Zagazig J. Agric. Res., Vol. 45 No. (4) 2018 1357-1371

Food, Dairy and Home Economic Research

http:/www.journals.zu.edu.eg/journalDisplay.aspx?JournalId=1&queryType=Master

EFFECT OF SOME PACKAGING MATERIALS AS WHEAT GRAIN DISINFESTATIONS TOOL AGAINST *Tribalism castanium* (Herbst.) AND *Rhyzopertha dominica* (Fab)

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Received: 16/04/2018 ; Accepted: 20/05/2018

ABSTRACT: Most packaged food products are subject to attack and penetration by insects. In addition reducing food quality, insects annihilate quantity, too. Since, different ways are designed for controlling stored-product pests without application of chemical methods. So, the present study included laboratory methods to evaluate the effectiveness of three packaging materials, namely high density polyethylene (HDPE), polyamide/polyethylene (PA/PE) and polyester/aluminum/polyethylene (PET/AL/PE) to prevent or minimize the insect infestation and grain wastage resulting in the attack of wheat grain and their products by two notorious insect species, the lesser grain borer *Rhyzopertha dominica* as primary infestation insect and red flour beetle, *Tribolium castanium* as secondary one. Two laboratory experiments were conducted to determine the protecting capacity of the three package materials through assessing some parameters, number of adults emerged (progeny), infestation (%), weight loss (%) germination (%) and moisture content. The first experiment contained cleaned and correct wheat grain in each bag with numbers of insects released external around the bags in glass container supplied with a lid to determine the penetration levels of both insects separately. The second experiment comprised infested wheat grain by the two tested insects packaging in each of the three materials separately with three replicates and stored for ten months. The same replicates without insect infestation were carried out to serve as control. In the first experiment, the results revealed that high density polyethylene was the susceptible packaging material because it had maximum number of holes and penetrations by insects into them. In the second experiment, results showed that all tested parameters significantly influenced by the type of packing materials and storage periods. Increasing storage periods of wheat seed up to 10 months significantly affected grain quality. Effect of time period showed significantly more number of adults emerged, increased insect infestation and weight loss percentages in wheat grains after 10 months than after 8, 6, 4 and 2 months. Oppositely, germination (%) and moisture content were decreased gradually through the periods of experiments. Packaged wheat grains in polyester/Aluminum/ polyethylene (PET/AL/PE) significantly recorded the most excellent results for all tested parameters, followed by polyamide/polyethylene (PA/PE) and lastly in high density polyethylene (HDPE).In addition that, *Rhyzopertha dominica* had penetration ability greater than *Tribolium castaneum*. Except *Rhyzopertha dominica* with (HDPE) material, the two insect species cannot penetrate any of the tested packing materials with no perforations. Eventually, the triple layer bag (PET/AL/PE) can be used in storing wheat grain against the attack of both *Rhyzopertha dominica* and *Tribolium castanium*.

Key words: Wheat grain, *Rhyzopertha dominica*, *Tribolium castaneum* packaging materials, punctures, penetration, quality.

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INTRODUCTION

Wheat grain (*Tritium aestivum* L.) is considered the most important crop and being the stable diet for human in the world. Grain storage occupies a vital place in the economies of developed and developing countries (**Ellis *et al.*, 1992**). Stored product insects caused extensive losses of food stuff and stored product as well as reduce the quality and quantity of stored grains.

Cereal grains losses during storage can reach 50% of total harvest in some countries (**Fornal *et al.*, 2007**). Lesser grain borer *Rhyzopertha dominica* fab, is one of the serious pests, it is a primary pest of stored grain. *Tribolium castanium* also one of common and secondary pest of stored grains. Overuse of synthetic pesticides, high toxicity and non- biodegradable properties of pesticides residues in soil, water and crop affect public health. Meanwhile, we must be needed to study the environmental friendly methods and techniques to reduce pesticides use during maintaining crop yields. Consumer demands products free of chemical and insect contamination to the application of non-residual technologies for the protection of stored grains. Safe storage of grains and food products against insect infestation and damage is a serious concern.

Packing is an essential part of a long term incremental development process to reduce losses (**Olsmats and Wallteg, 2009**). Use of plastic packing materials have been increased compared with the past as older packing material bags were made from paper and card board (**Riudavets *et al.*, 2007**) plastic packing can solve many problems such as damage caused by moisture content, smell and weight losses .... *etc.*

In recent years, packaging seeds in moisture-barrier packaging materials to prevent loss of viability and resistant or hermitically sealed packaging materials for storage and marketing has explored. The purpose of such packaging material is to maintain seeds at safe storage moisture levels (**Copeland and Mc Donald, 1995**).

The success of packing technique is that, the packed foodstuff is free from insects until they are consumed (**Mullen and Mowery, 2000**). Plastic based on polypropylene, polyethylene, polyvinylchloride and cellophane are usually used for packing purpose (**Odian, 2004**). Plastic packing materials provides benefit in the form of protection against insect contamination during its use (**Paine and Paine 1992**).**Ramadan (2016)** showed that normal storage (stored wheat grains in jute bags) and sealing storage (stored wheat in plastic jars and metal packages) significantly affected storage efficacy, characters, insect infestation, weight loss and final germination percentages.

Therefore, this study was carried out to evaluate the effect of three packaging materials, namely high density polyethylene (HDPE), polyamide/polyethylene (PA/PE) and polyester/aluminum/polyethylene (PET/AL/PE) and storage periods on the following criteria, progeny infestation percentage of *Rhyzopertha dominica* and *Tribolium castanium*as as well weight losses (%), moisture content and germination percentage under laboratory conditions.

MATERIALS AND METHODS

The present study was carried out at Department of Stored Product Pests, Plant Protection Research Institute, Sakha Agricultural Research station, Egypt.

Insects Used

Rust red flour beetle *Tribolium castanium* (Herbst.)

T. castanium adults collected from the stock culture, were released in sterilized jars at 30 ± 2C° and 70 ± 5% RH, each contain 300g of whole and erushed wheat grains and 200-300 adults of insects. Adults were left for two weeks until egg lying and then removed. Once adults emerged insects (1-2 weeks old) were collected to use in further experiments.

Lesser grain borer *Rhyzopertha dominica* (Fab)

Lesser grain borer were reared on wheat grains under 70 ± 5% relative humidity and 30 ± 2°C. The new emerged adults (1-2 week old) were used in the next experiments.

Source of wheat used

Wheat (Miser 2 variety was obtained from Field Crop Institute, Sakha Agricultural Research Station, Egypt.

Source of packing materials

The used packing film samples were high density polyethylene (HDPE), Polyamide/ Polyethylene (PA/PE) and Polyester/ Aluminum/ Polyethylene (PET/AL/PE). They were obtained from the Arabic medical packaging company (flexpack) Cairo, Egypt. Characteristic of different packing materials, mechanical, physical and permeability properties are shown in Table 1.

In order to study the management of packing materials as protectants to wheat grains against the attack of insect species, two experiments were conducted under laboratory conditions;

The First Experiment

Penetration ability of *R. dominica* and *T. castanium* through different packaging materials

In this experiment, three types of plastic materials mentioned above were used to examine the ability of *T. castanium* and *Rhyzopertha dominica* to create punctures and penetration. Plastic jars of half liter volume were used. Each jar contained three packets of the same type filled with 50 g of wheat grain and then 50 adults of *R. dominica* were released in the middle of jar. Immediately the jar was covered with lid containing small size openings for ventilation. Total of three jars with uniform packing type were taken. Similarly, the same procedure was repeated with *T. castanium* adults (**Hassan *et al.*, 2014**). The bags were examined after 3, 7, 14 and 21 days by sieving the wheat grains and then the number of insects and punctures were recorded.

The Second Experiment

Storage of infested wheat grain

In order to evaluate the efficacy of packing materials for suppression the life cycle development, bags of each type were filled with (250 g/bag) of wheat grains, immediately ten unsexed pairs of *R. dominica* or *T. castanium* (2-weeks old) were transferred separately to the middle of each bag and then bags were sealed by sealing machine. Wheat grain bags without insect infestation were used as control under the same conditions mentioned above. Three replicates of each packing type were made with every insect (**Jacob *et al.*, 2013**). All bags were stored in suitable containers for 10 months under the laboratory conditions of Stored Product Research Department. Samples were withdrawn every two months and examined for emerged adults, (%) infestation, (%) germination, (%) grain loss and moisture content.

Studied Characters

Number of adults emerged and insect infestation percentage

At the end of each storage periods (2,4,6,8 and 10 months), three bags per treatment combination infested and none infested were taken to examined for the number of insects emerged (progeny), meanwhile 100 grains from each treatment packets were picked randomly for damage assessment.

The grain was considered damage when contain one or more holes. Percentage damage was estimated according to the formula described by (**Jood *et al.*, 1996**).

Insect infestation (%) =

$$\frac{\text{Number of insect damage}}{\text{Number of total grains inspected}} \times 100$$

Weight loss percentage

The weight losses caused by insect infestation were calculated by the following equation:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Seed germination capacity (%)

To evaluate the germination capacity at the end of each storage period the rules of International Seed Testing Association **ISTA (1996)** were used, where random sample of 100 grains for each treatment were allowed to germinate on top filter paper in sterilized Petri-

Table 1. Mechanical, physical and permeability properties of used packaging materials

Characteristics	Packaging materials	HDPE	PA/PE	PET/AL/PE
Mechanical properties	Impact strength (N/cm^2)	3100	14570	2900
	Elongation	95	263	84
	Heat sealing Tem. (°C)	130	140	140
Physical properties	Printability	Poor	Medium	Medium
	Thickness (um)	50	90	90
	Clarity	Translucent	Translucent	Opaque
	Weight of meter square (g/m^2)	8.90	15.30	17.45
permeability properties	Water vapor (g/m^2 d)	4.7	3.0	0
	O_2 (CC/m^2 d)	2100	23	0

dishes (14 cm diameter) lined with filter paper and moistened with 4ml of distilled water in three replicates. Petri dishes containing wheat seeds were then incubated at 25°C temperature for five to seven days to germinate. Germination (%) was calculated according to the following equation:

Germination (%) =

$$\frac{\text{Number of germinated seed}}{\text{Total number of seeds}} \times 100$$

Moisture content (%)

The moisture content was determined in each grain sample by drying 3g sample in an air forced draft oven at a temperature of 105± 5°C till to constant weight. The procedure of **AACC (2000)** method No. 44-15A was followed for the estimation of moisture content in each sample. The moisture content of the grain sample was determined on a weight basis using the following formula:

Moisture content (%) =

$$\frac{\text{Weight of grain sample- Weight of dried grain sample}}{\text{Weight of grain sample}} \times 100$$

Statistical Analysis

Data obtained from experimental treatments were subjected to the analysis of variance using the Costat Statistical and treatments means were compared using LSD range test at 5% level according to **Gomez and Gomez (1984)**.

RESULTS AND DISCUSSION

Penetration Ability and Numbers of Holes of *T. castanium* and *R. dominica* through Different Packaging Materiel Types During Storage

Effect of packaging materials

Penetration ability and number of holes of *T. castanium* and *R. dominica* through packaging types, HDPE, PA/PE and PET/AL/PE were investigated. Analysis of variance revealed high significant difference in penetration and numbers of holes of *T. castanium* and *R. dominica* due to packaging material (Table 2).

The results showed that holes made by insects, insect penetrations mostly occurred in high density polyethylene type compared with PA/PE and PET/AL/PE. These results show that high density polyethylene proved to be a rather susceptible packaging types against these pests, with the highest number of penetrations and number of holes that valued 5.375, 4.833, respectively. While PA/PE and PET/AL/PE had neither penetrations nor holes until the end of storage period. These results are in agreement with **Qasim *et al.* (2013)**, who affirmed that red flour beetle is able to penetrate only through polyethylene packaging.

Effect of insects

Analysis of variance revealed high significant difference in penetrations and number of holes

Table 2. Effect of packaging type, insect specie and storage period on holes and penetrations by *R. dominica* and *T. castaneum* after 3, 7, 14 and 21 days post treatment

Treatment	Penetration (N-insects)	Number of holes
Packaging material (p)		
HDPE	5.375	4.833
PA/PE	0.00	0.00
PET/AL/PE	0.00	0.00
Sig.	***	**
LSD (0.05)	0.359	0.207
Infestation (I)		
R. dominica	3.583	3.22
T. castanium	0.00	0.00
Sig.	*	**
LSD (0.05)	0.547	0.207
Storage time (day), (T)		
3	1.05	0.89
7	1.88	1.67
14	2.11	1.94
21	2.11	1.94
Sig.	**	**
LSD (0.05)	0.121	0.189
Interaction between treatments		
P × I	**	**
P × T	**	**
I ×T	**	**
P × I × T	**	**

P >0.05 non-significant, P < 0.05 Significant

due to *T. castanium* and *R. dominica* (Table 2). Results showed that the highest number of penetration and number of holes by *Rhyzoperth dominica* recorded (3.583, 3.22), respectively, compared to *T. castanium* which had neither penetrations nor holes until the end of storage period.

Effect of storage period

Damages in packaging materials in the form of holes, insect penetrations were studied with respect to time intervals effect (Table 2). Increasing the storage periods from 3 to21 days had highly significant effects on tested penetration and number of holes. The highest penetration and number of holes after 14 days were more than that of 7 days. These results are in agreement with previous study in which it was observed that penetration by beetles varies due to time interval (**Qasim *et al.*, 2013).**

Also, the current results conform a study which reports that polymers like polyethylene and cellophane could be penetrated by certain stored grain insect pests (**Cline, 1978**) and coincide of **Allahvaisi and Safaralizade (2010)** who checked polymers permeability for some stored grain pest insects.

The interaction effects

The results revealed that, there no insect penetration or punctures in studied packing types caused by *T. castanium* (Fig. 1). On the other hand, *R. dominica*, recorded minimum insect penetration and punctures with HDPE (6.33) and (5.33) and maximum insect penetration and puncture values of (12.67), and (11.7) after three and 14 days, respectively.

These results disagreed with those results recorded by **Hassan *et al.* (2016)** they showed that maximum number of *R. dominica* punctures through PE was after less time period than after more time without significant differences. These results showed that, among the three packing materials (HDPE) were susceptible for penetration only by *R. dominica*. Thus it is important to evaluate the resistant packing phenomenon against different insects independently in packing type, thickness and insect species concerned. Therefore the results of the present study are in agreement with those of earlier authors showing PE as susceptible packing to insect attack comparing with the remainder films, (**Highland and Wilson, 1981**).

Moreover, **Mullen *et al.* (2012)** reported that PE is susceptible to insect attack while thick package proved resistant against insect attack for both species. In this regard, to begin a discussion of insect's penetration, it is important to understand the insect pests that most commonly attack packaged food separated packaged pests into two categories, penetrators and invaders. Invaders are insects that typically have weakly developed mouth parts at the larval and adult stages (**Wohlgemuth, 1979; Highland, 1991**). Invaders commonly enter package through opining resulting from mechanical damage, defective seals or holes made by other insects penetrating the package, some common invaders include the rust red flour beetle *T. castaneum*, confused flour beetle *T. castanium* and the flat grain beetle *Cryptolets pusillus* (**Mullen and Highland, 1988**). Insects such as lesser grain borer *R. dominica*, warehouse beetle, *Trogoderma* variable, the rice weevil *Sitophilus oryzae* are known to be good package penetrators and are capable of boring through one or more layers of packing materials. It must be summarized that, both penetrators and invaders will exploit package flows or other existing opening in order to reach to food product.

Storage of Infested Wheat Grains

Effect of packaging materials

Results in Table 3 show that, the three studied packaging types, HDPE, PA/PE and PET/AL/PE significantly differed for affecting on the all studied parameters *i.e.*, number of adults emerged, (%) infestation, (%) weight losse, moisture content and germination capacity (%). These results may be due to differences in characteristics of films used such as permeability and thickness.

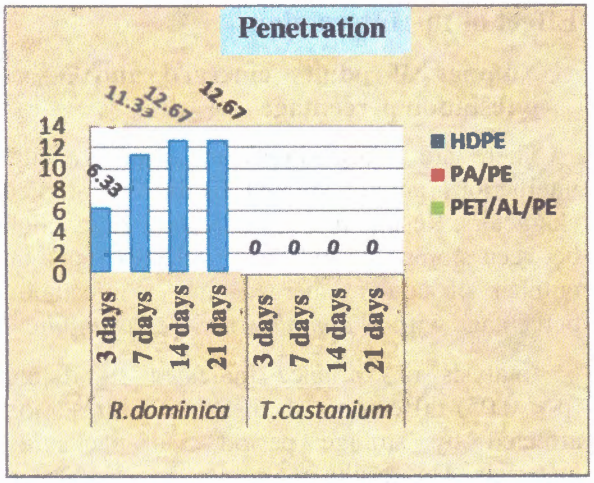
Results presented in Table 3 revealed that the highest number of adults emerged, (%) infestation and weight loss percentage were recorded with infested wheat grains stored in HDPE followed by PA/PE with (59.66, 8.48 and 6.92), (12.19, 2.07 and 2.73), respectively, compared to PET/AL/PE which had no any number of adults emerged and infestation percentage until the end of storage period. In addition, HDPE and PA/PE recorded the lowest number of final germination and moisture content percentage (81.46, 11.94), (87.00, 12.22%), respectively compared with those stored in PET/AL/PE who recorded the highest number of final germination percentage and moisture content (93.93, 12.37%), respectively.

Effect of insects

Results presented in Table 3 show that the highest number of adults emerged, (%) infestation, weight loss percentage and moisture content were recorded with wheat grains infested with *R. dominica* followed by *T. castanium* with (57.37, 8.63, 6.10 and 12.21%), (14.48, 1.93, 2.58 and 12.18%), respectively, compared to control which had (0.00, 0.00, 1.56, 12.15%), respectively, until the end of storage period. While, control (without insects) recorded the highest number of final germination percentage followed by *T. castanium* with (89.87 and 88.37%), respectively, but the lowest number of final germination percentage (84.15) was recorded with *R. dominica*.

Effect of storage period

It is cleared that, increasing storage periods of infested wheat grains from 2-10 months had



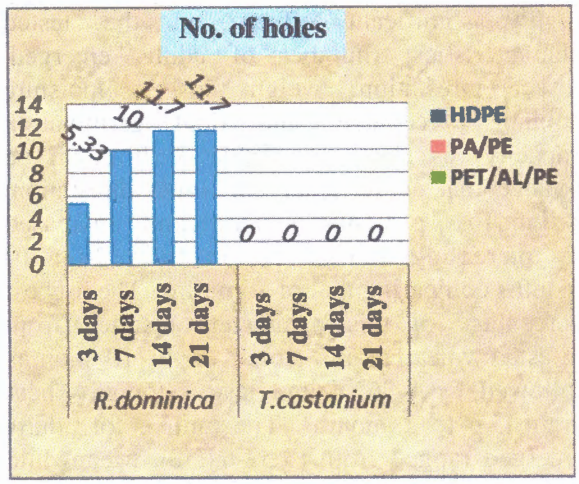


Fig. 1. The interaction effect of storage periods, packaging materials on penetration and number of holes for *R. dominica* and *T. castanium*

Table 3. Effect of packaging material, insects and storage period on No. of adults emerged, insect infestation, weight loss, final germination and moisture content percentage in infested wheat grains and their interactions

Treatment	No. of adults emerged	Infestation (%)	Weight loss (%)	Final germination (%)	Moisture content (%)
Packaging materials (p)					
HDPE	59.66	8.48	6.92	81.46	11.94
PA/PE	12.19	2.07	2.73	87.00	12.22
PET/AL/PE	0.00	0.00	0.58	93.93	12.37
Sig.	**	**	**	**	**
LSD (0.05)	1.437	0.294	0.12	0.51	0.035
Treatments (Tr)					
Control	0.00	0.00	1.56	89.87	12.15
R, dominica	57.37	8.63	6.10	84.15	12.21
T, castanium	14.48	1.93	2.58	88.37	12.18
Sig.	**	**	**	**	*
LSD (0.05)	1.437	0.294	0.12	0.51	0.035
Storage time (month), (T)					
0	0.00	0.00	0.00	100	12.46
2	3.52	0.67	0.86	100	12.29
4	12.04	1.81	1.81	98.81	12.23
6	24.33	3.52	3.95	83.85	12.17
8	39.30	5.96	5.53	74.56	12.04
10	64.52	9.15	8.32	67.56	11.87
Sig.	**	**	**	**	**
LSD (0.05)	2.032	0.415	0.17	0.72	0.05
Interaction					
p×tr	**	**	**	**	NS
p×t	**	**	**	**	**
tr×t	**	**	**	**	NS
p×tr×t	**	**	**	**	NS

highly significant effects on the tested characteristics, (number of adults emerged, insect infestation, weight losses, moisture content percentage, and final germination capacity) as shown in Table 3. It could be noticed that adults emerged, insect infestation, weight loss, percentages significantly increased by increasing storage period from 2-up 10 months comparing that of zero time. The highest percentage of this parameters resulted from infested wheat grains stored up to 10 months followed by 8, 6, 4 and lastly storage wheat grains up to 2 months. The number of adults emerged ranged from (3.52-64.52). Meanwhile the (%) infestation achieved (0.67-9.15). A continuous gradual loss in weight happened in wheat reached to 8.32% with the extend of the storage periods to 10 months in all treatments. These results may be owing to instability of the temperature and humidity during storage periods (**Attia *et al.*, 2014 and 2015**).

In contrary, the moisture content and germination capacity significantly decreased with the progresses of storage periods from 2-10 months (Table 3). Moisture content gradually decreased in all treatments which had (11, 87) at the last month of storage compared to 12.46 at zero time (before beginning the experiment). These results coincide the results reported by **Pessu *et al.* (2005)**. At the end of the storage period there were a significant decrease in moisture contents in all containers compared with the moisture contents before storage. Changes of moisture content were mainly due to de-sorption of moisture to the ambient air (**Shakeel *et al.*, 2012**). Concerning final germination percentage of wheat, the results of the present study indicated that germination capacity in wheat grains significantly decreased with the progress of storage periods up to 10 months which ranged from 67.56 at the end compared to 100% before storage. The seed deterioration during storage was due to the damage in membrane, enzyme, and proteins causing death of the seed and loss of germination (**Roberts, 1972**). These results are confirmed by **Singh *et al.* (2000)** who reported that 5-17% reduction in seed germination achieved when grain was stored approximately for five months.

Effect of the Interactions

Number of adults emerged and insect infestation percentage

There are many significant effects of the interactions among studied factors on studied characters. Results in Figs. 2, 3 show interaction between storage periods and packages types on number of adults emerged, insect infestation percentage with *R. dominica* and *T. castanium*.

Analysis of variance indicated significant ($p < 0.05$) differences in insect pest infestation affected by storage period and packaging materials. The results of present study indicated that insect' infestation of wheat grain stored in different types of packaging materials increased with the progress of storage period. Where, the highest number of adults emerged and insect infestation percentage were up to 10 months, followed by 8 months and lastly 2 months during storage period. These results may be due to instability of the temperature and humidity during storage periods (**Attia *et al.*, 2014 and 2015**). After two months of storage, results presented in Figs. 2 and 3 revealed that the highest number of adults emerged and infestation (%) of *R. dominica* were recorded with HDPE followed by PA/PE with (19.33, 3.67), (2.33, 0.76), respectively.

While after 10 months the results recorded (392.67, 52.33), (93.67, 15.70), respectively. Infestation (%) of *R. dominica* were observed compared to PET/AL/PE and control which had no any insect infestation until the end of storage period.

For *T. castanium* the highest number of adults emerged and infestation percentage, after two and 10 months of storage were (10.0, 1.67) and (94.33, 14.33) recorded with HDPE, respectively, compared with PA/PE and PET/AL/PE which had no any insect infestation until the end of storage. The reduction in percentage of insect infestation in wheat grains stored in PA/PE and PET/AL/PE packages may be ascribed to completely effective in maintaining seed moisture content and prevent the arrival of insects to seeds, which helps to reduce the incidence of insects (**Chattah *et al.*, 2012**).

It's worthy to conclude that, the PA/PE and PET/AL/PE were found to be the best packing

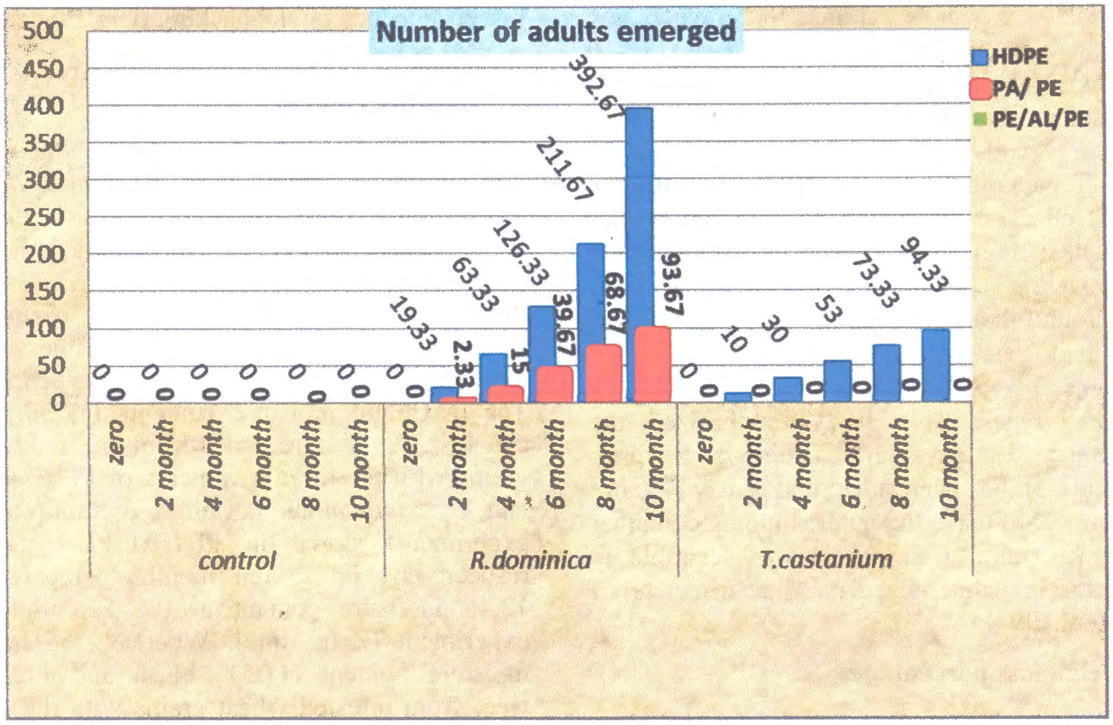


Fig. 2. Number of adults emerged of infested wheat grains as affected by packaging materials and storage periods

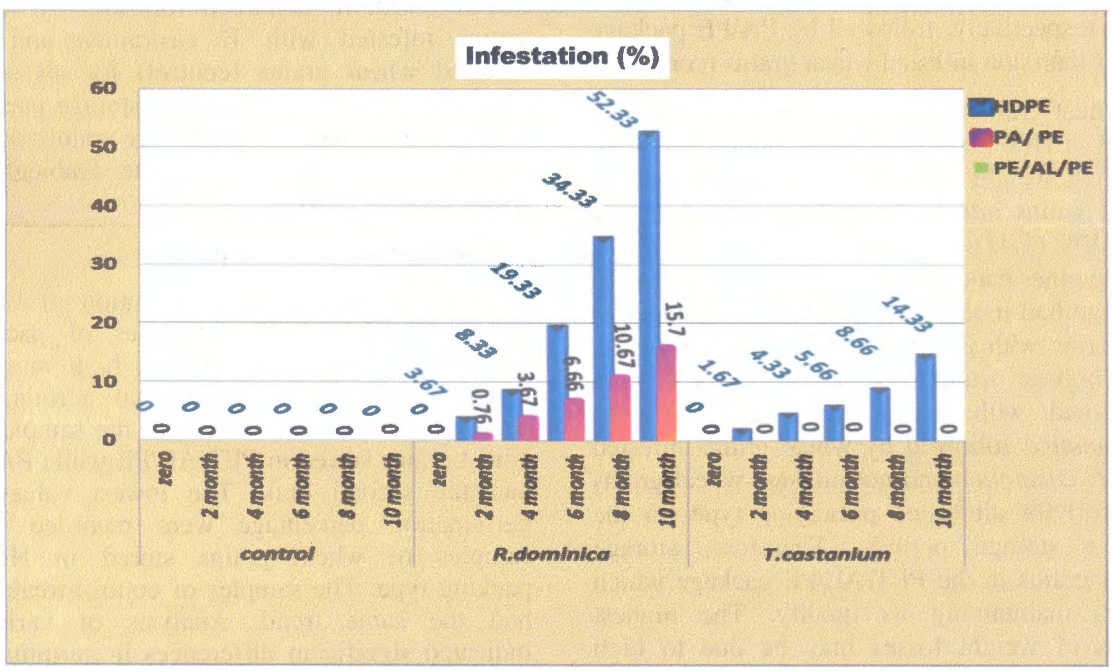


Fig. 3. Insect infestation percentage of infested wheat grains as affected by packaging materials and storage periods

materials for wheat grains to prevent any infestation by insect during storage period (2-10 months). The variation between the tested parameters may be due to the nature of *T. castanium* and *R. dominica* in addition to the type of packing materials. **Jianhua and Dan (2015)** checked infestation by cigarette beetles into wheat flour either packed in different sorts of packaging or in unpacked open wheat flour. They found that both aluminum foil and plastic bags had the greatest resistance to package invasion by *L. serricorne* compared with different types. This study emphasized the importance of packaging materials to pack foodstuffs. It has been stated that it may be more economical to make the outer shipping container insect resistant; it may be more desirable to make the consumer-sized package insect proof **(Mullen, 1994)**.

Weigh loss percentage

Wheat grains infested with *R. dominica* and *T. castanium* and stored in PET/AL/PE package kept the lowest weight loss percentage for the longest storage periods (Fig. 4). It has been demonstrated that at the end of 10 months storage, weight losses of wheat grains infested with *R. dominica* and *T. castanium* and stored in PET/AL/PE package were approximately (1.2, 0.92) respectively, followed by PA\PE package higher than non infested wheat grains (control).

Wheat grains infested with *R. dominica* and stored in HDPE package for 6 months recorded the high weight loss (%) (15.50) followed by wheat grains infested with *T. castanium* stored in PA\PE (5.42) comparing with control (3.22). On the other hand, wheat grains stored in PA\PE package had moderate value of weight loss (%) comparing with HDPE and PET/AL/PE package. The highest values of weight losses were concerned with wheat grains infested with *R. dominica* followed by wheat grains infested with *T. castanium* and not infested wheat grains (control) for all tested packaging type for the longest storage periods. Therefore, storage wheat grains in the PET/AL/PE package which allows maintaining its quality. The highest values of weight losses may be due to high insect infestation density. Additionally the resistance packing phenomenon against different insects depends on the packing type, thicknesses as well as insect species.

Moisture content

Results obtained of moisture content of infested wheat grains with *R. dominica* and *T. castanium* stored in three packing materials are presented in Fig. 5. The results indicated that, moisture content gradually decreased in all three types of studied packing materials throughout the storage period either with infested or not infested grain (control experiment). The maximum moisture contents (12.30,12.30 and 12.23%) were recorded from infested wheat grains with the three treatments of *R. dominica* and *T. castanium* and not infested grain (control experiment) stored in PET/AL/PE package, respectively, up to ten months compared to 12.46 moisture content at the beginning of experiment (Zero time). Whereas, the lowest moisture content (11.51, 11.36 and 11.25%) were from infested wheat grains with the three treatments mentioned above, respectively stored in HDPE package up to ten months. Infested wheat grains stored in PA\PE package had moderate value of moisture content comparing with HDPE and PET/AL/PE package. On the other hand, the highest values of moisture content were concerned with wheat grains infested with *R. dominica* followed by wheat grains infested with *T. castanium* and not infested wheat grains (control) for all tested packaging types for the longest storage periods. Changes of moisture content were mainly due to de-sorption of moisture to the ambient air **(Shakeel *et al.*, 2012)**.

Final germination capacity

The results of final germination of wheat grains stored in different types of packing materials were recorded in Fig. 6. It must be concluded that the highest final germination percentages were recorded with the samples of wheat grains stored in PET/AL/PE while PA/PE had the second rank. The lowest values of germination percentage were recorded with samples of wheat grains stored in HDPE packing type. The samples of control treatment had the same trend. Analysis of variance indicated significant differences in germination capacity affected by storage period and packing materials. The results indicated that the maximum

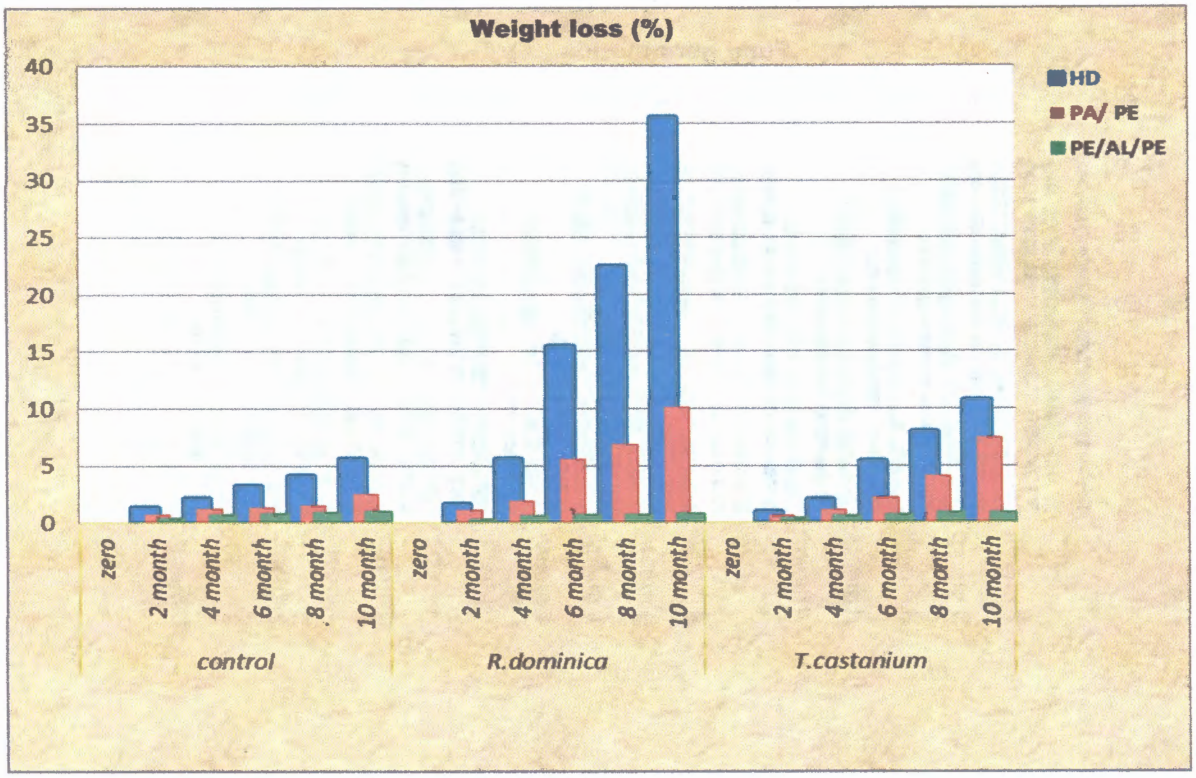


Fig. 4. Effect of packaging materials on weight loss percentage of infested wheat grains during storage periods

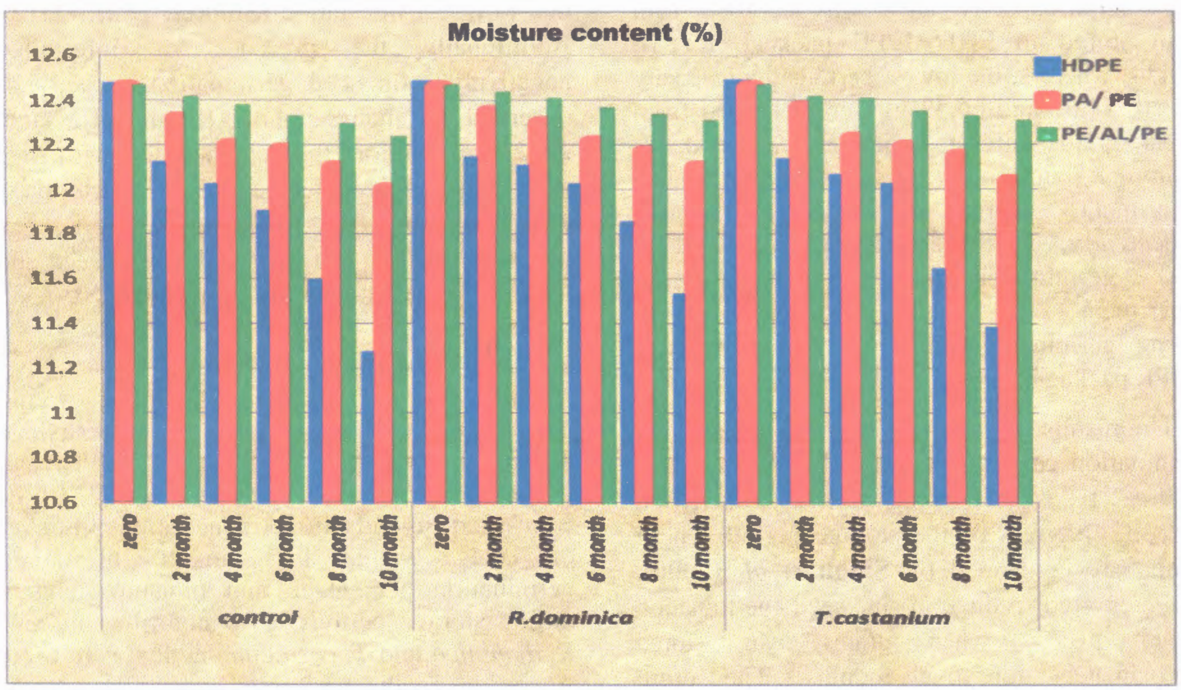


Fig. 5. Effect of packaging materials on moisture content of infested wheat grains during storage periods

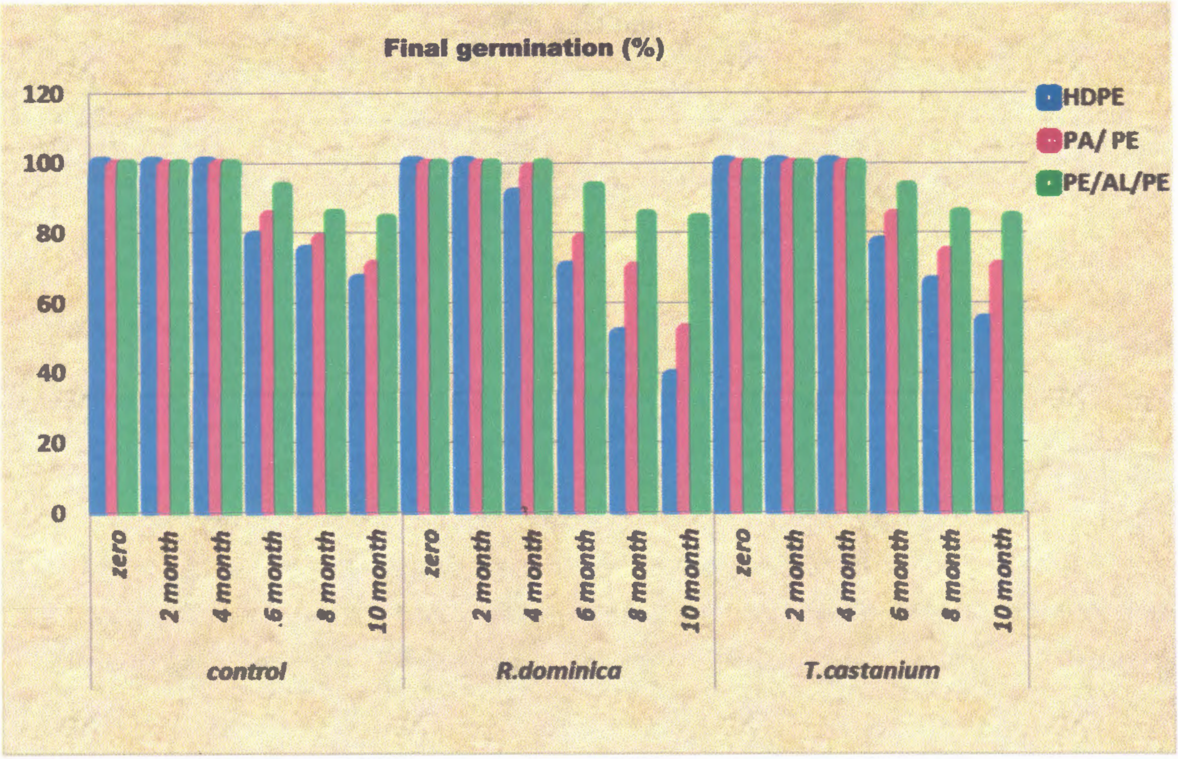


Fig. 6. Effect of packaging materials on final germination percentage (%) of infested wheat grains during storage periods

germination capacity (84%) was recorded from grain stored in PET/AL/PE package for 10 months, whereas, the lowest germination capacity (38.70, 54.67 and 66.33%) were recorded from wheat grains infested with *R. dominica, T. castanium* and not infested grain (control experiment) stored in HDPE package, respectively, up to ten months compared to (100%) germination capacity at the beginning of experiment (Zero time). The main reason of falling germination capacity of the grain in HDPE package may due to insect infestation.

The results of the present study indicate that germination capacity of wheat grains stored in different types of packing materials decreased with the progress of the storage period. These results are confirmed by **Singh *et al.* (2000)**, who reported reduction in seed germination valued 5-17% when grains was stored approximately for five months. The grain deterioration during storage was refer to the damage in membrane, enzyme, proteins and nucleic acids. The main reason of falling germination capacity of the grains in HDPE was due to insect infestation **(Shakeel *et al.*, 2012)**. Additionally the presence of infestation negatively influenced germination capacity as observed by many authors **(Fleurat-Lessard, 2002)**. In addition, the accumulation with time such degenerative changes result in complete disorganization of membranes and cell organelles and so causing death of the seed and losses of germination **Ramadan (2016)**.

Conclusion

Three types of packaging materials, varying in properties namely, high density polyethylene (HDPE), polyamide/polyethylene (PA/PE) and polyester/aluminum/polyethylene (PET/AL/PE) were used to study insect penetrations, number of holes, weight loss, insect infestation, germination percentage and moisture content during storage periods. Two notorious insects, *R. dominica* and *T. castanium* adults were used. According to the performed works the current results showed that the (HDPE) had the maximum of numbers of holes and penetration followed by (PA/PE) and (PET/AL/PE) which had the least of these parameters. In addition that the (PET/AL/PE) packing material was the better for reducing the insect infestation and weight loss along with the storage periods (10 months). Therefore, the rating of the tested materials is in the following rank: susceptible (HDPE), moderately tolerant (PA/PE) and resistant (PET/AL/PE) against the insect attack of *R. dominica* and *T. castanium*. These materials are chemical- free technology for grain storage, where they have many advantages, flexibility, transportability and ease of erection, simplicity of operation and maintenance and durability. Moreover, their availability in various sizes, capacities forms can suit a wide range of requirements to fit several levels of operation for medium to long term storage as well safe transport. Ultimately, in this study, the triple layer bags, (PET/AL/PE) can be used for protecting wheat grain against invading of *R .dominica* and *T. castanïum* adults. Further studies are needed to investigate some factors like climate and increased temperature on the effectiveness and longevity of the three tested materials to support the present findings.

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تأثير بعض مواد التعبئة والتغليف كوسيلة لمنع إصابة حبوب القمح بحشرتي خنفساء الدقيق الحمراء وثاقبة الحبوب الصغرى

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تتعرض معظم منتجات حبوب الغذاء المعبأة للهجوم والاختراق بواسطة الحشرات، تقوم الحشرات بتدمير كميات كبيرة من الحبوب بالإضافة إلى خفض جودة هذه الحبوب، ومن ثم، صممت طرق مختلفة لمكافحة آفات الحبوب المخزونة ومنتجاتها بعيدا عن استخدام الطرق الكيميائية، اشتملت الدراسة الحالية على بعض الطرق المعملية لتقييم كفاءة ثلاثة من مواد التعبئة والتغليف وهي البولي ايثيلين عالي الكثافة (HDPE) وبولي أميد/البولي إيثيلين (PA/PE) والبوليستر/الألمونيوم/البولي إيثيلين (PET/AL/PE) لمنع أو تقليل الإصابة الحشرية وكذا تقليل فقد الحبوب الناتج من مهاجمة حبوب القمح ومنتجاته من قبل نوعين من الحشرات الخطيرة وهى، ثاقبة الحبوب الصغرى *Rhyzopertha dominica* وهى أولية الإصابة، وخنفساء الدقيق الصدئية الحمراء وهى ثانوية الإصابة، أجريت تجربتان معمليتان لتقدير الكفاءة الوقائية للأنواع الثلاثة من مواد التغليف المستخدمة من خلال حساب بعض المعايير مثل عدد الحشرات الناتجة (الخلفة) والنسبة المئوية للإصابة، النسبة المئوية للفقد فى وزن الحبوب، وكذا النسبة المئوية للإنبات بجانب تقدير المحتوى الرطوبي للحبوب، اشتملت التجربة الأولى على حبوب قمح سليمة ونظيفة موضوعة فى كل نوع من الأكياس المستخدمة مع إطلاق عدد من الحشرات المختبرة خارجيا حول الأكياس التى وضعت فى صناديق زجاجية ذات غطاء وذلك لتقدير مستوى الاختراق لكلا الحشرتين على انفراد، تضمنت التجربة الثانية حبوب قمح مصابة بكلأ الحشرتين محل الدراسة معبأة فى كل مادة من مواد التغليف المختبرة كل على حدة مع استخدام ثلاث مكررات فى كل حالة وقد تم تخزين هذه الحبوب لمدة عشر شهور، أجريت نفس التجربة السابقة باستخدام حبوب قمح خالية من الإصابة لاستخدامها ككنترول، أظهرت النتائج المتحصل عليها في التجربة الأولى والتي استمرت ٢١ يوما و سجلت على أربع فترات زمنية هى ثلاثة، سبعة، أربعة عشر، واحد وعشرون يوما وذلك لمعرفة الضرر الحادث لمواد التعبئة متمثلا فى عدد الثقوب ونفاذية كلا الحشرتين داخل الحبوب، أظهرت النتائج أن أكبر عدد من الثقوب وجد في البولي ايثيلين عالي الكثافة (HDPE) وكذالك اكبر عدد من الاختراق واكبر عدد من الحشرات، وعليه فان البولي ايثيلين عالي الكثافة (HDPE) كان الأكثر حساسية لاحتوائه على اكبر عدد من الثقوب وكذا أعلى نفاذية للحشرات المختبرة، أظهرت نتائج التجربة الثانية أن كل المعايير المدروسة تأثرت معنويا طبقا لنوع مادة التعبئة المستخدمة وكذلك مدة التخزين، أظهرت النتائج أيضا أن زيادة فترة التخزين لمدة عشر أشهر كان لها تأثير ضار على جودة الحبوب، تسببت طول فترة التخزين فى زيادة عدد الحشرات الناتجة وزيادة نسبة الإصابة وزيادة نسبة الفقد فى الحبوب، وذلك بعد عشرة شهور عنها فى ٢، ٤، ٦ و٨ شهر، وعلى العكس من ذلك فان النسبة المئوية للإنبات والمحتوى الرطوبى انخفض تدريجيا خلا ل فترة التجربة، سجلت الحبوب المعبأة فى البوليستر/الألمونيوم/البولي إيثيلين (PET/AL/PE) أفضل النتائج بالنسبة للمعايير المدروسة متبوعة بالحبوب المعبأة فى البولي أميد/ البولي إيثيلين (PA/PE) وأخيرًا الحبوب المعبأة فى عبوات البولي ايثيلين عالي الكثافة (HDPE)، كانت قدرة الاختراق لحشرة ثاقبة الحبوب الصغرى *R. dominica* أكبر من قدرة خنفساء الدقيق الصدئية الحمراء *T. castaneum* عمومًا، باستثناء ثاقبة الحبوب الصغرى مع البولي ايثيلين عالي الكثافة، لم تستطع كل من الحشرتين اختراق أى من مواد التعبئة الأخرى المختبرة حيث لم يوجد بها ثقوب، وأخيرًا فإن العبوات المكونة من ثلاثة طبقات (PET/AL/PE) يمكن أن يوصى باستخدامها مع حبوب القمح ضد هجوم كل من حشرتي ثاقبة الحبوب الصغرى وخنفساء الدقيق الصدئية الحمراء طبقا للنتائج المتحصل عليها من الدراسة الحالية.

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