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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(3): 5456-5466

www.thepharmajournal.com
Received: 15-12-2022
Accepted: 17-01-2023

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To study the effect of storage period and storage structures on physical properties and nutritional quality of brown rice at ambient condition

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Abstract
Rice (*Oryza sativa L.)* is a cereal grain and an important staple food for a large part of the world's human population. Among cereals, rice is even more nutritious than wheat. Rapid growth in human population not only necessitates enhancing production but also requires proper storage of surplus. Proper food storage is of paramount importance in the present scenario of increasing incidences of localized food shortage. Proper storage conditions for rice can bring about considerable improvement in national economy through control of losses both in terms of quantity as well as quality. 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 shelf life of brown rice using different storage structures. Keeping in mind a study on storage of brown rice was conducted in three different storage structures namely gunny bag, polypropylene bag and ms container at ambient condition. Time of storage was taken as 0, 30, 60 and 90 days. Samples were withdrawn from each storage structures at 30 days interval to study various parameters like physical properties and nutritional characteristic (protein, fat, carbohydrates and ash content) and colour parameters (lightness, hue angle and chroma values) after storage.

Keywords: Physical property, nutritional property, colour parameters etc.

Introduction
Rice (*oryaza* sativa L.) is a staple food for more than 70% of the world's population, especially in Asia (Wei *et al*., 2007) [74]. As a primary dietary source of carbohydrates, Rice plays an important role in meeting energy requirements and nutrients intakes providing more than one fifth of the calories consumed worldwide by the human species (Yang *et al*., 2006) [71]. Rice produced is the second-highest worldwide production, after maize (corn), accounting for 20% of all world rice production. India produced 103 million tonnes in the year 2015-16.Rice can be grown in a wide range of environment and soil condition and is produced in over 100 countries. About 95% of the world rice is produced in developing countries, 92% of it in Asia.

Rice may be classified as brown rice, White rice, Basmati, Sweet rice, Jasmine Bhutanese red rice and forbidden rice few of the world's grain are available in as many forms as rice, these include rough rice brown rice, parboiled rice, regular milled white rice, precooked rice, individually quick frozen rice and crisped/fluffed/expanded rice.

Brown rice is rice without husk. The husk is removed by rubber rolls. It consists of pericarp, seed coat, testa, aleurone layer, germ and endosperm. Its nutritional quality is higher than milled rice (Ajimilah and Rosniyana 1994; Rosniyana *et al*. 1997; Ory *et al*. 1980) [2, 54, 45] particularly with respect to the fat, protein, crude fibre, minerals (Phosphorus, potassium, sodium, calcium and iron) and vitamins (Thiamine, naicine and riboflavin). Brown rice has high dietary fiber rich in B vitamins and minerals and high fat. Also brown rice contains high phytic acid and reported to decrease serum cholesterol and is considered a low glycemic index food (low starch, high complex carbohydrates which decrease risk to type 2diabetes). Post-harvest researchers reported that the milling recovery in brown rice is 10% higher than polished rice.

There are other benefits of brown rice-economics. The fuel savings in milling process is 50-60% the polishing and whitening steps are eliminated. In this way the milling time is also shortened with less labour requirements and the cost of equipment as the miller doesn't have to install polisher.

Also, the enhancement in output volume and the economy in milling indicated the business opportunity in brown rice. (Rogelio, 2003) [51].

Brown rice has the advantage of having three times more fibre than white. It has probably a bigger health benefit than the fortified vitamins (Sue Gilbert *et al*., 2000) [61]. In addition to being health food, brown rice has been reported to prevent a number of diseases e.g. diabetes and disorders related to the kidney, blood and heart. Through the consumption of brown is increase, it is easily available in local shops and supermarkets in normal and vaccum packaging.

Brown rice is expected to store for only 6 months under average condition. This is because of the presence of essential fatty acid which quickly go rancid as they oxidize (Anon. 2002) [4]. Storing brown rice offers considerable advantages i.e. handling a smaller quantity and the requirement of less space. As the husk contributes about one-fourth of the weight and over one third the volume of paddy (Houston 1972). Brown rice is more nutritious than milled rice but there is a traditional consumer preference for white (milled) rice which has better appearance, is translucent and more palatable. The short shelf life has been implicated as a deterrent to the amount of brown rice packaged for direct consumption (Schutz and Fridgen 1974) [59].

The limited consumption of brown rice is due to the accumulation of free fatty acid in rice stored under warm and humid condition. (Ibni *et al*. 1997) [26] reported that free fatty acid content is between 8.3% and 15.3%, and after 6 months the content is between 53.0% and 65.3%. Fatty acids can be released by lipase present in the rice aleurone (bran) layer of damaged grains and high lipase- containing bacteria and fungi adhering to rice (DeLucca *et al*. 1978) [17]. Both lipolytic bacteria and fungi are present in sufficient numbers to cause rancidity and off-flavour in stored brown rice, causing its quality to deteriorate during storage mainly because of oxidative changes (Sowbhagya and Bhattacharya 1976) [60] and lypolytic hydrolysis of about 3% oil present in it (Hunter *et al*. 1951) [23] Consumers also have a preference for rice that is transparent and not chalky. Chalky areas of the grain are a result of air spaces in between the starch granules that make up the endosperm. Variation in kernel whiteness and transparency can be due to differences in rice varieties, cultural management methods, weather conditions during the crop year, and storage conditions of the harvested rice. It results in a loss of vitamins, minerals and dietary fibre (Liang *et al*., 2008) [37]. In less developed countries, where rice is a major component of the people's diet, such nutritional losses may significantly impact human health.

Material and Methods

The methodology was carried out in the rice milling laboratory of Post- Harvest Process and Food Engineering department, College of Agricultural Engineering, JNKVV, Jabalpur. This chapter covers the methods applied, material used and instruments used to perform different operations, to achieve the objectives.

Experiment Procedure

1. Procurement of Brown rice

The study was conducted on Brown rice. Brown rice (MTU 1010) was procured from Parashar rice mill katangi road, Jabalpur. The moisture content was 11percent (wet basis).

2. Preparation of storage structures

Gunny (jute bag) and polypropylene woven bag was purchase from local market Jabalpur and specially designed. According to the need the shape of jute and polypropylene bag was restricted at Adhartal Jabalpur. Jute and polypropylene bag were equipped with movable zip and its capacity about 5 kg, and ms container was also prepared from gurandi (local market), its capacity also about 5 kg. Three different storage structures jute, polypropylene bag and ms container were prepared for research work.

3. Types of storage structures used in the experiment

The brown rice was stored into three different storage structures as below-

- Gunny bag
- Polypropylene bag
- ms container

5 kg of brown rice was stored in each storage structure. Its initial moisture content at the time of storage was 11% (w.b.) which is considered as safe moisture content for storage. The attempt was done to make storage structures air tight. For this purpose, In ms container for air tight packing of rice polythene papers are used to pack the lids of ms container. While in gunny and polypropylene bags zip arrangement is made to make it air tight.

Gunny bag Polypropylene bag Ms Container

4. Liquidation

Storage structures were open after 30 days and samples were drawn for observing physical properties i.e. moisture content and grain deterioration, nutritive quality and colour analysis

5. Equipment's and Instruments

5.1 Digital weighing balance (capacity-360g)

Digital electronics balance (Model: CY-3600, Manufactured by-Citizen, India) with measuring scale showing maximum-360 g and minimum-20 mg. It was used for weighing rice samples while determining moisture content. The least count of balance was 0.01g

5.2 Digital weighing balance (capacity-30 kg)

Digital electronic balance (Model: CTG-30, Manufactured by Citizen, India) with measuring scale showing maximum-20 kg and minimum- 20g. It was used for weighing rice samples. The least count of balance 1g.

5.3 Mercury Thermometer

Mercury Thermometer (Model: L0137, Manufactured by-Zeal, UK) having measuring range of -10 to 250 ºC was used for temperature measurement.

5.4 Hunter Calorimeter

Hunter colour Lab value of brown rice was determined by Hunter Calorimeter (Model: Colour Flex EZ, Manufactured by- Hunter Association Laboratory, Reston, Virginia) at 65%, 10º with reading response variable of L, and b. Where, L is lightness, a is yellow to redness, and b is green to blueness.

5.5 Digital gauge
It was used to measure the longitudinal and lateral dimension of rice, (Model: Quick- Mini Series 700-119-20, manufactured by-Mitutoyo, Range 0-12 mm, Japan).

5.6 Hot air oven
Hot air oven is electrical device used to determine moisture content of rice. The operating range Hot air oven was 50 to 300º C. The digital thermostat controlling system maintains the temperature. Hot air oven (Model: LCO- 3150H) which was used for experimentation was manufactured by Lab tech instruments, Indore (MP).

5.7. Digital thermometer
A laboratory model of LCD portal Digital multi- thermometer (Model: ST-9283B, Manufactured by-Global Instrument, India) was used to measure ambient temperature. The thermometer had measuring range of -50º C to 300 ºC and least count of 0.1 ºC.

6. Experiment design
The experiment was conducted in the department of Post-Harvest Process and Food Engineering. College of Agriculture Engineering, JNKVV, Jabalpur in the present study effect of storage periods and quality of brown rice during storage at different storage structure i.e. gunny bag, polypropylene bag and ms containers and number of days intervals (0, 30, 60 and 90 days) on physical deterioration of brown rice i.e. moisture loss and weight loss and and nutritive quality i.e. protein, fat, carbohydrates and ash and colour analysis i.e. Total colour change(ΔE), lightness (L), Hue angle (hº) and chroma value (C^*).

7. Measurement of temperature and relative humidity
Temperature and Humidity are the most crucial storage factors, which decide the shelf life of rice. As per USDA guidelines every 5.6 ºC drop in temperature, doubles the shelf life of dry food items like rice. (USDA, 2011)

To measure temperature throughout the storage periods, digital thermometer is used. Probe arrangement is given to this type of thermometer which gives ease while taking observations. Temperature readings were cross-checked by mercury thermometer which is known as standard instrument for measuring temperature observations were taken in º C. Humidity was measured by hair hygrometer which is well-known instrument for measurement of relative humidity. Humidity was measured in percent.Ambient temperature and relative humidity of the room where storage is done was measured daily at morning and evening and mean temperature and mean relative humidity is calculated.

8. Determination of moisture content
According to the standard procedure of AOAC (1980), weighed samples (5g) of finely ground material is kept in a dried and pre-weighed perty dish and dried in a hot air oven at 105 ºC later, it was cooled in a desiccators. The process of heating and cooling is repeated till a constant weight is obtained. Cooled Petri dish with dried material is then weighed:

Moisture % (w.b) = (Loss in weight/ weight of sample) × 100

9. Physical properties
9.1 Physical dimensions
One hundred seeds were randomly selected to determine the size and shape of the rice kernels of different samples. Three principal linear dimensions namely, length (l), breadth/width (w) and thickness (t) were measured using a digital dial gauge (accuracy – 0.01 mm) (Plate 3.5). Length was taken as the largest intercept of the kernel at resting position, breadth was taken as the largest intercept perpendicular to the length and thickness was measured as the largest intercept perpendicular to the length and breadth.

9.2 L/B ratio
In India, most of the rice varieties are rather long (more than 6mm) to slender with L/B ratio of 2.5 to 3. The shape of the grain influenced volume and weight. Slender varieties of paddy or rice occupy more volume than round varieties. Therefore, one ton of a slender variety of paddy will need more storage space than the same weight of round variety of paddy. Size and shape of rice affects many other properties, namely, sieving, dehusking, polishing, storage as well as cooking.

9.3 Size
Size and shape are important physical properties, and both are used to describe the object. Size measurement analyzed behaviour of grain during handling, processing, storage and designing the machinery using following expression. Similarly, shape is a dimension less parameter and can be described in terms of length, width, thickness or diameter size:

$$\text{Size} = (\text{length x width x thickness})^{1/3}$$

$$\text{Size} = (\text{L x W x T})^{1/3}$$

9.4 Geometric mean diameter
The geometric mean diameter D_p in mm considering a spheroid shape for a rough rice grain, was calculated by the following expression (Varnamkhasti *et al*., 2007) [65]:

$$D_p = \frac{(4L\ (W+T)^2)^{1/3}}{4}$$

Where, l = length of the kernel, in mm.
w = width of the kernel, in mm.
t = thickness of the kernel, in mm.

9.5 Sphericity
Sphericity defined as the ratio of the diameter of a sphere of same volume as that of the particle and the largest diameter of the particle. This parameter shows the shape character of the particle relative to the sphere having the same volume. The sphericity (φ) of the kernels were calculated as (Curray *et al.* 1951) [12]:

$$\phi = \frac{\text{Geometric mean diameter}}{\text{Major intercept}} = \frac{D_g}{l}$$

9.6 Surface area
The surface area of the individual rice kernels was measured by the analogy with a sphere of the same geometric mean

diameter (D_g), using the following equation (Varnamkhasti *et al*., 2007) [65]:

$$\text{Surface Area, S (mm}^2) = \pi . D_g^2$$

9.7 Volume
The unit volume of the rice kernels was calculated by the following relationship (Varnamkhasti *et al*., 2007) [65]:

$$\text{Volume, V} = \frac{\pi \times l \times b \times t}{6}$$

V = unit volume in mm^2.
l, b, t = length, breadth and thickness in mm.

9.8 Thousand grain weight
Thousand grain weights of different rice samples was determined by counting one hundred rice kernels, weighing them on a weighing balance (Plate 3.4) and then multiplying it with the factor of 10.

9.9 Aspect ratio
The aspect ratio (R) is used in classification of grain shape and it was calculated as:

R = W / L

Where, L = length of the kernel, in mm.
W = width of the kernel, in mm.

9.10 Density
The density of the grains is used in the design of storage bins and silos, separation of desirable materials from impurities, cleaning and grading, evaluation of the grain maturity etc.
The bulk density of the rice kernels is the density of whole grains (including the voids). It was determined by filling a 10 ml cylindrical vessel with rice kernels, tapping it twice to cover the extra space between the kernels and then weighing the contents of the vessel using a weighing balance. The volume of the vessel i.e. 10 ml, is taken as the volume of the rice kernels. Bulk density is the ratio of the mass of the sample to its total volume:

$$\text{Bulk density, } \rho_b = \frac{\text{Mass of sample}}{\text{Total volume}} \quad \frac{M}{V}$$

The true density of the rice kernels is the density of grains excluding the voids. This was determined by the toluene (C_7H_8) displacement method. In this method, 5 ml toluene was filled in a 10 ml measuring cylinder and then same mass of sample that was taken for bulk density was put into the vessel containing 5 ml of toluene. The displacement of toluene level in the vessel on putting rice kernels was noted down. The ratio of the mass of rice kernels to the volume of displaced toluene gave the true density:

$$\text{True density, } \rho t = \frac{\text{Mass of sample}}{\text{Volume of displaced}} \quad \frac{M}{V}$$

9.11 Porosity
The porosity of rice grains refers to the fraction of the pore spaces in the bulk grain that is not occupied by the grain. It is calculated from the values of true density and bulk density by the following relationship:

$$\text{Porosity, } \varepsilon (\%) = [(\rho_t - \rho_b) / \rho_t] \times 100$$

ρ_t=True density
ρ_b = Bulk density

Result and Discussion
The results obtained were analyzed statistically using asymmetrical factorial design. In this design, two independent variables were coded: factor D for various storage periods i.e. 0, 30, 60 and 90 days and factor B for type of storage structure i.e. gunny bag, polypropylene woven bag and ms container. The dependent variables are divided into following groups

1) Physical change i.e: Weight loss due to moisture and insect

2) Nutritional qualities
a) Crude protein content (P)
b) Fat content (F)
c) Carbohydrate content (C)
d) Ash content (A)

3) Colour parameters
a) Lightness (L)
b) Hue angle (h°)
c) Chroma value (C*)

Table 1: Weight loss in different storage structures due to moisture migration

Storage periods, (days)	Weight of sample(g)		
	Gunny bag	Polypropylene Bag	Ms container
0	5000	5000	5000
30	4942	4978	4985
60	4985	4981	4988
90	5073	4992	5005

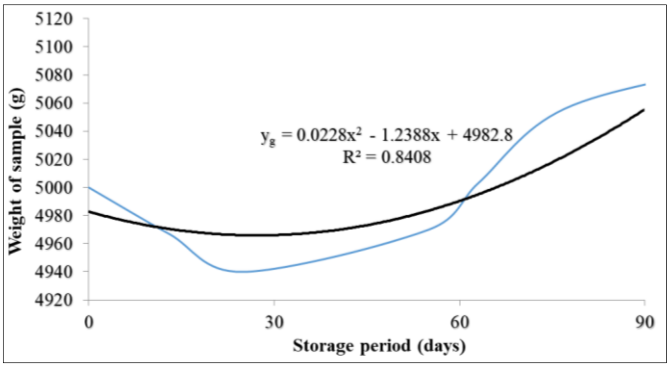

Fig 1: Weight changes due to moisture migration in (gunny bag)

The value of coefficient of determination (R^2) for gunny bag was found 0.84, which indicates that almost 84% of the inherent variability can be adequately described by these independent factors under consideration.
Weight loss due to moisture in gunny bag during storage is represented by following equation

$Y_g = 0.0228x^2 - 1.2388x + 4982.8$
Y_g = Weight loss in gunny bag
X = Storage period, days

In polypropylene bag initially (30 days) high weight loss (22g) was observed (fig.2) due to high ambient room temperature (37 ºC) and low relative humidity (54%) in the month of May (summer season) as shown in Table 1. After that there was only gain storage of 3g in stored grain during 60 days storage (R_H= 70%, Temp. = 35ºC) and similarly weight gain 11g was observed in 90 days storage (R_H = 90%, Temp. = 31ºC) during month of July.

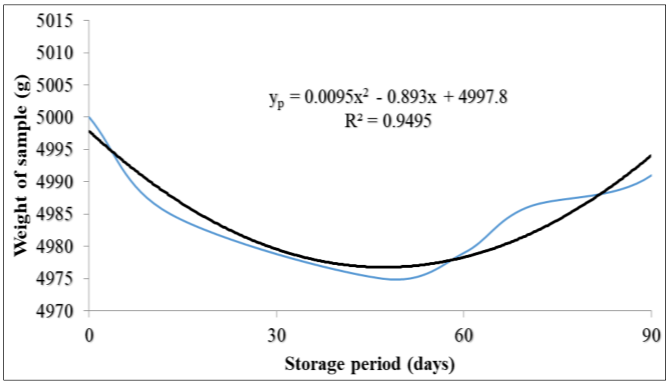

Fig 2: Weight changes due to moisture migration in (Polypropylene bag)

The value of coefficient of determination (R^2) for polypropylene bag was found to be 0.949, which indicates that almost 94.9 of the inherent variability weight loss can be adequately described by these independent factors under consideration.
Weight loss due to moisture in polypropylene bag during storage can be represented by following equation

Y_p= $0.0095x^2 - 0.893x + 4997.8$
Y_p= Weight loss in stored polypropylene bag due to moisture
X = Storage period, days

In ms container initially (0-30days) high weight loss (15g) was observed (fig.3) due to high ambient room temperature (37ºC) and low relative humidity (54%) in the month of May (summer season) as shown in Table1. After that 60 days there was a gain of 11g in stored grain during 60 days storage and similarly weight gain (17g) was observed in 90 days storage of July. Similarly 17g weight gain was observed in the month of July i.e.90 day's storage.

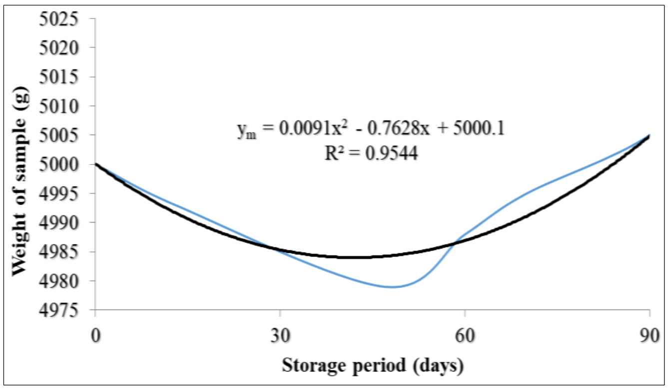

Fig 3: Weight changes due to moisture migration (ms container)

The value of coefficient of determination (R^2) for ms container was found to be 0.954, which indicates that almost 95.4% of the inherent variability weight loss can be adequately described by these independent factors under consideration.
Weight loss due to moisture in ms container during storage is represented by following equation

$Y_m = 0.0091x^2 - 0.7628x + 5000.1$
Y_m= Weight loss in stored ms container due to moisture
X = Storage period, days

Weight loss due to insect

Physical deterioration in brown rice was measured in terms of weight loss during storage due to insect and is shown in Table.2

Table 2: Weight loss due to insect

Storage periods, (days)	Weight loss (g)		
	Gunny bag	Polypropylene bag	ms container
0	0	0	0
30	15.4	5.6	2.3
60	22.6	10.1	6.2
90	30.15	13.1	11.2

There was slight deterioration in the stored grain (each sample-5kg) during storage in various storage structures due to insects. Maximum loss was observed in gunny bag (30.15 g) followed by polypropylene bag (13.1g) and ms container (11.2g). The minimum deterioration was observed in polypropylene bag and ms container because they were air tight during storage the moisture content (11.1% w.b.) which is not a favourable condition for the growth of insect. The results of this study were in agreement with earlier results reported by Hsieh *et al*. (1980) [25] who studied assessments of losses of stored rice due to insect damage in which weight loss in brown and milled rice infested by different insects was determined.

2. Nutritional characteristics

Under this parameter, the crude protein content, fat content carbohydrate content and ash content was determined in percentage.

2.1 Crude protein

The protein percentage changes during storage of brown rice in all type of storage structure and is shown in figure 4.

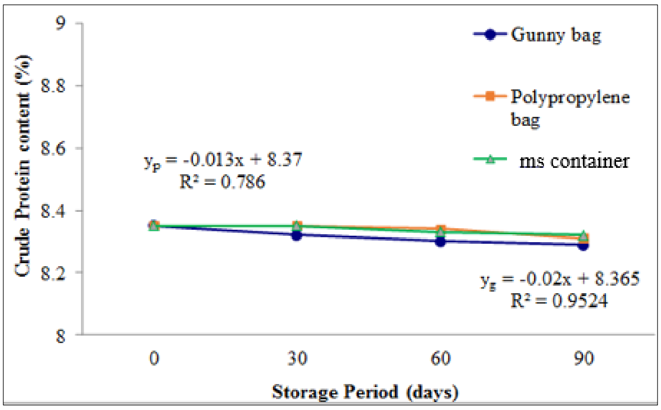

Fig 4: Variation of Crude protein content during storage

Results showed that crude protein content decreased with advance storage periods in every storage structures as shown is in fig 4. It was observed that crude protein percentage decreased very slightly with respect to types of storage structure and time of storage (ms container <polypropylene bag< gunny bag).

Table 3: Crude Protein content in brown rice during storage

Storage periods, days	Protein content (%)		
	Gunny bag	Polypropylene bag	MS container
0	8.35	8.35	8.35
30	8.32	8.35	8.35
60	8.30	8.34	8.33
90	8.29	8.31	8.32

The value of coefficient of determination (R^2) for gunny bag, polypropylene and ms container was found 0.786, 0.896 and 0.952 respectively, which indicates that almost 78.6%, 89.6% 95% of the inherent variability in protein content can be adequately described by these independent factors under consideration.
Protein content in storage structure during storage is represented by following equation
For gunny bag

$Y_g = -0.02x + 8.365$
For polypropylene bag
$Y_p = -0.013x + 8.37$
For ms container
$Y_m = -0.011x + 8.365$

Fig4 shows nearly constant graph for the protein content of brown rice throughout the storage period. No noticeable changes in observations were found in protein content during three months of storage (Table3). There was also no effect of type of storage structure on protein content. The results of this study were in agreement with earlier results reported by Baldi *et al*. 1980) [8] who studied changes in protein content, protein fraction and amino acid composition for stored rice.

2.2 Fat content

The fat percentage changes during storage of brown rice in all type of storage structure and is shown in figure 5.

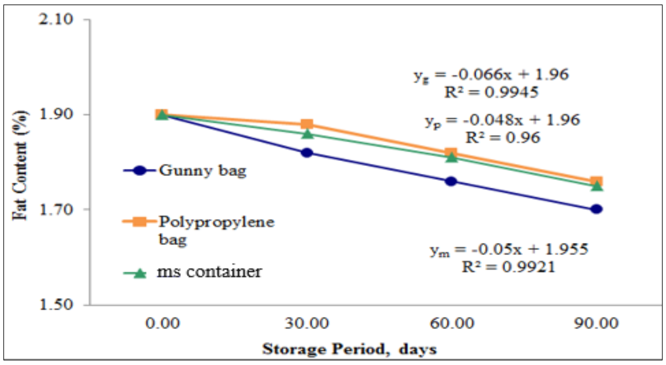

Fig 5: Variation of Crude fat content during storage

Results showed that fat content decreased with the storage periods in every storage structures (Fig 5). It was observed that crude fat percentage decreased slightly with respect to types of storage structures and time of storage (ms container < polypropylene bag <gunny bag)

Table 4: Fat content in brown rice during storage

Storage period, (days)	Fat content (%)		
	Gunny bag	Polypropylene bag	ms container
0	1.90	1.90	1.90
30	1.82	1.88	1.86
60	1.76	1.82	1.81
90	1.70	1.75	1.76

The value of coefficient of determination (R^2) for gunny bag, polypropylene and ms container was found 0.9945, 0.96 and 0.9921respectively, respectively, which indicates that almost 99.45%, 96% and 99.2% of the inherent variability in fat content can be adequately described by these independent factors under consideration.
Fat content in storage structure during storage is represented by following equation
For gunny bag

$Y_g = -0.066x + 1.96$
For polypropylene bag
$Y_p = -0.048x + 1.96$
For ms container
$Y_m = -0.05x + 1.955$

Fig.5 shows that fat content decreases as storage period increases. This decrease in fat content is slow but uniform throughout the storage period of three months. The results of this study are in agreement with earlier results reported by Villareal *et al.* (1976) [66] who studied the changes physiochemical properties of rice during storage. Fat content in all three storage structure has been reported in Table 4.When type of storage structure was taken into consideration, slight variations in graph were noted. Gunny bag shows more decrease while ms container shows least decrease in fat content as storage period goes increase but the difference between these two values was very less hence not noticeable. Due to airtight condition in polypropylene and ms container and low moisture reaction was very slow and result slight decrease in fat content.

2.3 Total carbohydrates

The carbohydrates percentage changes during storage of brown rice in all type of storage structure and is shown in figure. 6.

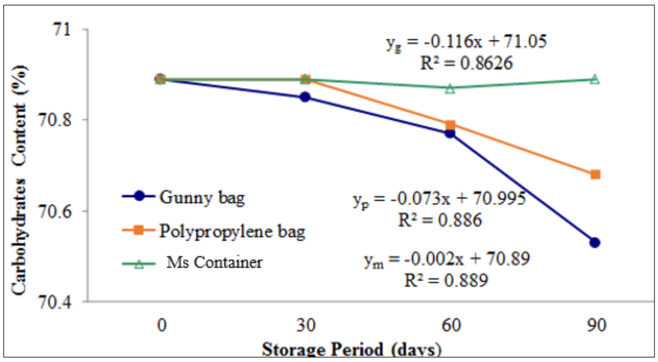

Fig 6: Variation of Carbohydrate content during storage

Results showed that carbohydrate content was slightly decreased during storage periods in every storage structures (fig6). It was observed that there was slight change observed in storage structures.

Table 5: Carbohydrate content in brown rice during storage

Storage period, (days)	Carbohydrate content (%)		
	Gunny bag	Polypropylene bag	Ms container
0	70.89	70.89	70.89
30	70.85	70.89	70.89
60	70.77	70.79	70.87
90	70.53	70.68	70.89

The value of coefficient of determination (R^2) for gunny bag, polypropylene bag and ms container was found 0.8626, 0.886 and 0.889 respectively, which indicates that almost 86.2%, 88.6% and 88.9% of the inherent variability in carbohydrate content can be adequately described by these independent factors under consideration.

Carbohydrate content in storage structure during storage is represented by following equation

For gunny bag

$Y_g = -0.116x + 71.05$

For polypropylene bag

$Y_p = -0.073x + 70.995$

For ms container

$Y_m = -0.002x + 70.89$

Fig 6 shows that carbohydrate content was nearly constant throughout the storage period. There was no differentiable change observed in different storage structures also. Carbohydrate content was nearly same in all storage structures in Table 5. The results of this study are in agreement with earlier results reported by Villareal *et al.* (1976) [66] who studied the changes in physicochemical properties of rice during storage.

2.4 Ash content

The ash content percentage changes during storage of brown rice in all type of storage structure and is shown in figure.7.

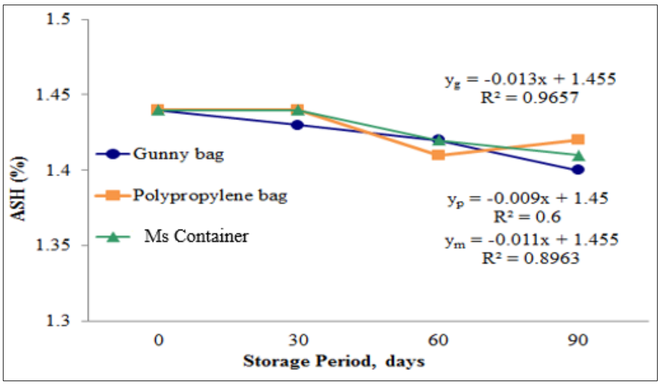

Fig 7: Variation of ash content during storage

Results showed that ash content was slightly changed during storage periods in every storage structures (fig.7). It was observed that there was slight change observed in storage structures

Table 6: Ash content in brown rice during storage

Storage period, days	Ash content (%)		
	Gunny bag	Polypropylene bag	Ms container
0	1.44	1.44	1.44
30	1.43	1.44	1.44
60	1.42	1.41	1.42
90	1.4	1.42	1.41

The value of coefficient of determination (R^2) for gunny bag, polypropylene bag and ms container was found 0.965, 0.6 and 0.896 respectively which indicates that almost 96.57%, 60% and 89.63%of the inherent variability in ash content can be adequately described by these independent factors under consideration

Ash content in storage structure during storage is represented by following equation

For gunny bag

$Y_g = -0.013x + 1.455$

For polypropylene bag

$Y_p = -0.009x + 1.45$

For ms container

$Y_m = -0.011x + 1.455$

Fig.7 shows that ash content was nearly constant throughout the storage period. There was no differentiable change observed in different storage structures also. Ash content of brown rice was nearly same in all storage structures in Table 4.6. The results of this study are in agreement with earlier results reported by Villareal *et al.* (1976) [66] who studied the changes in physiochemical properties of rice during storage.

3. Colour analysis

The parameters includes lightness L, a and b values. These a and b values were then used to determine hue angle and Chroma values.

3.1 Lightness

The change in Lightness during storage of brown rice in all type of storage structure is shown in figure 8.

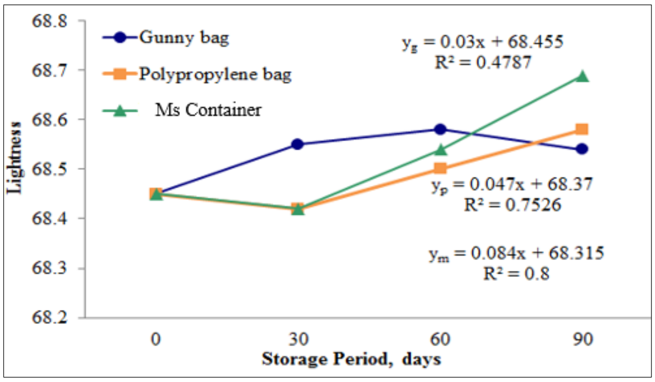

Fig 8: Lightness of different storage structure with respect to storage period

Results reveal that lightness of brown rice stored in different storage structures increases throughout the storage periods as shown in Fig 8. It has also been observed that the lightness value increases with type of storage Structures (ms container > Polypropylene bag > gunny bag).

Table 7: Lightness in brown rice stored in different storage structures during three month storage period

Storage period, (Days)	Lightness		
	Gunny bag	Polypropylene bag	ms container
0	68.45	68.45	68.45
30	68.48	68.50	68.52
60	68.52	68.56	68.57
90	68.56	68.58	68.65

The value of coefficient of determination (R^2) for gunny bag, polypropylene bag and ms container was found to be 0.4787, 0.7526 and 0.8 respectively, which indicates that almost 47.87, 75.26 and 80% of the inherent variability in lightness can be adequately described by these independent factors under consideration.
Lightness in storage structure during storage is represented by following equation
For gunny bag

$Y_g=0.03x+68.455$
For polypropylene bag
$Y_p=0.047x+68.37$
For ms container
$Y_m=0.084x+68.315$

Fig.8 shows gradual increases in lightness values with the storage period for all storage structures. The lightness value differs significantly for different storage structure in Table-8. As seen in graph ms container has highest value of lightness; while the polypropylene bag has the lowest value. The results of this study are in agreement with earlier results reported by Jang *et al*. (2009) [28] who studied on consumer perception of rice stored for believe months in which colour and texture analysis were done.

3.2 Hue angle
The change in hue angle during storage of brown rice in all type of storage structure is shown in Fig 9

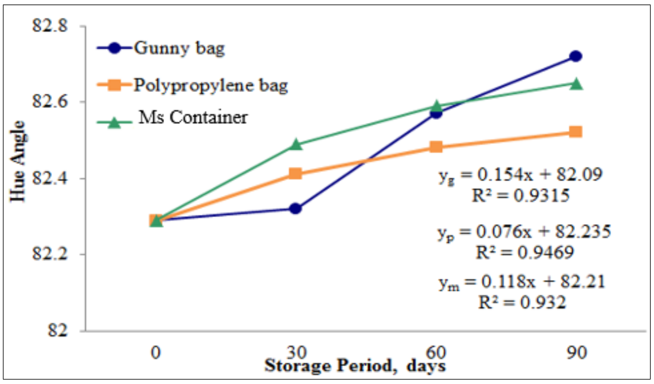

Fig 9: Hue angle in different storage structure with respect to storage period

Results reveals that hue angle of brown rice stored in different storage structures increases throughout the storage periods as shown in Fig 9. It also been observed that the hue angle increases with respect to type of storage structures (gunny bag > ms container > polypropylene bag).

Table 8: Hue angle in brown rice stored in different storage structures during three month storage period

Storage period, days	Hue angle		
	Gunny bag	Polypropylene bag	ms container
0	82.29	82.29	82.29
30	82.32	82.41	82.49
60	82.57	82.48	82.59
90	82.72	82.52	82.65

The value of coefficient of determination (R^2) for gunny bag, polypropylene bag and ms container was found to be 0.9315, 0.9469 and 0.932 respectively, which indicates that almost 93.15%, 94.69% and 93.2% of the inherent variability in hue angle can be adequately described by these independent factors under consideration.
Hue angle in storage structure during storage is represented by following equation
For gunny bag

$Y_g = 0.154x + 82.09$
For polypropylene bag
$Y_p = 0.076x + 82.235$
For ms container
$Y_m=0.118x+82.21$

Colour and surface finish are the important factors which have significant influence on marketability of rice (Mahapatra and Bal, 2007) [40], So the colour of rice was basically tried to be perceived as ranging from real through yellow, green and blue as determined by the dominant wavelength of the light (Laughrey, 2002) [38]. As evident from the figures. Hue angle was observed increasing in storage structures. It was also observed that hue angle differs in each storage structure. Highest value was observed in ms container and gunny bag while lowest (90 days)was observed in polypropylene bag in Table-4.12. The result of this study are agreement as reported by Dillahunty, (2001) [18] who studied the effect of temperature, exposure duration and moisture content on colour and viscosity of rice. They reported that temperature and exposure duration were important factors in colour change.

3.3 Chroma value
The change in Chroma value during storage of brown rice in all type of storage structure is shown in figure 10.

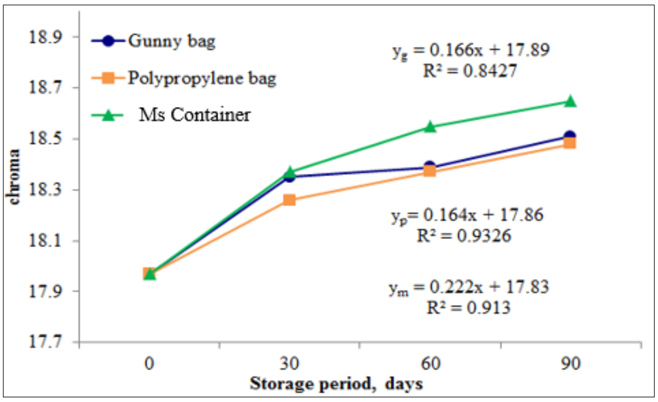

Fig 10: Chroma value in different storage structure with respect to storage period

Results reveal that chroma value of brown rice stored in different storage structures increases throughout the storage periods as shown in 10. It also been observed that the lightness value increases with type of storage structures (ms container > gunny bag> Polypropylene bag>).

Table 9: Chroma value in brown rice stored in different storage structures during three month storage period

Storage period, (days)	Chroma value		
	Gunny bag	Polypropylene bag	ms container
0	17.97	17.97	17.97
30	18.35	18.26	18.37
60	18.39	18.37	18.55
90	18.51	18.48	18.65

The value of coefficient of determination (R^2) for gunny bag, polypropylene bag and ms container was found 0.8427, 0.9326 and, 0.913 respectively, which indicates that almost 84.27%, 93.26% and 91.3% of the inherent variability in Chroma value can be adequately described by these independent factors under consideration.

Chroma value in storage structure during storage is represented by following equation

For gunny bag

$Y_g = 0.166x + 17.89$

For polypropylene bag

$Y_p = 0.164x + 17.86$

For ms container

$Y_m=0.222x+17.83$

Chroma is an aspect of colour in the Hunter colour system by which a sample appears to differ from a gray of the same lightness or brightness and that corresponds to saturation of the perceived colour (Loughrey, 2002) [38]. As evident from the fig.10, it is clear that there is increase in chroma value as per storage period goes on increasing. It is also seen that storage structures influence, chroma value of brown rice. Here in graph it is observed that chroma value is highest in ms container followed by gunny bag, while it lowest for polypropylene bag. The chroma values for different storage structure during three months of storage are given in Table 9 The results of this study are in agreement with earlier results reported by Dillahunty, (2001) [18] who studied on effect of temperature. Exposure duration and moisture content on colour and viscosity of rice. They reported that temperature and exposure duration were the important factors in colour change.

Conclusions

1. The study reveals that during first 30 days of storage there was 58 g weight loss in gunny bag followed by polypropylene bag (22 g) and ms container (50 g) due to high temperature (37 ºC) and low relative humidity (54%) in the month of May. After that there was gain 43 g, 3 g and 11 g in stored grain during 60 days due to high relative humidity (70%) and low temperature (35 ºC) in the month of June, similarly weight gain 88 g,11 g and 17 g was observed in the month (R_{H} = 90%, Temp. = 31 ºC) of July i.e. 90 day storage in the storage structure respectively.
2. Weight loss due to insect didn't show much effect on total weight loss. However there was 30.15, 13.1 and 11.2 g loss in weight due insect in gunny bag, polypropylene woven bag and ms container respectively. Minimum insect was observed in ms container followed by polypropylene and gunny bag.
3. No significant change in protein, carbohydrate and ash content in stored grain throughout the storage period. However fat content decrease slightly with advances storage period in gunny bag (1.70), polypropylene bag (1.75) and ms container (1.76) respectively.
4. Lightness increase with advances in storage period maximum lightness value (68.65) was recorded in ms container followed by polypropylene bag (68.58) and gunny bag (68.56), similarly highest chroma value (18.65) was observed in ms container followed by gunny bag (18.51) and polypropylene bag (18.48).

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