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Effect of storage on parboiling, milling and cooking properties of paddy varieties in Chhattisgarh

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Abstract

The present study was taken up to evaluate the degree of parboiling of rice grains, milling and cooking characteristics and then storage of both raw and parboiled paddy with their associated changes. Two varieties of paddy, Mahamaya and Swarna were purchased from the grain market of Raipur, C.G. Parboiling experiment was conducted by soaking paddy at 60 °C for 4 h, steaming for 15 min and then drying under shade for 24 h for both Mahamaya and Swarna varieties. Raw and parboiled samples were stored in polyethylene bags which were then kept in stainless steel containers. The stored samples were tested for milling and cooking qualities at 0, 20 and 40 days of storage. Head yield and milling quality of raw and parboiled samples initially decreased and then increased at the end of storage period in Mahamaya variety whereas in Swarna variety the raw and parboiled samples decreased throughout the storage period. Leaching loss and water uptake ratio of raw as well as parboiled grains showed, in general, decreasing trend with increasing storage period in both Mahamaya and Swarna varieties. EMC-S values are decreased at the end of storage period in Mahamaya variety whereas the EMC-S values are increased throughout the storage period in Swarna variety. Alkali spreading values of raw rice samples decreased at the end of storage period but for the parboiled rice samples, it increased at the end of storage period in both Mahamaya and Swarna varieties.

Keywords: Parboiling, milling, cooking, EMC-S, water uptake ratio, alkali spreading value

1. Introduction

The grain, called rice (*Oryza sativa* L.) for more than 8000 years, has been the companion of human kind. It is the most important food commodity in Asia, particularly in South and South-East Asia, where more than 90 per cent of rice is produced and consumed. It provides 20-80 percent of the daily calorie intake. The bulk of Asian population, the urban poor, landless rural population and the marginal farmers spend more than half of their income on rice, being the dominant staple food. The composition of paddy is approximately 72% rice, 5% rice bran and 23% husk (Singh and Sahay, 1999) [17].

Paddy is a major food grain in India. Over 7000 varieties are under cultivation in different parts of the country with variations in their duration, grain quality and other characters. Several varieties of paddy are being grown in the Chhattisgarh. Normally, the varieties of paddy which are more brittle, long, slender and fragile are usually preferred for parboiling. The paddy is converted into edible form of the rice for which the paddy undergoes several post-harvest operations. The maximum recovery of head rice, yield and the quality of rice depends mainly on the variety of the paddy as well as the parboiling characteristics of paddy. In Chhattisgarh, the varieties of rice which are suitable for parboiling are Swarna (IRRI 1001), Mahamaya, Mashuri and Kranti etc.

Parboiling is a process developed for improving rice quality. It consists of soaking, steaming and drying of the rough rice. The major reasons for parboiling rice include higher milling yields, higher nutritional value and resistance to spoilage by insects and mold. The parboiling process is applied to rice with a preliminary objective of hardening the kernel in order to maximize head rice yield in milling. Parboiling is a well-developed premilling treatment given to the paddy and is practiced throughout the world. Rice soaked, steamed, dried and milled is known as parboiled rice and the process is called parboiling. The purpose of parboiling is to produce physical, chemical modifications in rice with economic and nutritional advantages (Pandey, 1998) [14].

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Starch gelatinization has generally been defined as an irreversible swelling of the granules in hot water accompanied by loss of crystallinity and birefringence. Gelatinization occurs over a range of temperature rather than at a fixed temperature. This is akin to melting of a solid mass of fat which when heated on a pan melts over a period of time rather than at once, due to its component triglycerides having differing melting points. The range of gelatinization temperature could be low, intermediate or high. Gelatinization temperature is significant, because hydration or water absorption characteristics of native starch undergo substantial changes around and above this temperature. Any intended treatment of the grain (to reduce diffusion resistance) or manipulation in the process parameters (to accelerate diffusion) should take these facts into consideration. The degree of gelatinization can be estimated by determining equilibrium moisture content at saturation, sedimentation test, alkali dispersion test and water uptake ratio.

In general, efficient mills produce better quality rice, whereas inefficient mills waste energy, and result in losses. To improve the quality of rice two main factors have to be considered: one, the quality of paddy that goes in for milling; and two, the milling technique; although Bhattacharya has argued that the ultimate cause of breakage in rice milling resides more in the rice kernel than in the milling methods and equipment. Since the percentage of whole grain is the most important parameter in the rice industry, rice processing, therefore, becomes an important factor to be put into consideration in order to improve its quality.

Cooking quality is usually defined in terms of time of cooking, swelling capacity, expansion ratio, colour, solids in gruel and pastiness. Parboiled rice takes longer time to cook to the same degree of softness than raw rice of the same variety. The loss of protein and starch from parboiled rice in the cooking water is low. Water soluble vitamins and other water soluble nutrients diffuse into the endosperm during parboiling and hence the loss of nutrients is less in parboiled rice even after polishing.

There is urgent need to study the possibility of parboiling of some paddy varieties which are popularly grown in Raipur, Chhattisgarh to acquire the desirable properties. The parboiling of paddy grains will impart the required hardness to the grain. With parboiling, breakage of paddy grains during milling can be minimized because gelatinization of starch would fill the voids and cement the fissures and cracks. So that milling yield increases and the cooking quality is improved. The present investigation is therefore, undertaken to determine the parboiling, milling and cooking characteristics during storage of both raw and parboiled paddy.

Ilyas and Goel (2003)^[9] reported that parboiling is a method of processing that combines soaking with heating by external sources. It helps to strengthen the kernels and enables even weak soft grains to withstand milling without breakage. Miah *et al.* (2002)^[13] investigated the effect of soaking time on the quality of parboiled rice. The paddy was soaked in water at 25 and 80 °C for 15, 30, 45, 60 and 120 min the soaked paddy was steamed, dried, stored and milled. With increasing soaking time a significant increase in water absorption and head rice yield was observed. A large reduction in fissured grains was observed after soaking. Soaking in hot water greatly increases the diffusion rate of

water in the grains by the capillary movement of water from the surface towards the center and by molecular absorption of water. Therefore, soaking in hot water for an appropriate duration saves time and improves quality of parboiled rice studied the causes for fissures and cracks of rice grains that might cause breakage. Moisture absorption was of particular interest. Bosario (1965) reported that the parboiling process gelatinizes the starch granules and brings them together, sealing the cracks, making the grain translucent and results in better yield of edible head rice with a reduction in quantity of broken studied the effect of processing conditions on cooking qualities of parboiled rice. A laboratory scale experimental set up was fabricated to produce parboiled rice at lower temperatures (80, 90 and 100 °C) to determine cooking qualities for different processing conditions and sample sizes (75, 120, 200 and 400 g). A cooking time of 20-24 min was obtained for the improved quality parboiled rice produced at the processing conditions of 90 °C for 30 min and 100 °C for 30 min.

Agrawal (1984)^[4] conducted storage experiments on storage of raw and parboiled rice at 79.65% RH and 40°C temperature. Samples were taken in polythene bags, which were kept inside the dessicator. Samples were taken out after 7, 14- and 28-days interval and tested. Results revealed that after 7 days, moisture content of 27 samples of raw and parboiled rice reduced, after 14 days there was increase in moisture content. The moisture content of samples after 28 days was found more than that of 14 days stored samples. Head yield of parboiled samples decreased with increasing storage period. The loss of solids was highest at the initiation of storage and declined sharply with storage up to 28 days.

2. Materials and Methods

Two varieties of paddy, Mahamaya and Swarna were purchased from the grain market of Raipur city, Chhattisgarh. The cleaning of paddy grains was determined manually. Foreign matters, light impurities, stones, immature grains, damaged grains and discoloured grains all were removed manually.

2.1 Parboiling Experiment

2.1.1 Experimental set up for soaking experiment

The experimental set up for soaking of paddy grains consisted of cylindrical containers made of stainless steel, a water bath with heating capacity up to 110 °C, having temperature control arrangement (± 2 °C) and a mercury-in-glass thermometer (10 to 200 °C).

Cleaned paddy grains (2 kg) were taken in stainless steel containers. Grain to water ratio was kept 1:3 as suggested by Bhawana Sirsat (2003). In order to attain the desired mixture temperature, 6 litres of hot water at predetermined temperature was added to the container. The temperature was covered with lid and placed in the hot water bath whose temperature was controlled at a constant level. The water bath temperature was maintained 2 °C higher than the desired temperature. To ensure uniform soaking, the paddy water mixture was stirred at regular intervals by using an iron ladle. The container was taken out from the water bath after desired soaking duration and then water was drained out. Some amount of soaked sample, say 10 g was taken and surface moisture was removed by using blotting paper. The sample was weighed quickly and moisture content was determined by hot air oven drying at 105 °C for 24 h

(AOAC, 1984). Rest of the soaked paddy grains were subjected to steaming.

The variables involved in soaking are independent variables are initial moisture content, soaking temperature and soaking time. The dependent variables are rate of moisture absorption and degree of gelatinization.

2.1.2 Steaming

Steaming is done by introducing steam at a higher pressure in an autoclave loaded with soaked paddy. Steaming in autoclave leads hard parboiled rice known as pressure parboiled rice. The variables involved in steaming are independent variables 15 min as time of steaming, the dependent variables are moisture content, degree of gelatinization.

2.1.3 Drying

The steamed paddy samples were shade dried for 24 h. The samples were spread in thin layers in stainless steel trays of size 60 x 45 cm and frequently stirred for uniform drying of grains. The dried samples were then placed in polythene bags and tempered for 24 h.

1.2 Milling Experiment

Milling of paddy involves removal of husk and outer bran layer from the grain to produce edible rice. The milling efficiency, head yield and broken yield were calculated as suggested by Mandhyan and Sharma (1992)^[12].

$$1. \text{ hme } (\%) = \frac{W_{tr}}{W_{tp}} \times 100 \dots (1)$$

Where

hme = Milling efficiency, %

W_{tr} = Weight of total rice, (heads + brokens), g

W_{tp} = Total weight of paddy, g

$$2. \text{ } Y_h (\%) = \frac{W_{hr}}{W_{mr}} \times 100 \dots (2)$$

Where

Y_h = Head yield, %

W_{hr} = Weight of head rice, g

W_{mr} = Weight of milled rice, g

$$3. \text{ } Y_b (\%) = \frac{W_{bpr}}{W_{mpr}} \times 100 \dots (3)$$

Where

Y_b = Brokens, %

W_{bpr} = Weight of broken polished rice, g

W_{mpr} = Weight of total polished rice g

2.3 Determination of Moisture Content

Moisture content of the sample was determined by standard air oven method (Ranganna, 1995)^[15]. Test sample of 5 g was kept for 24 h in a hot air electric oven maintained at 105 °C. After 24 h, sample was drawn from the oven and placed in a dessicator for cooling. After cooling the weight of the sample was taken precisely. The loss in weight was determined and moisture content was calculated using the following expression:

$$\text{Moisture content, \% (w.b.)} = \frac{W_m}{W_m + W_d} \times 100$$

W_m = Weight of moisture

W_d = Weight of dry matter

2.4 Degree of gelatinization determination

2.4.1 Equilibrium moisture content at saturation

Small samples of rice (2 g) from each treatment including raw rice were taken in test tubes containing 10 ml of distilled water and kept undisturbed for 24 h at room temperature. After 24 h, the contents of test tubes were emptied into a perforated tray and surface moisture of soaked grains was removed by using blotting paper. Then the samples were weighed quickly and moisture content was determined by using hot air oven.

2.4.2 Sedimentation Test

For this test, samples from each treatment including raw rice were ground manually in a stone mortar pestle. A definite quantity of ground samples (2 g, 80 mesh) were taken in measuring cylinders (25 ml) and the initial volume of the material was noted. Then the volume of the material was made up to 15 ml by adding 0.05 N hydrochloric acid. Then, measuring cylinders were kept undisturbed for 4 h at room temperature. After 4 h, the volumes of sediments in the test tubes were measured. The difference of initial volume and final volume of each sample gave the value of increase in volume.

2.4.3 Alkali dispersion test

A solution of KOH (10 mL, 1.7% conc.) was taken in glass petri dishes. The petri dishes were placed on a black surface. Six whole kernels of each treated rice and raw rice were dropped in separate petri-dishes. The petri-dishes were covered and kept undisturbed for 24 h at room temperature. After 24 h, samples were observed minutely and rated for spreading according to following 7 point scale (Little *et al*, 1957)^[10] as shown in Table 1.

Table 1: Alkali Spreading Values on 7 Point Scale

Scale	Spreading value
1	Kernel not affected
2	Kernel swollen
3	kernel swollen, periphery narrow
4	Kernel swollen, periphery complete and wide
5	Kernel split
6	Kernel dispersed merging
7	Kernel completely dispersed and intermingled

2.4.4 Water uptake ratio (W62/W97)

Two grams of rice from each treatment including raw rice were taken in separate test tubes and to each test tubes 15 ml of distilled water was added. Then test tubes were placed in water bath at 97±1 °C for 30 min. After cooking contents of tests tubes were emptied into a perforated tray, surface moisture of cooked grains removed by using blotting paper and moisture content was determined by hot air oven drying method. Then again 2 g of each sample were taken and cooked in 15 ml distilled water in water bath at 67±1 °C for 45 min and then moisture content of cooked samples were determined by hot air oven method.

2.5 Storage experiment

The storage of paddy was done at room temperature. Raw and parboiled paddy samples were placed in polythene bags and mouth of bags were tied with rubber bands. Then the

polythene bags containing raw and parboiled paddy were kept in stainless steel containers, which were covered with lids. Then containers were placed in a separate shelf. Stirring of samples was done at an interval of 10 days to obtain the same storage effect throughout all individual samples. After desired storage duration (0, 20 and 40 days) samples were taken out and subjected to quality evaluation tests. Lay out of storage experiment has been depicted in the following Table 2.

Table 2: Lay out of storage experiment

S. No.	Sample size, g	Storage duration	Storage mode
1.	150	0	Room
2.	150	20	Room
3.	150	40	Room

2.6 Oil Content

The fats are fatty acid esters of glycerol. Fat as liquid is called oil. Fat was estimated as a crude ether extract of the material. Samples were ground and then 2-3 g sample was weighed accurately into a thimble and plugged with cotton. The thimble was then placed in a soxhlet apparatus and extracted with petroleum ether/hexane for 6 h. The ether extract was filtered into a weighed conical flask. The flask containing the ether extract was washed 4-5 times with small quantities of ether and the washing were also transferred. The ether was then removed by evaporation and the flask with the residue dried in an oven at 60-70 °C, cooled in a desiccator and weighed (AOAC, 945.16). The percentage of oil in raw and parboiled bran was calculated using the formula

$$\text{Oil, \%} = \frac{W_o}{W_d} \times 100$$

Where

W_o = Weight of oil, g

W_d = Weight of dry matter

Moisture content of the sample was determined by standard air oven method (Ranganna, 1995) [15]. The milling

efficiency, head yield and broken yield were calculated as suggested by Mandhyan and Sharma (1992) [12].

2.7 Statistical analysis

The data obtained for quality evaluation tests were subjected to statistical analysis. To test the effect of raw and parboiled paddy for 15 min steaming, storage and their interaction, the Factorial Completely Randomized Design was used for data analysis.

3. Results and Discussion

3.1 Parboiling experiment

In parboiling experiment, temperature (60 °C) and time of soaking (4 h) and steaming (15 min) were kept constant. Treatment MT1 represents raw grains for Mahamaya variety and treatment MT2 represents parboiled grains. Treatment ST1 represents raw grains for Swarna variety and treatment ST2 represents parboiled grains respectively.

Effect of soaking temperature on moisture content

The main purpose of soaking is to raise the moisture content of paddy prior to steaming to facilitate gelatinization of starch. Soaking of paddy was done at ambient and 60 °C to understand the hydration characteristics of paddy. The results of soaking experiment at ambient and 60 °C temperature of Mahamaya and Swarna varieties represented graphically in Fig. 1 and 2.

During soaking, moisture absorption was considerable up to 4 h at the 60 °C of water temperature. After 4 h, the rate of moisture uptake declined significantly. In present study, the moisture content of Mahamaya and Swarna varieties of paddy for 4 h soaking at ambient and 60 °C were found to be in the range 8.23 to 41.02%, 9.08 to 43.01% (Mahamaya) and 8.32 to 43.24%, 9.43 to 44.01% (Swarna).

From the Fig. 1 & 2, it was observed that the phase of sudden rise in moisture content lasted for 1 h only and after that moisture content of paddy increased much slowly. Further, as the soaking water temperature increased the moisture content of grains also increased for the same duration of soaking. This behaviour of paddy is in agreement as stated by Chakraverty (1981) that at high temperature the rate of moisture absorption is more.

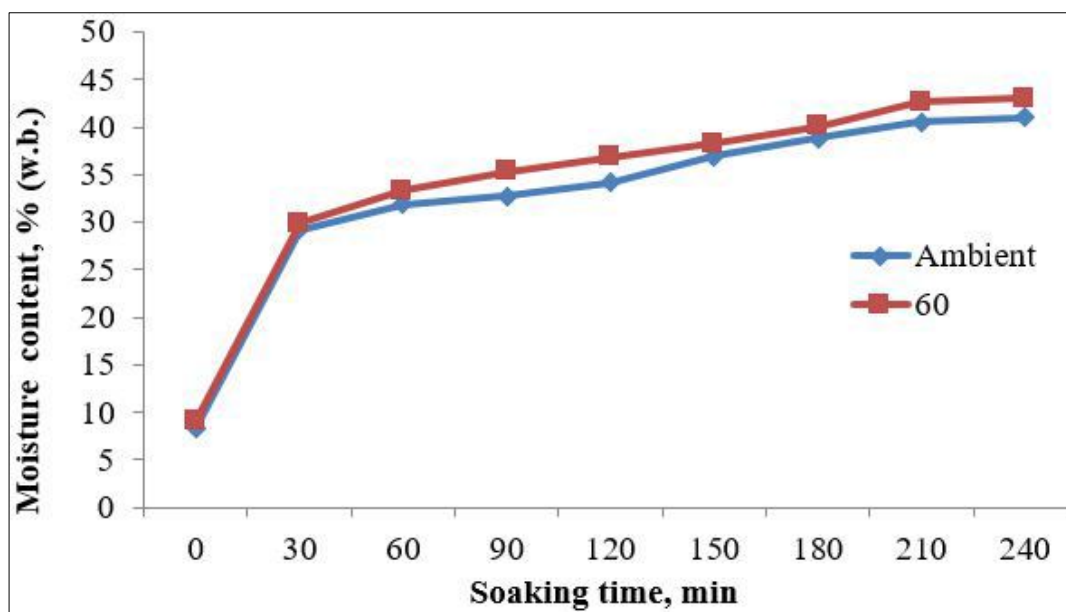


Fig 1: Effect of soaking time and temperature on moisture content of Mahamaya variety

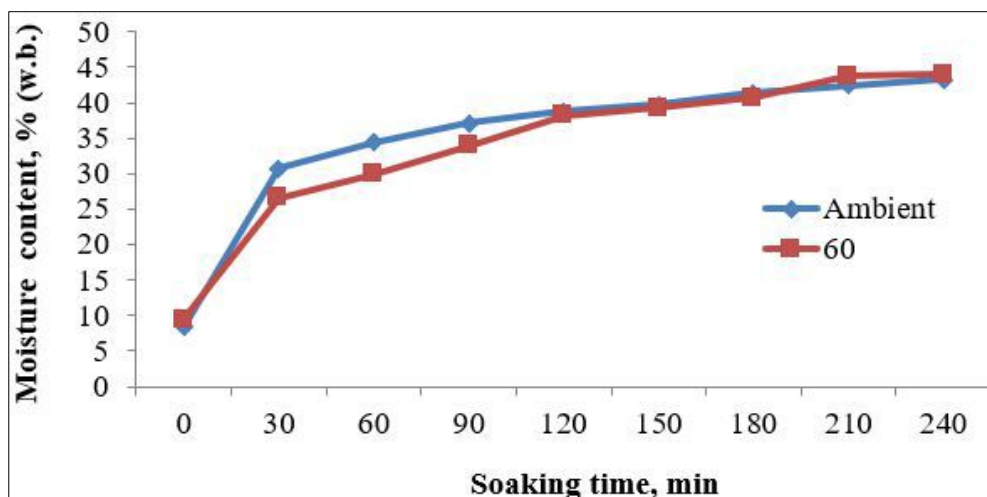


Fig 2: Effect of soaking time and temperature on moisture content of Swarna variety

3.2 Effect of storage on moisture content

Raw samples as well as parboiled samples showed a fluctuating trend for their moisture content throughout the storage period. Results of investigation have been represented graphically in Fig. 3.

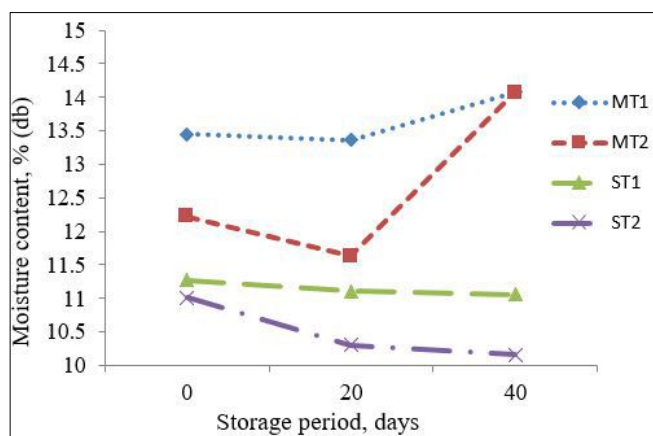


Fig 3: Effect of moisture content of raw and parboiled paddy

MT1 & MT2: Raw and Parboiled Mahamaya paddy
ST1 & ST2: Raw and Parboiled Swarna paddy

In Mahamaya variety, the moisture content of raw as well as parboiled samples initially declined because samples were stored in shade and during first 20 days atmospheric temperature was high (above 45 °C). So moisture migrated from all samples and showed decline in moisture content. For the rest storage period, moisture contents of all samples showed an increasing trend. After 20 days storage, atmospheric temperature came down. At the end of 40 days storage, moisture content of raw sample was 14.11 per cent while that of parboiled samples 14.08 per cent. But in case of Swarna variety, the moisture content of raw as well as parboiled samples declined throughout the storage period

because samples were stored at room temperature and atmospheric temperature was high. At the end of storage, moisture content of raw sample was 11.07% while that of parboiled samples 10.11%.

3.3 Effect of storage on milling quality

Effect of storage on milling quality of paddy have been represented graphically in Fig. 4, 5 & 6. It is clear that for raw paddy samples as the storage time increased, head yield and milling efficiency decreased up to 20 days storage period and then again increased up to 40 days storage in Mahamaya variety. But in case of Swarna variety, raw as well as parboiled samples showed a declining trend throughout the storage period. Broken percentage increased in raw and parboiled samples throughout the storage period for both Mahamaya and Swarna varieties. But at all stages of storage, parboiled samples showed better milling quality than that by raw samples.

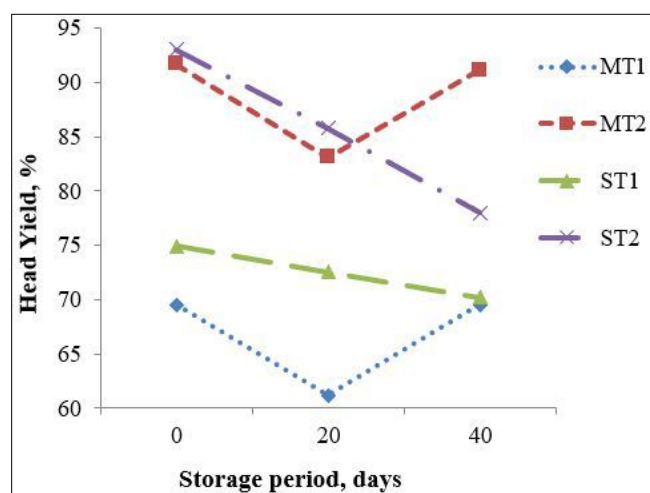


Fig 4: Effect of storage on head yield of raw and parboiled paddy

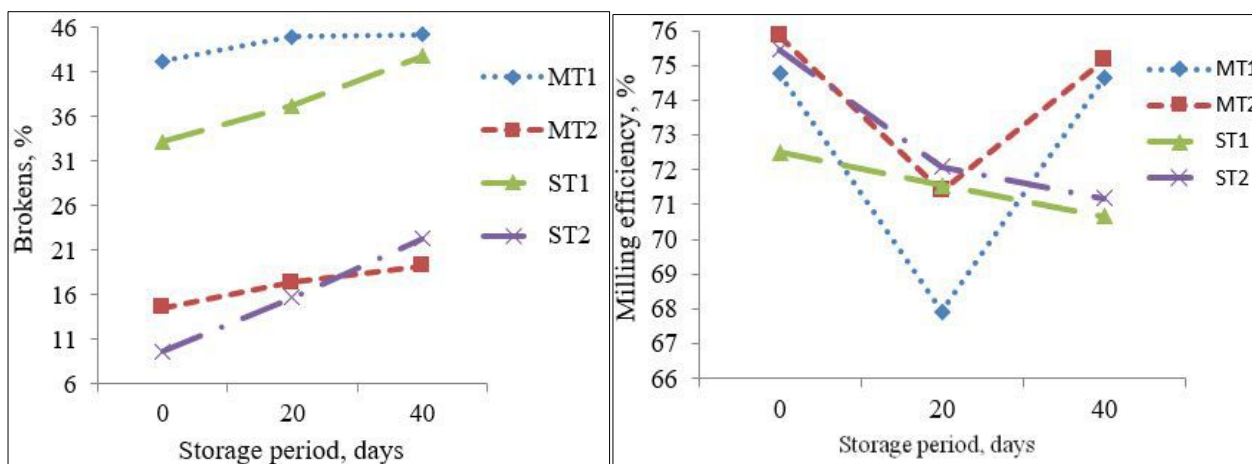


Fig 5 & 6: Effect of storage on broken yield and milling efficiency of raw and parboiled paddy

MT1 & MT2: Raw and Parboiled Mahamaya paddy

ST1 & ST2: Raw and Parboiled Swarna paddy

3.4 Effect of storage on cooking quality

3.4.1 Water uptake at 97 °C

Effect of storage on water uptake of raw as well as parboiled samples of rice have been represented graphically in Fig. 7. The results reveal that water uptake of raw and parboiled rice samples decreased up to 20 days and afterwards the water uptake increased for Mahamaya variety. But in case of Swarna variety, the results revealed that water uptake of raw and parboiled rice samples decreased throughout the storage period. It is evident from ANOVA Table that the treatments including raw and parboiled rice samples, storage and their interaction having significant effect on water uptake at 97 °C in both Mahamaya and Swarna varieties. The mean table of analysis of variance for the effect of treatments, storage and their interaction on water uptake has been given below Table 3.

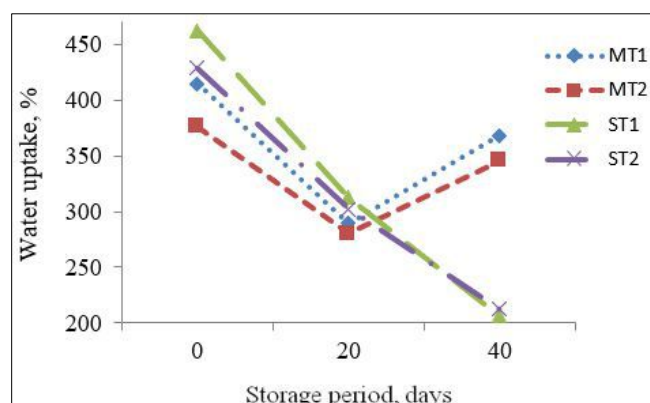


Fig 7: Effect of storage on water uptake at 97 °C of raw and parboiled rice

Table 3: Treatment storage mean table for uptake at 97 °C of rice

Treatments	Storage period (days)			Treatments mean
0	20			40
MT1	414.5433	289.0567	368.1667	357.2556
MT2	316.2933	280.30300	345.5233	334.0400
ST1	462.0300	312.2633	206.5333	326.9422
ST2	428.2933	302.1033	212.2533	314.2166
Mean	420.2899	295.9316	283.119	333.1135
SEm+		CD		
Treatment	0.0042			0.0122
Storage period	0.0036			0.01050
Treatment storage	0.0072			0.0210

It can be observed from Table 3 that all values of effect of treatments on water uptake differ significantly from each other in both Mahamaya and Swarna varieties.

3.4.2 Leaching of solids during cooking

The results of leaching of solids during cooking of rice in boiling water are represented in Fig. 8. The results reveal that loss of solids declined throughout the storage period for

raw and all parboiled rice samples. Leaching loss was higher at the beginning of storage period for all samples whether raw or parboiled. But at every stage of storage leaching loss of solids, for raw sample owing to its ungelatinized starch was found to be higher than all parboiled rice samples. Among all the samples, higher leaching loss was found with raw rice samples (26.39%, 20.23%: Mahamaya, Swarna) at the beginning of storage.

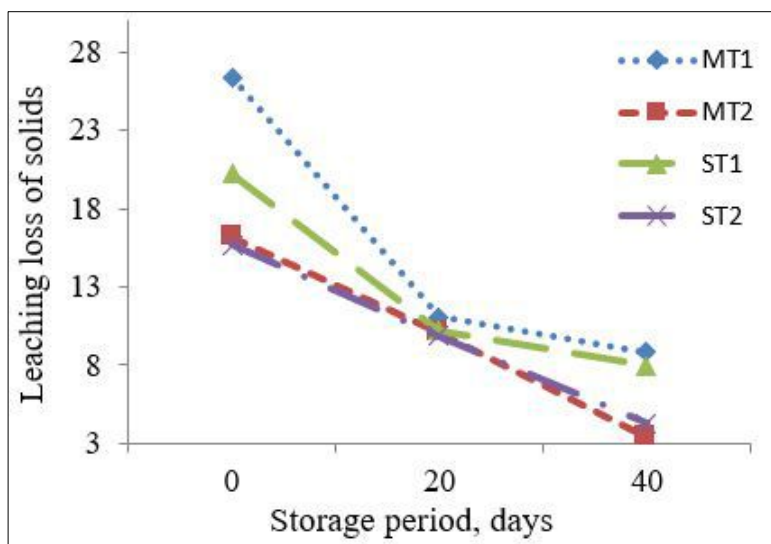


Fig 8: Effect of storage on leaching loss of solids with gruel of raw and parboiled rice

It is evident from ANOVA Table 4 that treatments including raw rice samples, storage and their interaction have significant effect on leaching loss of solids. But the treatments of parboiled rice samples and storage interaction have non-significant effect in both Mahamaya and Swarna varieties. The mean table analysis of variance for the effect of treatments, storage and their interaction on leaching loss has been given below Table 4.

Table 4: Treatment storage mean table for leaching loss of solids of rice

Treatments	Storage period (days)			Treatments mean
	0	20	40	
MT1	26.3820	11.0600	8.8167	15.4189
MT2	16.2167	10.1067	3.4367	9.9200
ST1	20.2233	10.2233	7.9600	1.8022
ST2	15.6600	9.8800	4.2533	9.9311
Mean	19.62	10.3175	6.1166	12.0180
SEm+				CD
Treatment	0.0040			0.0116
Storage period	0.0035			0.0102
Treatment storage	0.0069			0.0201

3.5 Effect of storage on degree of parboiling

3.5.1 Equilibrium moisture content at saturation

The results of effect of storage duration on EMC-S of raw and parboiled samples of rice have been represented graphically in Fig. 9. It can be observed that raw samples showed lower values than all parboiled samples at every stage of storage. In Mahamaya variety, the EMC-S of raw and parboiled rice samples showed an increasing trend up to 20 days and afterwards the samples are slightly decreased at the end of storage period. But in case of Swarna variety, the EMC-S of raw and parboiled rice samples showed an increasing trend throughout the storage period. Storage of samples was done at ambient temperature, which varied throughout the storage period and EMC-S of grain is greatly controlled by this factor. So changing atmospheric temperature may be the reason behind the changes in EMC-S of grains during storage.

It is evident from ANOVA Table that treatments including raw and parboiled rice samples, storage and their interaction have significant effect on EMC-S in both Mahamaya and Swarna varieties. The mean table analysis of variance for

the effect of treatments, storage and their interaction on EMC-S has been given below Table 5.

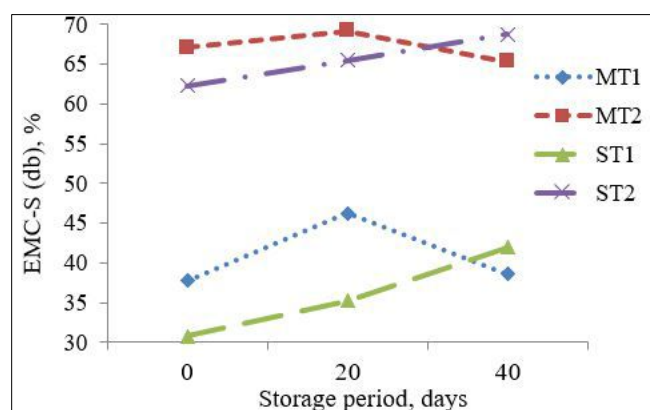


Fig 9: Effect of storage on EMC-S of raw and parboiled rice

Table 5: Treatment storage mean table for EMC-S of rice

Treatments	Storage period (days)			Treatments mean
	0	20	40	
MT1	37.7300	46.2267	38.6367	40.8644
MT2	67.0733	69.1800	65.3667	67.2067
ST1	30.7600	35.2633	41.9333	35.9856
ST2	62.2833	35.4600	68.7800	65.5078
Mean	49.4616	54.0325	53.6791	52.3911
SEm+				CD
Treatment	0.0420			0.1225
Storage period	0.364			0.1062
Treatment storage	0.0728			0.2124

3.5.2 Water uptake ratio

The results of effect of storage on water uptake ratio of raw and parboiled samples of rice have been represented graphically in Fig. 10. It can be observed that at all stages of storage, raw samples of rice showed much lower values than all parboiled samples of rice. Raw and parboiled rice samples of Mahamaya variety showed an increasing trend up to 20 days and then the samples are slightly decreased at the end of storage period. But the raw and parboiled rice samples of Swarna variety showed a declining trend throughout the storage period. But in all a decreasing trend

was observed in water uptake ratio of raw and parboiled rice samples.

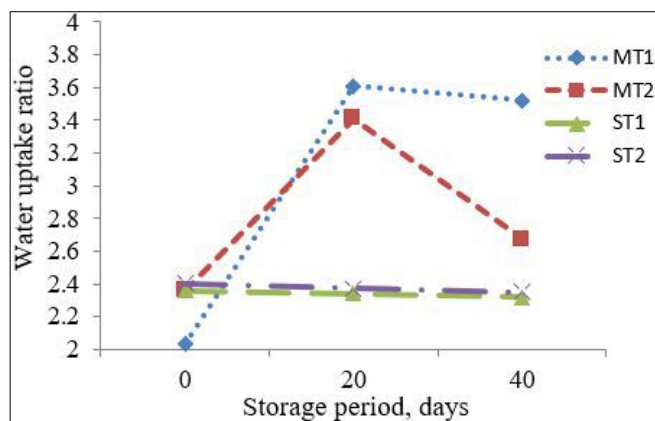


Fig 10: Effect of storage on water uptake ratio of raw and parboiled rice

It is evident from ANOVA Table 6 that treatments including raw and parboiled rice samples, storage and their interaction have significant effect on water uptake ratio in Mahamaya and Swarna varieties. The mean table analysis of variance for the effect of treatments, storage and their interaction on water uptake ratio has been given below Table 6.

Table 6: Treatment storage mean table for water uptake ratio of rice

Treatments	Storage period (days)			Treatments mean
0	20	40		
MT1	2.0300	3.616	3.5233	3.0567
MT2	2.3633	3.4167	2.6767	2.8189
ST1	2.36767	2.34300	2.32067	2.34378
ST2	2.40133	2.37333	2.3500	2.37489
Mean	2.29057	2.93742	2.71766	2.64856
SEm+		CD		
Treatment	0.0029		0.0084	
Storage period	0.0025		0.0072	
Treatment storage	0.0050		0.0145	

3.5.3 Alkali spreading value

The results of this experiment have been represented in Fig. 11. It can be easily observed that the raw rice samples initially increased up to 20 days and afterwards the samples were slightly decreased in both Mahamaya and Swarna varieties. But in case of parboiled rice samples the spreading value showed a declining trend up to 20 days and afterwards the samples are slightly increased at the end of storage period for both Mahamaya and Swarna varieties. At all stages of storage, spreading value for raw rice samples due to ungelatinized starch was much lower than that for parboiled rice samples.

It is evident from ANOVA Table 7, that the treatments including raw rice samples, storage and their interaction have non-significant effect on alkali spreading value. But the treatments of parboiled rice samples have significant effect on alkali spreading value in both Mahamaya and Swarna varieties.

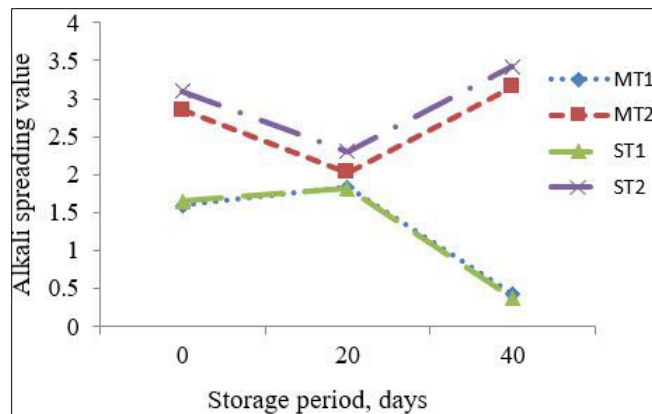


Fig 11: Effect of storage on alkali spreading value of raw and parboiled rice

The mean table analysis of variance for the effect of treatments, storage and their interaction on alkali spreading value has been given below Table 7.

Table 7: Treatment storage mean table for alkali spreading value of rice

Treatments	Storage period (days)			Treatments mean
0	20	40		
MT1	1.6000	1.8433	0.4333	1.2922
MT2	2.8500	2.0367	3.1500	2.6789
ST1	1.6500	1.8233	0.3833	1.2856
ST2	3.1000	2.3167	3.4200	2.9456
Mean	2.3000	2.0050	1.8466	2.0505
SEm+		CD		
Treatment	0.0075		0.0218	
Storage period	0.0065		0.0189	
Treatment storage	0.0130		0.0379	

3.5.4 Sedimentation test

Results of sedimentation test of raw and parboiled rice samples have been represented in Fig.12, which revealed that raw rice samples showed lower sedimentation value than that of all parboiled rice samples of every stage of storage. A general decreasing trend was observed for almost all the samples whether raw or parboiled for both Mahamaya and Swarna varieties. But all samples showed higher values at the beginning of storage. The lower values was observed for raw samples at the end of storage.

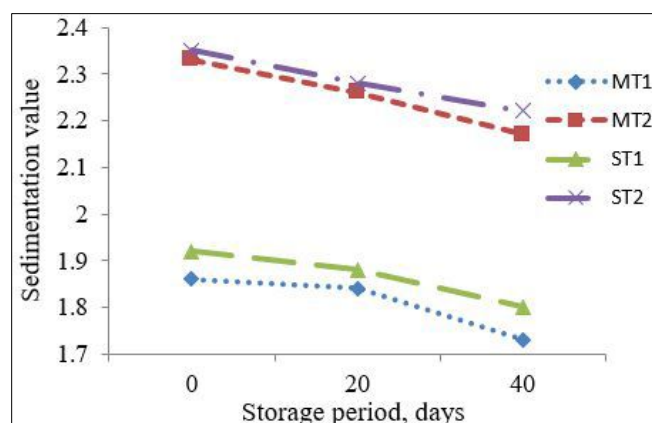


Fig 12: Effect of storage on sedimentation value of raw and parboiled grains

It is evident from ANOVA Table 8, that the treatments including raw rice samples, storage and their interaction have significant effect on sedimentation value. But the treatments of parboiled rice samples have non significant effect on sedimentation value in both Mahamaya and Swarna varieties. The mean table of analysis of variance for the effect of treatments, storage and their interaction on sedimentation value has been given below Table 8.

Table 8: Treatment storage mean table for Sedimentation test value of rice

Treatments	Storage period (days)			Treatments mean
0	20 40			
MT1	1.8667	1.8400	1.7333	1.8133
MT2	2.3333	2.2600	2.1733	2.2556
ST1	1.9200	1.8867	1.8033	1.8700
ST2	2.3533	2.2800	2.2233	2.2856
Mean	2.1183	2.0666	1.9833	2.0561
SEm+				CD
Treatment	0.0103			0.0300
Storage period	0.0089			0.0259
Treatment storage	0.0178			0.0519

3.6 Oil content

Effect of storage on oil content in bran of raw as well as parboiled samples of rice have been represented graphically in Fig. 13. The oil content of raw bran was lower than that of parboiled bran. The results revealed that the oil content of raw and parboiled bran sample showed a declining trend throughout the storage period for Mahamaya variety. But in case of Swarna variety, the raw and parboiled bran samples showed increasing trend with increasing storage period.

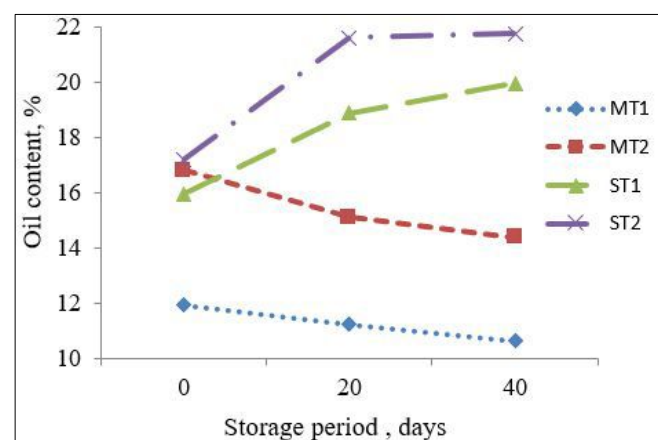


Fig 13: Effect of storage on oil content of bran in raw and parboiled rice

Table 9: Treatment storage mean table for oil content of rice bran

Treatments	Storage period (days)			Treatments mean
0	20 40			
MT1	11.9300	11.2333	10.6400	11.2678
MT2	16.7933	15.0900	14.3733	15.4189
ST1	15.9400	18.8867	19.9467	18.2578
ST2	17.1933	21.5967	21.7433	20.1778
Mean	15.4641	16.7016	16.6758	16.2805
SEm+				CD
Treatment	0.2886			0.8422
Storage period	0.2499			0.7293
Treatment storage	0.4999			1.4589

It is evident from ANOVA Table 9 given in Appendix H7 that treatments including raw and parboiled bran samples, storage and their interaction have significant effect on oil content of bran in both Mahamaya and Swarna varieties. The mean table analysis of variance for the effect of treatments, storage and their interaction on oil content has been given below Table 9.

4. Conclusion

It was concluded that the extent of gelatinization of rice samples increased as evidenced by higher values are obtained in alkali spreading value and water uptake ratio for parboiled rice samples at 15 min steaming time. The milling quality of paddy grains for Mahamaya variety was found increasing at the end of storage period in terms of higher milling efficiency, head yield and lower broken as compared to Swarna variety. The cooking quality tests showed that water uptake of stored samples increased slightly with days of storage. For all storage durations raw rice had higher moisture content than the parboiled rice samples in both Mahamaya and Swarna varieties. The cooking quality of rice grains was also found improving because of less loss of solids in gruel in both Mahamaya and Swarna varieties. The oil content in bran of parboiled rice samples are higher than that of raw rice samples in both Mahamaya and Swarna varieties.

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