Research Article

Evaluation of *Tribolium castaneum* Infestation against Different Packaging Materials

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Abstract | Post-harvest storage of chickpea in storage bags is commonly implemented practice, offers a chemical free tactics to control the stored grain pests. Barrier property of different types of packaging viz., polypropylene (green), polypropylene (white), polyethylene (gauge1), polyethylene (gauge 2), cotton, polymer, and china lamination were investigated in storage bag of chickpea against *Tribolium castaneum* (Coleoptera: Tenebrionidae) during the controlled condition. Adults of *T. castaneum* was released on all packaging to evaluate its damage in packaging and data recorded after 15 days interval. A series of laboratory tests were observed over three months to determine the penetration of *T. castaneum* in different packages. Results showed that the highest population of *T. castaneum* (larvae and adult) as well as greater weight loss (%) in chickpea was recorded in polypropylene (green) packet in contrast to polyethylene (gauge 2) and china lamination. Significant differences were observed in the overall adult population of *T. castaneum* ($p<0.05$) and chickpea percentage weight loss ($p<0.05$) than its larval population ($p>0.05$) during the storage period. However, more adult population and weight loss (%) occurred after more time period (after 90 days) as compared to the low time period (after 30 days). These results are important and used for the integrated management of foodstuffs i.e., chickpea to overcome the infestation of *T. castaneum* during its storage.

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1. Introduction

Cicer arietinum (chickpea) is a ranked at 5th and 3rd number among legume, and pulses crops, respectively, (FAO, 2011; Aslam *et al*., 2002). It is cultivated in both tropical and temperate regions of the world particularly in of Southeast Asia. Major chickpea growing countries are India, Turkey, Pakistan, Myanmar, Australia, Ethiopia, Mexico, Canada, USA and Iran. Chickpea is a major rabi cash crop of Pakistan (Ahmed *et al*., 1991). Pakistan is at third and fourth rank among pulses growing countries and production of chickpeas, respectively (Statista, 2019).

Chickpea is free of cholesterol and important source

of mineral (Duke, 1981; Huisman and Van der Poel, 1994; Wood and Grusak, 2007; Chibbar *et al*., 2010; Jukanti *et al*., 2012). It is also source of carbohydrates, ash, oil, fiber and protein (Hulse, 1989). As it is a cheap source of protein, so it fulfils the requirement of the protein of poor people in Pakistan (Ahmed *et al*., 1991). During out of season, farmers stored pulse and legume for their proper use. During storage, chickpea is suffering both qualitative and quantitative losses. Qualitative damage reduces the nutritional and aesthetic value; while, quantitative loss cause weight loss of seed (Padın *et al*., 2011). Optimum storage conditions are necessary to retain the quality of the seeds (Muir, 1994). Insect damage can be recognized as an important limitation to the pulse production (Khaire *et al*., 1992). The choice of this storage method by the farmer was made by local natural means because they are not known the application of improved methods (Hall, 1970). Pest devours 5 to 7% and more than 30 to 50% of the grain during storage (Agrios, 1988).

Tribolium castaneum (Coleoptera; Tenebrionidae) is cosmopolitan and international vicious pest. These feed on wide range of plants and animal's products and stored food such as grains, cereals, nuts, oilseed, dried fruits, pulses, cacao, beans, cottonseed etc. Both adult and larval stages of *T. castaneum* can feed on embryo of seed, broken kernels, grains dust and prefer floury materials (Arbogast, 1991). Its presence in stored commodity can causes contamination of product, economic damage and also reduce its nutritional value (Burkholder and Faustini, 1991). Its infested flour converted in to moldy and give bad smell in case of sever attack that is unfit for human consumption (Atwal and Dhaliwal, 2002). Food security is important issue that disturb the human activities, their health and nation independence. Losses at each stage of food chain reduced with help of proper packaging.

Protective packaging (Riudavets *et al*., 2007) is a good practice for insect management as integrated pest management (IPM) programs (Trematerra and Savoldelli, 2014). Packaging material help to give protection against insect pest and contamination. To decrease the infestation level of stored commodity insect pest, selection of the packaging material is necessary (Sanon *et al*., 2011). Plastic packaging materials such as polypropylene (PP) and polyethylene (PE) are often used for management of *T. castaneum* and *R. dominica* (Hassan *et al*., 2016). Polypropylene (PP) is an effective as packaging material of chocolate than polyvinylchloride (PVC) against larvae of Indian meal moth and almond moth (Bowditch, 1997).

In Pakistan, currently, packaging materials used for flour are made of cotton, polypropylene and jute (Nasir *et al*., 2004). There is need to explore the quality of the package materials for proper long-term storage of pulses to reduce the chances of insect attack. Recent work has been done in Bahawalpur, Pakistan for the management of *Tribolium castaneum* by using different packaging materials (Qasim *et al*., 2013; Hassan *et al*., 2014) but there is limitation that they did not tested packaging with respect to storage period.

After considering the above-mentioned facts, the present study was designed in which preventive and control measure for chickpea were tested to save it from the destructive pest under consideration. The present study was designed to test the effectiveness of commercially available packaging materials on penetration and weight loss in chickpea due to *T. castaneum*. Also, to evaluate the effect of time period on penetration of *T. castaneum* as well as weight loss in chickpea seed.

2. Materials and Methods

Research experiments were conducted on storage of black chickpea (NIAB-CH- 2016) for three months in the postgraduate lab, Institute of Plant Protection at Muhammad Nawaz Shareef University of Agriculture using Complete Randomized Design (CRD).

2.1 Collection and rearing of insect

The population of *Tribolium castaneum* (Coleoptera: Tenebrionidae) was collected from grain market of Multan. The population was reared in the rearing laboratory of Institute of Plant Protection at MNS-University of Agriculture, Multan. Insects were reared on a diet comprising of chickpea and yeast (95: 5 by weight) in plastic jars (1 kg) at 65 ± 5% relative humidity and 30 ± 2 °C. They were reared to F1 generation to get homogeneous population.

2.2 Plastic packaging materials

Seven different types of packaging materials were taken form local market of packaging. Thickness

measured with the help of Screwguage (as shown in Table 1). Plastic packaging available in 20-40 kg capacity so micro bags (having 14 × 19 cm dimensions) of some packaging materials such as PPW, PPG, CO, PO and CL of 200 g capacity were prepared with the help of impulse sealer while polyethylene bag are made and sealed by heat sealer. Each small bag was filled with 200 g healthy chickpea without contamination of sand or mud particles. All types of packaging materials were placed in a large plastic jar with random sequence and repeated thrice.

2.3 Penetration test

Hundred homogenous age adult of *T. castaneum* were released in each jar and kept for storage. After 15 days interval, sample was taken and then package was open. The number of live adult and larvae of *T. castaneum* per 200 g of chickpea was counted to check the entrance of *T. castaneum* into each packaging type. Data was observed and recorded.

2.4 Determination of weight loss

Chickpea were weighed 200 g and consider as initial weight (Wi) of chickpea. After 15 days interval, sample (200 g) were taken and sieved with a kitchen sieve (2 mm mesh). After sieving, weight of healthy grain was observed as final weight (Wf) by digital weighing balance. Percentage (%) weight loss was measure by following Equation 1.

$$\text{Weight loss (\%)} = (\text{Initial weight-final weight})/\text{initial weight} \times 100 \quad ...(1)$$

After data collection of penetration and measurement of weight loss, packets with chickpea again sealed and to note packaging impacts for upcoming data recording till 3 months.

2.5 Statistical analysis

Data were recorded and analysed as per statistical nature of the data. Analysis of variance was carried out using Statistix v.81 and v10 software (Minitab) for analysis the data of packaging. To find out the different variables and their interaction during storage period of plastic packaging, ANOVA was done by using factorial design under CRD. Tuckey test was used to comparison the mean and standard error of packaging and storage period. Linear model of regression was also used to find out main effect of packaging or storage period and the interaction of both factors.

3. Results and Discussion

3.1 Effect of package

Highest penetration or population growth of adults and larvae of *T. castaneum* found in PPW packet and lowest found in CL packet across all storage period (Table 1). Result showed that penetration of both adults (F=956.32, DF=6, p=0.00) and larvae (F=31.27, DF=6, p=0.00) in other package followed differently across different storage period but remains significant in relation to all tested packaging material. Similarly, maximum difference was found weight loss (%) among all package and across all storage period (P=0.00; Table 2). Highest weight loss (%) (F=517.61, DF =6, p=0.00) recorded in PPW (Polypropylene White packet) and followed by CO (Cotton packet), PO (Polymer packet), PPG (Polypropylene Green packet), PE1 (Polyethylene Gauge 1 packet), PE2 (Polyethylene Gauge 2 packet) and CL (China Lamination packet) (Table 2).

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

Treatment	Abbreviation	Packaging	Thickness
T1	PPW	Polypropylene (Green colour)	0.18 mm
T2	PPG	Polypropylene (White colour)	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

3.2 Effect of duration

Weight loss (%) were significantly highest in all treatments after 90 days than 65, 60, 45, 30, 15 days (F=192.17, DF =6, p=0.00), respectively) in Table 3. While population of *T. castaneum* larvae remain non-significant (F=1.01, DF =6, p=0.42) and adult remain significant (F=75.67, DF =6, p=0.00) across all storage period of three months but not increases with increase of storage period. Test statistics of package shows that high weight loss (02.01 mean ranks) and occur after 90 days (Table 3) and minimum observe after 15 days (00.30 mean rank). However, population of *T. castaneum* adult found more after 15 days (09.57 mean rank) and less after 90 days (04.60 mean rank). Similarly, population of *T. castaneum* larvae was less after 90 days (01.28 mean rank) and greater after 30 days (01.80 mean rank).

Table 2: Population (numbers per 200 g sample) of live adult and larvae of *T. castaneum* in different packaging during chickpea storage.

Packet	Storage period[a]					
	15 days	30 days	45 days	60 days	75 days	90 days
Adult						
PPG	03.00 ± 00.57c[b]	05.66 ± 00.33c	6.667 ± 00.15d	06.00 ± 00.00d	02.66 ± 00.33d	04.66 ± 00.88bc
PPW	30.00 ± 01.15 a	16.33 ± 00.33a	21.00 ± 00.57a	18.33 ± 00.66a	14.00 ± 01.15a	14.00 ± 01.15a
PE1	00.00 ± 00.00c	00.00 ± 00.00d	00.00 ± 00.00e	00.00 ± 00.00e	01.33 ± 00.33de	02.33 ± 00.33cd
PE2	0.00 ± 00.00c	00.00 ± 00.00d	00.00 ± 00.00e	00.00 ± 00.00e	00.00 ± 00.00e	00.00 ± 00.00d
CO	17.00 ± 01.15b	15.00 ± 00.57a	17.66 ± 00.88b	15.33 ± 00.88b	09.66 ± 00.33b	07.00 ± 00.57b
PO	17.00 ± 01.15b	10.33 ± 00.08b	13.66 ± 00.88c	11.33 ± 00.66c	06.66 ± 00.33c	04.33 ± 00.33bc
CL	00.00 ± 00.00c	00.00 ± 00.00d	00.00 ± 00.00e	00.00 ± 00.00e	00.00 ± 00.00e	00.00 ± 00.00d
Larvae						
PPG	00.66 ± 00.66c	02.66 ± 00.88ab	01.33 ± 00.33ab	02.00 ± 00.57ab	01.00 ± 00.57ab	01.67 ± 00.33ab
PPW	03.00 ± 01.52ab	04.00 ± 01.15a	03.66 ± 01.4ab	03.33 ± 01.45a	03.00 ± 00.57a	03.33 ± 00.88a
PE1	00.00 ± 00.00c	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b	00.33 ± 00.33b	01.00 ± 00.57a
PE2	00.00 ± 00.00c	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b
CO	04.00 ± 00.05a	02.00 ± 00.57ab	05.00 ± 01.52a	02.33 ± 00.66ab	02.66 ± 0.66a	02.00 ± 00.57ab
PO	01.33 ± 00.03ab	04.00 ± 01.15a	00.66 ± 00.33b	01.33 ± 00.33ab	02.00 ± 00.57ab	01.00 ± 00.57ab
CL	00.00 ± 00.00c	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b	00.00 ± 00.00b

[a]Storage was conducted from August to October. [b]Entries in the same column, for adult and larvae of *T. castaneum*, followed by different letters are significantly different (P < 0.05). Means were separated using Tuckey test. Data shown are means of three replications; values are means ± standard errors.

Table 3: Weight loss (%) by *T. castaneum* in chickpea stored in different packaging.

Packet	Storage period[a]					
	15 days	30 days	45 days	60 days	75 days	90 days
PPG	00.12 ± 00.07c[b]	00.64 ± 00.08b	00.89 ± 00.06b	01.50 ± 00.15b	02.00 ± 00.17b	02.84 ± 00.04b
PPW	00.93 ± 00.03a	01.66 ± 00.22a	02.87 ± 00.15a	03.89 ± 00.27a	04.90 ± 00.18a	06. 11 ± 00.34a
PE1	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.22 ± 00.06c	00.49 ± 00.07c
PE2	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c
CO	00.52 ± 00.03b	00.71 ± 00.02b	00.81 ± 00.03b	01.39 ± 00.31b	01.67 ± 00.33b	02.46 ± 00.29b
PO	00.54 ± 00.03b	00.56 ± 00.06b	00.71 ± 00.03b	01.16 ± 00.09b	01.45 ± 00.12b	02.16 ± 00.17b
CL	00.00 ± 0.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 00.00c	00.00 ± 0.00c

[a] Storage was conducted from August to October. [b] Entries in the same column, for weight loss (%), followed by different letters are significantly different (P < 0.05) and same letter show not significantly different (P > 0.05). Means were separated using Tuckey test. Data shown are means of three replications; values are means ± standard errors.

3.3 Interaction between treatments and duration

Highest significant interaction of treatment and package (D*T) was found in data of weight loss (%) (F=26.06, DF =36, p=0.000) and penetration of adults (F=25.19, DF =36, p=0.000) as compared to data of population of larvae (F=1.43, DF =36, p=0.0880) of *T. castaneum*.

Infestation in packaging was detected in the form of population growth of *T. castaneum* and percentage weight loss in chickpea with respect to different packaging type and storage time period intervals. In our study, maximum penetration of *T. castaneum* was observed in polypropylene package (white) while it was minimum in China lamination packet and polyethylene 2 (PE2). Similarly, Chung *et al.* (2011) tested that more damage assessed in linear low-density polyethylene (40 and 50 mm) and casted polypropylene (20 and 25mm) as compared to oriented polypropylene (20 and 30mm) and polyethylene terephthalate (12 and 16 mm). Contrarily, some previous studies (Yar *et al.*, 2017; Hassan *et al.*, 2014, 2016) have reported higher insect infestation of *T. castaneum* in polyethylene package

as compared to the polypropylene package. Similarly, Riudavets *et al.* (2007) also reported higher protection of polypropylene package against three stored grain pests (*R. dominica*, *S. oryzae* and *Lasioderma serricorne*) as compared to the polyethylene.

Table 4: Overall comparisons of weight loss (%) and adult population by *T. castaneum* in stored chickpea during 3 months.

Storage period	Weight loss (%)	Adult	Larvae
15 days	00.30 ± 00.07e[a]	09.57 ± 02.47a	01.28 ± 00.39ab
30 days	00.51 ± 00.12de	06.76 ± 01.49c	01.80 ± 00.44a
45 days	00.75 ± 00.21d	08.42 ± 01.87b	01.52 ± 00.49ab
60 days	01.13 ± 00.29c	07.28 ± 01.62c	01.33 ± 00.35ab
75 days	01.46 ± 00.36b	04.90 ± 01.12d	01.28 ± 00.30ab
90 days	02.01 ± 00.45a	04.60 ± 01.02d	01.28 ± 00.29ab

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

Mullen *et al.* (2012) also revealed that polyethylene is a susceptible against *T. castaneum* beetles among different testing packing types. Beetles, *T. castaneum*, entered by holes in polyethylene bag filled with wheat flour. These studies are in disagreement with our finding that showed that polypropylene packaging found susceptible as compared to polyethylene. It may be due to porous surface of polypropylene packaging as well as sealing by machine while polyethylene package has plane sheet and sealing by heat sealer. It also depends on thickness of polyethylene as it is 0.02 mm (Yar *et al.*, 2017) and 0.02 mm to 0.04 mm (Hassan *et al.*, 2016). Previous study described that insect penetration depend on thickness of packaging (Chung *et al.*, 2011). Their results assessed that more penetration of *T. castaneum* adult and *Plodia interpunctella* larvae found in package of less thickness and vice versa. Similarly, it was also observed that *P. interpunctella* larvae penetration affected by packaging thickness (Lee *et al.*, 2014) and if packaging was used alone then more insect penetration happens than double packaging (have extra cover) (Stejskal *et al.*, 2017).

Weight loss (%) was determined from initial amount packed. Significant difference was found among weight loss (%) of all packaging materials and across all storage period in our experiment. More weight loss (%) detected in PPW and CO packet but minimum in CL packet as well as PE2. Population of *T. castaneum* was noted zero in CL packet as well as PE2. Similarly, Atta *et al.* (2020) reported more *T. castaneum* population and more percent weight loss recorded in cloth packet followed by the trend of Jute bag > Plastic bag > Polypropylene bag > Hermetic Bag. Contrarily, more percentage weight loss reported in polyethylene package (Yar *et al.*, 2017).

With respect to storage bag, storage period can affect the insect penetration and percent weight loss. In present study, it was observed that weight loss (%) increased with increase in time period of storage (Table 3). Hell *et al.* (2010) also reported higher weight loss (0.3%) after 6-months of storage as compared to the lower infestation at the onset of storage period. Similarly, Ognakossan *et al.* (2013) also found higher weight loss of up to 6% at 5 months of storage due to infestation of *P. truncates* since it has the ability to puncture the bags during storage. Moreover, Yar *et al.* (2017) also reported that weight loss was found higher (due to infestation of *T. castaneum*) after 90 days of storage followed by 60 and 30 days because of multiplication of beetles over time. In another study, it is perceived that damage by *T. castaneum* increased with increasing storage period with trend of 150 d > 120 d > 90 d > 60 d > 30 d (Atta *et al.*, 2020).

Conclusions and Recommendations

Present study determines that China lamination may be an effective technique for safe post-harvest management of chickpea against *T. castaneum* and also for improving the food security. Results also showed that qualitative and quantitative losses of chickpea not alone depend on type of packaging, but also on storage periods. Moreover, further research is required to evaluate the multilayer films packing type for chickpea post-harvest management.

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Novelty Statement

In Pakistan, no work done on testing commercialized packages against this pest. This work is essential for the farmer community to secure food commodities.

Author's Contribuion

Shafqat Saeed plan and supervise all the research. he also provide facility to conduct this study. Mudssar Ali analysis the data and also supervise the procedure. Muqadas Younas, Huda Bilal help and Syeda Fatima Bukhari helps in conducting trial and data recording.

Ethical approval

This manuscript does not contain any studies involving human participants and/or animals.

Conflict of interest

The authors have declared no conflict of interest.

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