Storage of Rice. X.

Studies on Four Lots of Unhulled Rice Stored Forty-six to Eighty-four Years in Granaries.

By

Mantarō Kondō and Tamotsu Okamura.

[December 10, 1933.]

Introduction.

In an earlier paper[2], the authors reported the results of their studies on hulled rice stored air-tight 26 and 28 years. Recently they had an opportunity to continue the work, employing four lots of unhulled rice which had been stored respectively 46, 49, 62 and 84 years in granaries in anticipation of a bad harvest. It is believed that a comparison of the results obtained on these four lots with those previously reported is of special interest, since the rice was not hulled and was stored without hermetical sealing, whereas in the earlier investigation the rice was hulled and stored in air-tight containers. The investigation extended from November 1932 to March 1933.

I. Method of Storage.

Three of the lots of rice were stored in a granary of the Kanonko Association at Akita and the other one was stored in a large wooden vessel in a granary by a landlord named Katsumada.

The Kanonko granaries, erected at Bunsei 11th year, 1828, were of rational construction. The inside was always kept dry and cool, furthermore mice, insects, and other vermin, as well as moulds, were held in check. Before storage, the rice was thoroughly cleaned and dried. The rice was unhulled and the quantities stored were large. In general the results on these three lots may be regarded as illustrative of the quality of an unhulled rice stored under especially favorable conditions, although not taking advantage of further drying and storage in air-tight containers.

The lot stored by Katsumada in a large wooden container in a granary had not been given such careful attention as the three other lots. The storage was what is usual for unhulled rice, except that it was continued for a particularly long time. This lot was damaged somewhat by insects and mice.

II. General Quality of Rice.

At the outstart the authors studied the general quality of the unhulled rice, as well as the corresponding hulled rice.

The unhulled rice, 62 years old, had become medium or dark brown and its hulled kernels were moderately brown and lusterless, that 49 and 46 years old was moderately brown and its hulled kernels were light brown but had a luster. All three lots contained rice with red and green kernels and none showed damage by insects.

From the above stated facts, it may be seen that if unhulled rice be thoroughly cleaned and dried it may be stored in a well constructed granary, like that of the Kanonko Association, 50 to 60 years without damage by insects and with fair retention of its general quality, although the hulled kernels will become slightly brown and lose their luster.

The other lot of unhulled rice, which was stored by Katsumada 84 years, was dark brown and the hulled kernels were light brown, lusterless, and looked like glutinous rice. It contained plenty of red kernels. The rice had not been so well cleaned as the Kanonko lots and was damaged by mice and insects during the time of storage.

III. Physical Properties of Hulled Rice.

The four lots of unhulled rice stored by the Kanonko Association and Katsumada were hulled and the physical properties of the kernels studied. The results are given in Table 1.

(See Table 1 on next page.)

The moisture content of the hulled Kanonko rice was 14.4—15.2% and therefore fairly high, but, owing to the short summer in Akita, where the Kanonko granaries are located, there was little deterioration during the long storage. In a warmer locality it would have been necessary to dry the rice more thoroughly.

The Katsumada rice had a moisture content of 15.1% and the climate of the locality where it was stored is warm, consequently the unhulled rice was mouldy on the surface of the chaff and the hulled rice had changed in colour, lost its luster, and taken on the appearance of glutinous rice.

The rice of all the lots was of the small- and light-grained class, also the volume-weight was more or less low, but the hardness was normal or more or less high. Red kernels were particularly numerous in the Katsumada rice. This admixture of red kernels shows that the rice harvested 60 to 80 years ago, was not bred as it is today. Green kernels occurred in the Kanonko rice, showing that the unhulled grain had been stored in a relatively good condition.

Table 1.

Physical Properties of Hulled Rice.

Properties		Katsumada rice, 84 years old	Kanonko rice		
			62 years old	49 years old	46 years old
Moisture content	unhulled rice, %	14.63	14.85	14.50	14.0
	hulled rice, %	15.10	15.20	14.75	14.4
Size of hulled rice	length, mm.	5.05±0.02	5.11±0.01	5.02±0.02	5.12±0.02
	width, mm.	3.06±0.01	3.13±0.01	2.98±0.01	3.06±0.01
	thickness, mm.	2.19±0.01	2.17±0.01	2.07±0.01	2.11±0.01
	length×width×thickness, c.mm.	33.83	34.78	30.92	33.04
Weight of 1,000 grains	unhulled rice, g. ...	25.170	27.807	25.376	25.416
	hulled rice, g. ...	20.622	22.806	20.717	21.375
Weight of one hectoliter	unhulled rice, kg.	54.31	59.43	58.26	57.59
	hulled rice, kg. ...	82.35	83.76	80.49	80.05
Specific gravity	unhulled rice	1.1767	1.2462	1.2551	1.2555
	hulled rice	1.3659	1.3805	1.4172	1.4076
Hardness of hulled rice, resistance to	breaking, kg.	6.155	5.887	6.612	7.148
	crushing, kg.	7.864	7.742	7.467	8.180
Percentage of red kernels		6.0	0.8	0.1	0.4
Percentage of green kernels		0	4.8	13.1	16.0
Water absorbing capacity of grains, %		25.4	20.7	20.0	21.2
Swelling capacity of grains, %		28.0	27.3	27.8	27.9
Polishing loss, %		12.3	7.6	5.6	5.9
Time required for polishing, minutes		90	60	12	10
Kamabue, %		118.9	118.9	123.5	120.6
Viscosity of rice-paste		1.335	1.333	1.345	1.493
Percentage of hulled in unhulled rice	by weight, %	80.0	81.3	81.3	80.9
	by volume, %	53.0	59.0	60.0	59.0

Note: 1) Water absorbing and swelling capacity was determined after soaking the rice in water at 25—28°C. for 48 hours.

2) Viscosity of 5% rice-paste was determined at 40°C., the viscosity of water being 1.

3) "Kamabue" is the percentage of increase in volume of boiled rice compared to original volume of white rice.

The water absorbing capacity and swelling capacity of the stored rice were very low. In only one lot did the water absorbing capacity exceed 21% and in none of the lots did the swelling capacity exceed 28%, whereas in new Shinriki rice, for instance, the water absorbing capacity is usually 32.7% and the swelling capacity 45%.

The polishing loss of the old Kanonko rice was generally more or less small, because of the great hardness of the kernels, but that of the Katsumada rice was very large, since the quality was bad. In addition, the time required for polishing was longer than usual.

The "Kamabue" of the old rice was nearly equal to that of the new rice, which is usually 120%.

The viscosity of the rice-paste of the old rice was 1.3—1.5. These values are less than that of new rice which is usually 1.7.

IV. Analyses of Rice.

Comparative analyses were made of the old rice under investigation and the rice of the crop of 1932. The results are given in Table 2.

Table 2.

Composition of Rice.

Composition / Lot of rice	In the dry substance				
	Ash	Crude fiber	Crude fat	Crude protein	Starch
	%	%	%	%	%
Katsumada rice, 84 years old	1.506	1.600	0.469	10.146	86.944
Kanonko rice, 62 years old	1.529	1.221	1.989	9.066	85.030
Kanonko rice, 49 years old	1.461	1.316	2.112	8.592	85.806
Kanonko rice, 46 years old	1.445	1.144	2.294	8.519	84.270
New rice of 1932	1.324	1.215	2.884	8.683	83.847

According to Table 2, fat had decreased in the old rice in a great degree, but the other constituents had not decreased at all.

Supplementing the figures in Table 2, the percentages of glucose and dextrin were determined with the following results:

(See Table 3 on next page.)

Table 3 shows some decrement of glucose in the old Kanonko rice, but the decrement of dextrin was uncertain. The Katsumada rice contained high percentages of glucose and dextrin, caused perhaps by the presence of the moulds on the surface of the grain.

Table 3.

Glucose and Dextrin in Rice.

Lot of rice / Constituents	Katsumada rice, 84 years old	Kanonko rice			New rice of 1932
		62 years old	49 years old	46 years old	
	%	%	%	%	%
Glucose	2.39	0.69	0.54	0.43	0.88
Dextrin	3.70	2.46	1.63	1.42	2.52

V. pH Value of Rice.

Following is the method employed: To 50 cc. of distilled water were added 10 g. of rice powder and the mixture was kept one hour at 25°C. After filtering, the pH value was determined by the quinhydrone electrode. A table with the results follows:

Katsumada rice	Kanonko rice			New rice of 1932
	62 years old	49 years old	46 years old	
pH.....7.22	6.79	6.79	6.79	7.67

The above results show that the new rice was faintly alkaline, but that the three lots of the old Kanonko rice were faintly acid. In a preceding paper[3], the authors reported that if the moisture content is high, will become faintly acid during the time of storage. It would be expected that the formation of acidity is correlated in some degree with changes in quality. It cannot be explained why the Katsumada rice was not acid, having the pH value of 7.22.

VI. Enzymes.

The authors determined the activity values for peroxidase, catalase, urease, reductase, lipase, and diastase in the four lots of old rice and made a comparison with those of the new rice of 1932. The activity values for these enzymes in the new rice were set at 1 and those in the old rice were compared with them. The results are as follows:

(See Table 4 on next page.)

The above table brings out the following facts:

In the old unhulled rice, peroxidase was lost entirely or else remained only in small amount. Its presence depends upon the quality of rice as well as the condition of storage.

Table 4.

Comparison of Activities of Several Kinds of Enzymes in Old and New Rice.

Lot of rice		Peroxidase	Catalase	Urease	Reductase	Lipase	Diastase
Katsumada rice, 84 years old		0.5	0.30	0.58	0.2	0.99	3.28
Kanonko rice	62 years old	0.5	0.13	0.83	0.2	0.83	0.57
	49 years old	0	0.01	0	0.13	0.99	0.33
	46 years old	0	0.01	0	0.1	0.95	0.55
New rice of 1932		1	1	1	1	1	1

The catalase in the 46 and 49 years old Kanonko rice was nearly lost, but in the Katsumada and the 62 years old Kanonko rice it was present in somewhat higher amount due to moulds growing on the grains. In general it may be said that a decrement of catalase shows that the rice is old, but not that aging always causes a regular decrement.

In the 49 and 46 years old rice, the urease was entirely lost, but in the 62 years old rice, as well as in the Katsumada lot, the larger part remained. The case is similar to that of catalase.

Reductase remained only in small amount in all the lots of old rice.

The lipase activity of the old rice was nearly equal to that of the new.

The diastase activity of the Kanonko rice decreased to half of that of the new rice, but in the case of the Katsumada rice it increased three fold. This increase doubtless was caused by the moulds on the surface of the grains.

Summarizing the facts, it may be said that, with the exception of lipase, the activity of the several kinds of enzymes in the old rice was reduced in a great degree; peroxidase, catalase, and urease were entirely or almost entirely lost and diastase and reductase remained only in small amount, but lipase was present in amount equal to that of new rice.

It is noticeable that in the case of the Katsumada rice, as well as of the 62 years old Kanonko rice, the enzymes, particularly diastase, were present in much larger amount than in the other lots. This must be due to moulds.

VII. Vitamin-B.

The authors were particularly interested in studying the vitamin-B retention in the lots of unhulled rice which had been stored for many years. In February and March, 1933, the content of vitamin-B in the four lots was determined. White Leghorn fowls served as experimental animals, a set of four fowls having been used for each lot. For comparison, the rice of the 1932 crop, just two months after harvest, was also fed to fowls. In all the experiments 50% of the

powdered rice under investigation was mixed with 50% of the powdered clean polished rice. The latent period of beri-beri illness, living period of the fowls during the experiment, and daily body weight of the fowls were recorded. Employing the formula of OGATA[2] and MOARI, the comparative values of vitamin-B in the five lots of rice were calculated, on the basis of 100 for the content of vitamin-B in the rice of 1932. The latent period of illness, the living period of the fowls, and the comparative vitamin-B content are summarized in Table 5.

Table 5.

Results of Feeding Experiment with Fowls.

Lot of rice	50% of rice in question added		
	Latent period of illness	Duration of life	Comparative of vitamin-B content
White rice only	4.8 days	6.8 days	0
Katsumada rice, 84 years old	5.0 „	6.8 „	6.6
Kanonko rice, 62 years old	5.0 „	7.0 „	6.6
Kanonko rice, 49 years old	5.0 „	7.8 „	6.6
Kanonko rice, 46 years old	5.3 „	8.0 „	14.8
New rice of 1932	12.3 „	15.8 „	100

According to Table 5, the old rice under investigation had largely lost its vitamin-B, only 7—15% having been retained.

In their earlier paper, the authors[2] reported that, in the hulled rice stored air-tight 26 years, the vitamin-B content was 54.1% of that of new rice and, in the rice stored 28 years, it was 83.8%. The great difference between the vitamin-B content of the unhulled rice of the present investigation and that of the hulled rice of the former investigation must be due primarity to the different methods of storage and secondly to the different duration of storage. The rice in the former study was stored air-tight, but that in the present study was not so stored.

VIII. Germinating Power.

Examination of the four lots of unhulled rice showed that the germinating power had been entirely lost.

IX. Quality of Boiled Rice.

As tests of quality, the authors determined the taste, smell, viscosity, and colour of the boiled rice prepared from the lots in question after hulling and polishing.

The boiled rice prepared from the lot of Katsumada rice 84 years old was light brown with dark brown embryos, disagreeable in odour, rough on the tongue, and less viscous than that from fresh rice; nevertheless, it could be eaten in times of a short harvest.

The experimental portions of boiled rice made from the Kanonko and Katsumada lots were of similar quality. Those made from the three lots 46—62 years old were light brown, with dark brown embryos, disagreeable in odour, rough on the tongue, and deficient in viscosity; nevertheless, the rice would be edible in time of need.

In general, the quality of the boiled rice showed much deterioration during the many years of storage, but it was not so bad as expected; it would have been much better if the rice had been dried and stored air-tight, as the authors have so often asserted.

X. Discussion.

How long can unhulled rice be safely stored? This is a very interesting problem. The results of the study reported in this paper show that the unhulled Kanonko rice during the 46 to 62 years of storage deteriorated greatly, nevertheless, it would serve as a nutritious food in times of dire need. The unhulled Katsumada rice stored 84 years resembled that of Kanonko. In both these cases the chaff was light brown, dark brown or blackish brown, and more or less mouldy and the hulled rice was light brown and lusterless. The red rice became black. Owing to the great hardness of the kernels, a long time was required for polishing. After the polishing process, the rice was not white, but faintly brown. The unhulled Kanonko rice was preserved without appreciable loss, because it was protected from insects and other vermin, owing to the excellent construction of the granaries. It cannot be said, that the glumes always furnish a perfect protection against insects, because the unhulled Katsumada rice gave evidence of insect damage.

The moisture content of the unhulled rice stored by the Kanonko Association was 14.0 to 14.9%. Although the rice had not been thoroughly dried, it was fairly well preserved because the granaries are situated in the north where the duration of the hot summer is short. The unhulled Katsumada rice contained 14.6% of moisture, that is, about the same as the other lots, but the granary is situated in the south and as a consequence the deterioration was greater. As regards the percentage of moisture in unhulled rice suitable for safe storage for a long time, the authors are of the opinion that the drying must be carried out to a moisture content of 12%, furthermore, the grain must be stored in a well constructed granary.

Results obtained by KONDO[1] show that the water absorbing capacity and swelling capacity of hulled rice stored in straw bags decrease regularly with the length of storage. The present report on the old unhulled rice shows that

these values decreased in like manner and that much deterioration took place.

The hardness of the unhulled rice was greater than that of a new rice, nevertheless, the polishing loss was large, owing to the brown colour which necessitated long treatment.

One of the chief purposes of the investigation was to learn what change in the chemical composition had occurred during the time of storage. The analyses show that the fat as well as the sugar decreased in a great degree during storage, but that the protein, starch, fiber, and ash did not decrease. The pH value of the water extract of the old rice decreased and the solution was faintly acid. Peroxidase, catalase, urease, reductase, and diastase disappeared largely or entirely; lipase, however, was an exception since it remained practically the same as in new rice. Vitamin-B was lost to a great degree, since only 7—15% of the full amount was preserved. It thus appears that the unhulled rice stored 60 to 80 years had undergone marked changes in chemical composition. If such rice be used as food, the deficiencies in the nutrients must be compensated for by the addition of soy beans, fresh vegetables, and oily foods to the diet, as already proposed by Saeki.

It is noteworthy that, when the grains were mouldy, the enzymes were present in unexpectedly large amount; for instance, the unhulled Katsumada rice and the 62 years old Kanonko rice contained catalase, peroxidase, urease and diastase, as well as glucose and dextrin, in considerable amounts, which in some cases equalled to that in new rice.

The unhulled rice had lost its germinating power completely. This was expected since the rice was not thoroughly dried and not stored air-tight. If unhulled rice be dried thoroughly, for example to a moisture content of 12%, and stored air-tight in a cool place, it may be possible to retain the germinating power for a long time.

Is the 60 to 80 years old rice still edible? This is a very interesting question to settle, therefore the old rice was thoroughly polished and boiled. The boiled rice thus obtained was coloured light brown, was deficient in viscosity, and had a disagreeable taste and odour, but the general quality was not so bad as expected. In times of food shortage such rice would be classed as edible and, if cooked with other ingredients, would be even palatable. This is a highly significant conclusion.

A comparison of the results of a former investigation[2] on air-tight storage 26 and 28 years with those of the present investigation on storage in granaries 46 to 84 years shows the marked advantages of the former method.

The following quotation is from the report on experiments carried out at the Department of Agriculture, Straights Settlements and Malay States[4]: "Siam polished rice and Rangoon parboiled rice, stored for three years in 4-gallon kerosene tins with and without preservatives were examined during year, and the rice in every case, was still excellent. Commercial sacks of rice, kept for three years in a well-ventilated store room without fumigation, were still edible

after winnowing and cleaning, but were mouldy in flavour, and the loss in weight from weevils was approximately 30 per cent". It may be stated that the results of the experiment in the Malay States, a tropical region, are in accord with the authors' opinion regarding air-tight storage, a method of undoubted superiority.

Reviewing the data, it is logical to conclude that if after 80 years storage the rice was still intact and the changes in composition and culinary qualities were not such as to render it inedible, it may be confidently asserted that a more thorough drying at the out-start and storage in air-tight containers will assure keeping for a long period without appreciable deterioration.

Summary.

1) The authors secured four lots of unhulled rice stored 46, 49, 62, and 84 years respectively in granaries, the first three by the Kanonko Association in the northern and cooler part of Japan, the fourth by the landlord Katsumada in the southern and warmer part. From November 1932 to March 1933 the rice was examined in detail.

2) The general quality of the unhulled Kanonko rice was fairly good, although a brown colour had developed. The hulled kernels were somewhat brown and lusterless. Red and green kernels were also present. The Katsumada rice was also in fairly good condition. The results show that unhulled rice can be kept for 60 to 80 years without loss in quantity, if stored in rationally constructed granaries.

3) The water absorption and swelling capacity of the stored rice were very low and the time required for polishing was longer than usual, but the "Kamabue" (increment in volume of boiled rice) was nearly equal to that of new rice. The viscosity of the rice paste was low.

4) Fat decreased in all cases and sugar in some cases, but protein, starch, crude fiber, and ash did not decrease at all. A decrease in pH value of the water extract and a change in reaction from faintly alkaline to faintly acid was noted in some cases.

5) With the exception of lipase, the activity of the several enzymes in the stored rice was reduced in a great degree. Peroxidase, catalase, and urease were nearly or entirely destroyed and diastase and reductase were much reduced, but lipase was not appreciably affected, the amount present being about the same as in new rice.

6) Only 7—15% of the vitamin-B was retained during storage.

7) The germinating power of the rice was entirely lost.

8) Boiled rice, prepared from the polished kernels, was light brown, rough on the tongue, and had a disagreeable odour; nevertheless, it could be eaten in case of necessity and was far better than was expected.

9) The unhulled rice in question contained 14.0—14.9% of moisture, hence it was not dried sufficiently and some change in the quality was inevitable. Had the drying been carried to 12% of moisture and air-tight storage practiced, as often urged by the writers, the quality doubtless would have been much better.

Literature.

1) Kondo, M., The storage of rice and change of its physical properties during this period. Ber. d. Ōhara-Inst. f. landw. Forsch., Bd. III, Ht. 2, S. 153—175, 1926.

2) Kondo, M. and Okamura, T., Storage of rice VIII. Studies on hulled rice stored air-tight 26 and 28 years. Ber. d. Ōhara-Inst. f. landw. Forsch., Bd. V, Ht. 3, S. 413—420, 1932.

3) ———, ———, Storage of rice IX. Relation between varying moisture content and change of the quality of hulled rice stored in containers air-tight as well as with carbon-dioxide. Ber. d. Ōhara-Inst. f. landw. Forsch., Bd. VI, Ht. 2, S. 149—174, 1934.

4) Department of Agriculture, Straits Settlements and Federated Malay States. Rice storage experiment. Technical Report for the year 1931, p. 37, 1933.