



Aleksha KSK, Jha SN, Dixit AK (2016) Assessment of loss during bulk storage of wheat (*Triticum aestivum*) in India. Pp. 447–454. In: Navarro S, Jayas DS, Alagusundaram K, (Eds.) Proceedings of the 10th International Conference on Controlled Atmosphere and Fumigation in Stored Products (CAF2016), CAF Permanent Committee Secretariat, Winnipeg, Canada.



Assessment of loss during bulk storage of wheat (*Triticum aestivum*) in India

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ABSTRACT

Food Corporation of India (FCI) and Central Warehousing Corporation (CWC), the nodal central agencies of government of India, along with other state agencies, undertake procurement of wheat under a price support scheme to ensure remunerative prices to the farmers for their produce as an incentive for achieving better production. Millions of tonnes of foodgrains falling within the specifications of Government of India, procured by FCI and CWC are stored in depots such as godowns and cover and plinth (CAP), all over India. During 2014-15, unseasonal rains and hailstorms across North India and its connected states caused heavy damages to *Rabi* crop harvest mainly in March 2015. This unseasonal rainfall impacted the wheat crop which was at different stages of harvest. In view of this, the Government of India relaxed the uniform specification for wheat being procured during *Rabi* 2015-16, in Punjab, Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh. This study was undertaken to assess the changes in that wheat during three months storage in godown and CAP. The initial moisture content (m.c.) of wheat at the time of procurement ranged between 8.40 and 12.55% wet basis (wb). After three months of storage, the m.c. ranged from 9.20 to 12.55% wb. All the wheat stacks absorbed moisture during storage. The weight of wheat also increased (gain in weight) in the range of 0.41 to 0.43% in godown and 0.25 to 0.42% in CAP. In general, the study showed that there were appreciable gains in weight of wheat procured under relaxed specification requirements whereas there were no change in quality parameters during the three months storage period.

Key words: Bag storage, Bulk storage, Cover and plinth, Godown, Moisture content, Quality, Relaxed specification, Warehouse, Weight gain, Wheat

Food Corporation of India (FCI) and Central Warehousing Corporation (CWC), the nodal central agencies of Government of India (GoI), along with other state agencies, procure wheat under price support scheme to ensure remunerative prices to the farmers as an incentive for achieving better production. The stocks brought to the purchase centers, if typically comply with the Government specifications are purchased at the fixed support price. The millions of tonnes of foodgrains thus procured by FCI and CWC are stored in storage depots such as godowns and cover and plinth (CAP), all over India for varying periods.

During the year 2015, India experienced severe hailstorms over northwest, central and adjoining peninsular India at the end of February. Total

cultivable area in *Rabi* stands at 600 lakh ha and wheat is the major *Rabi* crop in India. Among this total area about 113 lakh ha in 14 states was affected by this unseasonal rains and hailstorms. Bihar, Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh were the worst hit, with wheat in the stage of maturity and/or harvest. Wheat crop that was harvested and left in the fields for collection suffered extensive damage.

Before every procurement season the uniform specification norms for foodgrains procurement are decided by an expert committee. These specifications should conform to the norm prescribed under the Food Safety and Standards Act, 2006. But as a major relief to wheat farmers affected by unseasonal rains and hailstorms, the Centre relaxed quality norms for wheat procurement in Haryana, Punjab, Uttar Pradesh, Madhya Pradesh and Rajasthan.

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Table 1 Depots provided by FCI and CWC and selected for storage study

State	Number of depot	Name of depot	Storage type (Warehouse/CAP)
Punjab	3	FSD Moga	CAP
		CWC Moga II	Warehouse
		SWC Rampuraphul	Warehouse
Haryana	2	FSD Barwala	Warehouse & CAP
		CWC Karnal	Warehouse
Rajasthan	4	FSD Sawai	Warehouse & CAP
		Madhopur	
		CWC Sri	Warehouse
		Ganganagar-I	
		CWC Sri	Warehouse
Uttar Pradesh	3	Ganganagar-II	
		CAP Alwar	CAP
		FSD Dhamora	Warehouse & CAP
Uttar Pradesh		CWC Basti	Warehouse
		FSD Raibareilly	Warehouse & CAP
Madhya Pradesh	3	FSD Chola	Warehouse
		FSD Ujjain	CAP
		CWC Indore	Warehouse

This wheat procured by the Food Corporation of India (FCI) under relaxed specifications was stored in godowns and CAPs. Since high moisture grains are susceptible to high rate of deterioration during storage, this study was undertaken with the procured URS wheat by storing them for three months at godowns and CAPs in the above mentioned states of India.

MATERIALS AND METHODS

Wheat procured by the Government of India under relaxed specifications during *Rabi* 2015-16 and stacked in the godowns and CAPs owned by FCI and CWC were selected for the storage study (Table 1). Totally 15 depots were selected in five states and two stacks in each depot under godown and / or CAP storage system (Table 6) were marked for storage study.

Allocation of godowns and CAPs: The centers of All India Coordinated Research Project on Post-Harvest Engineering and Technology (AICRP on PHET) namely PAU Ludhiana, CCSHAU Hisar, MPUAT Udaipur, ISRI Lucknow and JNKVV Jabalpur were allocated godowns and CAPs falling in their respective states for this study by the coordinating unit of ICAR's AICRP on PHET.

Stack constitution: All the study stacks of wheat were constituted in each of the above selected depots (godown and CAP) as per the norms and methods followed by FCI and CWC in the months of April - May 2015 (depending upon the arrival of commodity in FCI and CWC godowns). They were stored for a period

of three months till August 2015. After completion of storage period the stacks were liquidated by following the methodology and guidelines of FCI and CWC.

Sampling: The methodology being used by FCI and CWC (IS: 14818-2000) prescribed by BIS was adopted for sampling.

Data collection

During the storage period samples were drawn from the peripheral bags of the stacks fortnightly using above standard method by each centre in the presence of FCI and CWC personnel. Various refractions, *viz.* foreign matter, other foodgrains, damaged, slightly damaged grains, shrivelled, broken and weeviled were calculated on the basis of the sample weight and expressed as percentage. During stacking and dismantling the moisture content of samples were determined using the Universal moisture meter (OSAW make) and checked by hot air oven method (ASAE Standard S352.2). The weight of all wheat bags (weight of full stack) before and after liquidation of the stacks was taken using the nearby weigh bridge to know actual loss or gain in weight by URS wheat. From each sampling, data on the following parameters were recorded.

- Moisture content – whole stack moisture content at the time of stacking and dismantling; and peripheral moisture content on fortnightly basis
- Quality parameters of stack—fractions of foodgrains (percentage of foreign matter, other foodgrains, damaged, slightly damaged, shrivelled, weeviled and broken)
- Level of infestation (clear/ few/ heavy)
- 1,000 grain weight
- Number of spray / fumigation with the name of the chemicals used
- Incidences of rodents, birds, mites, monkey trouble during storage
- Type of gunnies used
- Weight of spillage
- Incidence of pilferage, if any
- Temperature and relative humidity inside storage depot
- Weather data with respect to ambient temperature, total rainfall and RH from the nearest meteorological station

Calculation of weight loss or gain in URS wheat:

The change in total weight of grains due to change in moisture content (w.b.) was computed using the following formulae:

$$\text{Weight change (\%)} = \frac{M_i - M_f}{100 - M_f} \times 100$$

where, M_i and M_f , initial and final moisture content of stacked grains respectively (% wet basis (wb)).

Loss or gain in weight (%) of food grains on actual weight basis was expressed by the following equation:

$$\text{Gain/loss (\%)} = \left(\frac{W_1 - W_2}{W_1} \right) \times 100$$

where, W_1 and W_2 , initial and final weight of stack (100% weight), kg

Analysis of data: Data collected from each stack were subjected to analysis of variance (ANOVA) and the results are reported along with their standard deviations.

RESULTS AND DISCUSSIONS

Region-wise loss/gain in URS wheat of Rabi 2015-16

Punjab: All the wheat stacks gained moisture during the storage months from May-August, 2015 (Table 2). Based on moisture content the gain in weight at Moga and Rampuraphul were 0.67 and 1.39%, respectively, in godown; whereas at Moga under CAP it was 0.83%. The difference between weight gain on actual weight basis of whole stack and on moisture

basis is because of the huge difference between the moisture content of peripheral and core samples. Bags which are inside the stacks did not absorb moisture as much as by the bags in periphery of the stacks.

During three months storage period the URS wheat inside godowns gained weight to the tune of 0.47% and 0.22% at Moga and Rampuraphul, respectively (Fig. 1) based on 100% actual weight. The gain in CAP storage system was found lower (0.17%) than the godown storage system at Moga, which may be due to less moisture gain by wheat under CAP.

No significant changes were observed in quality parameters of URS (Table 3) wheat during three months storage under godown and CAP at Moga and Rampuraphul.

Haryana: Wheat gained weight irrespective of storage system. The results showed that there were 0.16 and 0.72% gain at Karnal and Barwala godowns, respectively, on weight basis, whereas there was 0.67% gain under CAP at Barwala (Fig.2). At Karnal the moisture content of wheat was 10.5% at the time of procurement (Table 2). Owing to this the wheat did not gain more moisture even though the relative humidity increased similar to other depots (Fig. 6). It reflects lesser gain in weight at Karnal than that in other places.

Table 2 Agro-climatic region-wise data on storage loss or gain

Warehouse depot	Agroclimatic region	Storage gain (+)/ loss(-), % (weight basis)	Average storage loss/gain,%	Initial mc, %wb	Final mc, %wb
<i>Godown storage</i>					
Moga		0.47	0.43	9.75	10.35
Rampuraphul		0.22		9.10	10.35
Karnal		0.16		10.60	10.80
Barwala	Trans gangetic plain region	0.72		8.90	10.40
CWC I Sriganganagar		0.41		8.75	9.20
CWC II Sriganganagar		0.57		9.10	10.05
Indore	Western plateau and hills region	0.41	0.41	9.40	ND
Bhopal	Central plateau and hills region	0.31	0.43	8.85	11.45
Sawaimadhopur		0.55		8.65	9.80
Raibareilly		0.04	0.02	10.20	11.45
Basti	Upper gangetic plain region	0.10		11.65	11.95
Dhamora		-0.07		12.15	12.35
<i>CAP storage</i>					
Moga	Trans gangetic plain region	0.17	0.42	9.30	10.05
Barwala		0.67		8.90	9.55
Ujjain	Western plateau and hills region	0.27	0.27	8.65	9.85
Sawaimadhopur	Central plateau and hills region	0.22	0.25	8.50	10.35
Alwar		0.28		9.75	10.65
Raibareilly	Upper gangetic plain region	0.09	-0.02	12.55	12.55
Dhamora		-0.12		12.10	12.40

Table 3 Refractions of URS wheat during stacking and dismantling in Punjab

Fraction	Godown/CAP					
	Moga CAP		Moga		Rampuraphul	
	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation
Foreign matter, %	0.40	0.40	0.03	0.04	0.25	0.25
Other food grains, %	0.75	0.68	0.63	0.58	0.45	0.48
Damaged grains, %	3.70	3.65	3.10	2.25	2.75	2.78
Slightly damage grains, %	1.70	1.63	1.35	1.75	2.90	2.90
Shrivelled and broken, %	8.65	8.58	7.00	7.55	8.45	8.45
Weeviled grains, %	Nil	Nil	Nil	Nil	Nil	Nil
Level of infestation-clear, few, heavy	Clear	Clear	Clear	Clear	Clear	Clear

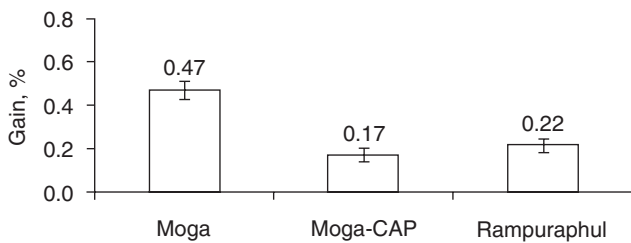


Fig. 1. Average storage gain in URS wheat in Punjab warehouses on weight basis

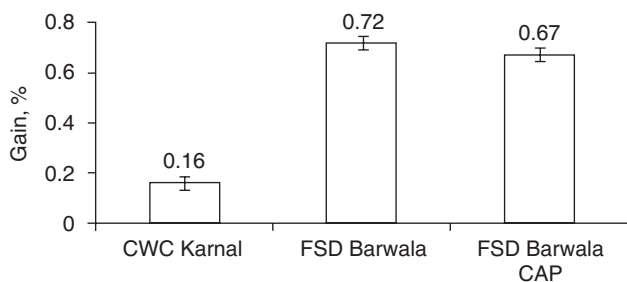


Fig. 2. Average storage gain in URS wheat in Haryana warehouses on weight basis

At Barwala, the initial moisture content was 8.9% and during storage due to increase in RH the moisture content of wheat increased to 10.4%. This increase in moisture content was more than the CAP wheat at Barwala. This may be due to the exposure of stacks to the surrounding environment conditions inside the godown whereas under CAP system the commodity is completely wrapped under cover.

The gain calculated based on moisture content indicated that gains were 0.22 and 1.67% at Karnal and Barwala godowns, respectively. The gain in Barwala CAP wheat was 0.72%. There was almost no change in quality parameters of URS wheat stored during the period of study (Table 4).

Uttar Pradesh: In Uttar Pradesh, initial moisture contents of URS wheat stacked were higher than all other depots under study; ranging from 10.2 to 12.55%. There were not much variations in the moisture profile of wheat during storage. Except Dhamora depot, wheat at all depots gained weight. The gains at Raibareilly

Table 4 Refractions of URS wheat during stacking and dismantling in Haryana

Fractions	Godown/CAP					
	CWC Karnal		FSD Barwala		FSD Barwala (CAP)	
	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation
Foreign matter (%)	0.5	0.5	0.37	0.37	0.37	0.37
Other food grains and other wheat (%)	1.2	1.2	0.5	0.5	0.37	0.37
Damage (%)	2.45	2.45	1.77	1.77	1.63	1.63
Slightly damaged (%)	1.5	1.5	-	-	-	-
Shriveled broken (%)	9.1	9.1	8.75	8.75	8.87	8.87
Weeviled grains (%)	Nil	Nil	Nil	Nil	Nil	Nil
Level of infestation-clear, few, heavy	Clear	Clear	Clear	Clear	Clear	Clear

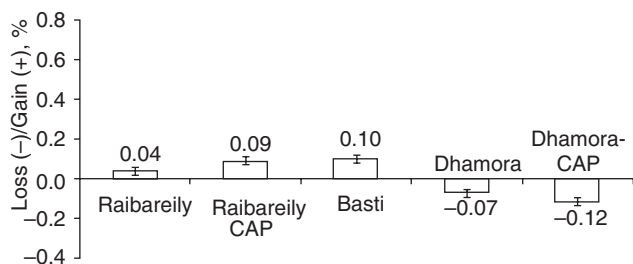


Fig. 3. Average storage gain/loss in URS wheat in Uttar Pradesh warehouses on weight basis

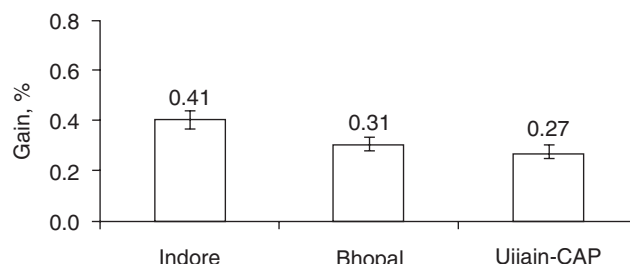


Fig. 4. Average storage gain in URS wheat in Madhya Pradesh warehouses on weight basis

and Basti under godown storage were observed as 0.04 and 0.10%, respectively, whereas under CAP it was 0.09% gain at Raibareilly. At Dhamora both in godown and CAP there were losses to tune of 0.07 and 0.12%, respectively (Fig.3).

Based on moisture content there were 1.41, 0.34 and 0.23% gain in the godown wheat at Raibareilly, Basti and Dhamora, respectively, and 0.00% and 0.34% in CAP wheat at Raibareilly and Dhamora respectively. There were no appreciable change in quality parameters (Table 5) of URS wheat stored for three months in UP also.

Madhya Pradesh: The moisture contents of wheat at the time of stacking in Indore, Bhopal and Ujjain were 8.65, 8.85 and 9.40%, respectively. During three months storage (Mid May to Mid August 2015) wheat absorbed moisture and reached up to the level

of 11.45%. The gain was up to 2.94% due to these changes in moisture contents in the above depots.

It reflected in the 100% weight of wheat also after three months storage period. Based on this there were 0.41 and 0.31% gain in weight at Indore and Bhopal depots, respectively, under godown storage and 0.27% gain under CAP storage at Ujjain depot (Fig. 4). The changes in the quality parameters during storage were not significant (Table 6).

Udaipur: Wheat stored in the warehouses of Udaipur experienced gain irrespective of the storage system. There were 0.41, 0.57 and 0.55% gains in weight of wheat at CWC I Sriganganagar, CWC II Sriganganagar and Sawai Madhopur, respectively, in godown storage. The gain under CAP at Sawai Madhopur and Alwar were 0.22 and 0.28%, respectively. These gains were lesser than those of

Table 5 Refractions of URS wheat during stacking and dismantling in Uttar Pradesh

Fraction	Godown/CAP										
	Raibareilly		Raibareilly (CAP)		Basti		Dhamora		Dhamora (CAP)		
	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	
Foreign matter,%	-	-	-	-	-	-	-	-	-	-	-
Other food grains,%	-	-	-	-	-	-	-	-	-	-	-
Damaged grains,%	2.34	2.86	3.77	3.82	3.04	3.18	2.21	1.44	2.24	2.72	
Slightly damaged grains,%	-	-	-	-	-	-	-	-	-	-	
Shrivelled and broken,%	4.76	5.27	6.17	6.34	4.80	5.52	3.31	4.90	4.57	5.86	
Weeviled grains,%	0.3	0.38	0.2	0.22	0.45	0.78	0.80	0.52	0.64	0.48	
Level of infestation-clear, few, heavy	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	

Table 6 Refractions of URS wheat during stacking and dismantling in Madhya Pradesh warehouses

Refraction	Godown/CAP					
	Indore		Bhopal		Ujjain (CAP)	
	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation
Foreign matter (%)	1.63	0.65	0.58	0.38	0.23	0.35
Other food grains and other wheat (%)	1.63	-	2.48	0.10	0.08	0.10
Damage (%)	0.63	0.78	0.75	0.15	0.18	0.45
Slightly damage (%)	5.63	5.18	5.38	5.40	3.55	3.40
Shriveled broken (%)	1.55	1.03	3.55	2.08	0.65	0.93
Weevilid	Nil	Nil	Nil	Nil	Nil	Nil
Brokens (%)	4.3	1.1	3.70	3.83	2.53	2.73
Level of infestation-clear, few, heavy	Clear	Clear	Clear	Clear	Clear	Clear

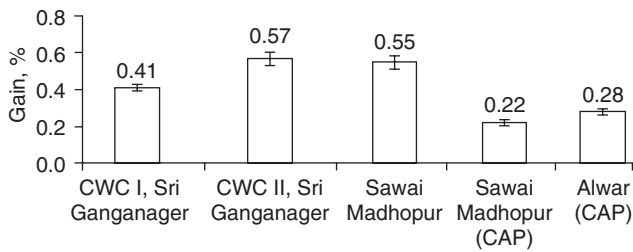


Fig. 5. Average storage gain in URS wheat in Rajasthan warehouses on weight basis

godown stacks (Fig.5).

In all the depots wheat absorbed moisture content irrespective of storage system. The increase in moisture contents were higher in CAP wheat than that

of the godown wheat. Based on moisture content the gain in wheat were 0.50, 1.06 and 1.28% in CWC I and II Sriganganagar and Sawai Madhopur, respectively, under godown storage and 2.06 and 1.01% in Sawai Madhopur and Alwar, respectively, under CAP system. There were no appreciable changes in quality parameters of URS wheat during three months storage period (Table 7).

Storage loss or gain based on agro-climatic region

Moisture content of wheat at the time of stacking ranged from 8.4 to 12.15% in godown and 8.4 to 12.55% in CAP. The initial moisture content was low in the Central plateau and hills region and high

Table 7 Refractions of URS wheat during stacking and dismantling in Udaipur warehouses

Refraction	Godown/CAP									
	CWC I-Sriganganagar		CWCII-Sriganganagar		Sawaimadhopur		Sawaimadhopur (CAP)		Alwar (CAP)	
	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation	At the time of stacking	At the time of liquidation
Foreign matter (%)	0.32	0.39	0.37	0.35	0.75	0.65	0.59	0.62	0.65	0.52
Other food grains and other wheat (%)	1.30	1.13	1.10	1.07	1.50	1.54	1.25	1.35	1.50	1.44
Damaged (%)	1.13	1.05	1.05	0.99	1.70	1.60	1.50	1.65	1.10	1.35
Slightly damaged (%)	3.50	3.96	3.30	3.65	4.50	4.20	4.00	4.40	1.70	1.35
Shriveled and brokens (%)	6.45	6.60	6.50	6.55	8.40	8.30	8.00	7.60	8.30	8.10
Weeviled grains	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Level of infestation-clear, few, heavy	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear

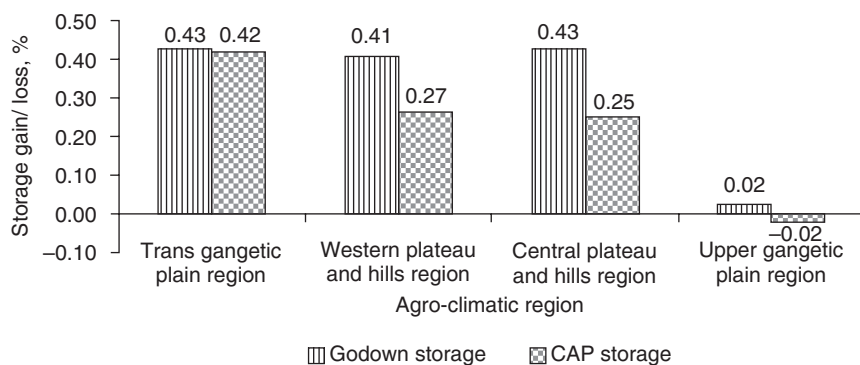


Fig. 6. Average storage gain or loss in wheat during three months storage period on weight basis in different agro-climatic zones under study

in the Upper Gangetic Plains region. In Uttar Pradesh the procured wheat had above 12% moisture content. Remaining procurements were within the safe moisture level. During the three-month storage period, the moisture content of wheat increased significantly in all the stacks irrespective of the region. The moisture contents of wheat at the time of liquidation were in the range of 9.2 to 12.45% in godown and 9.55 to 12.55% in CAP (Table 2). The liquidation moisture content was within the safe level of 12%, except in Uttar Pradesh depots.

The effect of agroclimatic region on the storage loss or gain in URS wheat is shown in Fig. 6. The gain in wheat was not significant under godown storage except in Upper Gangetic Plains region. Under CAP storage system the gain was lower than the Godown storage system. In the Upper Gangetic Plains region the gain in godown and the loss in CAP were not significant due to high initial moisture content.

Among the states selected for study, Uttar Pradesh received the highest rainfall (300 mm) and Madhya Pradesh the lowest (70 mm) during the storage period, which reflected in their moisture contents. It was also found statistically that the moisture at the time of procurement highly influenced the absorption of moisture from the surrounding atmosphere leading to the weight gain. The gain in wheat was higher when the procured moisture content was lower and vice versa.

Quality of stored wheat

Even though wheat was procured under relaxed specifications after three months of storage there were no significant differences in quality. All the study stacks of wheat were free of infestation during the storage period due to proper fumigation/spray of all the stacks. Microbial (fungal/mold) infection was also nil in all the samples of the stacks. For rye samples above 12% m.c. stored at 30°C, Rajaramanna et al. (2010) found that there were visible mold growth only

after 9 weeks. In the present study the storage temperature remained in the range of 26°C-35°C but the safe moisture levels remained throughout storage period, which complied with standards, might have restricted the growth of microorganisms in the stored wheat. Karunakaran et al. (2001) determined the safe storage time of high moisture wheat (15-19% wb) stored at constant temperatures or with a step decrease in storage

temperatures. Deterioration rates were determined by measuring germination capacity of the grain and respiration rates of grain and microorganisms. They found that the respiration rates and germination percentages of 15 and 16% m.c. (lower m.c. taken for their study) wheat stored at 25°C remained constant for 70 d. Al-Yahya (2001) stated that with reduced grain temperature and moisture content the safe storage time of wheat grains can be increased due to less intensive grain respiration.

CONCLUSION

The changes during storage of wheat procured under relaxed specifications during the year 2015-16, were determined under godown and CAP storage systems in four agro-climatic regions comprising Punjab, Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh. The moisture level of wheat at the time of procurement, during the storage period of three months and at the time of liquidation were within the safe limit (<12%) in all the depots, except those in Uttar Pradesh. All the wheat stacks absorbed moisture during storage irrespective of the storage system. The weight of wheat also increased in the range of 0.41 to 0.43% in godown and 0.25 to 0.42% in CAP neglecting the minimal change in the region of Upper Gangetic Plains during the three-month storage period where there was minimal loss in weight. Also there were no significant changes found in wheat quality parameters during three months storage period.

ACKNOWLEDGMENT

The authors thank the Food Corporation of India (FCI) for giving this opportunity and DDG (Engg), ADG (FE), Indian Council of Agricultural Research, New Delhi for their supports, Director, CIPHET, Ludhiana for his help and the Research Engineers of AICRP on PHET of the respective provinces of study for their contribution in data collection.

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