PHYSICO-CHEMICAL INVESTIGATIONS ON VARIETAL DIFFERENCES IN RICE.

I. Sorption and Desorption of Water Vapour by Rice Grains.*

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Introduction.

It is well known that different varieties of rice exhibit marked differences on cooking. The problem of varietal differences in rice is one of considerable importance as rice constitutes the chief article of diet of the majority of Indians and of several other Eastern nations.

The object of the present investigation was to correlate with quality the physico-chemical properties of rice. The information so far available on the subject is scanty. A great deal of parallel work has been carried out by Görtner[1] and others on wheat and wheat starches. Some work on rice has been carried out by Warth[2] and others at Pusa and by Japanese workers at Tokyo. It has been found that the quality of rice cannot be satisfactorily correlated with chemical composition. Tetsudaro Tadokoro[3] and his collaborators have attempted a study of the chemical differences between starch from glutinous and non-glutinous rices. They conclude that under similar conditions, the viscosity of glutinous rice starch suspensions is higher. The ash from glutinous rice is richer in silicate than in phosphate while the non-glutinous rice yields an ash richer in phosphate than in silicate.

Several important contributions to the colloid chemistry of starch have been made by Samec.[4] According to him starch granules consist of two different chemical entities—amylose and amylopectin, the latter being chiefly responsible for the colloidal behaviour of starch sols.

Work done in this laboratory by Sanjiva Rao[5] and his co-workers has given indications of the presence of fine capillaries in rice grains. Attempts to correlate the quality of rice with the capillary space available for sorption have not hitherto been successful. It was noticed that suspensions of rice powder in dilute alkali exhibit marked increase in viscosity with time. But the viscosity changes could not be correlated with quality. As cooking of rice is chiefly associated with imbibition of water, it was felt that a study of the sorption and desorption of water vapour by rice would throw light on its quality.

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Experimental.

(*a*) *Dehydration of rice grains by heating.*—Rice grains from seven different samples of paddy, aged as well as newly harvested, were kept in weighing bottles of identical size and shape, and were heated in a special type of steam oven which enabled the passage of a current of dry air over the rice during dehydration. The weighing bottles were removed at intervals, weighed, and the loss in weight due to dehydration noted. It was found in general that the dehydration was rapid for the first six to eight hours and then slowed down by a very appreciable extent. In some cases even seventy hours' heating was insufficient to bring about complete dehydration. It was noticed that rice from paddy stored for nearly two years lost more water than rice from freshly harvested paddy. In all these experiments the paddy was dehusked by gentle rubbing between two asbestos cement plates.

The results obtained are given in Table A. The percentage dehydration is expressed with reference to the *final* weight of the rice grains when dried.

(*b*) *Dehydration of rice by vacuum desiccation.*—Dehydration of rice grains in a vacuum desiccator over phosphorus pentoxide (Fig. 1), was also

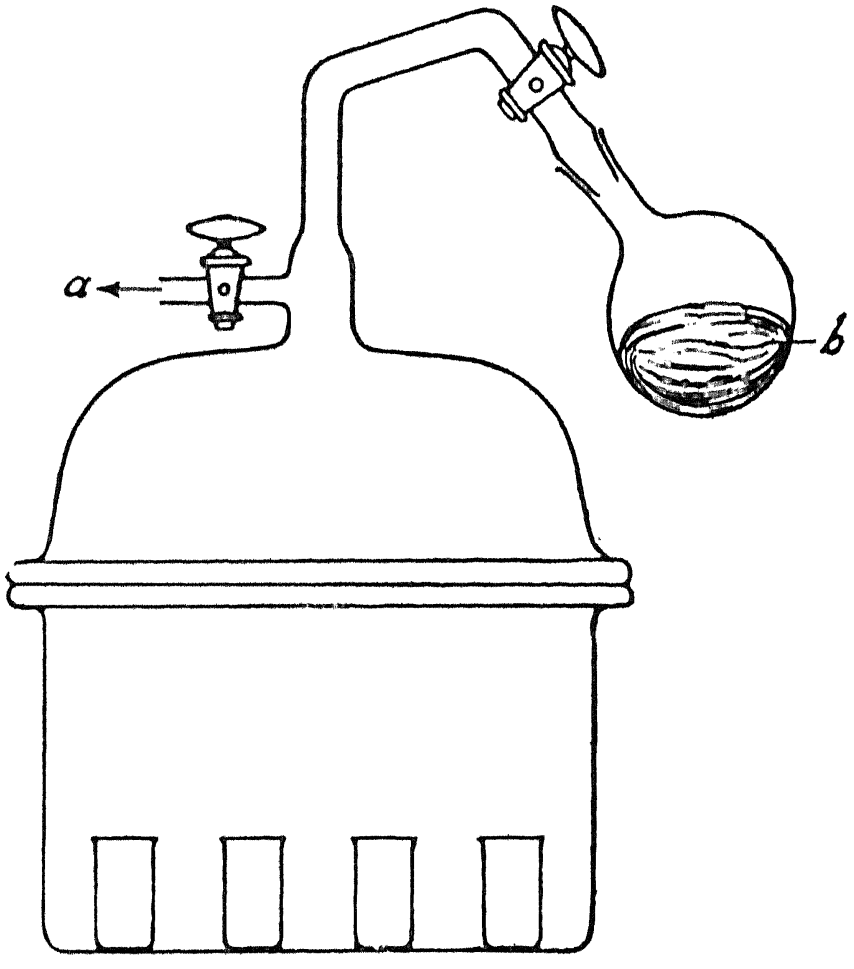

FIG. 1.

a = Lead for evacuation. *b* = Phosphorus pentoxide with glass wool

TABLE A.

Dehydration of rice grains on heating in a steam oven in a current of dry air.

Time of heating	Percentage dehydration observed													
	Mysore Kaddi		Coimbatore Sanna		Nagpur Sanna		Doddabyra		Doddabele		Jeddu Hegge		Walya	
	new	old	new	old	new	old	new	old	new	old	new	old	new	old
1 hour ..	5·03%	8·31%	4·81%	5·71%	5·59%	7·13%	4·83%	5·37%	4·59%	5·35%	4·59%	5·52%	4·12%	6.13%
2 hours ..	6·47	10·09	6·14	7·13	6·78	8·35	5·98	7·06	5·93	6·73	6·03	7·21	4·78	6·95
3 hours ..	7·20	10·85	6·72	7·75	7·31	8·99	6·68	7·70	6·63	7·48	6·77	8·02	5·42	7·70
4 hours ..	7·73	11·36	7·15	8·16	7·69	9·43	7·33	8·47	7·07	7·92	7·33	8·60	5·98	8·25
8 hours ..	8·77	12·44	8·14	9·10	8·69	10·38	8·18	9·32	8·17	8·96	8·36	9·58	6·80	9·05
24 hours ..	9·75	13·43	9·12	10·06	9·45	11·14	9·00	10·10	9·15	9·90	9·52	10·60	8·10	10·08
2 days ..	10·12	13·80	9·56	10·49	10·08	11·71	9·80	10·79	9·86	10·50	9·96	10·97	8·65	10·40
3 days ..	..	..	..	..	..	..	..	..	10·14	10·70	10·20	11·21	9·06	10·60

studied. The desiccator was kept in an air-thermostat at 32° C. Measurements were made at intervals. The dehydration was found to be very slow and incomplete even after four days. As in the case of dehydration on heating, the aged samples were found to lose more water than newly harvested ones. The values obtained are shown in Table B.

TABLE B.

Dehydration of rice grains in a vacuum over phosphorus pentoxide.

Period of dehydration	Percentage dehydration observed					
	Doddabyra		Coimbatore Sanna		Nagpur Sanna	
	new	old	new	old	new	old
70 minutes	1·29%	1·97%	1·34%	2·14%	1·58%	3·41%
165 minutes	2·34	3·18	2·42	3·40	2·55	4·81
4 hours	2·98	3·87	3·10	4·07	3·18	5·54
6 hours	3·61	4·54	3·82	4·74	3·81	6·20
15 hours	4·50	4·96	4·67	5·65	4·68	7·03
29 hours	5·30	5·58	5·42	6·34	5·39	7·72
50 hours	5·64	6·31	5·72	6·59	5·68	7·88
72 hours	5·97	6·63	6·02	6·89	6·01	8·18
108 hours	6·50	7·19	6·54	7·39	6·54	8·70

(*c*) *Isothermal desorption and sorption of water vapour by rice.*—The isothermal desorption and sorption of water vapour by four varieties of rice grains (Mysore Kaddi, Coimbatore Sanna, Doddabyra and Doddabele, all harvested in 1933) was studied using a modification of the sorption microbalance described by McBain and Bakr[6] (Fig. 2). The grains were kept in a gold bucket attached to the silica spring inside the sorption tube. By means of a thermostatic arrangement these grains were maintained at 40° C. The sorption tube was evacuated for half an hour with a Cenco Hyvac pump, and then for four hours with a Langmuir mercury vapour diffusion pump. The rate and the extent of dehydration during evacuation was followed with a travelling microscope. After evacuation, the dehydration was continued over phosphorus pentoxide until it became exceedingly slow. At this stage the phosphorus pentoxide bulb was shut off and water vapour, saturated at 25° C., was let into the sorption tube. The rate of

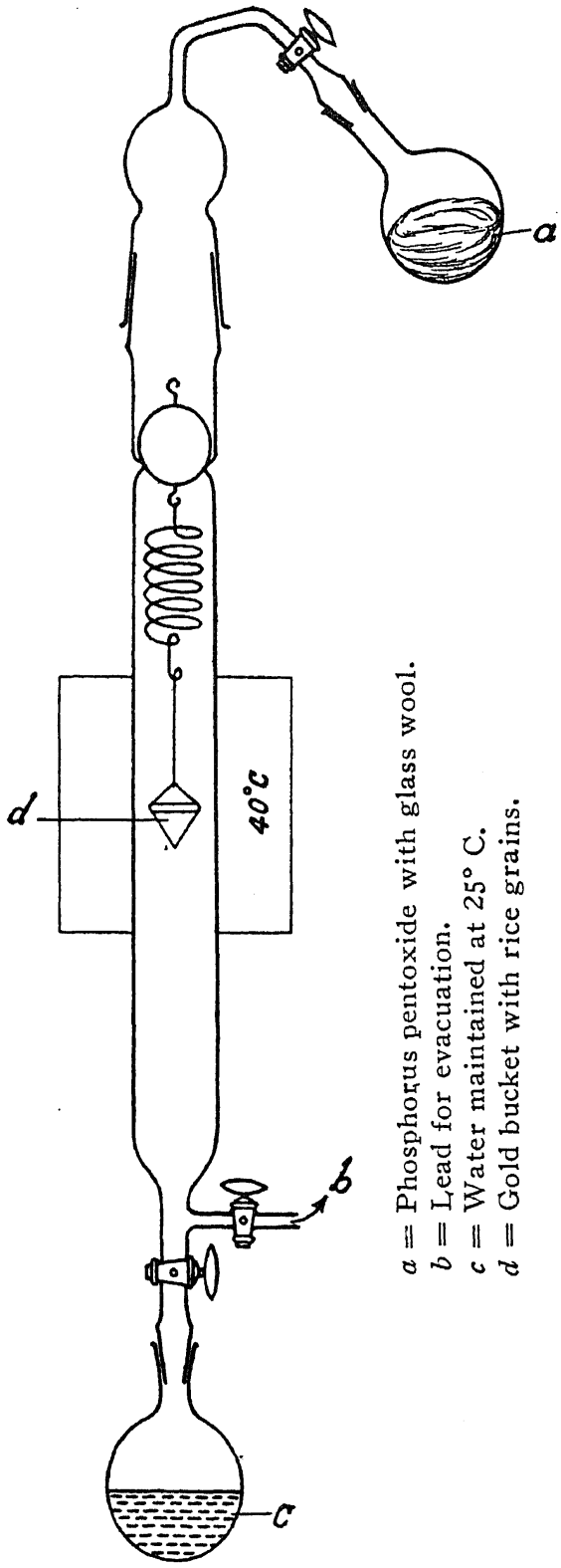

FIG. 2.

hydration of the grains at 40° C. was studied as before. Hydration was found to be complete in 24 hours. The grains were then allowed to cool down to the room temperature of 28–30° C. and the hydration at this temperature measured. The results obtained are shown in Tables C and D and Figs. 3 and 4.

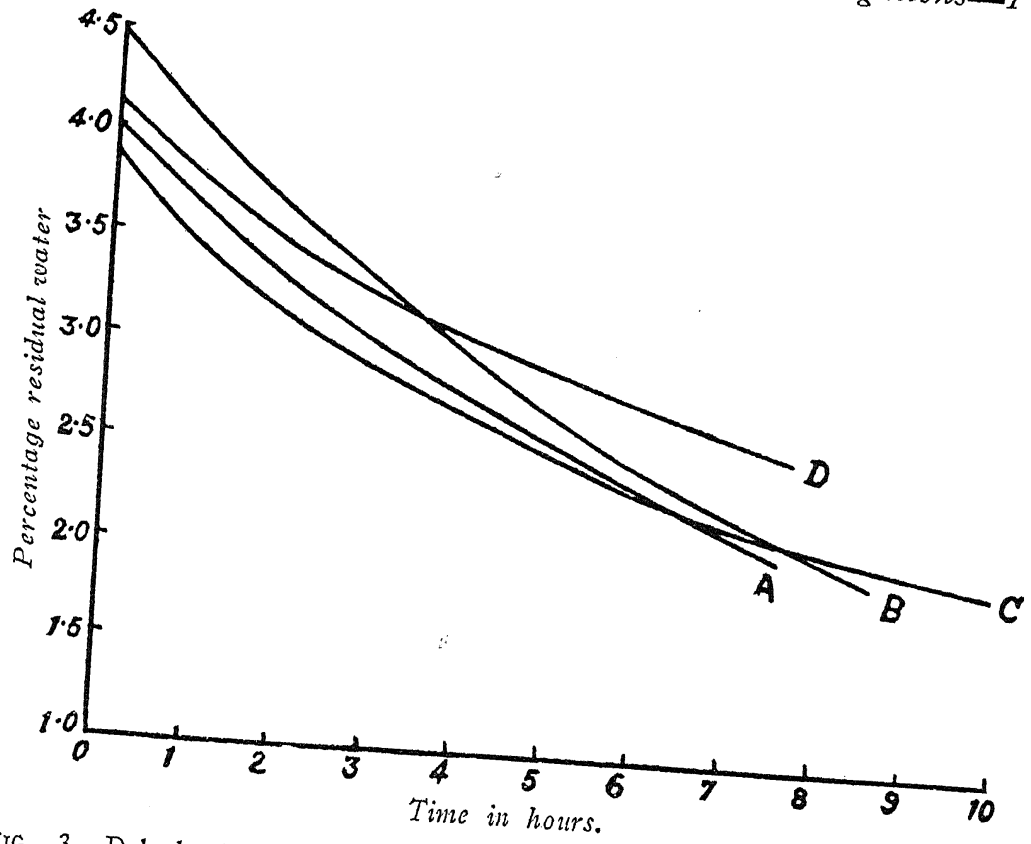

FIG. 3.—Dehydration of rice grains over phosphorus pentoxide in the sorption tube. *A* = Doddabyra. *B* = Mysore Kaddi. *C* = Doddabele. *D* = Coimbatore Sanna.

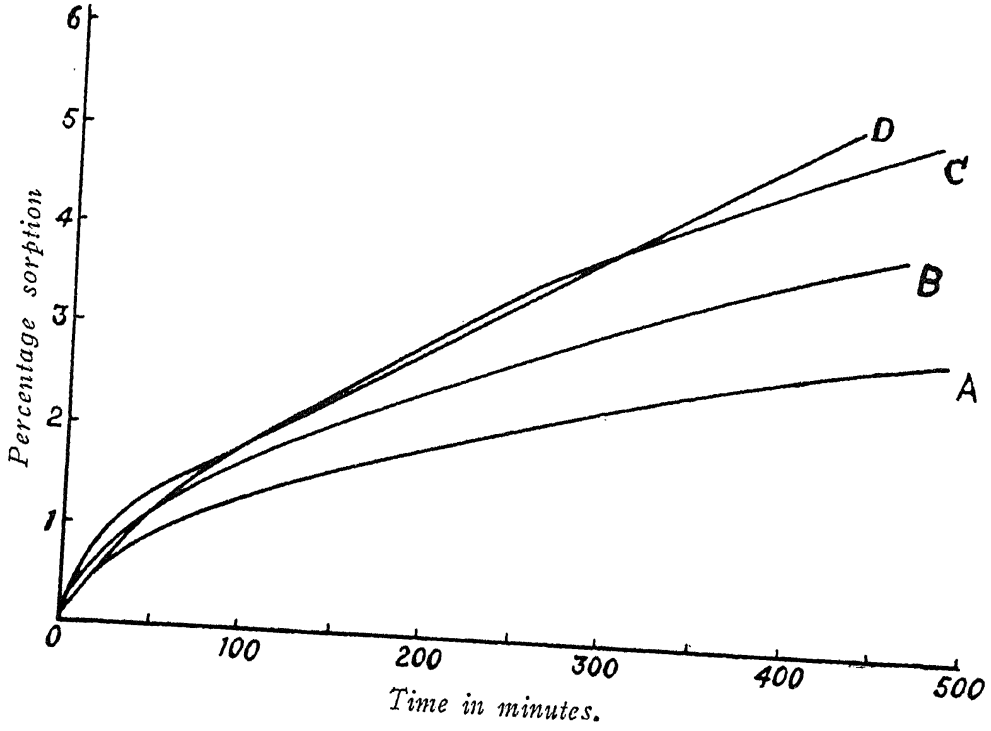

FIG. 4.—Sorption of water by dehydrated rice grains.

A = Doddabele. *B* = Doddabyra. *C* = Mysore Kaddi. *D* = Coimbatore Sanna.

TABLE C. *Desorption of water present in 'air-dry' rice grains.*

1. *Desorption on evacuation.*

Period of evacuation	Percentage water remaining in the grains			
	Mysore Kaddi	Coimbatore Sanna	Doddabyra	Doddabele
0 minutes	15·24%	10·03%	8·58%	9·36%
30 minutes 'Hyvac pump'	10·27	7·30	7·18	7·21
30 minutes 'Hg-vapour pump'	8·58	—	6·30	6·14
1 hour 'Hg-pump'	7·56	5·76	5·72	5·66
2 hours 'Hg-pump'	6·32	4·99	5·02	4·87
4 hours 'Hg-pump'	4·51	4·15	4·03	3·81

2. *Desorption over phosphorus pentoxide.*

Period of dehydration	Percentage water remaining in the grains			
	Mysore Kaddi	Coimbatore Sanna	Doddabyra	Doddabele
0 minutes	4·51%	4·15%	4·03%	3·81%
30 minutes	4·29	3·98	3·85	3·63
60 minutes	4·06	3·80	3·68	3·45
90 minutes	3·95	3·62	3·50	3·34
2 hours	3·67	3·50	3·38	3·22
4 hours	3·05	3·10	2·76	2·80
6 hours	—	—	2·34	2·45
8 hours	2·05	2·51 ?	2·08	2·02
24 hours	0·51	0·89	0·70	0·54
34 hours	0·14	0·30	0·20	0·15
2 days	0·00	0·00	0·00	0·00

TABLE D. *Sorption of water by dehydrated rice grains at 40° C., in contact with water vapour saturated at 25° C.*

Period of sorption	Percentage sorption observed			
	Mysore Kaddi	Coimbatore Sanna	Doddabyra	Doddabele
0 minutes	0·00%	0·00%	0·00%	0·00%
15 minutes	0·45	0·65	0·53	0·42
30 minutes	0·73	1·07	0·82	0·72
60 minutes	1·24	1·37	1·23	0·89
90 minutes	1·69	1·60	1·53	1·07
2 hours	2·09	1·92	1·87	1·43
3 hours	2·77	2·59	2·33	1·91
4 hours	3·41	3·32	2·66	2·15
6 hours	4·35	4·76	3·54	2·45
8 hours	5·31	6·00	—	3·04
12 hours	6·51	7·95	5·25	3·94
24 hours	7·22	9·02	6·54	5·36
36 hours	7·22	9·02	6·54	6·50
2 days	7·22	9·02	6·54	6·50

Sorption of water by rice grains at 28–30° C., in contact with water vapour saturated at 25° C.

Period of sorption	Percentage sorption observed			
	Mysore Kaddi	Coimbatore Sanna	Doddabyra	Doddabele
0 minutes	7·22%	9·02%	6·54%	6·50%
1 hour	9·48	11·27	9·81	8·35
2 hours	10·16	12·70	11·09	9·55
4 hours	11·45	14·45	12·72	11·03
12 hours	13·85	17·09	—	—
24 hours	16·97	18·69	20·43	19·86
2 days	18·17	—	22·90	—

It is of interest to note that rice exhibits hysteresis in the sorption of water vapour. In experiments with Doddabyra rice, for instance, it was noticed that the dehydrated rice would take up 22·9 per cent. of water vapour at 29° C. at a corresponding pressure of nearly unity. On a second dehydration, however, the capacity for subsequent hydration markedly diminished and only 18·4 per cent. water was taken up. This closely corresponds to the observations by Fairbrother[7] on hysteresis effects in wheat starches. A more detailed investigation of this phenomenon is being undertaken in this laboratory.

(*d*) *Sorption of pyridine by rice.*—Pyridine sorption has been found by Sanjiva Rao and Seetharama Rao[8] to work well in the determination of soil colloids. The sorption of pyridine by 'air-dry' and 'dehydrated' rice grains was therefore tried. The 'air-dry' grains did not take up any pyridine but lost part of the water already present in them. Fully 'dehydrated' grains, however, showed a small and inappreciable sorption, less than 0·5 per cent. at 40° C.

Discussion.

The tabulated results show that varietal differences are exhibited by rice both during sorption and desorption of water vapour. Mysore Kaddi, Coimbatore Sanna and Nagpur Sanna which are recognised to be superior varieties, are dehydrated more readily than Doddabyra, Doddabele, Jeddu and Walya accepted as inferior in quality. The differences exhibited during sorption are more striking. The rate of hydration is much higher with the superior varieties. Studies in hydration have been found in general to be more satisfactory for determining quality of the rice than experiments in dehydration.

There is a marked difference in the behaviour of rice from freshly harvested paddy and rice of the same variety obtained from paddy that has been stored for some months. Rice from stored paddy is more easily dehydrated and gives a greater percentage of dehydration than rice from freshly harvested paddy. The change in physico-chemical behaviour on storage is significant in view of the well-known fact that on ageing paddy improves in quality.

The greater ease in dehydration as well as hydration exhibited by older samples of the same variety and by samples of superior varieties as distinguished from rices of poorer quality, indicates that in rice of good quality the capillaries are broader. Investigations on the gels of silicic acid and alumina carried out in this laboratory have shown that the size of capillaries affects the behaviour of gels in sorption of vapours. The effect of storage

on paddy seems to be to bring about a widening of the capillaries. Further work on this aspect of the problem is in progress.

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Summary.

Dehydration of different varieties of rice has been studied employing for dehydration a current of hot air or vacuum desiccation over phosphorus pentoxide.

Sorption and desorption of water vapour by rice under isothermal conditions has also been studied in a modified form of the quartz spring microbalance devised by McBain and Bakr.

It is found that superior varieties of rice lose water more readily during dehydration and take up water at a faster rate and to a greater extent than varieties of poorer quality.

Rice obtained from paddy that has aged is capable of easier hydration and dehydration than a sample of the same variety from freshly harvested paddy.

The investigations indicate that the capillaries in superior varieties of rice are broader than those in inferior kinds. Storage of paddy seems to cause a widening of these capillaries.

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