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RESEARCH PAPER

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Effect of different storage condition on physiological weight loss and cooking quality of brown rice

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SUMMARY :

The physiological weight loss and cooking quality of four month stored brown rice at 12 per cent, 14 per cent and 16 per cent moisture contents (w.b.) were stored in different indigenous storage structures (mud bin, jute bag and polypropylene bag) at prevailing environmental conditions such as weight loss in percentage and cooking index (CI) of brown rice during storage were studied for single variety of paddy (Sugandha). It was found that weight loss percentages increased with number of storage days. The physical weight loss observed in polypropylene bag at the end of four month was 4.80, 5.33 and 6.44 per cent at 12, 14 and 16 per cent moisture content, respectively. While in mud bin was 4.98, 5.86 and 7.12 per cent and in jute bag 5.22, 6.55 and 8.00 per cent at 12, 14 and 16 per cent moisture content, respectively. While studying cooking qualities of brown rice, it was observed that cooking time reduces with advances in storage period. In polypropylene bag cooking time reduces to (65 seconds), followed by mud bin (50 seconds) and jute bag (42 seconds). Cooking time was no significant change observed at different moisture contents. However, the maximum cooking index was found in polypropylene bag followed by mud bin and jute bag in all moistures levels.

KEY WORDS : Brown rice, Weight loss percentage, Cooking characteristics, Indigenous storage structure, Moisture content, Ageing

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Rice (*Oryza sativa* L.) is an important cereal grain which feeds nearly half of the world's population. India is one of the world's largest producers of rice, accounting for 20 per cent of all world rice production. India stands first in area, second in production, followed and preceded by China on these two aspects. Rice is one of the important food crops forming staple diet to half of the world's population. It contributed 21 per cent of the global human per capita energy and 15 per cent of per capita protein (Chavan *et al*., 2016). The other major rice growing countries are Indonesia, Vietnam, Bangladesh, Thailand, Myanmar and Philippines among Asian countries. Now these days rice is excessively produced in whole of the world.

Brown rice is less desirable due to its poor cooking and eating qualities (Das *et al.,* 2008). However, from the point of health, brown rice should be the preferred due to it is rich in nutrients and bioactive components (Daomukda *et al.,* 2011). During cooking, rice was changed in the structure of starch, physical properties, chemical compositions and nutritional qualities (Mahadevamma and Tharanathan, 2007). Removal of bran layers during milling process enhances the appearance, cooking quality and palatability of rice though major loss of nutrients and high percentage of brokenness results during milling. Therefore, producing rice, with minimum breakage, retaining the maximum possible nutrients of brown rice and with preferable cooking attributes, has been the primary goal of rice processing industries.

Brown rice is richest in nutrients because of the nutrient dense bran layer found on the grain surface. The complete milling and polishing that converts brown rice into white rice destroys 67 per cent of the vitamin B3, 80 per cent of the vitamin B1, 90 per cent of the vitamin B6, half of the manganese, half of the phosphorus, 60 per cent of the iron and all of the fibre and essential fatty acids (Babu *et al.,* 2009). The hulling process also breaks up cells in the outer layer, releasing lipase enzyme which catalyzes break down of the oil in the bran layer, liberating free fatty acids that cause rancidity and off flavour. Both of these factors are responsible for the short life and poor acceptability of brown rice among the masses (Das *et al.,* 2012).

Rice grain quality is a major factor from consumer as well as marketing point of view which may be affected by infection of various disease and pests at different growth stages of plant (Singh, 2012). Safe storage of rice is very important factor. Deterioration and change in cooking characteristics during storage are serious problems that reduce the mass and quality of stored rice (Zhang *et al.,* 2007). In India, the types of storage structures vary from area to area depending on the climatic condition, requirement and availability of materials. The storage structures are made of locally available materials. Rice like other food grains is grown only once or twice in a year but it has to be eaten the year round. So rice has to be stored (Kumar and Tiwari, 2016).

An unusual property of rice is that its cooking and eating quality depends on its age after harvest. New rice swells poorly during cooking and gives out a thick and sticky gruel. These undesirable property gradually changes during storage of rice for a few months. This phenomenon of change in cooking and eating properties of rice during its storage is called ageing of rice. Ageing involves changes in physical, chemical and biological properties of the rice grain. Starch, protein and lipids are the main grain components which affect cooking and eating quality (Villareal *et al.,* 1976). Optimum cooking degree of rice is usually determined when rice reaches an end cooking point where it either absorbed a maximum amount of water or until the core of the cooked rice kernels gelatinized (Kasai *et al.,* 2005). It propose that release of free phenolic acids alters integrity of cell wall and at the same time the phenolic acids exerts an effect via their antioxidant activity on the formation of FFA that can further complex with amylose during storage (Zhout *et al.,* 2001).

Though appearance of brown rice is not so good, but considering its nutritional importance, it is recommended to use brown rice in daily diets. For this, storage of brown rice has a prime importance which has yet not been done using indigenous storage methods. So, it is decided to conduct a study on Storability of brown rice using different storage structures with different moisture content.

EXPERIMENTAL METHODS

The experiment was carried out in the rice milling laboratory of Post Harvest Process and Food Engineering Department, College of Agricultural Engineering, JNKVV, Jabalpur. In present investigation brown rice obtained by dehusking of sugandha variety of paddy by rubber roll sheller at different moisture levels was stored in different storage structures for four months (February 2014 to May, 2014). The experiment was aimed to study the effects of types of storage structures *i.e.* mud bin (traditional storage structure), polypropylene bag (air tight bag storage structure) and jute bag (air pervious bag storage structure) moisture content of paddy (12, 14 and 16 % wet basis) and five storage periods (0, 30, 60, 90, 120 days) on quality of brown rice. Samples of brown rice with different moisture contents stored in various storage structures were drawn at the initiation of the experiment and then after every 30 days intervals to study physical deterioration (total weight loss %), cooking quality (length expansion ratio, volume expansion ratio, water uptake ratio, optimum cooking time and cooking index) after storage.

Determination of physical deterioration during storage :

Physical deterioration was measured in terms of weight loss in percentage during storage. Observations were taken monthly during storage period. In this experiment weight of samples lost due to moisture. Weight loss due to moisture was calculated on the basis of moisture present in the brown rice at the beginning and end of storage.

Determination of moisture content :

Moisture content of sample (5 g) was determined by standard procedure of AOAC method (1980). The sample was dried in hot air oven maintained at 103±1°C for 24 hours and then cooled in desiccator.

$$\text{Moisture \% (w.b.)} = \frac{\text{Loss in weight of sample}}{\text{Initial weight of sample}} \times 100$$

Determination of cooking qualities:

Optimum cooking time (OCT) :

Head rice (2 g) samples of milled paddy were taken in test tube in three replicates and cooked in 20 ml distilled water in a hot water bath at 90°C. The cooking time was determined by taking out few grains at different time intervals during cooking and pressing them between two petri dishes until no white core was left (Chen *et al.*, 2012).

Length expansion ratio (LER) *i.e.* ratio of the length of cooked grain to that of the raw grain was calculated. Similarly volume expansion ratio (VER) was calculated *i.e.* the ratio of the volume of the cooked rice to the initial volume of the raw rice, using toluene displacement method. Water uptake ratio (WUR) as ratio of water absorbed during cooking to uncooked rice weight was calculated by weighing the initial raw rice and final cooked rice (Singh *et al.*, 2005).

LER=Length of cooked rice / Length of raw rice
VER = Volume of cooked rice / Volume of raw rice
WUR= Weight of cooked rice / Weight of raw rice

Cooking index (CI) :

Rice is considered to have good cooking quality if it has high volume expansion ratio, length expansion ratio, water uptake ratio and optimum cooking time. Length and volume expansion ratio and water uptake ratio are desirable economically for the food service industry as they lead to a fuller plate for the same amount of rice. Verma *et al.* (2015) reported that rice having higher water uptake ratio indicated better cooking quality (Fig. A).

Fig. A : Cooked brown rice

A cooking index (CI) was formulated, and defined as (Mohapatra and Bal, 2007):

CI = (LER × VER × WUR) / OCT

EXPERIMENTAL FINDINGS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarised and analyzed statistically using asymmetrical factorial design under following heads:

Physical deterioration during storage :

Physical deterioration in brown rice includes weight loss during storage period. Weight loss in brown rice occurred due to moisture evaporation which is resultant of weather condition. It was measured in term of percentage. The effect of storage periods on weight loss at 12, 14 and 16 per cent moisture content in different storage structures are shown in Table 1.

The weight loss percentage was calculated with respect to initial weight of brown rice. Table 1 shows increasing pattern of weight loss during storage periods for all types of storage structures. The study reveals that material stored in polypropylene bag suffers minimum loss because this structure is air tight and water proof also. Whereas brown rice stored in jute bag showed maximum loss among three types of storage structures as showed in Fig. 1, 2 and 3. The rate of loss was higher during 60-90 days in each type of storage structures this is because the ambient temperature during this period was higher. After three month storage the rate of moisture removal was slower and followed falling rate period.

While moisture contents were taken into consideration it has been observed that the trend of weight loss per cent increases with respect to moisture contents (16% >14% >12%) throughout the storage periods.

The analysis of variance (ANOVA) for weight loss was performed using asymmetrical factorial design for model 4.1 presented. It indicates, that the interaction among three factor S x M x D (structure x moisture x storage days) was highly significant at 1 per cent level of significance.

The reason being, during summer weight loss was higher due to increase in ambient temperature and decrease in relative humidity. As storage was initiation during beginning of summer season, there was gradually rise in temperature and decrease in humidity. Temperature and humidity are the most important factors that affect the moisture content of the grain and this loss in moisture is in agreement with studies conducted by Kudos *et al.* (2006).

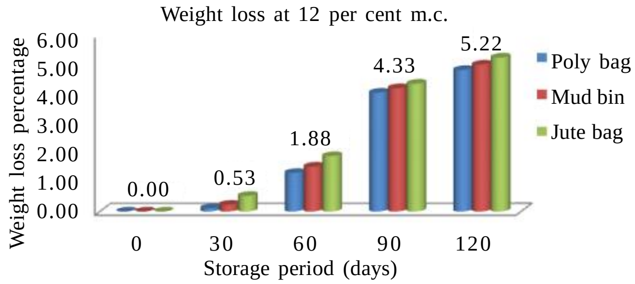

Fig. 1 : Effect on weight loss at 12 per cent moisture content during storage

Cooking qualities :

Newly harvested rice when cooked becomes a sticky or pasty mass, swells only slightly and loses a fair amount of solids into the cooking water, yielding a thick gruel. Upon storage for a few months, the rice swells

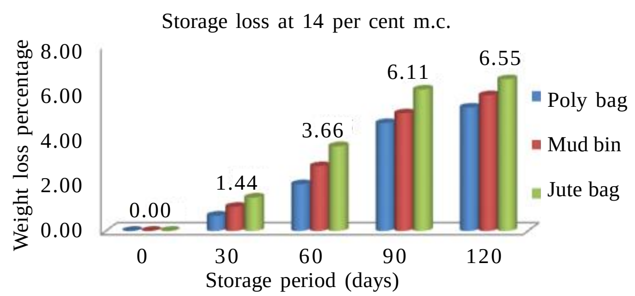

Fig. 2 : Effect on weight loss at 14 per cent moisture content during storage

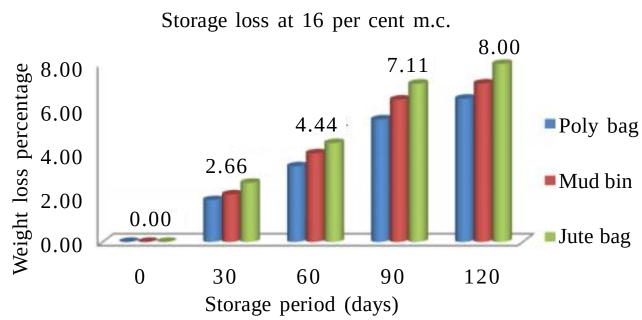

Fig. 3 : Effect on weight loss at 16 per cent moisture content during storage

Table 1 : Weight loss percentage in brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, per cent (w.b.)		
		12	14	16
Mud bin	0	0.00	0.00	0.00
	30	0.23	1.04	2.14
	60	1.52	2.80	3.98
	90	4.18	5.08	6.40
	120	4.98	5.86	7.12
Jute bag	0	0.00	0.00	0.00
	30	0.53	1.44	2.66
	60	1.88	3.66	4.44
	90	4.33	6.11	7.11
	120	5.22	6.55	8.00
Polypropylene bag	0	0.00	0.00	0.00
	30	0.11	0.66	1.88
	60	1.31	2.02	3.40
	90	4.03	4.66	5.50
	120	4.80	5.33	6.44

more easily, the cooked rice become flakes, the grains remain integral and the gruel becomes thin. Its linear elongation upon cooking is more than in fresh rice. Most of these changes occur within the first 3 to 4 months after harvest at storage temperatures over 15° C (Tani *et al.,* 1969).

Cooking index :

Rice is considered to have good cooking quality if it has high length expansion, volume expansion, water uptake ratio and minimum cooking time. Cooking index increased with increase in length expansion ratio, volume expansion ratio, water uptake ratio and decreased with increase in cooking time.

The effect of storage periods on cooking index when stored at 12, 14 and 16 per cent storage moisture in different storage structures are shown in Table 2.

The cooking index increases with increase in storage period (Table 2) for all types of storage structures. Results reveal that highest value of cooking index was observed in brown rice stored in polypropylene bag whereas cooing index in jute bag has lowest value.

While moisture contents were taken into consideration the value of cooking index increases when material stored at higher moisture content *i.e.* 16 per cent followed by 14 per cent and then 12 per cent moisture.

The analysis of variance (ANOVA) for cooking index was performed using asymmetrical factorial design for model 4.1 presented. It indicates, that the interaction among three factor S x M x D (structure x moisture x days) was significant at 1 per cent level of significance. The effect of structures and number of storage days was highly significant to change the cooking index.

In this investigation maximum cooking index of brown rice was varied from 0.391 to 0.639 throughout storage periods. This increase in cooking index appears to be due to ageing of rice. Ageing of rice brought desirable changes in cooking qualities of rice. The results of this study are in agreement with earlier results reported by Meullenet *et al*. (1998). One factor may be temperature, ambient temperature increase gradually from 0 day to 120 days hence higher temperature lead to greater expansion so cooking index values high. The results of this study are in agreement with earlier results reported by Zhou *et al*. (2007) who studied effect of storage temperature on cooking behaviour of rice. The effect of moisture content on cooking index of samples stored in different storage structures is significant at 5 per cent level of significance (Gujral and Kumar, 2003). Who studied that storage at high moisture result increased elongation in length and width, water uptake and cooking time.

Conclusion:

Weight loss percentage was found minimum in polypropylene bag at low moisture content (at 12 %) throughout the storage *i.e.* 4.80 per cent and highest weight loss percentage found in jute bag at higher moisture (at 16 %) *i.e.* 8.00 per cent. The cooking time reduces with advances in storage period. It was observed that cooking time reduces due to ageing. In polypropylene

Table 2 : Cooking index in brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, per cent (w.b)		
		12	14	16
Mud bin	0	0.391	0.393	0.394
	30	0.418	0.420	0.429
	60	0.451	0.460	0.466
	90	0.515	0.520	0.526
	120	0.585	0.595	0.605
Jute bag	0	0.391	0.393	0.394
	30	0.407	0.409	0.414
	60	0.430	0.434	0.439
	90	0.483	0.484	0.491
	120	0.548	0.554	0.557
Polypropylene bag	0	0.391	0.393	0.394
	30	0.437	0.438	0.440
	60	0.477	0.489	0.505
	90	0.562	0.570	0.573
	120	0.620	0.628	0.639

bag cooking time reduces to (65 seconds), followed by mud bin (50 seconds) and jute bag (42 seconds). However, the maximum cooking index was found in polypropylene bag followed by mud bin and jute bag in all moisture levels. While moisture contents were taken into consideration not very effective to increase the cooking index *i.e.* in case of polypropylene bag highest cooking index 0.620, 0.628 and 0.639 corresponds to 12, 14 and 16 per cent moisture content, respectively.

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