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EFFICACY OF PACKAGING MATERIALS AGAINST PULSE BEETLE *CALLOSOBRUCHUS CHINENSIS*

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ABSTRACT

Ecofriendly and cost-effective management of chickpeas is very important for improving food security. Barrier property of different packaging materials viz., polypropylene (white), polypropylene (green), polyethylene (gauge1), polyethylene (gauge 2), polymer, cotton, and china lamination was evaluated against the pulse beetle *Callosobruchus chinensis* (Coleoptera: Bruchidae). Results revealed that when chickpea was placed in the package after cleaning then no penetration and fecundity of *C. chinensis* were recorded in the closed package. A significant difference was observed among all the tested packages materials (closed and open) and storage periods in terms of the fecundity of *C. chinensis*. On the closed package, higher fecundity was observed in PE1 and PE2 packages while in the open package highest infestation was recorded in the CL package. However, fecundity increased with storage period in both open and closed packages.

Key words: Chickpea, *Callosobruchus chinensis*, damage, weight loss, polypropylene, polyethylene, storage period, fecundity, penetration, polymer, cotton, lamination

In Pakistan, *Cicer arietinum* (chickpea) is a major rabi cash crop (Ahmed et al., 1991). Due to the cheap source of protein, it accomplishes the protein requirement of poor people in Pakistan (Ahmed et al., 1991). For the storage of grain seeds, optimum storage conditions are needed to maintain their quality (Muir, 1994) and quantity (weight loss) against insect damage (Khaire et al., 1992; Padın et al., 2002). During storage, insect pest consumes 30 to 50% of the grains (Agrios, 1988). Some bruchids cause seed damage to chickpea from field to store and result in both nutritional quality and quantity losses (Demianyk et al., 2007; Sharma et al., 2007). *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae) is a primary, cosmopolitan, and destructive pest of chickpea under storage (Aslam and Suleman, 1999). It causes serious loss of pulses cause in India, Pakistan, Bangladesh, and various countries around the globe (Farooq, 1978; Islam, 1980; Saleem and Saleem, 1982). In tropical countries, 10-40% of the total production is lost annually valued at billions of dollars (US) due to *Callosobruchus* spp. (Ukeh and Mordue, 2009).

It infested the material from the field primary and then it may re-infest the dried and healthy seeds during storage (Sarwar, 2015). In India, a report revealed that *C. chinensis* causes 32-64% grain loss from April to October (Pandey et al., 1983). Gujar and Yadav (1978) reported that *C. chinensis* and *C. maculatus* cause losses of 45.50-66.30% and 55-60% in protein content and seed weight, respectively. It also causes 50-90% quantitative and qualitative losses, consequently reducing the germination ability of seeds, weight, and market value (Ofuya, 2005; Brisibe et al., 2011). With an increase in storage period, the population of *C. chinensis* increased which causes germination loss (Venkatesham et al., 2015; Singh et al., 2017). Protective packaging material protects grains against stored insect pests and any contamination (Riudavets et al., 2007). Packaging is a good and cheap practice for controlling the stored grain pests as IPM (integrated pest management) programs (Trematerra and Savoldelli, 2014). The selection of packaging material is an important step to minimize the infestation of stored grain insect pests (Sanon et al., 2011). Plastic packaging materials such as polypropylene (PP) and Polyethylene (PE) are frequently used for controlling *Tribolium castaneum* and *Rhyzopertha dominica* (Hassan et al., 2016). Presently in Pakistan, packaging materials of cotton, jute, and polypropylene are used for flour packaging (Nasir et al., 2004). There is a prerequisite to access the quality of the different packaging materials against stored grain insect pests for long time storage of pulses/grains. In Bahawalpur Pakistan, recent work has been done on different packaging materials against *Tribolium castaneum* (Qasim et al., 2013; Hassan et al., 2014) but there is some restriction regarding test organisms, host, and packaging materials with respect to storage period and against chickpea pest (*C. chinensis*). The present study was aimed to evaluate the efficacy of commercially available packaging materials, (such as polypropylene (green and white), polyethylene (gauge1 and gauge 2), polymer, cotton and china lamination) for protective storage of chickpea against *C. chinensis*.

MATERIALS AND METHODS

The experiment was conducted on black chickpea (NIAB-CH- 2016) for storage of three months. The culture of *C. chinensis* was collected from the Multan grain market and reared on a diet of chickpea and yeast (95: 5 by weight) in plastic jars (1 kg) under controlled conditions (30± 2 °C, 65± 5% RH) in the rearing laboratory of Institute of Plant Protection at MNS-University of Agriculture, Multan. Target organisms were reared till the F1 generation (get a homogeneous population). Various types of packaging materials were purchased from the local grain market. Their thickness was accessed by digimatic caliper (Table 1). Some plastic packaging (such as PPW, PPG, CO, PO, and CL) has a storage capacity of 20-100 kg. Their micro bags (having 14 × 19 cm dimensions) with a capacity of 200 g were prepared by using an impulse sealer. A heat sealer is used to seal the polyethylene bag. Healthy chickpea (200 g) was filled in each mini bag (free from any contamination of mud or sand particles). All prepared packaging materials were placed in a large plastic jar randomly and replicated thrice. A hundred adults of *C. chinensis* (homogenous age) were released in each jar and retained for storage. After 15 days, the package was taken, open and counted the number of *C. chinensis* adults penetrating into each package. Data of *C. chinensis* eggs on inside and outside the package was observed and recorded. After recording data, all package was closed by common pins and stored from August to mid-November (15, 30, 45, 60, 75, 90, and 105 days) following the procedure of early researchers (Venkatesham et al., 2015). Data were analyzed as per the statistical nature of the data. The data of penetration egg-laying and weight loss was subjected to take the analysis of variance by using Statistics Software (v.81) for analysis. To check the different variables and their interaction during the storage period of plastic packaging, ANOVA was done using factorial design under CRD.

RESULTS AND DISCUSSION

Penetration of *C. chinensis* was not observed in the sealed package as compared to the open package across all storage periods. In the closed package, the highest *C. chinensis* eggs were noted outside the package of PE1, PE2, and CL packages among all tested packages. While in the open package, greater fecundity was observed in the CL package compared to others. Results showed that *C. chinensis* eggs were accessed differently in the different packages during the different storage periods. After 30, 60, 75, 90, and 105 days, data of *C. chinensis* eggs on all packages were observed to be significantly varying ($p \leq 0.05$).This is in comparison to the ones observed after 15 days and 45 days ($p \geq 0.05$) with closed package. In open package highly significant across all storage periods ($p \leq 0.05$) (Table 2). In a closed package, eggs of *C. chinensis* were observed greater and significantly different across different packages (p=0.00, *F*=11.93, d.f=6,96) as shown in Table 3. The highest eggs were noted on PE1 and PE2 packages and followed by PPG, CL, PPW, PO, and CO. Similarly, *C. chinensis* eggs were found highly significant (p=0.00, *F*=62.11, d.f=6,96) across all tested package. The lowest number of eggs were found on chickpeas present in the PE1 package as compared to other packages.

Eggs of C. *chinensis* were recorded significantly different across closed package (p=0.00, *F*=32.48, d.f=6,96) and open package (p=0.00, *F*=72.99, d.f=6,96) in relation to different storage period as shown in Table 4. The highest eggs were recorded after 105 days in both closed and open packages and found lowest after 15 and 30 days. Interaction was observed

Table 1. Determination of plastic packaging thickness (mm) by digimatic Caliper

Treatment	Coding	Packaging	Thickness
T1	PPW	Polypropylene (Green color)	0.18 mm
T2	PPG	Polypropylene (White color)	0.22 mm
T3	PE1	Polyethylene Gauge 1	0.05 mm
T4	PE2	Polyethylene Gauge 2	0.10 mm
T5	CO	Cotton	0.25 mm
T6	PO	Polymer	0.27 mm
T7	CL	China lamination	0.28 mm

Table 2. Comparisons of C. *chinensis* eggs vs. in packaging materials

Packet	Closed package	Open package
PPG	48.143± 14.40ab[a]	116.43± 07.01b
PPW	27.38± 7.32bc	80.95± 06.13d
PE1	68.19± 12.82a	99.24± 06.240c
PE2	79.66± 21.92a	123.86± 06.02b
CO	10.09± 3.38c	116.00± 07.41b
PO	11.23± 3.63c	111.71± 06.01bc
CL	54.38± 15.61ab	166.48± 07.15a

[a] Entries in the same column, for weight loss (%), followed by different letters are significantly different ($p < 0.05$) and the same letter show not significantly different ($p > 0.05$). Means were separated using Tukey's HSD test. Data shown are means of three replications; values means ± standard errors.

Table 3. Overall comparisons of C. *chinensis* eggs on different packaging vs. storage periods

Storage period	Closed package	Open package
15 days	00.86± 00.42d[a]	77.76± 05.30d
30 days	05.14± 02.50d	88.00± 05.14d
45 days	25.29± 07.23cd	103.05± 05.80c
60 days	12.48± 02.43d	117.24± 29.95b
75 days	55.24± 09.74bc	130.14± 06.54b
90 days	77.10± 15.40b	144.95± 06.59a
105 days	123.10± 19.82a	153.52± 07.14a

[a] Entries in the same column, for weight loss (%), followed by different letters are significantly different ($p < 0.05$) and the same letter show not significantly different ($p > 0.05$). Means were separated using Tukey's HSD test. Data shown means ± standard errors

highly significant ($p=0.001$, $F=2.16$, d.f=6,36) between Duration and Closed Package (D*CP). In contrast, interaction was found non-significant ($p=1.000$, $F=0.13$, d.f=6,36) between Duration and open Package (D*OP). Penetration of *C. chinensis* was not observed in the closed package than in the open package. Infestation to the different packages was accessed in the form of eggs on outside the package and on the chickpea. In this study, the fecundity of *C. chinensis* was noted highest on both polyethylene packages (PE1, PE2) among tested closed packages while on the CL package. A lot of research work was published regarding the testing of different packages against different stored grain pests except pulse beetle. In a research study, the highest damage of *Plodia interpunctella* larvae and *Tribolium castaneum* was assessed in casted polypropylene and low-density polyethylene package (Chung et al., 2011). Some earlier studies also found a high infestation of *Tribolium castaneum* on polyethylene packages than on polypropylene packages (Yar et al., 2017; Hassan et al., 2014; Hassan et al., 2016). Riudavets et al. (2007) also recorded a higher infestation of *R. dominica*, *S. oryzae,* and *Lasioderma serricorne* to polyethylene. Mullen et al. (2012) also accessed that polyethylene is a susceptible package against *T. castaneum* infestation.

Thus, different insect pests have different modes of infestation and it varies with packages. Their infestation also depends on the thickness of packages (Chung et al., 2011). High penetration of *Plodia interpunctella* larvae and *Tribolium castaneum* adult was observed in the package with less thickness and vice versa. Lee et al. (2014) reported that penetration of *P. interpunctella* larvae is affected by the thickness of the package. Proctor and Ashman (1972) concluded that polyethylene layers (up to 65 μm thickness) in plastic bags were the most suitable and effective. During storage, insect penetration and population, infestation, and weight loss do not alone depend on package type but also depend on storage period. In the present study, high fecundity of *C. chinensis* was observed and it varied with storage periods in both open and closed packages (Table 1, 3). Hell et al. (2010) observed with *Prostephanus truncatus* and more weight loss after storage of 6-months storage period. Ognakossan et al. (2013) also found higher weight loss due to infestation of *P. truncatus* after storage of 5 months. Yar et al. (2017) also reported that weight loss due to the infestation of *T. castaneum* was more after 90 days of storage. A higher population of *T. castaneum* was observed after150 days (Atta et al. 2020). Jute bags with multiple (2-5) polythene lining inside (7.7%), tin containers with polythene lining inside by mixing sand with pulses (8.2%), plastic boium (8.6%), and RC bottles (8.4%) showed better performance for storing of pulses (Mannan ad Tarannum, 2011).

Bowditch (1997) experimented to check the penetration of 1st and 5th larval instar of *Ephestia cautella*, *P. interpunctella,* and adults of *Tribolium confusm* through two types of packaging polyvinylchloride and polypropylene. They found that polyvinylchloride was only resistant to the penetration of 1st larval instar of *E. cautella,* while polypropylene was resistant against the penetration of species. Polypropylene with a thickness of 29 μm proved to be the most resistant and suitable for foodstuff packaging (Allahvaisi et al., 2010). Improper sealing, lack of proper product rotation improper handling during shipment, manufacturing, storage caused package flaws. Increased restriction on pesticide use was essential for the consumer and manufacturer to developed insect-resistant packaging for sanitation

Table 4. Fecundity of C. *chinensis* on packaging materials and storage periods

Packet	Storage period[a]						
	15 days	30 days	45 days	60 days	75 days	90 days	105 days
Closed package							
PPG	00.00± 00.00a[b]	02.00± 02.00b	21.66± 16.29a	11.66± 03.17ab	60.66± 22.82ab	80.33± 12.03ab	160.67± 58.33a
PPW	00.00± 00.00a	00.33± 00.33b	10.33± 07.42a	05.33± 00.88b	39.33± 07.51ab	59.66± 25.30ab	76.66± 08.35a
PE1	03.33± 02.02a	26.00± 12.34a	53.00± 29.40a	29.33± 12.25a	104.33± 29.67a	117.00± 09.45ab	144.33± 27.55a
PE2	01.00± 01.00a	07.66± 02.66ab	34.33± 14.71a	19.33± 02.18ab	93.00± 18.35ab	188.67± 66.39a	213.67± 71.65a
CO	01.66± 01.66a	00.00± 00.00b	01.00± 00.57a	05.00± 00.00b	10.33± 02.72b	20.00± 05.29b	32.66± 17.90a
PO	00.00± 00.00a	00.00± 00.00b	01.66± 01.66a	05.66± 01.20ab	10.00± 03.21b	18.00± 04.50b	43.33± 12.78a
CL	00.00± 00.00a	00.00± 00.00b	55.00± 26.38a	11.00± 01.73ab	69.00± 25.35ab	56.00± 22.50ab	189.67± 45.48a
Open Package							
PPG	77.00± 07.57bc	85.00± 04.16b	102.00± 10.06bc	115.67± 09.76bc	136.67± 08.19ab	144.33± 14.65ab	154.33± 14.40ab
PPW	47.33± 07.96c	55.33± 05.48c	68.66± 06.64bc	80.33± 07.880c	91.00± 08.96c	111.00± 13.50b	113.00± 13.57b
PE1	60.33± 05.84bc	75.00± 05.77bc	86.00± 05.560bc	99.67± 07.96bc	109.00± 06.00bc	128.33± 07.26b	136.33± 13.34b
PE2	82.00± 01.73b	95.00± 02.64b	113.33± 01.33b	126.33± 02.84b	139.33± 02.84ab	151.00± 04.16ab	160.00± 02.51ab
CO	77.33± 04.33bc	86.33± 05.36b	101.67± 11.62bc	116.33± 15.30bc	133.33± 17.40bc	144.33± 17.32ab	152.67± 17.70ab
PO	77.67± 09.73bc	86.66± 05.04b	98.33± 07.53bc	110.00± 08.96bc	121.00± 08.71bc	139.00± 05.51b	150.33± 04.17ab
CL	122.67± 08.00a	133.67± 04.09a	151.33± 04.66a	172.33± 05.04a	180.67± 07.21a	196.67± 13.17a	208.00± 13.50a

[a]Storage from August to Mid-November; [b]Entries in same column, for egg-laying, followed by different letters are significantly different ($p < 0.05$). Means separated using Tukey's HSD test. Data shown means of three replications; values means± standard errors.

and safe food. In consumer-sized packaging, they want the assurance to remain insect-free packaging until consumption. Further research should be made in that aspect to developed more effective packaging and manufacturer also adopted these to protect against loss of goodwill and lawsuits arising from insect infestation. The present study concludes that proper packaging of chickpea is an effective technique against *C. chinensis*.

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AUTHOR CONTRIBUTION STATEMENT

Mahreen Hanif concluded the study and wrote the manusxript; Shafqat Saeed and Mudssar Ali supervised the research and helped in planning the research work; Muqadas Younas aided in data recording.

CONFLICT OF INTEREST

There is no conflict of interest among authors.

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