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A comparative study on biochemical qualities of speciality rice of Assam during storage at ambient condition

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The speciality rice of Assam, both "Joha", (variety *Kon*) and pigmented rice (variety *Chakhao*) in whole and broken form were stored at ambient condition and dark for 180 days under four different packaging materials. The moisture content, crude fat and acid value together with the phenolic compound of rice were recorded during storage. The vacuum packaging was found to be the best method of packaging for both "Joha" rice and pigmented rice (both whole and broken). Retention of aroma in "Joha" rice was the maximum (very strong, ++++) under vacuum packaged condition up to 120 days, which decreased to strong (+++) for both vacuum packaged and aluminium foil bag packaged condition at 180 days. Microbial study indicated that bacterial infestation was the cause for spoilage of pigmented rice during storage.

Keywords: Aromatic rice, Phenolics, Pigmented rice, Storage, Vacuum packaging

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Rice is one of the major cereal crops that play a significant role in diet, culture and economy of millions of people across the world. It is the leading food source in terms of calories and feeds about 60% of world's population. India is the second largest producer of rice, and also a leading customer of rice in the world[1]. Rice is cultivated in India in 43.39 million ha with 104.32 million tons production[2].

Assam being one of the centers of origin, has wide variation in rice cultivars among which aromatic rice enjoys the top position. The "Joha" rice varieties of Assam, famous for aroma and taste are comparable to other scented rice varieties of rest of India[3]. More than 100 varieties of scented rice are available in North-Eastern region of India, the intensity of aroma in some of these indigenous scented rice varieties is higher compared to improved basmati rice[4].

A lot of diversity in genotypes are observed for aromatic rice, "Joha" of the state[5]. Ahmed *et al*.[4] analysed 22 cultivars of "Joha" rice for which aroma was ranging from very strong (++++) to slightly strong (++), they also determined the 2-acetyl-1-pyrolline (2AP) content of 22 cultivars of "Joha" rice.

Rice can be stored for longer period only if some conditions are maintained like the moisture level of the grain must be below 14% and that of the seed should be below 12%. Grains must be protected from pests, insects, birds and imbibing moisture from the atmosphere[6]. The moisture content of rice increases with time which induces the growth of pests and microorganism and adversely affects the storability of rice. Brown form of rice cannot be stored for longer period as the acid value of crude fat increases which results in rancidity. Zhou *et al*.[7] studied the fatty acid composition of three rice varieties stored up to seven months. Tananuwong and Tangsrianugul[8] studied about effects of storage conditions and cooking on colour and antioxidant activities of organic pigmented rice and they reported that although, qualitative and quantitative determination of phenolic compounds isolated from rice as well as analysis of their antioxidant activities and other biological effects were extensively performed, studies on the impacts of processing and storage of pigmented rice on those aspects were still limited. Yanxia *et al*.[9] reported about changes in cooking, physiochemical and sensory characteristics of rice. Lu *et al*.[10] studied the fatty acid content of rice during storage at 25°C for 8 months and reported that the values increased with storage time.

Though, there are a few reports on quality analysis of both aromatic rice and pigmented rice of Assam[11-14], there is hardly any study conducted to know the

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changes that occur during storage. Though, there are work done on biochemical quality analysis of aromatic rice[4,15] and pigmented rice[16,17] of India and abroad, there is only handful of reports[8,18-20] on biochemical qualities of both aromatic rice and pigmented rice as affected by different storage conditions. However, in Assam, both aromatic rice and pigmented rice (whole), for which commercial importance has been increased day by day, are mostly marketed as either in sealed form using food grade polythene pack of 1kg or in open pouch, in which there is lot of chance of loss of aroma. Vacuum packed speciality rice is yet to be found as common commodity in the market. Though, some cereal products, are found in the market in double packed form or in bags made of aluminium foil, locally produced speciality rice is yet to be stored following these methods. Moreover, there is need to study the quality of pigmented rice (broken) during storage as pigmented rice (whole) is difficult to cook due to attachment of bran. There is possibility of lowering the cooking time due to exposure of more surface area due to breakdown of rice grain. The nutrient content of broken rice is almost same with that of whole rice. Considering lack of studies, involving changes in quality of specialty rice during storage, the present study was proposed to know the effect of different packaging practices on retention of quality parameters of speciality rice.

Materials and Methods

The present study was conducted at the Department of Biochemistry, Assam Agricultural University, Jorhat, Assam. The freshly harvested paddy (pigmented rice, variety *Chakhao*) and "Joha" rice, variety *Kon Joha* were collected from Instructional cum Research Farm AAU, Jorhat.

The packaging materials *viz.*, food grade polythene bags (thickness of 200 microns), food grade polythene bags for vacuum packaging, food grade aluminium foil bags and the food grade plastic containers (used for double packaging) were procured from local market.

Processing of paddy/rice

Polishing of *Kon Joha* was done on the same day of de-husking with a polishing percentage of 14.6%. However, the pigmented rice was not polished after removal of husk. Another lot of whole form of pigmented rice was broken using laboratory mixer grinder. The broken rice that passed through sieve no. 140 (106 micron) and the ones which did not pass through 200 (75 micron) were retained as broken pigmented rice.

Storage of rice grain

Rice grain (each packet of 250 g with six replications) were kept inside the following packaging materials, sealed and stored (Fig. 1).

i. Food grade polythene bag (200 micron) packaging (control)

ii. Aluminium foil bag packaging

iii. Double packaging (after food grade polythene bag packaging, six bags were kept in side one food grade plastic container)

iv. Vacuum packaging (Vacuum packaging and sealing was done using 2 in 1 automatic vacuum sealing machine, consuming 90-watt power and operated at voltage AC 100- 240V with vacuum degree -60 Kqa)

The packed samples were stored at ambient condition (at average temperature 30°C and 94% RH) and at dark for 180 days.

Moisture content and the crude fat were determined by using the method of AOAC[21]. Aroma of Joha rice was determined qualitatively as described by Sood and Siddiq[22]. Two grams of powdered sample was taken in three small glass petriplates. Ten millilitre of 1.7% potassium hydroxide solution was added to each of the petriplate and petriplates were covered immediately and kept at room temperature for 10 min. Then the petriplates were immediately opened and content in each petriplate were smelt by a panel of four skilled persons of the Department. The aroma was scored as ++++, +++, ++ and + for very strong, strong aroma, slightly strong aroma and low aroma, respectively. The acid value was determined using the standard method (AOAC, 2020)[21]. The total phenol content (TPC) was estimated by the method given by Singleton *et al.*[23]. The total flavonoid content (TFC) was measured by colorimetric method, given by Wu and Ng[24]. Total anthocyanin content was determined using the method described by Fuleki and Francis[25].

The length (L) and breadth (B) of the whole rice and broken rice were measured using a Vernier scale and the L/B ratios were calculated out. The measurements were taken in triplicate and average value was calculated out. For the determination of cooking time, 5 g of rice from was weighed and taken in wide glass tubes and equal amount of water was added and immersed in a boiling water bath, at 100°C. At certain intervals, 1 to 2 nos. of the cooked rice grain were taken out with the help of glass rod and

Fig. 1 — Joha rice stored using different packaging materials (a) Polythene bag packaging (Control), (b) Aluminium foil bag packaging, (c) Vacuum packaging, (d) Double packaging (Polythene bag packaging inside food grade plastic container)

were pressed in between two glass plates to check whether it reached the optimal cooking. When it was found satisfactory, the time was noted as optimal cooking time. This was done in replicates of three. After the cooking was done, the test tubes were emptied in order to remove the remaining water. The cooked kernels were placed on a filter paper and gently rolled to remove the moisture and then weight was recor After that, the rice kernels (0.5 g) were immediately transferred into a burette containing toluene up to 25 mL mark. The displaced volume of toluene indicated by the rise of toluene was taken as the volume of the sample. The water absorption ratio was determined using the following formula:

$$\text{Water absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

Where,
Initial weight of rice = W_1 g
Weight of rice after cooking = W_2 g

The stored grain insect pest was identified after confirmation with Agricultural Entomologist. Nutrient agar media was prepared to check the bacterial growth of the sample and PDA was used to check the fungal growth of the sample. Media was prepared separately using nutrient broth, agar powder and potato dextrose agar in conical flasks and the mouth was covered with cotton plugs and were autoclaved at 121°C for 45 min at 15 lbs pressure and were kept inside the laminar air hood after cooling to room temperature. After that, 1 g of visibly infected sample was dissolved in 100 mL of sterile water and kept overnight in the shaker in order to dissolve properly. For fungal isolation, Cycloheximide and for bacterial isolation, streptomycin was used. The former was prepared by adding 1 g of cycloheximide in 10 mL methanol and the streptomycin was prepared adding 1 g streptomycin in 10 mL distilled water. For serial dilution, 9 mL of sterile water was poured into the tubes and were marked from 10^{-1} to 10^{-6} and 1 mL of sample was

pipetted to the first tube and serial dilution was carried out. From each dilution, an amount of 40 µL was pipetted out and spread over the petriplates containing media. The petriplates were incubated inverted at 37°C and checked after every 24 h up to 48 h. The colonies were counted and expressed as cfu/g.

The experiments were done in completely randomized design (CRD). All the analyses were done in triplicate and the average was calculated out. The data were analyzed by one-way analysis of variance (ANOVA) using Microsoft excel (2007). The standard error of the mean difference (S. Ed ±) was calculated. The treatment means were compared among themselves by calculating critical difference (CD at $p<0.05$).

Result and Discussion

Moisture and crude fat content of rice

The moisture content (Table 1 & Table 2) of "Joha" rice, pigmented rice (whole) and pigmented rice (broken) ranged from 10.30% to 12.04%, 10.44% to 14.07% and 10.85% to 14.92%, respectively. Moisture content was observed to be the highest in the polythene bag packaging (control) at 180 days while the same was the least at initial period.

It was reported that the change in moisture content was due to the moisture exchange between the rice and the surrounding[9].

The crude fat content (Table 1 & Table 2) of "Joha" rice, pigmented rice (whole), pigmented rice (broken) ranged from 1.12% to 2.93%, 2.73% to 4.43% and 2.21 to 4.03%, respectively. The pigmented rice variety showed the higher content of crude fat content than polished rice, because of the presence of the bran.

The crude fat content was the highest during the initial period of storage which decreased with increasing period of time. The lowest crude fat content was observed in the control at 180 days after storage in "Joha" rice whereas, in pigmented rice (whole) it was the lowest at 120 days in double packaging and in broken rice the lowest was observed in double packaging at 180 days.

Ahmed[4] reported that fat content of scented rice ("Joha") varieties of Assam ranged from 1.93 to 3.26%. Mudoi and Das[13] reported crude fat content of raw colored rice ranged from 1.11 to 3.70%. Priya *et al*.[6] reported the range of crude fat content to be 1.6 to 2.8% in brown rice, 0.5 to 2.3% in white rice (polished) and 1.15 to 3.19% in red rice variety. It was reported that the crude fat content in *Chakha*o varieties to be in the range of 1.90 to 3.73%[26].

Table 1 — Moisture (% on fresh weight basis) and crude fat content (% on dry weight basis) of Joha rice

Treatment	Moisture content (%, on fresh weight basis)				Crude fat (%, dry weight basis)			
	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days
Control	10.30	10.87	11.43	12.04	2.93	1.73	1.54	1.12
Double packaging	10.30	10.51	10.87	11.33	2.93	2.06	1.67	1.33
Aluminium foil bag packaging	10.30	10.33	10.61	10.84	2.93	2.35	1.94	1.53
Vacuum packaging	10.30	10.36	10.58	10.71	2.93	2.56	2.20	1.74
C.D. (0.05)	-	NS	NS	NS	-	0.347	0.371	0.389
SE (d)					-	0.157	0.168	0.176

NS = non-significant, C.D. (0.05) = critical difference at 0.05 significance level, SE(d) = standard error deviation

Table 2 — Moisture (% on fresh weight basis) and crude fat content (% on dry weight basis) of pigmented rice

Treatment	Pigmented rice (Whole) Moisture content (%, on fresh weight basis)				Pigmented rice (broken) Moisture content (%, on fresh weight basis)				Pigmented rice (Whole) Crude fat (%, dry weight basis)				Pigmented rice (broken) Crude fat (%, dry weight basis)			
	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days
Control	10.44	12.14	12.87	14.07	10.85	12.22	13.27	14.92	4.43	3.36	-	-	4.03	3.43	-	-
Double packaging	10.44	11.84	12.05	13.14	10.85	12.06	13.12	14.07	4.43	3.53	2.73	-	4.03	3.56	2.43	2.21
Aluminium foil bag packaging	10.44	10.73	10.87	11.30	10.85	11.23	11.37	12.19	4.43	4.03	3.43	2.93	4.03	3.82	-	-
Vacuum packaging	10.44	10.47	10.50	10.77	10.85	11.04	11.17	11.24	4.43	4.16	3.76	3.23	4.03	3.87	2.96	2.49
C.D. (0.05)	-	0.361	0.682	0.348	-	NS	NS	NS	-	0.81	0.76	0.71	-	0.44	0.38	0.20
SE (d)	-	0.164	0.309	0.158	-	NS	NS	NS	-	0.57	0.61	0.63	-	0.03	0.08	0.19

NS = non-significant, C.D. (0.05) = critical difference at 0.05 significance level, SE(d) = standard error deviation

Acid value of crude fat

The acid value of crude fat (Fig. 2) of "Joha" rice variety, pigmented rice (whole) and pigmented rice (broken) ranged from 10.27 mg KOH/g crude fat (51 mg oleic acid equivalent /g crude fat) to 16.06 mg KOH/g crude fat (80 mg oleic acid equivalent /g crude fat), 8.08 mg KOH/g crude fat (40 mg oleic acid equivalent /g crude fat) to 10.69 mg KOH/g crude fat (54 mg oleic acid equivalent/g crude fat) and 8.37 mg KOH/g crude fat (41 mg oleic acid equivalent /g crude fat) to 11.27 mg KOH/g crude fat (56 mg oleic acid equivalent/g crude fat), respectively.

The acid value was the lowest during the initial period which gradually increased with increasing period of time. The acid value of "Joha rice" was the highest at 180 days in control, whereas in pigmented rice (whole) it was the highest at 180 days in aluminium foil bag packaging and in pigmented rice (broken) the highest value was observed in double packaging at 180 days.

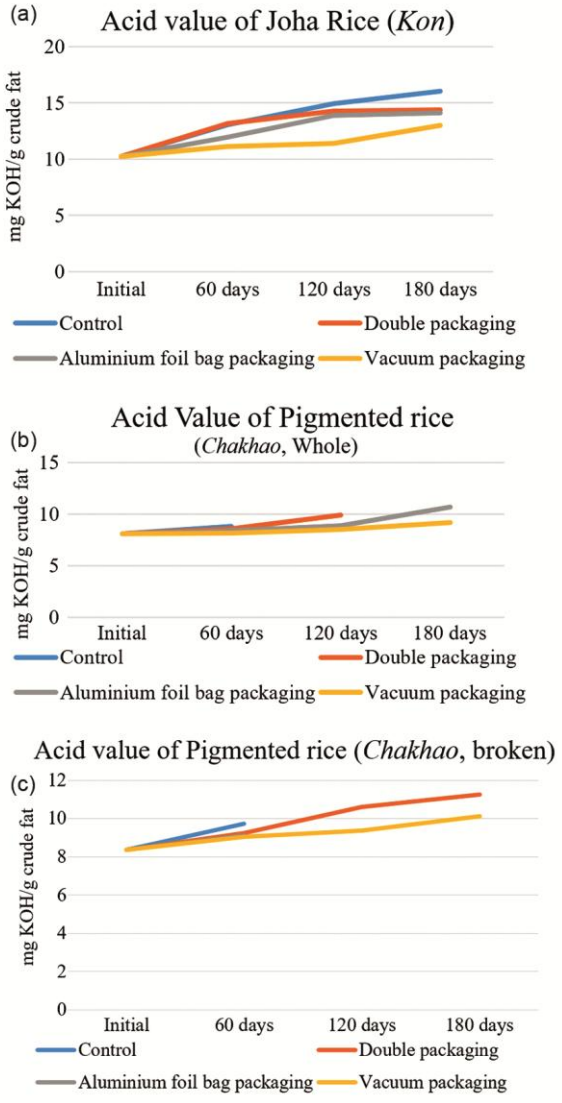

Fig. 2 — Acid value (mg KOH/g crude fat) of speciality rice at different time intervals of storage

The present investigation was found comparable to Zhou *et al*.[7]. Choi *et al*.[27] reported slight fluctuation of fatty acid value throughout the storage period. The brown rice samples at two months and four months storage ranged in 15.45 to 25.18 mg KOH/100 g and 22.70 to 35.86 mg KOH/100 g dry weight basis, respectively and the initial values ranged from 15.77 to 20.00 mg KOH/g dry weight basis. Chen *et al*.[28] reported that the fatty acid values of rice samples were 17.14 mg/100 g, which reached a maximum value of 57.44 mg/100 g at the end of the storage *i.e.*, 36th day. It was found that when the values reached a range of 35.0 mg/100 g, it was no longer suitable for storage.

However, the report on changes in acid value expressed as mg KOH/ g crude fat during storage of rice is limited.

Aroma intensity of "Joha" rice

The aroma intensity (Table 3) of "Joha" rice (variety: *Kon*) was found to be very strong (++++) during initial period and also for aluminium foil bag packaging (60 days after storage) and vacuum packaging (up to 120 days after storage), and detected to be low aroma (+) during 120 and 180 days after storage in control. It was found that the aroma of rice was best retained under vacuum packed condition followed by aluminium foil bag packaging.

The present investigation was found comparable to Priya *et al.*[6], who reported the aroma of 22 Joha rice varieties of Assam to range from very strong (++++) to slightly strong (++). Bharti *et al*.[29] carried out a work on aroma of rice of some aromatic rice varieties in eastern part of India and the aroma intensity ranged from very strong to average.

Table 3 — Aroma intensity of Joha rice (variety *Kon*) at different time intervals

Treatment	Days after storage			
	Initial	60 days	120 days	180 days
Control	++++	+++	+	+
Double Packaging	++++	+++	++	++
Aluminium bag Packaging	++++	++++	+++	+++
Vacuum Packaging	++++	++++	++++	+++

++++ : Very strong aroma, +++: strong aroma, ++:slightly strong aroma, +: low aroma, mm = millimeters, mins - minutes

Total phenol content

The total phenol content (Table 4 & Table 5) of pigmented rice (whole) and pigmented rice (broken) ranged from 2.033% to 2.737% (varied significantly at all the stages after storage) and 1.542% to 2.730% (varied non significantly), respectively. It was the highest during the initial storage which gradually decreased with the increasing storage period and in pigmented rice (whole) the lowest was observed after 180 days of storage in aluminium foil bag packaging whereas in pigmented rice (broken) the lowest was observed in double packaging at the same (180 days) stage after storage. The result of the present study was found to be comparable to the results of Tananuwong and Tangsrianugul[8]; Mudoi and Das[30] and Devi and Badwaik[31].

Total flavonoid content

The flavonoid content (Table 4 & Table 5) of pigmented rice (whole) and pigmented rice (broken) ranged from 1.584% to 2.420% (varied significantly at 60 and 120 days after storage) and 0.873% to 2.137% (varied significantly at all the stages), respectively. The total flavonoid content was the highest during the initial storage which gradually decreased with the increasing storage period and in pigmented rice (whole) the lowest was observed after 120 days after storage in double packaging whereas in pigmented rice (broken) the lowest was observed in vacuum packaging at 180 days.

The result of the present study was found to be comparable to the results of Devi and Badwaik[31] who reported the total flavonoid content in four pigmented (*Chakhao*) variety to be 0.47 to 6.12 mg quercetin equivalent/g.

Total anthocyanin content

The anthocyanin content (Table 5 & Table 6) of pigmented rice (whole) and pigmented rice (broken) ranged from 0.021% to 0.186% (varied significantly

Table 4 — Total phenol, flavonoid and anthocyanin contents (%, on dry weight basis) of pigmented rice (whole) (variety *Chakhao*)

Treatment	Total phenol content				Total flavonoid content				Total anthocyanin content			
	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days
Control	2.737	1.678	-	-	2.420	1.661	-	-	0.186	0.105	-	-
Double Packaging	2.737	2.204	2.121	-	2.420	1.940	1.584	-	0.186	0.117	0.050	-
Aluminium bag Packaging	2.737	2.605	2.106	2.033	2.420	2.269	1.703	1.637	0.186	0.162	0.077	0.021
Vacuum Packaging	2.737	2.636	2.443	2 .201	2.420	2.435	2.075	1.755	0.186	0.169	0.087	0.038
C. D (0.05)	-	0.406	0.226	0.093	-	0.292	0.233	NS	-	0.040	NS	NS
SE(d)	-	0.184	0.102	0.045	-	0.133	0.121	NS	-	0.018	NS	NS

NS = non-significant, C.D. (0.05) = critical difference at 0.05 significance level, SE (d) = standard error deviation

Table 5 — Total phenol, flavonoid and anthocyanin contents (%, on dry weight basis) of pigmented rice (broken) (variety *Chakhao*)

Treatment	Total phenol content				Total flavonoid content				Total anthocyanin content			
	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days	Initial	60 days	120 days	180 days
Control	2.730	2.129	-	-	2.137	1.871	-	-	0.212	0.104	-	-
Double Packaging	2.730	2.187	2.097	1.542	2.137	1.977	1.668	0.921	0.212	0.121	0.050	0.013
Aluminium bag Packaging	2.730	2.226	-	-	2.137	2.021	-	-	0.212	0.133	-	-
Vacuum Packaging	2.730	2.309	2.106	1.811	2.137	2.107	1.891	0.873	0.212	0.148	0.078	0.018
C.D (0.05)	-	NS	NS	NS	-	0.292	0.485	0.219	-	NS	NS	NS
SE(d)	-	NS	NS	NS	-	0.133	0.220	0.117	-	NS	NS	NS

NS = non-significant, C.D. (0.05) = critical difference at 0.05 significance level, SE (d) = standard error deviation

Table 6 — Morphological characters, cooking time and water absorption ratio of speciality rice before and after cooking after 180 days of storage

Rice varieties/form	Morphological character before cooking			Morphological character after cooking			Cooking time (minutes)	Water absorption ratio (%)
	Length (L, mm)	Breadth (B, mm)	L/B ratio	Length (L, mm)	Breadth (B, mm)	L/B ratio		
Pigmented rice(whole) (variety: *Chakhao*)	6 mm	2 mm	3:1	7 mm	3 mm	7:3	13.33 min	151.20
Pigmented rice(broken) (variety: *Chakhao*)	4 mm	2 mm	2:1	6 mm	2 mm	3:1	8.30 min	155.60
Joha rice (Variety: *Kon*)	4 mm	2 mm	2:1	5 mm	4 mm	5:4	10.00 min	201.78

mm = millimeters, mins - minutes

60 days after storage) and 0.013% to 0.212% (varied non significantly), respectively. The total anthocyanin content was the highest during the initial storage which gradually decreased with the increasing storage period and in pigmented rice (whole) the lowest was observed at 180 days after storage in aluminium foil bag packaging whereas, in pigmented rice (broken) the lowest was observed in double packaging at 180 days after storage. However, the decrease in phenolic compound in pigmented rice (broken) at 180 days was higher than that of pigmented rice (whole). Sahewalla[32] reported a range of 1.15 to 21.66 mg cyanidin-3-chloride equivalent anthocyanin content per 100 g in few pigmented rice varieties of Assam. Devi and Badwaik[31] reported the total anthocyanin content in four pigmented (*Chakhao*) variety to be 0.17 mg to 4.56 mg cyanidin-3 glucoside per g.

Pest infestation during storage

Infestation of pest identified to be *Sitophilus oryzae* was seen in "Joha" rice after 180 days whereas in pigmented rice (whole) it was observed first after 60 days in polythene bag packaging (control) and in pigmented rice (broken) it was observed at the same stage (after 60 days) in polythene bag packaging (control) and aluminium foil bag packaging. However, rice weevil, *Sitophilus oryzae* is reported as primary storage pest of rice.

Identification of fungal and bacterial growth

As localized microbial growth was seen in some of the replications, it was later confirmed to be bacterial growth which was seen mostly in the polythene bag packaging (control) and aluminium foil bag packaging. The bacterial growth was observed to be the most in pigmented rice (broken) with 4.2×10^7 cfu/g infected sample, whereas in pigmented rice (whole) it was observed to be 4.6×10^6 cfu/g infected sample and in “Joha” rice it was 6×10^5 cfu/g infected sample. Though, there was hardly any contamination in "Joha" rice during storage which might be due to absence of bran, in one of the replications of control, bacterial growth was detected (6×10^5 cfu/g infected sample). The higher moisture content detected for pigmented rice (whole) during storage (both at 120 and 180 days for control and at 180 days for double packaging) might be the reason for observed bacterial growth. Similarly, higher moisture content together with broken surface might lead to bacterial contamination of pigmented rice (broken) at 120 and 180 days after storage for control and aluminium foil bag packaging. However, the vacuum packing showed no bacterial population as well as pest infestation because of its impervious nature, which acts as barrier to moisture content. Naik *et al*.[33] carried out a work on storage of rice/paddy and revealed that vacuum bags showed lower fungal population while gunny bags showed higher fungal growth during 18 months.

Morphological characters, cooking time and water absorption ratio of speciality rice before and after cooking

The morphological characters, cooking time and water absorption ratio (Table 6) of speciality rice are presented in Table 6. The length and breadth of “Joha” rice (variety: *Kon*), pigmented rice (variety: *Chakhao*) both whole and broken, were observed to be increased in size after cooking (3:1 to 7:3 for pigmented rice (whole), 2:1 to 3:1 for pigmented rice (broken) and 2:1 to 5:4 for "Joha" rice). The cooking time was the highest (13.33 min) for pigmented rice (whole) where as for pigmented rice (broken) and “Joha” rice, the same were found to be 8.30 min and 10 min, respectively. Water absorption was the highest in “Joha” rice with 201.78%, followed by pigmented rice which was 155.60% (broken) and 151.20% (whole), respectively. It was found that the pigmented rice (broken) showed less cooking time as compared to the pigmented rice (whole) which might be due to exposure of higher surface area available for entry of water during cooking.

The present investigation was found comparable to Yadav *et al*.[34] regarding cooking time and water uptake; Das *et al.*[35] and Devi and Badwaik[31] regarding L: B ratio and Tiwari *et al*.[36] regarding cooking qualities. It was reported that although brown rice took more time for cooking but water uptake ratio was the higher in polished rice due to presence of oil in bran in brown rice, which acted as barrier for water[36].

Conclusion

The present study indicated that among all the different packaging materials used, the vacuum packaging was found to be the best method of packaging for both the rice varieties. Retention of aroma was the maximum (very strong, ++++) in vacuum packaged condition at 120 days of storage and strong (+++) for both vacuum packaged and aluminium foil bag packaged condition at 180 days of storage. Pigmented rice contains higher content of total phenol, total flavonoid and total anthocyanin during the initial period and was seen to be decreasing

with the storage period. Among all, pigmented rice (broken) showed higher bacterial growth and the least was detected in "Joha" rice variety, whereas no fungal growth was detected. The vacuum packing showed no bacterial population as well as pest infestation because of its impervious nature, which acts as barrier to moisture content. Due to bacterial growth, the storage cannot be continued for pigmented rice (whole) for control (after 60 days of storage) and for double packaging (after 120 days of storage). For the same reason, the storage cannot be continued for pigmented rice (broken), after 60 days for both control and aluminium foil bag packaging. As the loss of phenolic compound in broken rice was higher than that of whole form of pigmented rice during storage, it can be suggested that pigmented rice may be broken just before cooking which may be helpful to lower the cooking time in comparison to pigmented rice (whole).

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Conflict of Interest

There is no conflict of interest among the authors.

Author Contributions

Conducting research: PB; Manuscript writing: PB, DLA, PD; Conceptualization of research: PD; Technical advice: TN, MSB.

Ethics Statement

The study does not involve any ethical issue.

Data Availability

All data generated during this study are included in this paper.

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