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Research Article

Effect of Ageing, Moisture Contents and Storage Structures on Nutritional and Cooking Characteristics of Brown Rice during Storage

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Abstract

The nutritional and cooking characteristics of four month stored brown rice at 12%, 14% and 16% moisture contents (w.b) were studied. Brown rice was stored in different indigenous storage structures (mud bin, jute bag and polypropylene bag) at ambient conditions such as nutritional characteristics i.e. crude protein, crude fat and total carbohydrates and cooking quality includes elongation ratio and water uptake ratio (WUR) were studied for single variety of paddy (Sugandha). The experimental results showed that nutritional characteristics namely protein and carbohydrate content dropped slightly with the advance in storage periods. However the fat content decreased largely in jute bag followed by mud bin and polypropylene bag and same behaviour showed for protein and carbohydrate corresponding storage structures. The elongation ratio and water uptake ratio was improve with the advance in storage period. The elongation ratio and WUR was greatest increase in polypropylene bag followed by mud bin and then jute bag while moisture content taken into consideration elongation ratio was higher at 16% moisture content followed by 14% and 12% moisture content. While in case of water uptake ratio it was inverses in case of moisture content i.e. WUR was highest at lowest moisture content during storage.

Keywords: Brown rice, storage structures, ageing, moisture contents, nutritional and cooking quality characteristics.

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Introduction

Rice is one of the important food crops forming staple diet to half of the world's population. India stands first in area, second in production, followed and preceded by China on these two aspects [1]. The rice crop forms the basic economy activity directly or indirectly for about 150 million rural house-holds in India [2].

Though appearance of brown rice is not so good, but considering its nutritional importance, it is recommended to use brown rice in daily diets. Brown rice is wealth of nutrients that are contained in the bran layer. It is rich in dietary fibre, minerals oils, and vitamins particularly thiamine [3]. Moreover, brown rice contains large amount of insoluble fibre, which may prevent a variety of cancers. The process that produces brown rice removes only the outermost layer of the rice kernel and is the least damaging to its nutritional value. The complete milling and polishing that converts brown rice into white rice destroys 67% of the vitamin B3, 80% of the vitamin B1, 90% of the vitamin B6, half of the manganese, half of the phosphorus, 60% of the iron and all of the fiber and essential fatty acids [4] and [5]. 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 [6].

Brown rice is less desirable due to its poor cooking and eating qualities [7]. 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 during storage results in numerous changes in the chemical and physical properties of rice [8] and [9].

For a stable supply, it is necessary to increase rice production and to minimise losses during post harvest process. Storage is the one of the most important processes, because inadequate storage causes qualitative and quantitative grain losses [10]. Nowdays in other countries, airtight storage of brown rice has been attractive as an economically viable and ecologically oriented storage system because it can preserve rice quality without refrigeration [11], [12] and [13]. Storability of brown rice is influenced by the moisture content of rice. Many researchers have reported on the superiority of decreased moisture content of grain in storage [14]. The principles involved are reducing the chemical reaction rates and water activity by reducing the moisture content. The respiration rate of rice decreases with decreasing moisture content [15] and the growth of microorganisms are inhibited at low water activity [16].

Limited research work has been done on storability of brown rice with decreased moisture content at different storage structure in order to evaluate in term of quality parameters such as nutritional characteristics includes crude protein, crude fat and total carbohydrates and for cooking quality includes elongation ratio and water uptake ratio during storage at ambient condition.

Materials and Methods

Freshly harvested Sugandha variety of paddy has been procured from Krishi Upaj Mandi, Jabalpur. The moisture content was 16% (wet basis) at the time of procurement. The raw material procured was cleaned and graded by three screen air cleaner (Osaw Grader and Cleaner, Model–Delux, S.No: T.S.G./135/85) at seed processing plant College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidhyalaya Jabalpur. The impurities which were present in the paddy lot were removed, and clean graded paddy was used for shelling. The moisture content at the time of procurement was 16 percent as discussed earlier. Since 14 percent and 12 percent samples were also required so paddy was dried in the floor of Agricultural Engineering farms for limited period of time and samples of 12 percent and 14 percent moisture content were prepared. The procured paddy was converted into brown rice by dehusked through rubber roll sheller at Sarda Rice Mill, Panager, Jabalpur. It is unpolished whole grain rice in which only outer husk is removed. 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), three moisture levels of stored brown rice (12%, 14% and 16% wet basis) and five storage periods (0, 30, 60, 90, 120 days) on quality of brown rice.

Samples were taken out from each storage structure at 30 days interval to determine nutritional properties were determined in lab by using following formulae as per standards of AOAC and cooking qualities were measured by cooking stored brown rice samples till optimum cooking time following the standard Ranghino test.

Nutritive properties

Estimation of crude protein

The protein content of a food product was obtained by estimating the nitrogen content of the material and multiplying the nitrogen value by 6.25. The estimation of nitrogen is done by Kjeldhal method [17].

$$\text{N\%} = \{(\text{Volume of 0.1N } H_2SO_4 \text{ used} \times 0.0014) / \text{Weight of sample}\} \times 100$$

$$\text{Crude protein\%} = \text{N\%} \times 6.25$$

Estimation of crude fat

Fat was estimated as crude ether extract of the dry material [17].

$$\text{Crude fat \%} = (\text{Weight of fat, g/ Weight of sample, g}) \times 100$$

Estimation of total carbohydrate

Total carbohydrate in the samples was estimated by hydrolysis method as described in AOAC [18].

$$\text{Dextrose \%} = (\text{Factor} \times 250 \times 100) / (\text{Titrated value} \times \text{Weight of sample})$$

$$\text{Total carbohydrates (\%)} = \text{Dextrose \%} \times 0.9$$

Determination of cooking qualities

Elongation ratio

Cumulative length of 10 cooked rice kernels was divided by length of 10 uncooked raw kernels and the result was reported as elongation ratio [19].

Water uptake ratio

Head rice samples (2 g) for each cultivar were cooked in 20 ml distilled water for a minimum cooking time in a boiling water bath. The contents were drained and the superficial water on the cooked rice was sucked by pressing the cooked samples in filter paper sheets. The cooked samples were then weighed accurately and the water uptake ratio was calculated according to Singh *et al.*, [19].

$$LER = \text{Length of cooked rice} / \text{Length of raw rice}$$

$$WUR = \text{Weight of cooked rice} / \text{Weight of raw rice}$$

Results and Discussion

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:

Nutritive characteristics

In this study, the crude protein, crude fat and total carbohydrate were determined

Crude protein

The effect of storage periods on protein content of brown rice when stored at 12, 14 and 16 percent moisture content in different storage structures are shown in **Table 1**.

Table 1 Protein content (percent) of brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, percent (w.b.)		
		12	14	16
Mud bin	0	8.94	9.02	9.15
	30	8.91	8.96	9.10
	60	8.86	8.92	9.08
	90	8.81	8.87	9.01
	120	8.78	8.84	8.98
Jute bag	0	8.94	9.02	9.15
	30	8.88	8.95	9.09
	60	8.84	8.90	9.06
	90	8.79	8.84	8.98
	120	8.75	8.80	8.95
Polypropylene bag	0	8.94	9.02	9.15
	30	8.92	8.99	9.12
	60	8.88	8.93	9.09
	90	8.84	8.90	9.04
	120	8.81	8.87	9.01

The protein content percentage decreases with increase storage periods for all storage structures, as depicted in Table 1. Result reveals that brown rice in polypropylene bag has less degraded value of protein content i.e highest value of protein content in polypropylene bag whereas brown rice in jute bag has lowest values after storage (Table 1). Degradation of protein was clearly showed associated with storage periods and storage structures.

It has also been observed when moisture content taken into consideration, the protein reduction percentage during ageing was almost equal since role of moisture content was not significant to change the protein content.

The analysis of variance (ANOVA) for crude protein content was performed using asymmetrical factorial design indicates, that the interaction among three factors S x M x D (structures x moisture levels x storage days) was not significant at 1 % level of significance.

The results of this study are in agreement with results reported by Baldi *et al.*, [20] who studied changes in protein content, protein fraction and amino acid composition for stored rice.

Crude fat

The effect of storage periods on crude fat of brown rice when stored at 12, 14 and 16 percent moisture content in different storage structures are shown in **Table 2**.

Table 2 Fat content (percent) of brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, percent (w.b.)		
		12	14	16
Mud bin	0	2.38	2.02	1.84
	30	2.18	1.76	1.52
	60	1.88	1.40	1.22
	90	1.72	1.29	1.14
	120	1.58	1.09	1.02
Jute bag	0	2.38	2.02	1.84
	30	2.04	1.58	1.38
	60	1.68	1.26	1.02
	90	1.62	1.12	0.92
	120	1.48	1.01	0.88
Polypropylene bag	0	2.38	2.02	1.84
	30	2.24	1.88	1.68
	60	2.02	1.68	1.40
	90	1.92	1.52	1.32
	120	1.78	1.38	1.18

Result showed that fat content decreased with the storage periods in every storage structures, (Table 2). Observation indicates that there was higher degradation of fat in stored brown rice in jute bag (from 1.84 upto 0.88 percent) followed by mud bin (from 1.84 to 1.02) and polypropylene bag (from 1.84 to 1.18) at higher moisture content are shown in Table 2.

In this observation reveals that the retained values of fat content was higher at low moisture (12%) i.e. low moisture content has less reduction percentage of fat respective of storage periods in different storage structures.

The analysis of variance (ANOVA) for fat content was performed using asymmetrical factorial design indicates, that the interaction among three factor S x M x D (structures x moisture levels x storage days) was significant at 1 % level of significance.

The results of this study are in agreement with earlier results reported by Deepa *et al.*, [21] who studied on Physio chemical and genetic analysis of an endemic rice variety, njavara in comparison two popular south Indian cultivars Jyothi and IR-64.

Total carbohydrate

The effect of storage periods on carbohydrate content of brown rice when stored at 12, 14 and 16 percent moisture content in different storage structures are shown in **Table 3**.

The total carbohydrate percentage was nearly constant during storage periods. Result reveals that brown rice stored in polypropylene bag has lesser rate of degradation (Table 3) as compared with mud bin and jute bag. There was no significant change observed in different storage structures at different moisture levels.

The analysis of variance (ANOVA) for total carbohydrate was performed using asymmetrical factorial design indicates, that the interaction among three factor S x M x D (structures x moisture levels x storage days) was not significant at 1 % level of significance.

The results of this study are in agreement with results of Villareal *et al.*, [22] who studied the changes in physicochemical properties of rice during storage.

Table 3 Total carbohydrate (percent) of brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, percent (w.b.)		
		12	14	16
Mud bin	0	71.46	71.82	72.24
	30	71.29	71.68	72.12
	60	71.08	71.39	71.92
	90	70.94	71.24	71.69
	120	70.72	71.12	71.50
Jute bag	0	71.46	71.82	72.24
	30	71.24	71.60	72.08
	60	71.02	71.32	71.82
	90	70.86	71.12	71.58
	120	70.52	70.89	71.32
Polypropylene bag	0	71.46	71.82	72.24
	30	71.38	71.73	72.18
	60	71.26	71.48	72.04
	90	71.02	71.31	71.85
	120	70.90	71.24	71.70

Cooking qualities

In this study elongation ratio and water uptake ratio was determined. Rice is considered to have good cooking quality if it has high elongation ratio and high water uptake ratio. Water to rice ratio affected on hardness, chewiness and cohesiveness of cooked brown rice. Ratio of water to rice also affected the eating quality of brown rice [23]. 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. Most of these changes occur within the first 3 to 4 months after harvest at storage temperatures over 15°C [24].

Elongation ratio

The effect of storage periods on elongation ratio of brown rice when stored at 12, 14 and 16 percent moisture content in different storage structures are shown in **Table 4**.

Table 4 Elongation ratio in brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, percent (w.b.)		
		12	14	16
Mud bin	0	1.14	1.15	1.15
	30	1.15	1.16	1.20
	60	1.18	1.20	1.22
	90	1.28	1.30	1.32
	120	1.33	1.35	1.38
Jute bag	0	1.14	1.15	1.15
	30	1.15	1.16	1.17
	60	1.17	1.18	1.20
	90	1.24	1.27	1.28
	120	1.30	1.32	1.34
Polypropylene bag	0	1.14	1.15	1.15
	30	1.18	1.20	1.21
	60	1.21	1.24	1.28
	90	1.30	1.32	1.34
	120	1.35	1.38	1.41

The elongation ratio of brown rice gradually increased respective of number of storage days. The maximum elongation was found in Polypropylene bag followed by mud bin and less elongation was observed in jute bag. The effect of moisture content was not effective to change the elongation.

The results of this study are in agreement with earlier results reported by Meullenet *et al.*, [25]. One factor may be temperature, ambient temperature increase gradually from 0 day to 120 days hence higher temperature lead to greater expansion. The results of this study are in agreement with earlier results reported by Zhou *et al.*, [26] who studied effect of storage temperature on cooking behaviour of rice.

Water uptake ratio

The effect of storage periods on water uptake ratio of brown rice when stored at 12, 14 and 16 percent moisture content in different storage structures are shown in **Table 5**.

Table 5 Water uptake ratio of brown rice stored at different storage structures and moisture contents

Storage structure	Storage period, Days	Moisture content, percent (w.b.) 12	14	16
Mud bin	0	1.68	1.66	1.65
	30	1.74	1.72	1.69
	60	1.79	1.78	1.76
	90	1.82	1.79	1.77
	120	1.85	1.83	1.80
Jute bag	0	1.68	1.66	1.65
	30	1.71	1.69	1.66
	60	1.74	1.72	1.70
	90	1.79	1.74	1.73
	120	1.80	1.77	1.75
Polypropylene bag	0	1.68	1.66	1.65
	30	1.76	1.72	1.70
	60	1.82	1.80	1.78
	90	1.84	1.81	1.78
	120	1.88	1.85	1.82

The water uptake ratio increases with increase in storage period (Table 5) for all types of storage structures. Results reveal that highest value of water uptake ratio of brown rice was observed in polypropylene bag whereas jute bag has lowest value during storage. The effect of moisture was not significant to increase the water uptake ratio. However comparative studied while moisture contents were taken into consideration the value of water uptake ratio was increases when material stored at lower moisture content i.e. 12 percent followed by 14 percent and then 16 percent moisture.

Except to water uptake ratio, all parameters of cooking quality i.e. elongation ratio, volume expansion ratio, breadth expansion ratio and cooking index was higher at higher moisture content. The agreement of this result with results reported by Gujral and Kumar [27] who studied that storage at high moisture result increased elongation in length and width, water uptake and cooking index.

But in my research found that water uptake ratio was higher at lower moisture content it may be cleared by formula to determine water uptake ratio i.e. ratio between weight of cooked rice and weight of raw rice. It is cleared that lower moisture of raw rice has higher value of water uptake ratio.

Conclusion

From the present investigation it may be concluded that nutritional characteristic of stored brown rice was decreased respective of storage periods. Fat content of brown rice was highly degraded (0.96% in jute bag at 16 % moisture content) followed by mud bin and then polypropylene bag has highly retained of fat content during storage. Protein content was comparatively highly retained in polypropylene bag from 8.94 to 8.81 followed by mud bin at lower moisture content and jute bag has comparatively high degraded of protein at high moisture content during storage. Carbohydrate content was nearly constant but it reduced respective of storage periods same trend like protein content about storage structures i.e. jute bag has high reduction of carbohydrate followed by mud bin and polypropylene bag high retained. Effect of storage periods and storage structures on nutritional content of brown rice was significant but role of moisture content was not significant. The elongation ratio of stored brown rice during storage was highly increased in polypropylene bag at higher moisture content i.e. from 1.15 to 1.41 followed by mud bin and then jute bag at high moisture content. Water uptake ratio gradually increased during ageing respective of all type of storage structures. Maximum water uptake ratio observed in polypropylene bag at lower moisture content i.e. from 1.68 to 1.88 followed by mud bin and jute bag has lowest increased at high moisture content among all variables i.e. 1.65 to1.75. However effect of ageing was significant role on water uptake ratio but effect of moisture content was not significant role to increase the water uptake ratio.

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