it is one of the important results in this study that in the case of insect penetration, the main role is played by polymer type and subsequently its thickness. On the one hand, fumigation of different products is frequently carried out under nylon covers, where it is important for the polymer to be gas-permeable and transmit enough concentration of the fumigant inside. Hall (1970) and Stout (1983) consider that plastic sheeting (polyethylene and polyvinyl chloride) less than 0.1 mm thick is permeable to phosphine. Appert (1987) claims that opaque polyethylene or polypropylene with 300 μm thickness in plastic packages is suitable for conserving fumigated grain seeds. He believes that polyethylene films of 150-200μm thickness are suitable for fumigation. Iqbal (1993) showed that polyethylene sheetings with 200μm thickness are 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 have a low permeability to methyl bromide. According to the results of this research and some other studies, a polymer cover of polypropylene is the most suitable one for packaging from the viewpoint of preventing insect penetration. Such covers also reduce the danger of cross-infestation and they are permeable to stored gases e.g. phosphine. On the one hand, the results showed there was a significant difference between both 16.5 and 29 μm thicknesses. It is evident that polypropylene liners with 29 μm thickness are suitable for foodstuffs packaging, to allow the fumigant to enter the packages (because of their high permeability) and so, to prevent insect pests from entering the packages, thus protecting the products from recontamination. Such a change would undoubtedly reduce excessive usage of chemical pesticides in stores for maintaining food products and therefore, the results presented here would lead to a reduction in the economic losses associated with infestation and minimize injury to company image as a manufacturer of high quality foodstuffs.

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