Pasting characteristics of stored wheat in hermetic bags and conventional methods

Sunil Kumar[1*], Nitin Kumar[1] and M. K.Garg[2]

(1. Department of Processing & Food Engineering, CCS Haryana Agricultural University, Hisar, Haryana;
2. Professor & Head, Department of Processing & Food Engineering, CCS Haryana Agricultural University, Hisar, Haryana)

Abstract: This study was performed in India to observe the effect of a type of storage structure on pasting characteristics of stored wheat. Wheat of WH-711 variety was stored in hermetic bag and two conventional grain storage structures, viz. steel bin and gunny bag piles which are usually employed in India. Pasting characteristics of wheat flour were measured in the Rapid Visco-Analyzer (RVA-4500). The results revealed the significant influence of type of structure on pasting properties of stored wheat. Highest values of peak, trough, setback and final viscosity were observed in steel bins storage and the minimum were in the gunny bag piles. Peak, trough, and final viscosity increased with the advancement of storage time in all structures. Setback and breakdown viscosity decreased with time. Breakdown viscosity was minimum in hermetic bag storage. Gelatinization temperature and peak time of all structures were the same and remained constant. A small increase in the value of pasting temperature was observed in all the structures but maximum increase (about 1.5˚C) was recorded in gunny bags and minimum (0.8˚C) in hermetic storage.

Keywords: wheat, pasting characteristics, viscosity, storage, hermetic bags

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1 Introduction

India, the world's second largest wheat producer, produced about 93.90 million tonnes wheat in 2011-2012 (Anankware et al., 2012). Around 60%-70% of food grains produced are stored at home level in indigenous storage structures (Kanwar and Sharma, 2003). Wheat is used primarily for producing bread and cakes, and a high quality of wheat is required. There are various intrinsic and extrinsic factors in storage that may affect nutritional value, such as moisture, insects, rodents, fungi (Yadav and Garg, 2010) and lack of proper storage facilities (Sharon et al., 2014). Cereals can easily be damaged, leading them to be inappropriate for baked products. Quality of wheat depends on many factors. One of these factors is storage, which is a step between harvest and consumption. Successful storage is not only just placing grains inside a suitably sized storage structure until it is needed, but it requires protection from insects or animal pests, prevention of contamination by molds or physical contaminants, and maintenance of the viability with its nutritional and manufacturing properties. The metal bins, silos, gunny bags and conventional storage techniques of different sizes and shapes are used throughout India (Sharon et al., 2014). Conventional storage practices do not guarantee protection against major storage pests of staple food crops, leading to higher percentage of quality losses, particularly due to post-harvest insect pests and grain pathogens (Tefera et al., 2011).

The use of hermetic bags for storing grain for human consumption has been adopted successfully in recent years in Asia, Africa and Latin American countries (Bartosik, 2011). For bio-friendly and effective storage,

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***Corresponding author: Nitin Kumar,** Department of Processing & Food Engineering, CCS Haryana Agricultural University, Hisar 125004, Haryana, India. Email: nitin3012@yahoo.com, Tel: +919466263889.

sealed or hermetic storage systems are a very effective means of controlling grain moisture content and insect activity for grain stored in tropical regions (Anankware et al., 2012). The respiration process of the biological agents in the grain ecosystem (grain, insects, mites and microorganisms) increases carbon dioxide (CO_2) and reduces oxygen (O_2) concentrations (Navarro, 2006; Subramanyam et al., 2012). This modified atmosphere inhibits the biotic activity, promoting a suitable environment for grain conservation (Abalone et al., 2011). Concerned with the quality of stored materials, both gunny bags and steel silos had failed to preserve quality in hot humid area (Anankware et al., 2012). Experiments revealed that wheat stored in a non-punctured bag that meets an equilibrium moisture limit (12%) is expected to maintain all processing quality parameters for 9-12 months storage (Darby and Caddick, 2007).

The pasting characteristics of wheat had a very important application in the baking industry. These pasting properties decide the product shape and the texture. Wheat flour is composed of 70%–80% dry matter of starch. Amylopectin is the major component of starch and normal wheat starch is comprised of about 75% amylopectin. The distribution of starch granule types and structure of amylose and amylopectin and their relative ratios in starch granules play an important part in determining pasting, gelation, and retrogradation properties of starch and end-product quality and stability (Jane and Chen, 1992). The Rapid Visco Analyser (RVA- 4500) can be considered as a method that gives idea about the starch quality, in terms of its potential swelling and gelatinisation behaviour. The current experiment was aimed to observe the effect of moisture content and type of storage structure on pasting characteristics of stored wheat using the RVA.

2 Materials and methods

2.1 Wheat storage setup

Six metric tonnes of freshly harvested seed grade wheat of the variety WH-711 was procured from Haryana agricultural university farm for the study. Two hermetic silo bags (Grain Safe II^{TM}, Grain Pro Inc.) were purchased with each having a capacity of one metric tonnes and had the following dimensions 1.2 m × 1.2 m × 1.9 m (L×W×H). These bags were impermeable to moisture and gases in order to provide gas tight conditions. These bags were rested on specially designed metallic frame of the dimensions 75 cm × 75 cm × 150 cm with rodent proof measures on each leg (Figure 1). Each hermetic bag had an outer propathene jacket to act as a strength member. The intended initial moisture content levels for wheat to be stored in the hermetic bags were 12% with replication. Two metallic silos with each having two meters height and one meter diameter were purchased and filled with wheat with an intended moisture content of 12% (Figure. 2). Forty gunny bags of 50 Kg capacity each were procured with the following dimensions (84 cm ×50 cm ×20 cm). Two piles of twenty gunny bags each were stacked side by side with intended initial moisture content of 12% (Figure 3). Wheat was delivered in the third week of July and was rather dry for the desired initial moisture content required for the study. In order to obtain the desired moisture content, it was spread uniformly on the floor and was sprinkled with the required amount of water and mixed thoroughly thereafter. Individual experiments started on July 22nd, 2013 and it took almost a week for all the eight experiments to be put in place. Hermetic bags were consistently monitored for any possible damage. The experimental design and related information is shown in Table 1.

Figure 1 A view of table shaped metallic frame (1), sensor rod installation (2), final experiment setup with rat cone (3) and drain tube (4) of the hermetic bags.

Figure 2 A view of sensor rod installation (1), sealing of infiltration with wheat flour paste (2) and final experiment setup (3) of the steel bins.

Figure 3 A view of sensor rod installation in gunny bag (1), Gunny bags piles on wooden crates (2) and manual insect infestation (3) of the hermetic bag.

2.2 Sampling procedure

Wheat samples were collected at the beginning and then at continuous intervals of one month from all the storage structures. Samples were collected from each of the three layers in case of metallic silos and from top, bottom and middle level gunny bags in case of gunny bag piles. For hermetic bags, it was not easy to make orifices in the horizontal plane due to the outer propathene jacket. So sampling orifice was made on the top also partly due to the fears of failure of orifice to be sealed because of grain pressure. Sampling probes were used to collect wheat samples from all the three types of storage structures and approximately 300 g of wheat sample were collected from each layer in case of metallic silos, same amount was collected from the top, mid and bottom gunny bags in case of gunny bag piles. Samples were collected vertically in case of hermetic bags using the orifice at the top. Later on these orifices were sealed using silicone sealant. All the samples from an individual storage structure were then pooled together to form representative samples for each month. These samples were sealed in the polyethylene bags and later used for qualitative analysis.

2.3 Sample preparation

The collected wheat samples were milled by the Brabender junior mill (Quadrumat) to produce white flour. These samples were kept in the polyethylene bag, sealed and stored in a refrigerator (4˚C) for further analysis. The sample of wheat was taken from all the three layers of the individual structures namely top, bottom and center, with the help of sampling probe (Figure 2) and then pooled together to make representative samples. These samples were sealed in the plastic zipper bags for further qualitative analysis.

2.4 Moisture content

Moisture content was estimated from the samples using AOAC method (1995). Five grams of sample was weighed and transferred to pre-dried, covered dish. Weighed sample was dried in hot air oven at 130˚C±1˚C for two hours. The dish with dried sample was transferred to the desiccator, cooled to room temperature and weighed. Moisture content in percent was calculated from loss in weight.

$$\text{Moisture content (\%)} = (W_1-W_2)/W \times 100 \quad (1)$$

Where, W is Weight of sample;

W_1 is Weight of sample + moisture dish;

W_2 is Weight of dried sample + moisture dish.

2.5 Pasting characteristics

Samples of wheat flour of different storage structures were assessed for the following pasting characteristics: peak viscosity, peak time, break down, final viscosity, set back and pasting temperature using Rapid Visco Analyzer, Newport Scientific Australia (AACC, 1995). All the experiments were done in triplicates and a mean ± standard deviation value was taken as the final value.

Than 25 ml of distilled water was filled into a canister. 3.5 g of sample (14% moisture basis) was weighed and transferred to the water in canister. The paddle was placed into the canister and jogged to disperse the sample. Canister with paddle was inserted into Rapid Visco Analyzer (RVA) and pressed down the tower. Test was run for 13 min. Canister was removed on completion of test. From Thermocline windows the following observations were recorded:

Peak viscosity: Maximum viscosity developed during or soon after the heating portion of the test.

Trough viscosity: Highest viscosity after the peak, normally occurring around the commencement of sample cooling.

Peak time: Time taken at which peak viscosity occurred.

Pasting temperature: It is the temperature at which viscosity first increases by at least 25 cP over a 20 second period using the standard 1 profile.

Break down viscosity: Peak viscosity minus trough viscosity.

Final viscosity: Viscosity after completion of experiment.

Set back: Viscosity where recrystallization of starch starts again.

Gelatinization temperature: Temperature on which heat crack intermolecular bonds and allow hydrogen bonding.

3 Results and discussions

Moisture content reduction of wheat occurred for all storage structures. First three months, showed maximum drop in the moisture content of about 2% but with the onset of winter, the level was stabilized in both hermetic bags on 8.3% (average) with about 1% reduction. Moisture content changes of steel bins and gunny bag piles responded in same manner as changes in ambient relative humidity. The final recorded moisture content was 8.6% and 8.3% in steel bins and gunny bag piles respectively. This dependence on ambient relative humidity was more in case of gunny bag piles than the steel bins.

Pasting properties is an important index in determining the cooking and baking qualities of flours

(Brites et. al., 2008). Starch when heated increases in viscosity as a result of the swelling of the starch granules and in their difficulty in moving past one another (Doublier et. al., 1987). The trends of all the structures were almost the same regarding the nature of change in nine months duration. The pasting properties of stored wheat under different storage structures are shown in Figure 4 and Figure 5.

A significant difference of pasting properties of stored wheat was found over a storage period. The result showed that the peak, trough, final viscosity and setback of steel bins were higher than hermetic bags and gunny bags. Moreover, the changes in pasting properties observed for stored wheat in gunny bags were higher than hermetic bag and steel bin storage. The results showed that the significant effect of storage on the pasting properties depended on storage structure, initial moisture content and duration. The peak, final and trough viscosity of all structures increased gradually to maximum value after nine months storage. The peak viscosity shows the ability of the starch granules in the flour to swell freely before they are physically broken down (Ikegwu & Okechukwu, 2010). Trough viscosity (hot paste viscosity) is the viscosity that develops after holding the paste at 95℃ and it measures the ability of the paste to withstand breakdown during cooling (Sanaa et al., 2006). The most commonly used parameter to determine starch-based samples quality is final viscosity, it indicates starch/flour ability to form a gel after cooking. Final viscosity is obtained during the cooling process of a cooked paste to 50˚C and is attributed to the re-association between starch molecules especially amylose leading to increase in viscosity which results in the formation of a gel. This phase is related to retrogradation and reordering of starch molecules (Sanaa et al., 2006). The nature of change in final viscosity of hermetic bags and steel bins was remained the same and had equal values.

The breakdown and setback viscosity of stored wheat decreased with the advancement of storage time in all structures. Breakdown viscosity is the viscosity difference between the peak viscosity and the trough viscosity and occurs as a result of holding slurries at high temperature and mechanical shear stress which leads to further disruption of the swollen starch granules resulting in leaching of amylose into the solution (Sanaa et al., 2006). Decreasing of breakdown value indicated that the capacity of starch granules to rupture after cooking was significantly reduced by ageing process (Tulyathan and Leeharatanaluk, 2007). The resistivity against the breakdown of the starch was found maximum in the gunny bag storage. Setback viscosity is useful in defining the quality of starch contained in a food material. Decrease of setback value indicates a lower degree of retrogradation as a result of product firmness was decreased (Tulyathan and Leeharatanaluk, 2007). Setback was observed maximum in the hermetic bags.

Pasting temperature of hermetic bags and steel bins was observed lowest and had an increase of 0.8˚C in compare initial values. On the other hand in gunny bags the increase was 1.5˚C. Pasting temperature is one of the properties which provide information of estimated minimum cooking time or cooking temperature for a particular food material and the energy costs that may be involved. High pasting temperatures have been associated with higher amylose content and high resistance towards swelling (Ikegwu and Okechukwu, 2010)

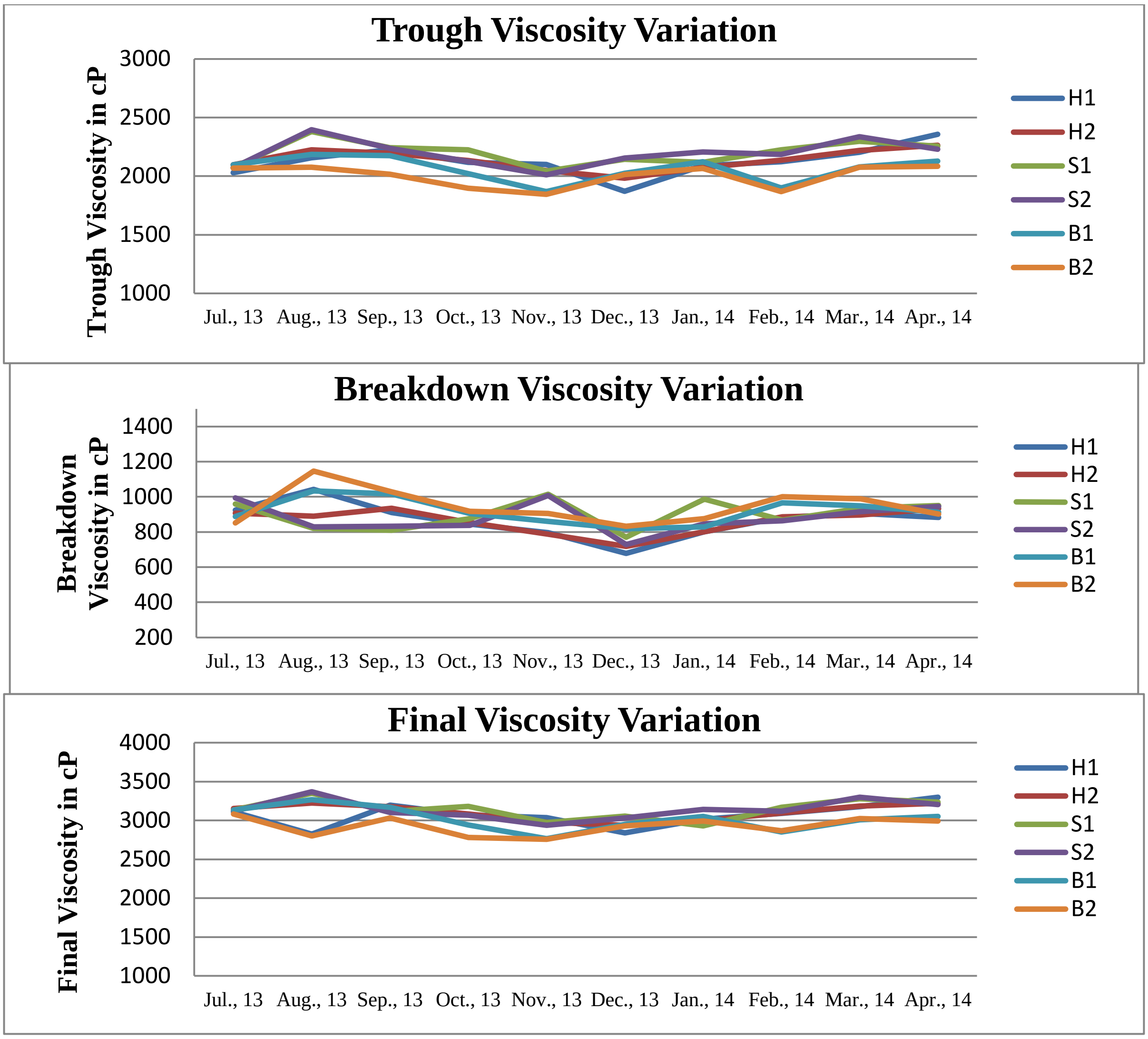

Figure 4 The peak, trough, breakdown and final viscosity of hermetic bags, steel bins and gunny bag piles

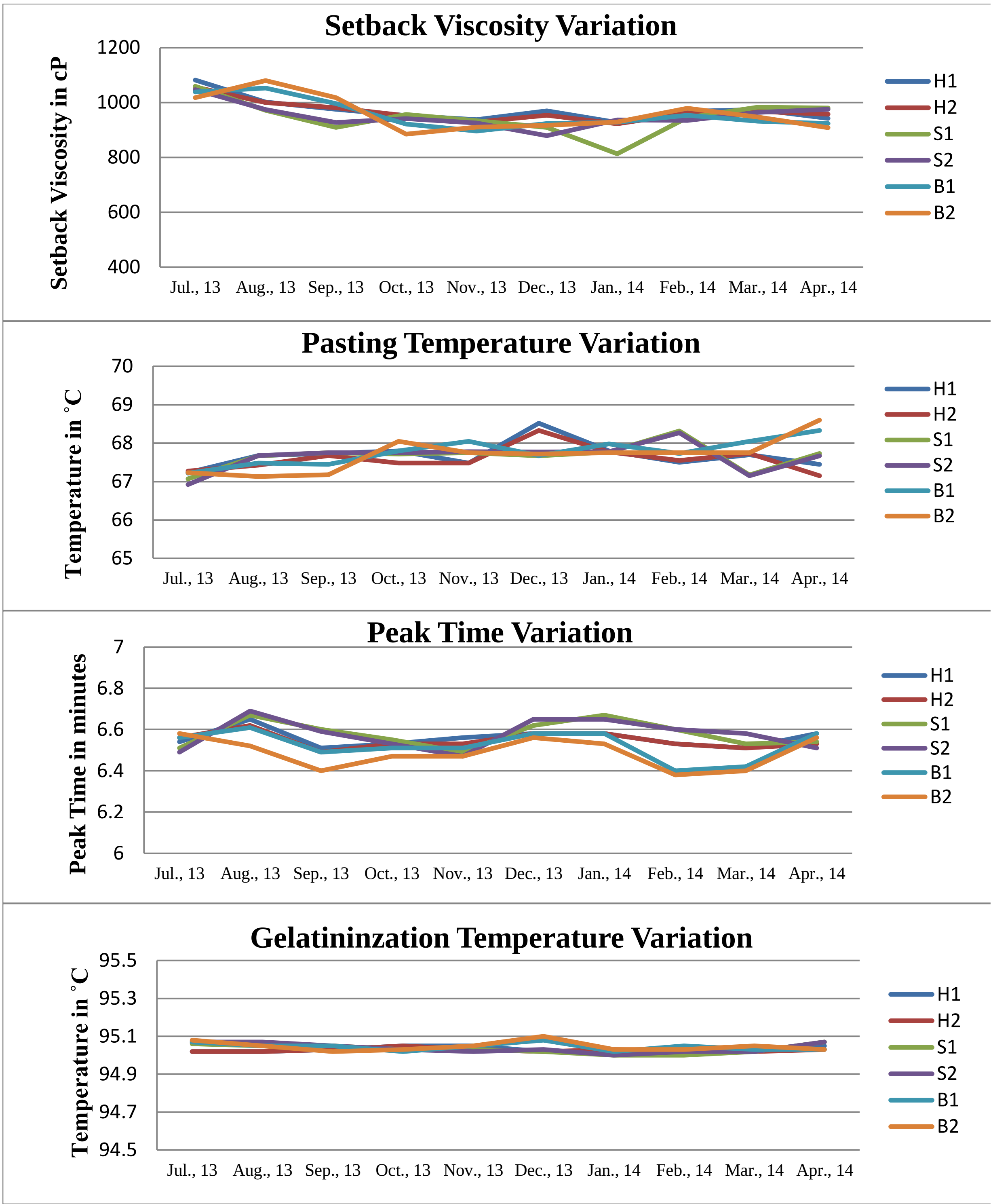

Figure 5 The setback viscosity, pasting temperature, peak time and gelatinization temperature variation of the hermetic bags, steel bins and gunny bag piles

Peak time, which is the time required to attain peak viscosity, remained constant in all the structures. Peak time is associated with the rate of absorption of water by swelling starch granules and hence their swelling. (Sanaa et al., 2006). The gelatinization temperature of all the structures remained constant on about 95.03˚C. On this temperature the heat cracks the intermolecular bonding and allow the hydrogen bonding.

Table 1 Overview of the experimental setup

Sr no.	Method & Experiment Name		Start Date	Stored Capacity	Moisture content(w.b.)
1.	Hermetic Storage	H1	24.07.2013	1 Tonne	11.53%
2.	Hermetic Storage	H2*	24.07.2013	1 Tonne	11.80%
3.	Metallic Bin	S1	22.07.2013	1 Tonne	11.76%
4.	Metallic Bin	S2	22.07.2013	1 Tonne	11.70%
5.	Gunny Bag Pile	B1	26.07.2013	1 Tonne	12.23%
6.	Gunny Bag Pile	B2	26.07.2013	1 Tonne	12.26%

Note: Deliberate introduction of 80 adult specimens of Rhizopertha dominica on 13.08.2013.

4 Conclusions

This study was conducted with six tonnes of wheat stored using three different storage techniques, i.e. hermetic bag, steel bin and gunny bag pile of one tonne capacity each for nine months. The six tonnes of wheat was tempered to obtain desired moisture content of about 12% and remaining two tonnes of 14% moisture content. Six tonnes of low moisture wheat was filled in two hermetic bags, two metallic bins and 40 gunny bags. Later, 40 gunny bags were stacked in two piles on the wooden crates about 15 cm above ground surface. Remaining left two tonnes of high moisture wheat was filled in two hermetic bags.

The variations in pasting characterises were observed between different storage structures. Steel bin storage of 12% moisture content wheat had the highest peak, trough, setback and final viscosity in comparison to the hermetic bags and gunny bags storage in nine months duration. The minimum peak, trough, final viscosity was observed in the gunny bag storage.

The pasting temperature was observed the minimum in the hermetic storage which reduces the minimum time needed in cooking of the starch. Temperature may be a very important factor in viscosity change. Decrease in viscosity in December occurred due to low temperature.

The decrease was similar in all the structures. Peak time and gelatinization temperature of all structures remained constant in nine months. The peak, trough and final viscosity increased with storage time in all the structures whereas the setback viscosity and breakdown viscosity decreased with storage time in all the structures.

Regarding final viscosity, the hermetic bags and steel bins were found good but on an overall basis, (comprising all the pasting parameters) the hermetic storage can be attractive alternate environment friendly solution for preventing quality losses during storage in India and other subtropical countries. The fact that no chemical fumigants are required makes them environment friendly as well.

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