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Abiotic and biotic changes in wheat (*Triticum aestivum*) bulks stored under Indian traditional practice of cover and plinth structure

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ABSTRACT

An experiment was conducted to study the moisture and temperature changes in bulk stored wheat (*Triticum aestivum* L.) in traditional Cover and Plinth (CAP) type of storage and placed in open space on a raised platform. Four wheat bulks with 5 tonnes wheat in each of them were used. Each stack made of 100 jute bags of wheat. Of the four wheat bulks, three covered with PVC coated polyester sheet and the fourth one with black polyethylene sheet. The sheets were weighted to the concrete floor with a series of double layer of sand snake bags. In addition, the sheets were taped using surgical tapes on the floor to avoid entry of rodents, dust and water. The temperature and moisture changes in the bulk, the quality parameters such as the colour and gluten content and the insect infestation were monitored for six months, starting October 2014 to March 2015. The temperature values were recorded at a frequency of 6 h using an automatic data logger. The other parameters were determined by drawing wheat samples from 24 places in each of the stacks at an interval of 15 days. The data from the three stacks covered with PVC coated polyester sheets were averaged. The moisture content of wheat in both stacks increased from November to January and decreased from February to March. The increase in moisture content in black polyethylene covered bulk stacks was nearly 4% (based on wet basis) higher than the PVC coated polyester covered stacks. The temperature of the wheat bulks decreased from November to January and increased afterwards. The highest temperature recorded during the 6 months of storage was 35.4º and 36.1ºC in PVC coated polyester and black polyethylene covered stacks, respectively, and it was near the centre of the wheat bulk stacks in both the covers. The average number of insects in the black polyethylene covered wheat bulk stacks was three times higher than the PVC coated polyester covered stacks during the storage period. The ‘a*’ value of wheat in black polythyne covered stacks was 5.5% less than the PVC coated polyester covered bulk stacks, indicating that the wheat covered in PVC coated polyester sheet retained its glossy colour than the wheat covered in black polyethylene sheet. The dry gluten content of wheat decreased during the storage period in wheat stacks covered by both sheets. The loss was 4.5% higher in the wheat stacks covered with the black polyethylene sheets. Based on overall observations, the quality of wheat covered in PVC coated polyester sheet was found better and safer than the wheat covered in black polyethylene sheet.

Key words: Cover and plinth storage, Grain quality changes, Temperature and moisture distributions, Wheat

In India, wheat (*Triticum aestivum* L.) after harvesting is procured from the farmers by government agencies like Food Corporation of India (FCI), the Central Warehousing Corporation (CWC) or the State Warehousing Corporation (SWC), and stored in bulk for public distribution and future purposes as buffer stock. Whenever the conventional godowns and silos

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are full, grain stacks are built outdoor on a raised area (plinth), the grain bags are stacked on a wooden platform and stacks are covered with 250 micron polyester covers, having five sides, leaving the bottom open (Sahay and Singh, 2001) and stored for 6 to 12 months. The grain stored by this method is called Cover and Plinth storage (CAP). These structures can be constructed in less than 3 weeks and economically on a large scale (Mishra, 1985). During the harvest glut periods, government stores the procured grains over CAP structures. A typical CAP storage size is 8.55 m × 6.3 m for 3000 bags of 50 kg per bag (i.e. 150 tonnes of grains).

The grains under CAP storages are easily susceptible to spoilage by rodents, moisture, birds and insects, if not maintained properly. Unexpected rainstorms and bad weather spoils the grain quickly. When the grain moisture and storage temperature exceed a particular level, microflora and insects multiplies spoiling the grain quickly. Among these stored grains insect pests, the red flour beetle [*Tribolium castaneum* (Herbst)] and the lesser grain borer [*Rhyzopertha dominica* (Fabricius)], are capable of doing severe damage to the stored grains.

In a storage ecosystem, several biotic and abiotic factors interact to cause damages to the stored grains. The insects, mites and the microorganisms that attack stored grains and the stored grain itself constitute the biotic factors of the storage system. The physical environment includes the temperature and the moisture content of the stored grain, and the inter-granular gaseous environment. The biotic factors like storage insects, for instance, grow and multiply fast in dry and warm grains, and microorganisms prefer wet and warm conditions. Controlling the role of biotic factors on quality of stored wheat by monitoring the temperature fluctuations and moisture migration within the storage systems is essential during the storage period.

The scientific knowledge about the effects abiotic and biotic factors on stored wheat grains in jute bags on the CAP structure is important to understand the changes of the grains during storage. The present investigation was undertaken to study the temperature and moisture variations in Cover and Plinth storage of wheat bulk and also quality changes of stored grain for a period of six months.

MATERIALS AND METHODS

Cap storage structure

A reinforced cement concrete (RCC) plinth structure of size 17 m (l) × 7.5 m (b) × 0.9 m (h) was used for CAP storage studies of wheat bulk. The wooden crates having the size of 1.1 m (l) × 1.1 m (b) × 0.6 m (h) were used as dunnage material for wheat bulk stacks. The sheets used for CAP storage of wheat bulk were PVC coated polyester and black polythene (control). The thickness of sheets used was 0.215 mm and 0.175 mm for PVC coated polyester and black polyethylene respectively.

Wheat bulk stacks

The grain chosen for the CAP bulk storage is wheat 'Sabarmati' cross, procured from Bhopal, Madhya Pradesh, with initial m.c. of 9.5 ± 0.5% w.b. The selected wheat variety was packed in 50 kg gunny bags, having size of 0.67 m (l) × 0.56 m (b) × 0.25 m (h). About 4 bulk stacks of 5 tonnes capacity each (i.e. 100 jute bags per stack) for the floor area of 2.2 m × 2.2 m and nine bag height (2.25 m) was stacked. Up to eight bag height, about 12 bags were stacked in each layer in criss-cross direction. The ninth layer was stacked only with four bags for the easy runoff of rainwater without any stagnation on the top of the wheat bulk stacks. The three bulk stacks were covered with PVC coated polyester cover and the fourth one with normal black polythene as the control cover. The sheets were weighted to the concrete floor with a series of double layer of sand snake bags. In addition, the sheets were taped using surgical tapes on the floor to avoid entry of rodents, dust and water. The top view arrangement of wheat bulk stacks is shown in the Fig 1. The three wheat bulk stacks were then covered with the PVC coated polyester covers and the fourth stack with black polyethylene cover (control).

Storage

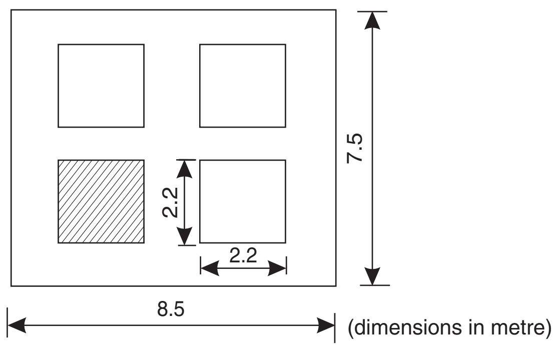

Fig. 1. Top view of 4 wheat bulk stacks under cover and plinth storage

The wheat grains were subjected to storage study under the ambient conditions in the CAP storage, starting from October (2014) to March (2015) for 6 months. During the storage period, the temperature and moisture changes in the wheat bulk, the quality parameters such as the colour and gluten content,

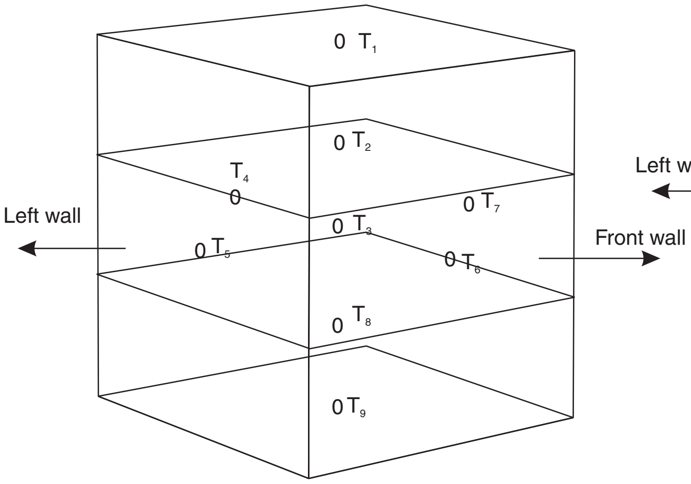

Fig. 2. Schematic presentations of positions of thermocouples for measuring temperature distribution in bulk wheat stack

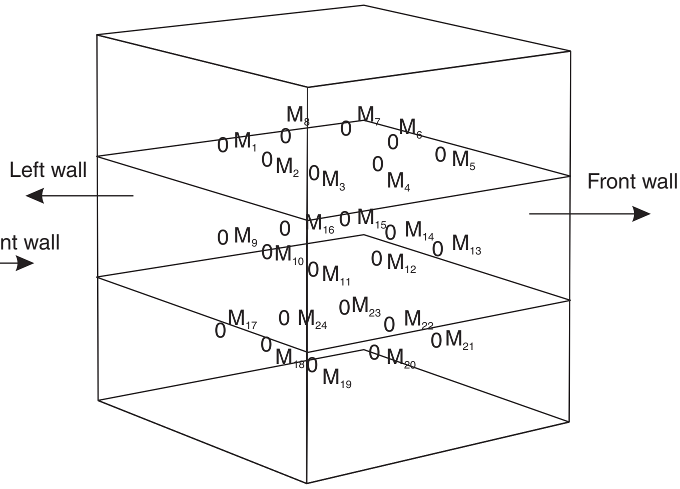

Fig. 3. Schematic presentation of wheat bulk stack showing the sampling positions for measuring the moisture content

and the insect infestation were measured at regular period of intervals. The data from the three stacks covered with PVC coated polyester sheets were averaged.

Temperature measurement : The t-type thermocouple having a temperature range of –200º to 350ºC was used for measuring the grain temperature during the storage period. The thermocouples were placed at nine locations, as shown schematically in Fig. 2. The thermocouples were connected to 36 channel temperature data logger (Data taker DL2e, Delta-T Devices Ltd, United Kingdom), interfaced with a computer for auto recording of temperature at every 6 h interval during the storage period. All temperature measurements recorded at 6 h intervals were averaged for daily measurements.

Moisture content measurement : The wheat samples from the bulk stack were taken from different locations using the sampling probe at an interval of 15 days. The moisture content sampling positions for a wheat bulk stack are schematically shown in Fig. 3. The moisture content of wheat was determined by drying 10 g wheat in a hot air oven (Thermo Electron Corporation, Marietta, Ohio) at 130°C for 19 h (ASAE Standard, 2002). The moisture content was calculated using.

$$\text{Moisture content, \% w.b.} = \frac{W_i - W_f}{W_f} \times 100 \quad ...(1)$$

where, W_i, initial weight of wheat before keeping to hot air oven, g; W_f, final weight of wheat after taking out of hot air oven, g.

The average moisture content was calculated by dividing bulk stack into three layers: top, middle and bottom and calculated using the equation 2 to 4.

$$\text{Average moisture content in top layer} = \frac{(M_1 + M_2 + M_3 + M_4 + M_5 + M_6 + M_7 + M_8)}{8} \quad ...(2)$$

$$\text{Average moisture content in middle layer} = \frac{(M_9 + M_{10} + M_{11} + M_{12} + M_{13} + M_{14} + M_{15} + M_{16})}{8} \quad ...(3)$$

$$\text{Average moisture content in bottom layer} = \frac{(M_{17} + M_{18} + M_{19} + M_{20} + M_{21} + M_{22} + M_{23} + M_{24})}{8} \quad ...(4)$$

where, M_1 to M_8, moisture sampling locations in top layer; M_9 to M_{16}, moisture sampling locations in middle layer; M_{17} to M_{24}, moisture sampling locations in bottom layer.

Measurement of colour : The colour of the wheat sample was measured at ambient condition in Hunter colour meter (Color Flex EZ, Hunter Associates Laboratory Inc., Virginia, USA) in the reflectance mode at regular intervals of 15 days. The variation of in L (lightness to darkness), a*(redness to greenness) and b* (yellowness to blueness) values of wheat in both the stacks were measured during the storage period.

Measurement of gluten content : The gluten content of wheat was determined by hand washing method (AACC, 2000) at regular intervals of 15 days. The dry gluten content was calculated using equation 5.

$$\text{Dry gluten (\%)} = \frac{\text{dry gluten weight, g}}{\text{flour weight, g}} \times 100 \quad ...(3)$$

Insect infestation: The insect infestation in the wheat bulk stack was determined at regular intervals

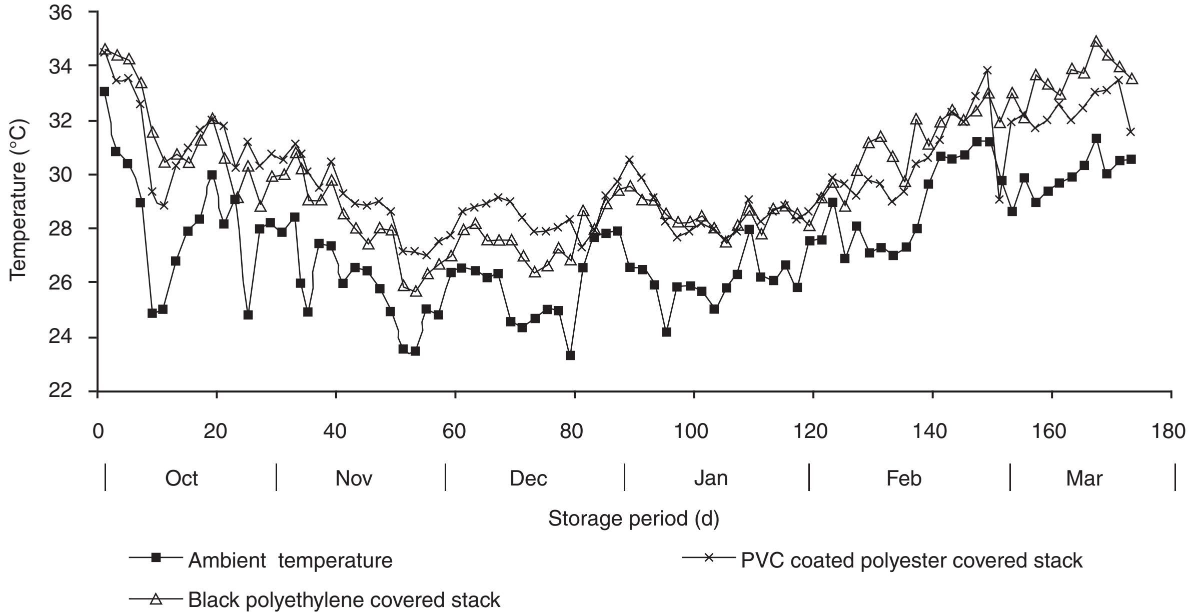

Fig. 4. Ambient temperature and mean temperature distributions in bulk wheat stack from October (2014) to March (2015) storage period

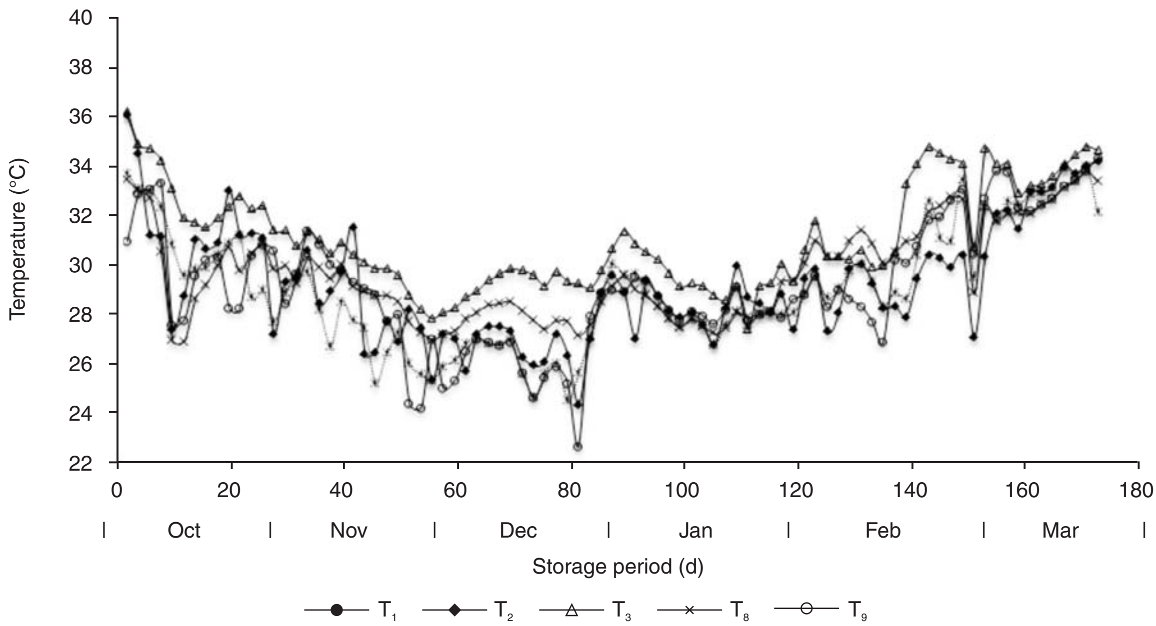

Fig. 5. Mean temperature distribution at different locations in the central axis of wheat bulk stack covered with PVC coated polyester cover during storage period from October (2014) to March (2015)

of 15 days by drawing 100 g grain sample randomly and counting the number of insects present in it (Hangstrum, 2001).

Analysis of data

The experimental data of storage parameters were analysed by Statistical Program for Social Sciences (SPSS 21.0, Chicago, IL, USA) software under analysis of variance (ANOVA) technique. The temperature distribution at different locations in the CAP storage was analysed using data analysing and graphing software Origin Pro 9.2.

RESULTS AND DISCUSSION

Temperature distribution in wheat bulk stacks

The variation in the ambient temperature and the mean temperature in the wheat bulk stacks during the storage period from October (2014) to March (2015) months is shown in Fig. 4. The temperature inside wheat bulk in PVC coated polyester and black polyethylene covered stacks was found 2.5°C and 2.6°C, respectively, higher than that of the ambient temperature. The temperature was 2.6 ± 1°C higher at the end of the storage period (March 2015) than the

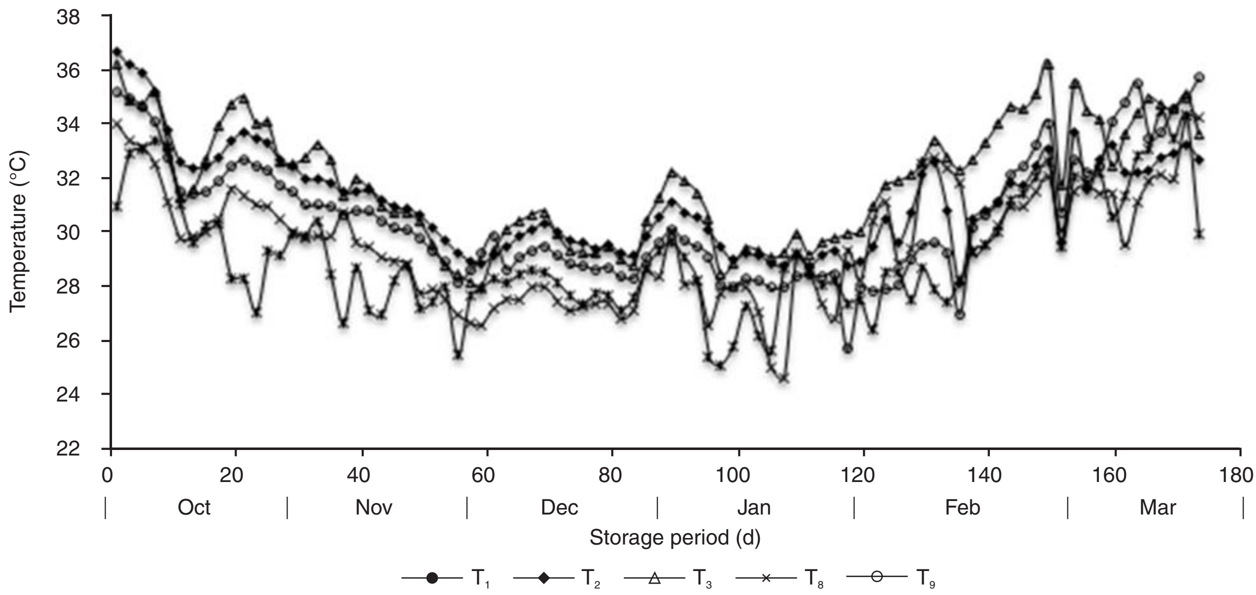

Fig. 6. Mean temperature distribution at different locations in the central axis of wheat bulk stacks covered with PVC coated polyester cover during storage period from October (2014) to March (2015)

beginning (October 2014) due to changes in weather from cold to hot condition. The highest temperature inside the wheat bulk stacks was observed usually during the noon and lowest in the morning. These results indicated that the hot sun temperature warmed up the grain during the day time. Similar results were obtained by Jian et al. (2009) for wheat stored in metal silo.

The variation in temperature along the central axis in both PVC coated polyester and black polyethylene covered stacks are shown in Fig. 5 and Fig. 6 respectively. The highest temperature was observed at the centre of the middle layer (T_3) in both PVC coated polyester covered and black polyethylene covered stacks. The lowest temperature was observed at the lower surface (T_9) of the wheat stacks. The centre of the middle layer (T_3) of wheat bulk stacks was found to have 2.1°C higher than that of the temperature at the bottom surface of the stacks (T_9) in PVC coated polyester covered stacks. Similarly, in black polyethylene covered stack, it was found to have 2.4°C higher than that of the temperature at the bottom surface (T_{15}). Jian et al. (2009) also observed high temperature at the centre of grain bulk in wheat stored in metal silo.The minimum and maximum temperatures at the centre of the middle layer (T_3) observed within PVC coated polyester covered stacks was 28.0 ± 1°C (59 day) and 35.4 ± 1°C (8 day) while that of black polyethylene covered stack 27.4 ± 1°C (28 day) and 36.1 ± 1°C (172 day) respectively. The lowest temperature during the storage period was observed during December (i.e. 27.0 ± 1ºC and 26.56 ±1ºC in PVC coated polyester and black polyethylene covered stacks respectively).

The temperature at different positions along the central axis in PVC coated polyester covered stacks were compared using least square difference (LSD) method at α= 0.05. There was a significant difference between the temperatures at the centre and bottom of the wheat bulk stacks ($P<0.05$) in PVC coated polyester covered stacks. In black polyethylene covered stacks, there was significant difference between the temperatures at the centre of the middle layer (T_3) and the top surface of the wheat bulk (T_1). There was also a significant difference between the temperatures at the centre of the middle layer (T_3) and the lower surface of the wheat bulk (T_9) in black polyethylene covered stacks.

The variation in mean temperature distribution near the four side walls under PVC coated polyester and black polyethylene covered stacks during the storage period from October (2014) to March (2015) are shown in Fig. 7 and Fig. 8 respectively. The standard deviation for the mean temperature near the wall in black polyethylene covered stacks was 7.8% more than the PVC coated polyester covered stacks, which implies that the temperatures near the walls were mainly influenced by seasonal weather changes in the outside ambient conditions. Similar observations were reported by Jian et al. (2009) in wheat stored in metal silos.

The mean temperature distribution near the four sides in PVC polyester coated covered stacks were compared using least square difference (LSD) method at α = 0.05. There was no significant difference ($P>0.05$) observed in the temperatures among the four

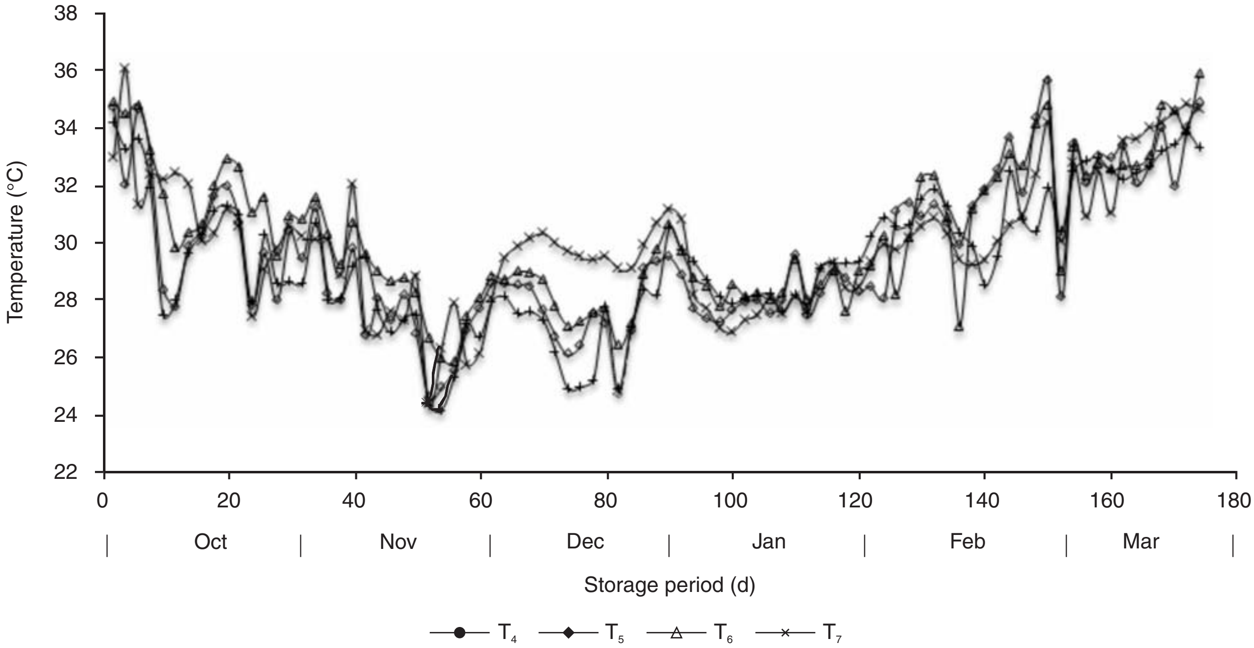

Fig. 7. Mean temperature distribution near the side walls of PVC coated polyester covered bulk wheat stack during storage period from October (2014) to March (2015)

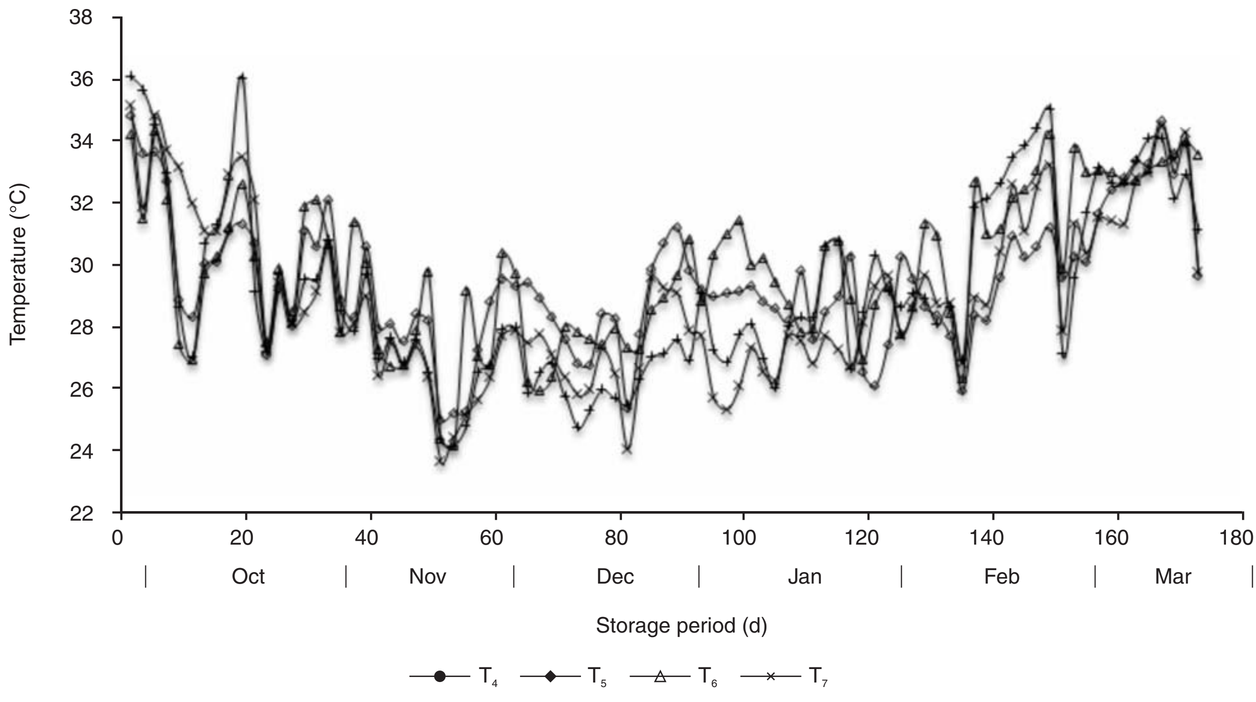

Fig. 8. Mean temperature distribution near the side walls of black polyethylene covered bulk wheat stack during storage period from October (2014) to March (2015)

walls of PVC coated polyester and black polyethylene covered wheat bulk stacks.

The mean temperature distribution near the walls of the wheat bulk stacks showed similar trends during the storage period from October (2014) to March (2015) in PVC coated polyester and black polyethylene covered stacks. The lowest temperature near the walls during the storage period was observed in December (2014). The mean temperature near the walls were found to be 27.59 ± 1ºC and 26.98 ± 1ºC in PVC coated polyester and black polyethylene covered stacks, respectively, during December (2014). The highest temperature near the walls during the storage period was during March (2015). The mean temperature during March was 33.09 ± 1ºC and 33.42 ± 1ºC in PVC coated polyester covered and black polyethylene covered wheat bulk stacks

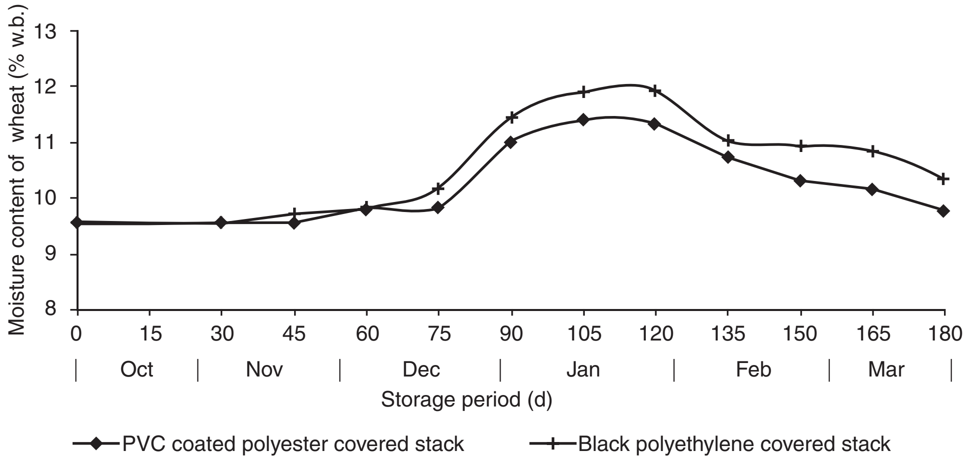

Fig. 9. Moisture changes in wheat grain under PVC coated polyester and black polyethylene covered bulk stacks from October (2014) to March (2015)

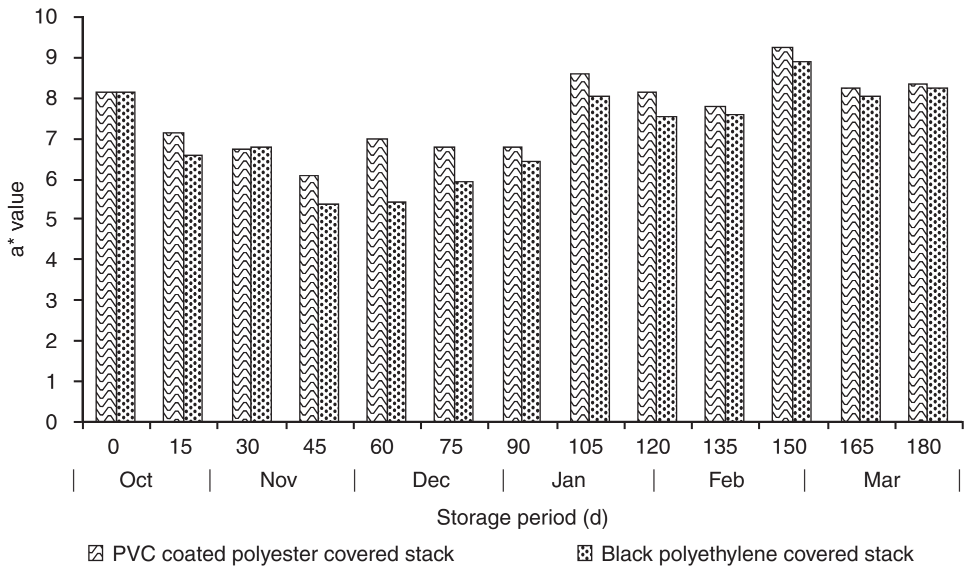

Fig. 10. Changes in a* value of wheat in PVC coated polyester and black polyethylene covered bulk stacks from October (2014) to March (2015)

respectively.

Grain moisture distribution in wheat bulk stack

The relationship between grain moisture content in PVC coated polyester cover and black polyethylene covered stacks during storage period from October (2014) to March (2015) is shown in Fig. 9. The initial m.c. of wheat was 9.6% (w.b.). The moisture content of wheat showed increasing trend with respect to the storage period starting from November to January months. During the storage period from November to January, the grain m.c. increased from 9.5 to 11.5% (w.b.) and then decreased slowly to 10.3% (w.b.) from February to March in the PVC coated polyester covered wheat bulk stacks. Similarly, the grain m.c. increased from 9.5 to 12% (w.b.) from November to January and then decreased slowly to 10.8% (w.b.) from February to March in the black polyethylene covered wheat bulk stack.

The increase in the moisture content in the wheat stacks from November (2014) to January (2015) was observed due to the rain pours during that season. The increased relative humidity in the outside environment may have resulted in the absorption of moisture by the wheat grain bulk during the period of rains. Sawant et al. (2012) reported similar trend in the increase of moisture content of wheat bulks stacks in outdoor storage during rainy season. During the storage period from November to January the m.c. of the wheat at the bottom of the stacks was found 0.18% higher than the top of the wheat bulk stacks. This may be due to the moisture migration from the wooden crates (soaked with rain water) to the nearest bottom layer of the wheat grain in bulk stack. Sawant et al. (2012) also found similar results in their study, that the wooden dunnage provided at the bottom of bags soaked with water during the rainy season resulted in the increase of moisture content at the bottom layer of CAP storage of wheat grains.

In black polyethylene covered stacks, the moisture content was found to be 3.1% higher than the PVC coated polyester covered stacks. This may be due to the increased insect growth and their respiration which might have resulted in the increased moisture content of the grain. Kusinska (2003) also reported increase in the moisture content of grain bulk due to increased infestation.

Changes in colour

The variation of L (lightness to darkness), a* (redness to greenness) and b (yellowness to blueness) values of wheat in both stacks during storage period from October (2014) to March (2015) month were

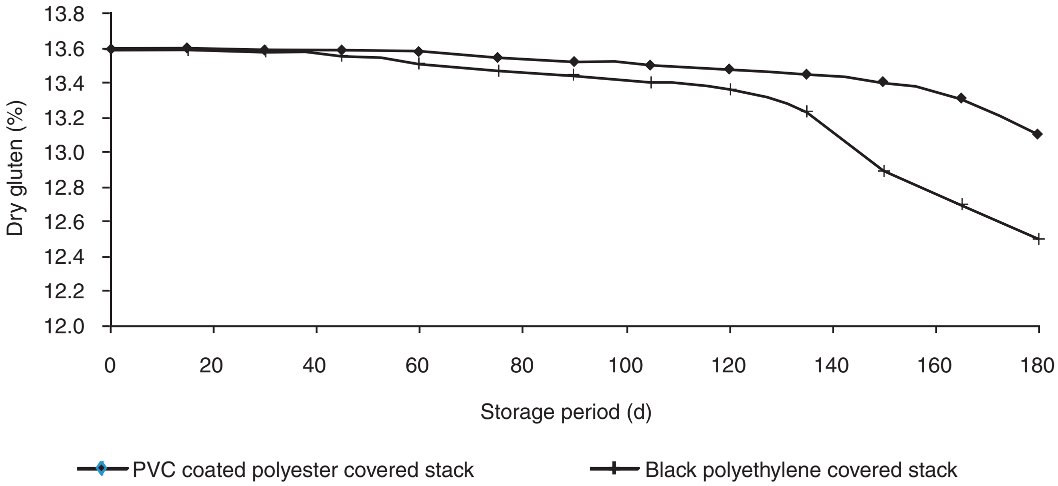

Fig. 11. Changes in dry gluten content of wheat grains in PVC coated polyester and black polyethylene covered bulk stacks from October (2014) to March (2015)

analysed statistically. There was no significant difference (P>0.05) in the L and b* values of wheat during storage period in both the stacks. A significant difference (P<0.05) was observed in the a* value of the samples during the storage period in both the stacks. The changes in a* value of wheat grains in PVC coated polyester and black polyethylene covered bulk stacks during storage period from October (2014) to March (2015) is shown in Fig. 10. The a* value of the wheat grains was found to be 8.14 ± 1 initialy and it decreased to 6.77 and 5.99 in PVC coated polyester and black polythene covered stacks, respectively, from October to November. During storage period from December (2014) to March (2015) months, a* value increased to 8.32 ± 1 and 8.22 ± 1 in PVC coated polyester and black polythene covered stacks respectively. This variation in the colour value of the wheat grains may be due to the variaion in the temperature and moisture content in the wheat bulk stacks. The a* value of wheat in black polythyne covered stacks was 5.5% less than the PVC coated polyester covered bulk stacks. Similar trend of decrease in the a* value of wheat during storage period due to infestation by *Tribolium* species was observed by Masood et al. (2004).

Changes in gluten

The dry gluten content showed a decreasing trend during the storage period in PVC coated polyester and black polyethylene covered stacks Fig. 11. The initial dry gluten content of wheat was 13.6 ± 0.2% and at the end of the storage period, it decreased to 13.1 ± 0.2% and 12.5 ± 0.2%, respectively, in PVC coated polyester and black polythene covered stacks. The gluten values compared statistically using F test exhibited significant difference (P<0.05) between the dry gluten values of wheat in PVC coated polyester and black polythene covered stacks. In black polyethylene covered wheat stacks, the loss was found to be 4.5% higher than the PVC coated polyester covered stacks which may be due to insect infestation. More et al. (2013) reported similar trend in the decrease in dry gluten during storage of wheat.

Insect infestation

Insect species *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (Fabricius) were found in the wheat bulk stacks which, could be due to immigration from outside environment (i.e. cross contamination). The average number of total insects in the black polyethylene covered wheat stack was found to be three times more than the PVC coated polyester covered wheat stack during the storage period (Fig. 12). This was reflected in the quality of the wheat which started turning to powdery mass after 5 months of storage in black polyethylene covered stack. The infestation values compared statistically using F test revealed significant difference (P<0.05) between the values of PVC coated polyester and black polyethylene covered stacks.

CONCLUSION

The moisture content of wheat in both stacks increased from November (2014) to January (2015) and decreased from February to March (2015). The temperature of the wheat bulks decreased from November (2014) to January (2015) and increased afterwards. The insect infestation observed in the black polyethylene covered wheat bulk stacks was three times higher than the PVC coated polyester

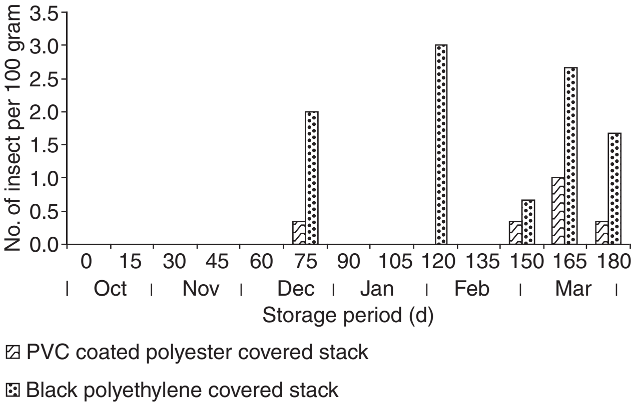

Fig. 12. Insect infestation in PVC coated polyester and black polyethylene covered bulk wheat stacks during storage period from October (2014) to March (2015)

covered stacks during the storage period. The ‘a*’ value of wheat in black polythyne covered stacks was found to be 5.5% less than the PVC coated polyester covered bulk stacks. The loss of dry gluten was 4.5% higher in the wheat stacks covered with the black polyethylene sheets. Based on overall observations, the quality of wheat covered in PVC coated polyester sheet was better and safer than the wheat covered in black polyethylene sheet.

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