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Effect of storage on the physicochemical properties of rice starch and the cooking quality of rice grain

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Summary

Twelve different varieties of rice including two flavorful varieties grown in the State of Maharashtra (India) have been studied with respect to the effect of storage, at ambient conditions, for 180 days on the physicochemical properties of the starch component as well as cooking quality.

Zusammenfassung

12 verschiedene Sorten von Reis aus Indien wurden im Hinblick auf die Auswirkung einer Lagerung bei verschiedenen Umgebungsbedingungen für die Dauer von 180 Tagen auf physikalisch-chemische Eigenschaften des Stärkeanteils und auf die notwendigen Garzeiten sowie die beim Garen eintretenden Verluste an Trokkensubstanz bzw. die Wasseraufnahme untersucht. Die Viskosität der Stärke nahm bei allen Reissorten während der Lagerung zu. Bezüglich der Garungszeiten waren keine größeren Unterschiede zwischen den Sorten zu beobachten, während die Wasseraufnahmen sehr unterschiedlich sein konnten.

Key words: rice starch, cooking quality, physicochemical properties, storage

Introduction

Rice is generally considered to be a tropical crop. It is the principal cereal food in Asia and in some countries in Africa and Latin America (1, 2). In many Asian countries, the average individual gets half or more of his total calorie intake from rice (1). India is one of the largest rice-growing countries in the world. Nearly a third of the cultivated area in India belongs to rice, and three-quarters of the people in this country subsist on it.

The importance of the storage of rice with optimal retention of the nutritional and organoleptic characteristics does not need any emphasis, particularly in the context of the present global food crisis. There are two aspects of storage changes in rice: (a) the chemical and bio-chemical changes under different storage conditions; (b) the changes brought about by micro-organisms, insects and pests. The chemical and bio-chemical processes govern the changes of rice on aging which in turn modify its cooking, eating and nutritional properties and thus ultimately influence

its commercial value. The cooking behaviour of rice is greatly affected by its age after harvest (1, 3). Milled rice obtained from freshly harvested paddy is less suitable both for processing and culinary utilization whereas adequate aging or storage brings about desirable properties for these purposes (4–7).

The tendency of rice kernels to stick together and disintegrate is appreciably reduced on storage for a few weeks (8–10). Storage of rice also results in improved culinary properties such as drier surface, less solids lost in the cooking fluid, larger volume and firmer texture of cooked kernels (4–7). Curing of rice causes similar changes (11–14). Barber et al. (15, 16) have also reported the organoleptic characteristics of milled and undermilled rice samples on storage under a wide range of conditions.

The swelling capacity of old rice is more than that of new rice (10, 17, 18). The freshly harvested and milled rice loses more solids in the cooking water than stored rice (4, 6, 19–21). Cooking quality and digestibility improve on storage (10). Although the starch content remains practically constant, its physicochemical characteristics undergo significant changes during storage (21, 22). Affinity for iodine and limiting viscosity increase with time. Reducing sugars increase and non-reducing sugars decrease on storage (10, 23–26). The amylase activities have also been reported to decrease on storage (10, 17, 27).

Stored rice has improved water absorption capacity during cooking and is more resistant to breakage during milling (28–30). The tensile strength of the grain also increases during storage (31).

The are many reports on the composition and cooking quality of several Indian rice varieties (32–35). No information has been provided in the literature on changes in the cooking quality and physicochemical properties of main rice constituent, i.e. starch, during aging. It is with these views in mind that the present work on studies on quality changes in rice varieties due to storage was carried out.

Materials and methods

For these studies, paddy samples of twelve selected varieties collected from the Rice Research Station, Konkan Krishi Vidyapeeth, Karjat, were subjected to storage, at room temperature, in loosely tied gunny bags, for a period of six months. These varieties were selected on the basis of preliminary examination of their proximate composition. At various intervals of storage, the following determinations were made:

(1) Effect of storage on gelatinization temperature of starch was determined at regular intervals of four weeks on samples of rice varieties by the method of MacMasters (36).

(2) Effect of storage on viscosity of starch was determined by using 5 % starch suspensions prepared from starch isolated at regular intervals, employing the Brookfield Synchro-lectric viscometer (RVT Model). Viscosity of the starch suspensions at 60 °C when the gelatinization of the starch granules just begins and at 90 °C when starch granules are completely gelatinized was determined.

(3) Changes in the cooking quality were also determined on the basis of parameters such as volume expansion or the swelling index of the cooked grains, water uptake on cooking and increase in the length and breadth of rice kernel and loss of solids in cooking medium.

Table 1. Changes of viscosity* of rice starch during storage of rice.

No.	Name of variety	Freshly harvested		After 45 days		After 90 days		After 120 days		After 180 days	
		(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
1.	Taichung native	300	250	384	302	476	378	482	362	474	360
2.	Karjat-184	306	226	402	248	486	312	480	306	484	302
3.	IR-8	1084	848	1242	962	1462	1046	1446	1100	1458	1096
4.	Ratnagiri-24	474	362	562	404	746	562	796	586	788	592
5.	Pusa-2-21	686	468	742	502	806	582	812	576	808	568
6.	Karjat-7-3-A	346	160	452	182	564	204	556	192	562	198
7.	Jaya	284	226	462	312	582	362	568	358	580	346
8.	Pankaj	646	562	862	642	968	722	942	708	958	714
9.	Karjat-7-3-11-2	356	246	482	302	516	342	506	328	502	332
10.	Basmati-257	840	682	972	732	1020	842	1018	818	1006	822
11.	Ambemohor	726	544	864	676	932	718	908	702	922	718
12.	Pusa-33	882	726	946	748	1032	882	1022	868	1008	872

* Viscosity in cps determined at (A) 60 °C and (B) 90 °C. Results average of three readings.

Table 2. Gelatinization temperatures* of rice starch during storage of rice.

No.	Name of variety	Freshly harvested	45 days	90 days	120 days	180 days
1.	Taichung native	67–85 °C	68–83 °C	68–83 °C	67–80 °C	67–82 °C
2.	Karjat-184	68–82 °C	69–80 °C	70–80 °C	69–82 °C	70–82 °C
3.	IR-8	70–81 °C	72–81 °C	69–82 °C	68–79 °C	71–82 °C
4.	Ratnagiri-24	69–85 °C	69–80 °C	72–85 °C	70–84 °C	71–84 °C
5.	Pusa-2-21	72–84 °C	71–84 °C	70–84 °C	72–82 °C	71–83 °C
6.	Karjat-7-3-A	71–84 °C	70–83 °C	71–85 °C	70–84 °C	73–85 °C
7.	Jaya	68–84 °C	66–80 °C	68–82 °C	67–81 °C	66–80 °C
8.	Pankaj	76–82 °C	78–81 °C	77–84 °C	76–84 °C	76–85 °C
9.	Karjat-7-3-11-2	75–85 °C	76–84 °C	76–84 °C	75–84 °C	76–84 °C
10.	Basmati-257	71.5–80 °C	74–86 °C	71–84 °C	72–84 °C	71–85 °C
11.	Ambemohor	73–85 °C	72–84 °C	71–80 °C	71–84 °C	72–82 °C
12.	Pusa-33	70–84 °C	71–80 °C	72–82 °C	70–83 °C	71–81 °C

* Results average of three determinations.

Results and discussion

The changes in the physicochemical properties of the isolated starches from these varieties are listed in table 1 and table 2. It was found that the viscosity values was observed for any of the varieties stored beyond four months. Also, as demonstrated in table 1, in all the varieties, viscosities of 5 % starch suspensions determined at 60 °C were always greater than those at 90 °C suggesting that for maximum thickening effect, rice pastes should be used below 90 °C which is beyond the limit of gelatinization temperature of rice starch as is indicated in table 2. Of all the varieties, freshly harvested Jaya had the lowest value of viscosity (at 60 °C), which was found to almost double by the end of storage for 120 days. In Taichung (native) the increase was about 1.5 fold during 120 days. In Ambemohor and Basmati-257, over 120 days of storage, the viscosity at 60 °C improved by almost 1.25 folds. IR-8 had the highest initial viscosity (at 60 °C) of 1084 which increased by about 1.4 folds at the end of only 90 days of storage. The changes in viscosity of the various varieties observed here are difficult to explain exclusively on the basis of starch or amylose content of the variety as no such generalisations could be made from the present observations in this respect. It is true that the changes are influenced by varietal differences in the grains, but the probable changes in the crystalline structure of starch components as examined by X-ray diffraction patterns (37) during storage may also be responsible.

Changes in the gelatinization temperature ranges are reported in table 2. It is concluded that storage of rice has no effect on the gelatinization temperature range of starch granules as is also observed in case of other varieties of rice (4).

Changes in the cooking quality of rice during storage studied with respect to cooking time, increase in length/breadth ratio on cooking, water uptake and loss of solids in cooked medium during cooking are shown in tables 3 and 4. As observed in table 3, the time taken for all the rice varieties to cook increased gradually during the storage period. Fine

Table 3. Effect of storage on the time taken for cooking and increase in length/ breadth of cooked grains*.

No.	Name of variety	Time taken for cooking (min)					Ratio of increase in length to breadth on cooking**				
		(A)	(B)	(C)	(D)	(E)	(A)	(B)	(C)	(D)	(E)
1.	Taichung native	18	18	19	20	20	2.00	2.50	2.66	2.80	2.80
2.	Karjat-184	18	18	19	20	20	2.00	3.00	3.00	3.80	3.80
3.	IR-8	16	16	16	17	19	2.00	2.00	3.00	4.00	4.00
4.	Ratnagiri-24	19	19	20	22	22	2.66	3.00	3.07	3.20	3.20
5.	Pusa-2-21	20	22	23	23	24	3.00	3.20	3.25	3.50	3.50
6.	Karjat-7-3-A	20	20	21	22	24	2.00	2.20	2.30	2.50	3.00
7.	Jaya	17	17	19	20	21	2.00	2.00	2.60	3.40	3.40
8.	Pankaj	18	18	18	22	22	1.66	2.00	2.00	2.25	2.50
9.	Karjat-7-3-11-2	19	19	20	22	23	2.00	2.00	2.50	2.70	3.00
10.	Basmati-257	20	22	22	23	24	2.00	3.20	3.33	3.90	4.20
11.	Ambemohor	20	22	21	23	24	2.00	2.00	2.50	2.60	2.60
12.	Pusa-33	19	19	21	22	23	2.00	2.00	2.20	2.50	2.50

A = Freshly harvested rice, B = Stored for 45 days, C = Stored for 90 days, D = Stored for 120 days, and E = Stored for 180 days.
* Results mean of three determinations, ** Average of ten grains per determination.

varieties like Ambemohor and Basmati-257 took a relatively longer time to cook than the other varieties. IR-8 required the least time of 16 min. Certain coarse varieties like Jaya, Pankaj and Taichung Native cooked within 18–19 min which could be responsible for their pasty texture

Table 4. Effect of storage on the water uptake by cooked grains and loss of solids in cooking water*.

No.	Name of variety	Water uptake (g/100 g of rice)					Loss of solids (g/100 g rice)				
		(A)	(B)	(C)	(D)	(E)	(A)	(B)	(C)	(D)	(E)
1.	Taichung native	211	215	222	247	250	6.9	6.6	6.7	6.6	6.5
2.	Karjat-184	176.9	185	192	202	217	7.2	7.0	7.1	6.6	6.2
3.	IR-8	272.6	302	322	341	352	8.2	8.0	8.1	7.6	7.4
4.	Ratnagiri-24	207.4	217	221	242	245	6.7	6.7	6.6	6.4	6.0
5.	Pusa-2-21	251.9	258	269	285	302	7.1	7.0	6.6	6.2	6.0
6.	Karjat-7-3-A	230.4	244	258	265	282	6.0	6.0	5.8	5.6	5.6
7.	Jaya	238.8	245	259	286	298	7.2	7.0	7.0	6.8	6.8
8.	Pankaj	259.9	271	282	291	302	7.0	7.0	6.8	6.7	6.6
9.	Karjat-7-3-11-2	266.0	282	298	304	322	6.8	6.8	6.4	6.2	6.0
10.	Basmati-257	298.8	312	328	342	356	6.4	6.2	6.0	6.0	5.6
11.	Ambemohor	282.0	298	312	324	346	6.8	6.4	6.0	5.6	5.6
12.	Pusa-33	268.4	296	322	344	352	6.6	6.6	6.2	6.0	5.6

A = Freshly harvested rice, B = Stored for 45 days, C = Stored for 90 days, D = Stored for 120 days, and E = Stored for 180 days.
* Results average of three determinations.

attained on cooking. In all the cases, within 90 to 120 days, maximum values were reached in this respect. The effect was probably due to toughening of the grain during aging, which may influence the swelling behaviour and cooking time in turn. There was also a gradual increase in length/breadth ratio of the cooked rice grains during aging. Over a period of 120 days, the ratio of increase in length to increase in breadth of the cooked grains, increased in the range of 20 % to 110 %, the maximum being in the case of Basmati-257, followed by IR-8 where an increase of 110 % was observed.

In table 4 observations on the water uptake by cooked grains and loss of solids in the cooked medium during storage are included. It is clear that in almost all the rice varieties, the loss of water solubles decreased as the aging period increased. Over a period of four months, the loss of solids ranged between 94.45 % to 82.35 % with respect to the values at the beginning of storage taken as 100 %. Observations on other varieties have also indicated aging to result in decrease in water solubles, the loss being of the order of 40 % to 70 % over a period of eight months (4). This may probably be due to the hardening of the grain with decreased capacity to leach out the starch and also a decrease in the water solubles, such as reducing sugars or others, as aging proceeds, which may be due to the corresponding changes in activity of enzymes like amylase during storage (27).

Also, associated with aging, an increased uptake of water by the rice grains was observed. In this respect, of all the varieties, Basmati-257 had the highest water uptake value of 356 g per 100 g of rice followed by Pusa-33 and IR-8 rice varieties with 352 g per 100 g of rice. The water uptake values increased by about 18 % to 25 % in the different varieties during 120 days of storage. They were found to increase continuously even at the end of four months of storage as against other parameters, which seem to reach a maximum around 90 to 120 days of storage.

The water uptake depends upon the ability of the grain to absorb water and hold it which in turn depends upon the nature of the starch granule and the gross structure of the grain.

The foregoing observations indicate that there was no positive correlation between the amylose content (38a) and the changes in cooking quality of rice during storage. Decrease in the activity of α-amylase during storage, perhaps, may be the contributory factor for the improvement in the cooking quality of rice. It appears that the changes in the crystallinity of starch during aging results in cooked kernels which have drier surface, larger volume, less cohesive character and firm texture (4, 6, 7, 38b). It is also observed that the water uptake by the cooked kernels improves on aging together with an increase in the viscosity which seems to be the consequence of a decrease in the loss of solids in the cooking water. The reduction of the loss of solids, mainly starch, in the cooking water may be due to the improvement of the granular nature of starch, and also decreased levels of amylase, leading to the formation of lesser amounts of soluble solids like reducing sugars.

All the foregoing observations indicate that the storage changes are rapid in the first three months which seems to be the optimum period to bring about improvement in the culinary properties of rice.

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