Boll. Zool. agr. Bachic.
Ser. II, 36 (2): 257-273

30 August 2004

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Flexible, biaxially oriented, polypropylene packaging: physical features and resistance to attack by *Plodia interpunctella* (Hbn.) (Lepidoptera Pyralidae) larvae

Abstract - Investigation into the possible relationship between the physical features of polypropylene packaging (resistance, welding, perforation, friction coefficient, longitudinal breaking elongation) and resistance to the attacks of III instar larvae of *Plodia interpunctella* were carried out.
The test was carried out on 23 different types of biaxially oriented polypropylene of various thicknesses, currently used for packaging confectionery.
Female larvae of *Plodia interpunctella* can perforate a greater number of packages and carry out more frequent attempts to penetrate the packages than males. After 12 days, both sexes could perforate unprinted films of co-extruded, biaxially oriented polypropylene (17, 20, 25 μm), clear expanded (35, 40 μm) and printed films of co-extruded, biaxially oriented polypropylene (17, 20 μm) acrylic two side coated (20 μm) and clear expanded (40 μm). The printed films of biaxially oriented acrylic two side coated (25, 30 μm) and acrylic two side coated clear expanded (40 μmm), the latter also in the case of unprinted film, were perforated only by females.
A relation between the values of the physical tests and the biological ones emerges in the case of longitudinal breaking elongation. The films with values below 50 N/15 mm are perforated, except in the case of unprinted film of acrylic polypropylene two side coated (20, 25 μm). The acrylic coating prevents the aroma of the packaged substance from escaping from the packaging and consequently the larvae are not stimulated to perforate it. On the other hand, film of the same thickness but printed is perforated; the treatment used to print the film decreases the thickness of the acrylic coating and so the aroma can escape through the packaging to the outside.

Riassunto - *Imballaggi in polipropilene biorientato: caratteristiche fisiche e resistenza all'attacco di larve di* Plodia interpunctella *(Hbn.) (Lepidoptera Pyralidae).*

Si è voluto indagare se esiste una correlazione tra le caratteristiche fisiche dei film in polipropilenre (resistenza saldatura e perforazione, coefficiente attrito, allungamento e carico a rottura longitudinale) e la loro resistenza all'attacco di larve di III età di *Plodia interpunctella*.

La sperimentazione è stata effettuata su 23 differenti tipi di polipropilene biorientato, di differente spessore, attualmente utilizzati per il confezionamento di prodotti dolciari.
Le larve di sesso femminile di *Plodia interpunctella* sono in grado di forare un numero maggiore di imballaggi e tendenzialmente eseguono maggiori tentativi di penetrazione rispetto ai maschi. A distanza di 12 giorni entrambi i sessi sono riusciti a forare le pellicole non stampate di polipropilene biorientato coestruso (17, 20 e 25 µm), bianco espanso (35 e 40 µm) e i film stampati di polipropilene biorientato coestruso (17 e 20 µm), bilaccato acrilico (20 µm), bianco espanso (40 µm). Polipropilene biorientato stampato bilaccato acrilico (25 e 30 µm) e bianco espanso bilaccato acrilico (40 µm), quest'ultimo anche nel caso non stampato, sono stati forati esclusivamente dalle femmine.
Una correlazione fra i valori dei test fisici e quelli biologici si evidenzia nel caso del carico a rottura longitudinale. I film con valori inferiori a 50 N/15 mm sono perforati, eccetto che nel caso di polipropilene bilaccato acrilico non stampato (20 e 25 µm). La presenza della laccatura acrilica non permette la diffusione all'esterno della confezione degli aromi del prodotto confezionato e le larve di conseguenza non sono stimolate a forare questi imballaggi non percependo l'odore della fonte alimentare. Film di uguale spessore ma stampati sono invece forati; il trattamento necessario per stampare la pellicola diminuisce infatti lo spessore della lacca acrilica e gli aromi possono diffondersi all'esterno della confezione.

Key words: *Plodia interpunctella,* flexible, biaxially oriented polypropylene packaging, physical test.

INTRODUCTION

The materials used to package foodstuffs are chosen according to several technical and commercial requirements: ease of use, recycling possibilities, biodegradability, protection of foodstuffs from mechanical damage and from oxygen, humidity and heat. Consequently, the choice of material is fundamental as a mistake at this stage would affect the product and could ultimately render it unmarketable.

Previous studies carried out into packaging materials only investigated the chemical-physical properties of the materials, rather than the biological ones. In fact, there is such a wealth of information about permeability of plastic materials to oxygen, steam and other gases, that standardized methods of measure have been defined. These methods can be used when choosing packaging materials to prolong the preservation period. When it comes to evaluating the resistance of the package to attack by insects, on the other hand, no fast physical test exists, only a biological one which takes time.

Apart from chilled and frozen products, packaged food is generally kept in environments without air conditioning, thus permitting the life and the development of insects. It is important, therefore, to use packages which can protect food from attack by pests.

The susceptibility of packages to insect damage depends on many factors such as: insect species, developmental stage of the insect, type of package and its contents (Gerhardt & Lindgren, 1954; Highland *et al.*, 1964; Highland, 1984; Cline, 1978a,b; Schmidt, 1979; Noack, 1982; Yerington, 1983; Pagani, 1984; El-Kady & Hekalam, 1986; Bowditch,1997).

Plodia interpunctella, a polyphagous moth, is one of the most frequent infesting insects of foodstuffs and it is particularly able to perforate packages. Various Authors have carried out tests to evaluate the resistance of different types of plastic packaging films to attack by this moth. Yerington (1975) observed that polypropylene and polyethylene laminate films are more resistant than other types of film. Polypropylene-ethyl vinylacetate and co-extruded polypropylene-polyethylene show a better resistance to penetration than saran coated polypropylene and polyethylene coupled with cellophane. Biaxially oriented polypropylene is more resistant than non-axially oriented polypropylene.

Studies conducted by Cline (1978a) showed that *Plodia interpunctella* larvae can easily move on polypropylene films with an inclination of 90°.

I and II instar larvae cannot perforate polypropylene film with a thickness of 26.5 and 31.3 µm, while the same films are pierced by III instar larvae. The polypropylene-polyethylene laminates (27.8 µm), polypropylene-metallized polyethylene laminate (39.3 µm) and bipolypropylene-metallized polyester (31 µm) prove to be resistant to attack by this moth (Locatelli & Garavaglia, 1994).

A film of heat-sealable, biaxially oriented polypropylene, acrylic-coated on one side and on the other coated with polyvinylidene chloride (28 µm) is not perforated by *P. interpunctella* larvae (Bowditch,1997).

This study investigated the possible relation between physical features of the films and their resistance to attack by *P. interpunctella* larvae as these insects are the main culprit in infestations of packaged foodstuffs. The experiments were carried out on biaxially oriented polypropylene film as this film is used above all others in the packaging of confectionery.

MATERIALS AND METHODS

III instar larvae of *P. interpunctella* were used as they are particularly able to perforate packaging.

The test was carried out on 23 different types of biaxially oriented polypropylene of varying thicknesses, generally used for packaging confectionery products. In detail these types were: co-extruded (17, 20, 25, 30 µm), acrylic two side coated (20, 25, 30 µm), clear expanded (35, 40 µm), clear expanded acrylic two side coated (40 µm) each for printed [(1)] and unprinted versions. Laminates: printed, co-extruded (17 µm) + biaxially oriented, co-extruded (20 µm), printed co-extruded (20 µm), + clear expanded (35 µm), printed co-extruded (25 µm) + co-extruded (20 µm), printed acrylic two side

(1) Printed biaxially oriented, clear expanded polypropylene (35 µm) was not tested as it isn't for sale as a single film.

coated (20 μm) + clear expanded acrylic two side coated (40 μm).

The packages were prepared by cutting a rectangular sheet of the film to be tested, measuring 8 x 14.5 cm. The welds were obtained by using a knurling welding machine into which the required temperature (140°C), pressure values (4 bar) and the time of the bars contact with the film (1 second) had been programmed.

Tests with different compounds were carried out to select the most suitable food for *P. interpunctella* larvae. The most attractive food proved to have a composition similar to the substrate of laboratory rearing, but with a greater quantity of hazel-nuts and bitter cocoa [(2)]. In fact several studies have shown that cocoa and chocolate are very appetizing foods for this species. Hazel-nuts stimulate oviposition and development while dried fruit provides thiamine and fatty acids required for the development of this species (Fraenkel & Blewett, 1943; Morére and Leberre, 1967).

The prepared food (7±0.1 g) was placed in the package, which had been made by performing welds on the sheet of film; a fin weld on the smaller sides of the packaging and another weld positioned orthogonally to the first in order to form the bottom. A third weld, similar to the latter, made it possible to seal the package. The surface of the package, welds included, was 5.5 x 8 cm (44 cm^2).

Tests were carried out in a white, conical-shaped, polystyrene food container (the smaller Ø: 10 cm; the larger Ø: 11.5 cm; height: 6 cm), fitted with a lid of metal wire (120 mesh) to permit ventilation.

Each package was placed at the bottom of the container, 5 larvae were added and a little quantity (0.1 mg) of the food substrate [(3)] used in the laboratory for rearing the species. The quantity of food substrate was sufficient to guarantee survival of the individuals and to prevent, but was not enough to permit their development. The objective was to stimulate individuals to seek further food sources.

20 replications of the test were carried out for each sex. Tests were conducted in a thermostatic cell at 27±1°C and 70±5% r.h.. Larvae were kept in contact with the packages for periods of 3, 7 and 12 days. At the end of the test the number of live and dead larvae, abrasions, (divided according to the dimension and location on the packages) and the presence of holes, were counted. The number of holes and abrasions was checked under a stereomicroscope (x 60 enlargement) while the dimensions of the abrasions were surveyed by transmitted light microscope connected to the computer; the images were processed by "Image Pro-Measure" program for Windows.

The packages used were subjected to a laboratory test to evaluate their physical features:

- Resistance to welding (ASTM, 1994a): the edges of the wrapping (15 mm x 10 cm) were put into clamps connected to a dynamometer to measure the force (Newton/15 mm) required to cause the breakage of welding.

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(2) Ingredients of the food substrate placed inside packages: bran 4 parts, wheat meal 1 part, wheat-germ 1 part, cornflour 1 part, powdered yeast $^1/_2$ part, minced hazel-nuts 4 parts, honey 1 part, glycerin 1 part, bitter cocoa 1 part.

(3) Ingredients of food substrate placed outside the packages: bran 4 parts, wheat meal 1 part, wheat germ 1 part, cornflour 1 part, powered yeast $^1/_2$ part, minced (ground) hazel-nuts 1 part, honey 1 part, glycerin 1 part.

- Resistance to perforation (Cellografica Gerosa Method): the circular shaped sample (Ø 80 mm), with the side to test turned towards the perforating tool, was placed at the center of the locking device; the perforating tool was inserted in the mobile clamps of the dynamometer connected with the load cell of the dynamometer which registers the maximum force (Newton) required for its complete penetration through the plane of the sample.
- Coefficient of dynamic friction exterior/interior (Cellografica Gerosa Method): a dynamometer was connected to a thread which dragged a slide covered with the material to test over a second wrapping which was fixed to the sliding plane. The force required to move the slide was noted and the value obtained expressed as a number.
- Longitudinal breaking elongation (ASTM, 1994b): the edges of the wrapping (15 mm x 10 cm) are fixed to the clamps of the dynamometer to measure the breaking elongation which is expressed as a percentage, this being the ratio between the length of the wrapping at the moment of breaking and its initial length.
- Longitudinal breaking load (ASTM, 1994b): the edges of the wrapping (15 mm x 10 cm) are fixed to the clamps of the dynamometer to measure the force required to break the wrapping (Newton/15 mm).

10 replications were carried out for each test and the results were subjected to a statistical elaboration, according to ANOVA and Duncan's test.

RESULTS AND DISCUSSION

Tables 1-3 show the number of abrasions, their surface area, and the holes registered on the different packages after 3, 7 and 12 days.

The greatest abrasions of the film are due to attack by females. A high number of abrasions occur near the welding points of the films, while the holes are found in the areas of the packaging not adjoining the seals.

After 12 days larvae of both sexes managed to perforate the non-printed films of co-extruded biaxially oriented polypropylene (17, 20, 25 μm), clear expanded (35, 40 μm) and the co-extruded printed films (17, 20 μm), acrylic coated 2 sides (20 μm), clear expanded (40 μm). Biaxially oriented polypropylene acrylic coated 2 sides (25, 30 μm) and clear expanded acrylic coated 2 sides (40 μm), also in the case of the non-printed film, were pierced only by females. The larvae of both sexes were not able to perforate the laminates.

Tables 4-8 show the values of the physical tests and whether larvae can make at least 1 hole in the packaging within 12 days.

Resistance of welding

No significant relation emerged between this feature and the ability of penetration by larvae (Table 4).

The values recorded are higher than 2 N/15 mm, a value considered sufficient to

Table 1 - Mean number (±S.D.) of III instar larvae of Plodia interpunctella *(Hbn.) alives and deads of the correspondent abrasions and holes observed after 3 days on different films of biaxailly oriented polypropylene.*

BIAXIALLY ORIENTED POLYPROPYLENE	FEMALES						MALES					
	Alives	Deads	Abrasions (mm)			Holes	Alives	Deads	Abrasions (mm)			Holes
			0.1-0.5	0.6-1.0	1.1-3.0				0.1-0.5	0.6-1.0	1.1-3.0	
NOT PRINTED FILMS												
Co-extruded 17μm	4.8±0.5	0.3±0.5	2.0±1.9	0.3±0.5	0.5±0.6	A	4.8±0.5	0.3±0.5	1.3±1.5	1.0±1.4	A	0.5±0.6
Co-extruded 20μm	5.0±0.0	0.0±0.0	1.3±1.9	A	A	A	5.0±0.0	0.0±0.0	0.5±0.6	A	0.5±1.0	A
Co-extruded 25μm	4.5±0.6	0.5±0.6	1.3±1.3	A	0.3±0.3	A	5.0±0.0	0.0±0.0	1.5±1.7	0.5±0.6	A	A
Co-extruded 30μm	4.8±0.5	0.3±0.5	0.8±1.0	0.3±0.5	A	A	4.0±0.8	1.0±0.8	0.5±1.0	A	A	A
Acrylic coated 2 sides 20μm	4.8±0.5	0,5±0,5	A	A	A	A	4.3±0.5	0.8±0.5	0.5±0.6	A	A	A
Acrylic coated 2 sides 25μm	5.0±0.0	0.0±0.0	0.3±0.5	0.5±1.0	A	A	3.8±1.9	1.3±1.9	0.8±1.5	A	A	A
Acrylic coated 2 sides 30μm	4.5±0.6	0.5±0.6	0.3±0.5	A	A	A	5.0±0.0	0.0±0.0	0.5±1.0	A	A	A
Clear expanded 35μm	4.8±0.5	0.3±0.5	0.3±0.5	1.0±1.2	A	0.5±1.0	4.3±0.9	0.8±0.9	0.5±1.0	0.3±0.5	A	A
Clear expanded 40μm	5.0±0.0	0.0±0.0	A	A	A	0.3±0.5	5.0±0.0	0,0±0.0	A	A	A	0.8±0.5
Clear expanded acrylic coated 2 sides 40μm	4.8±0.5	0.3±0.5	0.3±0.5	A	A	A	3.8±0.5	1.3±0.5	0.3±0.5	A	1.0±2.0	A
PRINTED FILMS												
Co-extruded 17μm	4.3±0.9	0.8±0.9	1.3±2.5	2.0±2.2	0.8±1.5	A	4.8±0.5	0.3±0.5	0.3±0.5	0.3±0.5	A	A
Co-extruded 20μm	4.0±0.0	1.0±0.0	0.5±0.6	0.3±0.5	A	A	4.8±0.5	0.3±0.5	1.0±8.0	0.5±1.0	A	A
Co-extruded 25μm	4.3±0.9	0.8±0.9	0.8±1.5	A	A	A	5.0±0.0	0.0±0.0	A	A	A	A
Co-extruded 30μm	4.5±0.6	0.5±0.6	A	A	A	A	4.3±0.5	0.8±0.5	A	A	A	A
Acrylic coated 2 sides 20μm	4.5±0.6	0.5±0.6	0.5±0.6	0.5±0.6	0.5±0.6	A	5.0±0.0	0.0±0.0	1.8±3.5	0.3±0.5	A	0.3±0.5
Acrylic coated 2 sides 25μm	4.5±0.6	0.5±0.6	A	A	A	A	4.8±0.5	0.3±0.5	A	A	A	A
Acrylic coated 2 sides 30μm	5.0±0.0	0.0±0.0	0.3±0.5	0.3±0.5	A	A	4.3±1.5	0.8±1.5	A	A	A	A
Clear expanded 40μm	4.0±1.4	1.0±1.4	A	0.5±0.6	0.5±0.6	0.8±0.5	5.0±0.0	0.0±0.0	0.3±0.5	1.0±2.0	1.3±1.9	1.0±0.8
Clear expanded acrylic coated 2 sides 40μm	3.5±1.9	1.5±1.9	A	A	A	A	5.0±0.0	0.0±0.0	0.3±0.5	0.3±0.5	A	A
LAMINATED FILMS												
Co-extruded17μm+co-extruded 20μm	4.5±0.6	0.5±0.6	A	A	A	A	5.0±0.0	0.0±0.0	A	A	A	A
Co-extruded 20μm+clear expanded 35μm	4.5±0.6	0.5±0.6	0.3±0.5	0.5±1.0	A	A	3.5±1.3	1.5±1.3	A	A	A	A
Co-extruded 20μm+co-extruded 25μm	5.0±0.0	0.0±0.0	0.3±0.5	A	A	A	3.8±1.5	1.3±1.5	A	A	A	A
Acrylic coated 2 sides 20μm+clear expanded acrylic coated 2 sides 40μm	3.5±0.6	1.5±0.6	0.3±0.5	0.5±1.0	A	A	4.8±0.5	0.3±0.5	A	A	A	A

A: absences of holes

Table 2 - Mean number (±S.D.) of III instar larvae of Plodia interpunctella *(Hbn.) alives and deads of the correspondent abrasionsand holes observed after 7 days on different films of biaxailly oriented polypropylene.*

BIAXIALLY ORIENTED POLYPROPYLENE	FEMALES						MALES					
	Alives	Deads	Abrasions (mm)			Holes	Alives	Deads	Abrasions (mm)			Holes
			0.1-0.5	0.6-1.0	1.1-3.0				0.1-0.5	0.6-1.0	1.1-3.0	
NOT PRINTED FILMS												
Co-extruded 17μm	2.3±0.5	3.8±0.5	4.3±2.9	1.0±1.2	0.5±0.6	0.3±0.5	3.0±2.3	2.0±2.3	2.0±1.6	1.0±1.4	0.3±0.5	0.5±0.6
Co-extruded 20μm	1.0±1.4	4.0±1.4	1.8±2.4	1.3±1.9	0.8±0.9	A	2.0±1.4	3.0±1.4	2.3±0.9	0.5±0.6	1.0±0.0	A
Co-extruded 25μm	2.8±1.5	2.3±1.5	1.3±1.3	0.3±0.5	0.3±0.5	0.5±1.0	0.8±0.9	4.3±0.9	1.5±1.7	1.0±0.8	A	A
Co-extruded 30μm	2.5±1.3	2.5±1.3	1.0±0.8	0.3±0.5	0.3±0.5	A	1.3±1.3	3.8±1.3	2.0±2.0	0.8±0.9	0.3±0.5	A
Acrylic coated 2 sides 20μm	2.3±1.7	2.8±1.7	0.3±0.5	0.3±0.5	A	A	2.0±1.8	3.0±1.8	0.5±0.6	0.3±0.5	A	A
Acrylic coated 2 sides 25μm	2.5±1.9	2.5±1.9	1.0±1.4	0.5±1.0	0.5±1.0	A	1.8±0.9	3.3±0.9	2.0±3.4	0.3±0.5	A	A
Acrylic coated 2 sides 30μm	2.6±1.5	2.3±1.5	1.3±1.3	1.0±1.4	0.5±0.6	A	1.5±1.3	3.5±1.3	1.3±1.9	0.3±0.5	0.5±0.6	A
Clear expanded 35μm	4.3±1.5	0.8±1.5	0.5±1.0	1.0±1.2	0.8±1.5	1.8±0.9	4.8±0.5	0.3±0.5	2.3±3.3	3.8±2.2	0.5±0.6	1.0±0.8
Clear expanded 40μm	3.5±1.3	1.5±1.3	1.0±2.0	0.8±0.9	1.0±1.4	0.8±0.9	3.3±1.7	1.8±1.7	0.5±0.6	0.3±0.5	0.8±0.9	0.8±0.5
Clear expanded acrylic coated 2 sides 40μm	2.5±1.3	2.5±1.3	0.8±0.9	0.8±0.9	0.8±0.9	A	2.5±1.3	2.5±1.3	3.8±2.4	1.5±2.4	1.0±2.0	A
PRINTED FILMS												
Co-extruded 17μm	2.5±1.7	2.5±1.7	1.3±0.9	2.0±2.2	1.8±2.4	0.3±0.5	2.3±1.9	2.8±1.9	2.3±2.6	1.3±1.9	0.3±0.5	0.3±0.5
Co-extruded 20μm	2.0±1.4	3.0±1.4	0.5±1.0	0.5±0.6	A	A	2.8±0.9	2.3±0.9	1.0±8.0	0.5±1.0	A	0.3±0.5
Co-extruded 25μm	0.8±0.9	4.3±0.9	0.8±0.9	0.5±1.0	A	A	1.5±1.0	3.5±1.0	A	A	A	A
Co-extruded 30μm	2.3±0.9	2.8±0.9	1.3±1.3	A	A	A	3.0±1.6	2.0±1.6	0.3±0.5	A	0.3±0.5	A
Acrylic coated 2 sides 20μm	3.0±1.4	2.0±1.4	2.8±3.1	1.3±1.3	0.5±0.6	0.3±0.5	2.0±1.2	3.0±1.2	1.8±3.5	1.8±2.4	A	0.3±0.5
Acrylic coated 2 sides 25μm	1.3±1.3	3.8±1.3	0.5±1.0	0.5±1.0	A	A	2.8±1.5	2.3±1.5	0.8±0.9	0.5±1.0	A	A
Acrylic coated 2 sides 30μm	2.0±1.2	3.0±1.2	0.3±0.5	0.5±0.6	A	0.3±0.5	2.8±1.7	2.3±1.7	0.3±0.5	0.3±0.5	0.3±0.5	A
Clear expanded 40μm	4.8±0.5	0.3±0.5	1.5±1.3	3.3±1.9	1.0±1.4	1.5±1.0	2.3±1.1	2.8±2.1	1.5±1.3	1.3±0.5	1.3±0.5	1.0±0.8
Clear expanded acrylic coated 2 sides 40μm	3.5±1.3	1.5±1.3	1.3±1.3	2.3±2.1	0.5±1.0	0.3±0.5	1.0±0.0	4.0±0.0	2.3±2.6	1.0±1.4	0.3±0.5	A
LAMINATED FILMS												
Co-extruded 17μm+co-extruded 20μm	1.0±0.8	4.0±0.8	1.0±0.8	A	A	A	3.3±1.3	1.8±1.3	1.5±2.4	A	0.8±1.5	A
Co-extruded 20μm+clear expanded 35μm	2.0±0.8	3.0±0.8	1.8±2.2	0.3±0.5	0.3±0.5	A	3.8±0.5	1.3±0.5	0.8±1.5	0.3±0.5	A	A
Co-extruded 20μm+co-extruded 25μm	3.5±1.0	1.5±1.0	0.8±1.5	A	0.3±0.5	A	3.3±1.3	1.8±1.3	0.3±0.5	A	0.3±0.5	A
Acrylic coated 2 sides 20μm+clear expanded acrylic coated 2 sides 40μm	2.3±0.9	2.8±0.9	1.0±0.8	0.3±0.5	A	A	2.5±0.6	2.5±0.6	0.8±0.9	0.3±0.5	A	A

A: absences of holes

Table 3 - Mean number (±S.D.) of III instar larvae of Plodia interpunctella *(Hbn.) alives and deads of the correspondent abrasions and holes observed after 12 days on different films of biaxailly oriented polypropylene.*

BIAXIALLY ORIENTED POLYPROPYLENE	FEMALES						MALES					
	Alives	Deads	Abrasions (mm)			Holes	Alives	Deads	Abrasions (mm)			Holes
			0.1-0.5	0.6-1.0	1.1-3.0				0.1-0.5	0.6-1.0	1.1-3.0	
NOT PRINTED FILMS												
Co-extruded 17µm	0.5±0.6	4.5±0.6	4.3±2.9	2.3±2.9	1.0±1.4	0.3±0.5	3.0±1.6	2.0±1.6	2.0±1.6	1.0±1.4	1.3±0.9	0.5±1.0
Co-extruded 20µm	2.0±1.4	3.0±1.4	3.3±1.3	1.3±1.9	1.3±0.5	0.3±0.5	1.0±1.2	4.0±1.2	3.8±2.9	1.3±1.9	0.8±1.5	0.3±0.5
Co-extruded 25µm	1.5±1.7	3.5±1.7	1.3±1.3	0.8±0.9	0.3±0.5	0.5±1.0	2.0±2.0	3.0±2.0	1.5±1.7	1.0±0.8	0.3±0.5	0.3±0.5
Co-extruded 30µm	0.0±0.0	5.0±0.0	2.5±1.9	1.0±1.4	0.3±0.5	A	0.5±0.6	4.5±0.6	2.0±2.0	0.8±0.9	0.3±0.5	A
Acrylic coated 2 sides 20µm	0.3±0.5	4.8±0.5	0.8±0.5	0.3±0.5	A	A	0.5±1.0	4.5±1.0	0.8±0.5	0.3±0.5	0.3±0.5	A
Acrylic coated 2 sides 25µm	0.5±0.6	4.5±0.6	1.3±1.9	0.5±1.0	0.5±1.0	A	1.5±1.3	3.5±1.3	2.0±3.4	0.8±0.5	0.5±0.0	A
Acrylic coated 2 sides 30µm	1.0±0.8	4.0±0.8	1.5±1.0	1.3±1.9	0.5±0.6	A	4.3±0.9	0.8±0.9	1.3±1.9	0.5±0.6	0.5±0.6	A
Clear expanded 35µm	3.0±2.4	2.0±2.4	3.0±2.9	1.8±0.9	0.5±0.6	1.8±0.9	4.8±0.5	0.3±0.5	2.3±3.3	3.8±2.2	1.0±0.8	1.5±1.3
Clear expanded 40µm	5.0±0.0	0.0±0.0	0.5±1.0	0.8±0.9	1.5±0.6	1.8±0.5	5.0±0.0	0.0±0.0	0.5±0.6	0.3±0.5	0.8±0.9	1.0±0.0
Clear expanded acrylic coated 2 sides 40µm	2.3±1.9	2.8±1.9	3.8±3.9	1.8±2.4	0.8±0.9	0.3±0.5	2.5±1.7	2.5±1.7	3.8±2.4	1.5±2.4	1.0±2.0	A
PRINTED FILMS												
Co-extruded 17µm	2.0±2.0	3.0±2.0	2.3±1.9	2.0±2.2	1.8±2.4	0.3±0.5	3.8±1.3	1.3±1.3	2.8±2.4	1.3±1.9	1.0±0.8	0.3±0.5
Co-extruded 20µm	2.5±1.9	2.5±1.9	1.0±0.8	0.8±0.5	0.3±0.5	0.5±0.6	2.8±2.1	2.3±2.1	2.8±4.9	0.5±1.0	0.3±0.5	0.3±0.5
Co-extruded 25µm	1.3±0.5	3.8±0.5	1.0±1.3	0.5±1.0	0.3±0.5	A	3.0±1.2	2.0±1.2	1.5±2.4	A	A	A
Co-extruded 30µm	1.0±1.4	4.0±1.4	1.3±1.3	0.3±0.5	0.5±1.0	A	1.8±2.2	3.3±2.2	0.3±0.5	0.5±0.6	0.3±0.5	A
Acrylic coated 2 sides 20µm	1.8±0.9	3.3±0.9	2.8±3.1	1.3±1.3	0.5±0.6	0.8±0.9	2.0±2.3	3.0±2.3	2.8±1.9	1.8±2.4	0.8±1.5	0.3±0.5
Acrylic coated 2 sides 25µm	0.8±0.9	4.3±0.9	1.5±1.0	2.3±1.9	1.0±0.8	0.3±0.5	3.0±1.8	2.0±1.8	0.8±1.5	0.8±0.9	0.3±0.5	A
Acrylic coated 2 sides 30µm	0.5±1.0	4.5±1.0	0.3±0.5	0.8±0.9	0.5±1.0	0.3±0.5	0.5±1.0	4.5±1.0	0.8±0.5	0.3±0.5	0.3±0.5	A
Clear expanded 40µm	3.8±2.5	1.3±2.5	1.5±1.3	3.3±1.9	1.3±1.3	1.5±1.0	4.5±1.0	0.5±1.0	1.5±1.3	3.0±3.2	1.3±0.5	1.3±0.5
Clear expanded acrylic coated 2 sides 40µm	1.5±2.4	3.5±2.4	1.3±1.3	2.3±2.1	0.8±0.9	0.3±0.5	1.0±1.4	4.0±1.4	2.8±1.5	1.3±1.5	0.3±0.5	A
LAMINATED FILMS												
Co-extruded 17µm+co-extruded 20µm	1.5±1.3	3.5±1.3	1.0±0.8	0.3±0.5	A	A	3.0±2.0	3.0±2.3	1.5±2.4	0.3±0.5	0.8±1.5	A
Co-extruded 20µm+clear expanded 35µm	2.3±2.2	2.8±2.2	1.8±2.2	0.3±0.5	0.3±0.5	A	1.0±0.8	4.0±0.8	0.8±1.5	0.5±1.0	A	A
Co-extruded 20µm+co-extruded 25µm	0.8±0.9	4.3±0.9	0.8±1.5	A	0.3±0.5	A	1.8±0.9	3.3±0.9	0.3±0.5	0.3±0.5	0.3±0.5	A
Acrylic coated 2 sides 20µm+clear expanded acrylic coated 2 sides 40µm	1.3±0.5	3.8±0.5	1.0±0.8	0.5±0.6	0.5±1.0	A	0.8±.0.5	4.3±0.5	0.8±0.9	0.3±0.5	0.3±0.5	A

A: absences of holes

Table 4 - Mean values (±S.D.) of welding resistance of different films of biaxially oriented polypropilene.
For each film the presence (F) or the absence (A) of holes by III instar larvae of Plodia interpunctella *(Hbn.) within 12 days.*

BIAXIALLY ORIENTED POLYPROPYLENE	RESISTANCE OF WELDING Newton/15 mm	HOLES
Clear expanded 35µm *	2.20±0.04 a	F
Clear expanded 40µm *	2.36±0.04 ab	F
Clear expanded 40µm **	2.35±0.06 ab	F
Co-extruded 17µm **	2.50±0.08 bc	F
Co-extruded 20µm *	2.60±0.05 cd	F
Co-extruded 20µm+clear expanded 35µm ***	2.73±0.05 de	A
Co-extruded 17µm *	2.84±0.04 e	F
Co-extruded 20µm **	2.95±0.08 e	F
Acrylic coated 2 sides 20µm+clear expanded acrylic coated 2 sides 40µm ***	3.36±0.05 f	A
Acrylic coated 2 sides 20µm **	3.38±0.07 e	F
Acrylic coated 2 sides 20µm *	3.37±0.08 f	A
Co-extruded 25µm **	3.55±0.09 fg	A
Acrylic coated 2 sides 25µm **	3.65±0.06 g	F
Co-extruded 20µm+coestruso 25µm ***	3.67±0.07 g	A
Co-extruded 25µm *	3.76±0.06 gh	F
Co-extruded 30µm **	3.92±0.09 hi	A
Clear coated 2 sides acrylic coated 2 sides 40µm *	4.08±0.08 il	F
Clear expanded acrylic coated 2 sides 40µm **	4.15±0.05 il	F
Co-extruded 30µm *	4.17±0.10 l	A
Co-extruded 17µm+co-extruded 20µm ***	4.16±0.11 il	A
Acrylic coated 2 sides 25µm *	4.51±0.05 m	A
Acrylic coated 2 sides 30µm **	4.54±0.18 m	F
Acrylic coated 2 sides 30µm *	4.93±0.02 n	A

* *not printed films*
** *printed films*
*** *laminated films*

guarantee that packages are hermetically sealed. The aroma of the packaged product filtering from imperfectly sealed packages, attracts insects and favors their entry (Highland *et al.* 1964).

Thickness increases the values of resistance to the welding as a greater pressure occurs and it allows the weight to be distributed more homogeneously.

The clear expanded film, even if it is notably thicker, offers lower resistance to

Table 5 - Mean values (±S.D.) of resistance to the perforation of different films of biaxially oriented polypropylene.
For each film the presence (F) or the absence (A) of holes by III instar larvae of Plodia interpunctella *(Hbn.) within 12 days.*

BIAXIALLY ORIENTED POLYPROPYLENE	RESISTANCE TO PERFORATION	HOLES
Co-extruded 17µm **	9.41±0.08 a	F
Acrylic coated 2 sides 20µm **	10.01±0.22 b	F
Co-extruded 17µm *	10.75±0.10 c	F
Acrylic coated 2 sides 20µm *	11.74±0.16 d	F
Co-extruded 20µm *	12.09±0.02 d	F
Co-extruded 20µm **	12.28±0.16 de	F
Clear expanded 40µm *	12.77±0.20 ef	F
Clear expanded 40µm **	12.93±0.21 f	F
Clear expanded 35µm *	12.98±0.13 f	F
Co-extruded 25µm *	14.37±0.24 g	F
Co-extruded 30µm **	15.26±0.08 h	A
Co-extruded 25µm **	15.33±0.13 h	A
Acrylic coated 2 sides 25µm *	15.31±0.22 h	A
Clear expanded acrylic coated 2 sides 40µm *	15.53±0.20 h	F
Acrylic coated 2 sides 30µm *	16.22±0.10 i	A
Co-extruded 30µm *	16.31±0.10 i	A
Clear expanded acrylic coated 2 sides 40µm **	16.69±0.20 i	F
Acrylic coated 2 sides 25µm **	16.73±0.21 i	F
Acrylic coated 2 sides 30µm **	19.38±0.08 l	F
Co-extruded 17µm+co-extruded 20µm ***	20.86±0.39 m	A
Co-extrused 20µm+clear expanded 35µm ***	25.94±0.44 n	A
Acrylic coated 2 sides 20µm+clear expanded acrylic coated 2 sides 40µm ***	26.29±0.33 n	A
Co-extruded 20µm+coestruso 25µm ***	28.08±0.28 o	A

* *not printed films*
** *printed films*
*** *laminated films*

the welding due to the empty areas of the cavitated structure. Acrylic lacquer increases the resistance to welding, in fact the values increase by about a third in the case of transparent 2 side coated films and by a factor of two for clear expanded ones. When the above-mentioned films are printed, the values of resistance of the welding can be

Table 6 - Mean values (±S.D.) friction coefficient biaxially oriented polypropylene. For each the presence (F) or the absence (A) of holes by III instar larvae of Plodia interpunctella (Hbn.) within 12 days.

BIAXIALLY ORIENTED POLYPROPYLENE	FRICTION COEFFICIENT	HOLES
Clear expanded 40µm *	0.17±0.007 a	F
Clear expanded 40µm **	0.18±0.021 ab	F
Clear expanded 35µm *	0.18±0.031 abc	F
Acrylic coated 2 sides 20µm **	0.20±0.015 abcd	F
Acrylic coated 2 sides 25µm *	0.20±0.020 abcd	A
Co-extruded 20µm+co-extruded 25µm ***	0.21±0.021 abcd	A
Co-extruded 30µm *	0.22±0.006 bcd	A
Co-extruded 20µm+clear expanded 35µm ***	0.22±0.006 bcd	A
Co-extruded 17µm+co-extruded 20µm ***	0.22±0.012 bcd	A
Co-extruded 20µm *	0.23±0.006 cd	F
Co-extruded17µm *	0.23±0.007 cd	F
Acrylic coated 2 sides 20µm *	0.23±0.012 cd	A
Acrylic coated 2 sides20µm+clear expanded acrylic coated 2 sides 40µm ***	0.23±0.015	A
Co-extruded 25µm *	0.24±0.004 d	F
Acrylic coated 2 sides 30µm *	0.24±0.009 def	A
Clear expanded acrylic coated 2 sides 40µm **	0.24±0.018 d	F
Co-extruded 25µm **	0.24±0.022 de	A
Clear expanded acrylic coated 2 sides 40µm *	0.28±0.026 efg	F
Acrylic coated 2 sides 30µm **	0.29±0.005 fg	F
Clear expanded 2 sides25µm **	0.30±0.024 g	F
Co-extruded 17µm **	0.32±0.006 g	F
Co-extruded 20µm **	0.32±0.012 g	F
Co-extruded 30µm **	0.33±0.008 g	A

* *not printed films*
** *printed films*
*** *laminated films*

modified by the interaction of inks with the non-printed area during the bobbin winding, however such alterations are not significant.

Resistance to perforation

Also in this case no significant relation emerges between the results of biological and physical test (Table 5). Penetration tests use a metal drift (or awl) which enters the

Table 7 - Means values (±S.D.) of longitudinal breaking elongation of different films of biaxially oriented polypropylene.
For each film the presence (F) or the absence (A) of holes by III instar larvae of Plodia interpunctella (Hbn.) within 12 days.

BIAXIALLY ORIENTED POLYPROPYLENE	LONGITUDINAL BREAKING ELONGATION %	HOLES
Clear expanded 40µm **	103.36±2.46 a	F
Acrylic coated 2 sides 20µm + clear expanded acrylic coated 2 sides 40µm ***	104.06±2.94 a	A
Clear expanded acrylic coated 2 sides 40µm *	107.56±2.36 a	F
Clear expanded 35µm *	108.76±1.54 a	F
Clear expanded crylic coated 2 sides 40µm **	111.11±2.40 ab	F
Clear expanded 40µm *	119.06±1.61 bc	F
Co-extruded 20µm+clear expanded 35µm ***	119.60±1.49 bc	A
Co-extruded 20µm+co-extruded 25µm ***	121.26±1.73 c	A
Co-extruded 17µm **	126.02±3.59 c	F
Co-extruded 20µm **	126.09±4.23 c	F
Acrylic coated 2 sides 20µm **	147.63±4.62 d	F
Co-extruded 25µm **	148.46±2.84 d	A
Acrylic coated 2 sides 20µm *	149.20±2.10 d	A
Co-extruded 17µm+co-extruded 20µm ***	150.96±2.20 d	A
Acrylic coated 2 sides 30µm **	151.70±1.87 d	F
Acrylic coated 2 sides 25µm **	170.54±2.51 e	F
Acrylic coated 2 sides 25µm *	171.68±1.82 e	A
Co-extruded 20µm *	185.68±6.26 f	F
Co-extruded 17µm *	186.99±2.78 f	F
Co-extruded 30µm **	200.80±3.73 g	A
Co-extruded 25µm *	202.34±1.34 g	F
Acrylic coated 2 sides 30µm *	209.29±3.75 g	A
Co-extruded 30µm *	220.28±5.30 h	A

* *not printed films*
** *printed films*
*** *laminated films*

film thanks to a compressive movement whereas the larva makes a series of bites in the surface with its mandibles, applying a force opposite to that exerted by the metal drift.

In the case of transparent films, the perforation values increase as the thickness augments; this doesn't happen for clear expanded films, whose cavitated core, characterized by empty areas, favors penetration. Lacquering and printing processes don't

Table 8 - Means values (±S.D.) of longitudinal breaking load of different films of biaxially oriented polypropylene.
For each film the presence (F) or the absence (A) of holes by III instar larvae of Plodia interpunctella *(Hbn.) within 12 days.*

BIAXIALLY ORIENTED POLYPROPYLENE	LONGITUDINAL BREAKING LOAD Newton/15 mm	HOLES
Co-extruded 17µm *	27.52±0.09 a	F
Co-extruded 17µm **	28.00±0.88 a	F
Acrylic coated 2 sides 20µm *	32.05±0.81 b	A
clear expanded 35µm *	33.73±0.36 bc	F
Co-extruded 20µm **	34.55±0.43 bcd	F
Acrylic coated 2 sides 20µm **	35.54±3.35 cde	F
Co-extruded 20µm *	37.34±0.72 de	F
Clear expanded 40µm **	38.69±0.12 ef	F
Clear expanded acrylic coated 2 sides 40µm *	41.55±0.46 fg	F
Co-extruded 25µm *	41.82±0.27 fg	F
Acrylic coated 2 sides 25µm **	42.11±0.54 fg	F
Acrylic coated 2 sides 25µm *	43.89±0.34 gh	A
Clear expanded 40µm *	46.39±0.31 hi	F
Clear expanded acrylic coated 2 sides 40µm **	47.90±0.93 il	F
Acrylic coated 2 sides 30µm **	49.22±0.51 il	F
Co-extruded 30µm *	50.76±0.41 lm	A
Co-extruded 25µm **	52.63±0.55 mn	A
Co-extruded 30µm **	53.27±0.77 mn	A
Acrylic coated 2 sides 30µm *	55.23±3.10 no	A
Co-extruded 17µm+co-extruded 20µm ***	58.30±0.50 o	A
Co-extruded 20µm+co-extruded 25µm ***	62.11±0.35 p	A
Co-extruded 20µm+clear expanded 35µm ***	64.31±0.16 p	A
Acrylic coated 2 sides 20µm+clear expanded acrylic coated 2 sides 40µm ***	71.56±1.7 q	A

* *not printed films*
** *not printed films*
*** *laminated films*

contribute to an increase or a decrease in the resistance to film perforation. Only in the case of laminates was a relation recorded as the package is formed by coupling 2 films and therefore the greater thickness increases the material resistance.

Friction coefficient

Friction coefficient is exclusively concerned with the superficial features of the film and not with the structure of the film itself; therefore it doesn't affect the perforation ability of *P. interpunctella* larvae, but rather it influences their ability to adhere and climb (Table 6). The printed films are characterized by higher values of friction coefficient as there is a deposit of a series of pigments on their surface which makes them more rough. The lowest values occur in unprinted films and in laminated films as in this case the print is inside the film and consequently does not impact on the slipperiness of the surface.

Longitudinal breaking elongation

The values referring to the longitudinal breaking elongation of film are not related to larvae ability to perforate a packaging (Table 7). The elongation concerns the percentage increase in the dimension of the sample at the moment of breakage. A high value of elongation indicates plasticity of the material.

For all the materials tested it was observed that the increase in thickness, increases the values of longitudinal breaking elongation. The print doesn't affect the values of longitudinal breaking elongation except for co-extruded biaxially oriented polypropylene films.

Longitudinal breaking load

As the thickness increases so do the values of longitudinal breaking load (Table 8). In the case of film with a crystal and so relatively inelastic structure, a greater force is needed to cause the break in the material. As the values increase so a greater resistance by biaxially oriented polypropylene films to attacks by *P. interpunctella* larvae is observed. The insect mostly uses mandibles to bite the surface.

The films with values lower than 50N/15 mm are perforated, except for unprinted polypropylene acrylic 2 side coated (20, 25 μm). These 2 films are characterized by values of longitudinal breaking load which allow the insect to perforate the packaging easily, but this does not happen as the acrylic lacquering prevents the larva from sensing the aroma of the packaged product.

CONCLUSIONS

. The holes observed in the packages during the test have an average diameter of 1.5 mm; this size allows the insect to enter, as Fleurat-Lessard (1990) had already observed with the same species.

Female larvae of *P. interpunctella* can perforate a greater number of packages and they can make more numerous attempts at penetration compared to males. Cline & Higland (1977) observed this behavior also with adult females of *Rhyzopertha dominica*.

The film of co-extruded biaxially oriented polypropylene, as already noticed by Cline (1978b) is easily perforated to the thickness of 25 μm, while clear expanded biaxially oriented polypropylene is pierced to a thickness of 40 μm. In fact this film is obtained by combining air and titanium dioxide among the mesh of propylene molecules; this causes an increase in film thickness with no corresponding increase in volume. The film with a cavitated core is characterized by zones of dense material alongside empty spaces; this causes a lesser resistance of the film to larvae attacks compared to that of a transparent polypropylene film with a crystal structure.

The films of acrylic, two-side coated polypropylene, without print, were not perforated. In fact acrylic lacquering acts as a barrier to gases and aromas (Kail, 1984); the larva does not perceive the product flavors inside the package and so is not stimulated to make attempts to perforate. On the other hand, films similar to the previous ones, but in this case printed, are perforated to a 30 μm thickness. This happens because, during the print process, the lacquering is placed in contact with ethyl acetate, an ink solvent; to remove this liquid afterwards it is brought to a temperature ranging from 60 to 100°C; this causes both a lowering in efficiency of the lacquering due to the thickness reduction and to an increase in permeability to gases and aromas. This alteration is more evident in thinner films.

A relation between the values of physical tests and the biological ones only emerges in the case of longitudinal breaking load. This physical analysis can be used by film manufacturers or by final users as a guide to the choice of materials resistant to attack by *P. interpunctella* larvae. Food can be attacked by different species so it is necessary to investigate the resistance of films to other insects.

The results of this study show that a package which doesn't allow the filtering to the outside of the packaged product's flavour, can protect food, even if its physical structure could easily be attacked by insects.

REFERENCES

ASTM, 1994a. - Test Method for Seal Strength of Flexible Barrier Materials: F 88-85.

ASTM, 1994b - Test Methods for Tensile Properties of Thin Plastic Sheeting: D 882-91.

Bowditch T.G., 1997 - Penetration of polyvinyl chloride and polypropylene packaging films by *Ephestia cautella* (Lepidoptera: Pyralidae) and *Plodia interpunctella* (Lepidoptera: Pyralidae) larvae, and *Tribolium confusum* (Coleoptera: Tenebroinidae) adults. - J. Econ. Ent., 90: 1028-1031.

Cline L.D., 1978a - Clinging and climbing ability of larvae of eleven species of stored product insects on nine flexible packaging materials and glass. - J. Econ. Ent., 71: 689-691.

Cline L.D., 1978b - Penetration of seven common flexible packaging materials by larvae and adults of eleven species of stored product insects. - J. Econ. Ent., 71: 726-729.

Cline L.D., Highland H.A, 1977 - Penetration by adult Lesser grain borers through multiwall kraft bags. - J. Econ. Ent., 70: 156-158.

El-Kady E.A., Hekalam, 1986 - Penetration of various packaging polymer films by certain stored grain insects. - Medeldelingen van Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent. 51: 1261-1266.

FLEURAT-LESSARD F., 1990 - Resistance des emballages de denrèes alimentaires aux perforations par des insects nuisibles. 1. Mèthodes d'ètude et protocoles expèrimentaux. - Sci. Aliments, 10: 5 -16.

FRAENKEL G., BLEWETT, 1943 - The basic food requirements of several insects. - J. Exp. Biol., 20 (1): 28-34.

GERHARDT P.D., LINDGREN D.L., 1954 - Penetration of various packaging films by common stored-product insects. - J. Econ. Ent., 47: 282-287.

HIGHLAND H.A, DAVIS D.F., MARZKE F.O., 1964 - Insectproofing multiwall bags. - Mod. Pack., 37 (12): 133-138.

HIGHLAND H.A, 1984 - Insect infestation of packages. In: F. B. BAUER (Ed.), Insect Management for Food Storage and Processing., AACC, St. Paul, Minnesota: 311-320.

KAIL J.A.E., 1984 - Flavour barrier evaluation enhances material selection. - Packaging 9: 68-70.

LOCATELLI D.P., GARAVAGLIA E., 1994 - Suscettibilità di confezioni per prodotti dolciari all'attacco di alcuni insetti. Workshop CNR-RAISA "Imballaggio funzionale per una migliore qualità degli alimenti confezionati". Milano:147-152.

MORÉRE J.L., LE BERRE J.R., 1967 - Étude au laboratoire du development de la pyrale *Plodia interpunctella* (Hübner) (Lepidoptera: Phycitidae). - Bull. Soc. Ent. Fr., 72: 152-156.

NOACK VON S., 1982 - Widerstandsfähigkeit von Kunststoff-Folien gegenüber *Tribolium confusum* nach mechanischer Beanspruchung in einem Knittergerät., - Anz. Schädlingskd. Pflanzenschutz Umweltschutz, 55: 19-23.

PAGANI M., 1984, - Vulnerabilità agli insetti di alcune confezioni per alimenti. Ricerche preliminari. - Atti III Simposio sulla difesa antiparassitaria nelle industrie alimentari e la protezione degli alimenti. Piacenza, 1982: 309-317.

SCHIMIDT H. U., 1979 - Die mechanische Wiederstandsfähigkeit von Packstoffen (Folien) gegen den Getridekapuziner (*Rhizopertha* (sic!) *dominica* F.), den Brotkäfer (*Stegobium paniceum* L.), den rotbraunen Reismehlkafer (*Tribolium castaneum* Hbst.) und die Larven der Dörrobstmotte (*Plodia interpunctella* Hbn.). - Material und Organismen, 14 (4): 241-258.

YERINGTON A.P., 1975 - Insect resistance of polypropylene pouches. - Mod. Pack. 48 (5): 41-42.

YERINGTON A.P., 1983 - Efficiency of various overwraps and seal tightness in excluding insects from dried-fruit cartons. - Environ. Ent., 12: 1310-1311.

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Accepted 20 July 2004