BIOCHEMICAL STUDIES ON RICE STARCH. V. COMPARATIVE STUDIES ON RICE, BOILED RICE AND MOCHI.

By Wei Sun TAO.

Received June 20, 1930. Published July 28, 1930.

In our daily life, in the Orient, it is our custom to eat rice at every meal, the best of food, after it is boiled with water, or steamed and pounded into a cake called mochi (usually prepared from glutinous rice). Mochi is said to be much more digestible for the digestive organs than even boiled rice. Therefore, the chemical changes of the starch of rice in the process of boiling with water, and also in the trituration process of making mochi aroused our interest, and induced us to investigate the subject from the point of view of bio-chemistry, and the following experiments were undertaken.

Preparation of Materials and Their Analysis. 1. *Boiled rice*: The rice named Asahi, which was used in the previous experiments,[2] polished, and

(2) This Bulletin, **5** (1930), 64, 69, 87 & 91.

boiled with water in the following quantities: 500 gr. of polished rice boiled with 750 c.c. of water at 105°C. for 25 min., then, taken off the fire but otherwise untouched left for about 10 min.

2. *Mochi*: 500 gr. of polished rice, washed and soaked in water over night, and steamed for 45 min. at 99°–110°C., triturated with a wooden pestle to make a sticky mass with the addition of a little water, and no more individual rice granules are to be seen.

In analysis, the boiled rice and mochi were soaked in cold acetone and let stand in a cold place for 3 days, filtered, and the filtrate was evaporated to dryness and the fat remaining in the residue was extracted with petroleum ether. With the residual substance the content of reducing sugars was determined as usual.

The insoluble residue in acetone was dried, ground into powder in a stone mill, treated with water at room temperature for a few hours, and filtered. The content of reducing sugars in the filtrates was estimated before and after the hydrolysis with 3 % H_2SO_4 as usual. The starch-content in the final residue was determined after it was hydrolysed with the mineral acid. The results are shown in the following table with the data for polished rice in comparison.

	Rice		Mochi	Seedlings
	Polished	Boiled		
H_2O	13.6%	62%	55%	—%
Starch	76	67	68	56
Red. sugars	0	0.7	0.7	4
Sol. polysacch.	0	9	9	10

As may be seen from this table, the polished rice contained no reducing sugar or soluble polysaccharides, but they were found in boiled rice and mochi, and their formation was assumed to occur from the hydrolysis of starch. When the chemical changes which happen to the rice starch during cooking are compared with those in the germination of seeds, it may be noticed that hydrolysis of starch occurs in both cases, but the complete decomposition of the sugar molecule into CO_2 and H_2O, is to be found only in the germination.

To learn the difference in digestibility of two kinds of cooked rice—boiled rice and mochi—which would arise due to the differentiation of their physical state, the action of diastase and saliva under various P_H on the freshly prepared boiled rice and mochi was investigated. In the experi-

ment, they were ground in a mortar and suspended in water, and 100 gr. of the sample, 500 c.c. of water, 4 gr. of Taka-diastase, and 20 c.c. of the writer's saliva were mixed separately. The mixtures were allowed to stand at 35°C. for 3 hours, and the colour test with iodine, and determination of the content of soluble sugars by means of Fehling's solution were made, and the results are shown in the table below.

	Boiled rice		Mochi	
	Diastase	Saliva	Diastase	Saliva
Rotatory power	19	15	23	19
Red. sugars	17	12	12	15
Sol. polysacch.	26	17	45	15

	Rice starch	
	Rice diastase	Saliva
Red. sugars	25	38
Sol. polysacch.	25	39
Starch	46	20

As will be seen in the table, the conversion of rice starch by saliva into soluble sugars is greater than that by rice diastase, but the reaction to starch of boiled rice and of mochi is reciprocated with diastase and saliva in each case. In any way, starch in mochi seems easy to convert into soluble sugars by means of the hydrolytic enzyme in diastase and saliva.

In order to learn more precisely the chemical nature of the reaction products which were produced by the action of diastase and of saliva from boiled rice and from mochi, the water soluble substance separated from the reaction products was treated with basic lead acetate, and filtered, H_2S gas was passed to remove the lead in the solution, and the filtrate was concentrated into a small volume. Alcohol was added to make 80% of an alcohol solution. The first precipitate thus formed was separated, and the filtrate was concentrated and the second precipitate was formed with 90 % of alcohol. Finally, the filtrate was evaporated to a thick syrup and treated with absolute alcohol to form the third precipitate. Of these precipitates, the rotatory power and reducing power of the Fehling solution were deter-

mined, and confirmed for the occurrence of glucose and maltose in the products by the osazone test. The results are shown in the following table.

Boiled rice

	Diastase				Saliva			
	Yields %	$[\alpha]_D$	R.p.	Osazone test	Yields %	$[\alpha]_D$	R.p.	Osazone test
A	26	136	32	M	17	168	30	M
B	11	109	52	M	—	—	—	
C	6	107	58	M+G	12	138	40	M

Mochi

	Diastase				Saliva			
	Yield %	$[\alpha]_D$	R.p.	Osazone test	Yield %	$[\alpha]_D$	R.p.	Osazone test
A	45	145	38	M	15	169	26	M
C	12	112	56	M+G	15	139	47	M

where: A=80 % alcohol precipitate,
B=90 % ,, ,,
C=absolute ,, ,,
M=moltosazone,
G=glucosazone,
R.p.=Reducing power indicated as the percentage of d-glucose.

By the action of diastase on boiled rice and mochi, maltose as well as glucose were produced, but with saliva only maltose was noticed to form.

In mochi, the reaction product consisted mostly of soluble polysaccharides, and the production of reducing sugars and soluble polysaccharides from boiled rice by diastase and saliva is proportionately similar.

The action of diastase and saliva on boiled rice and mochi seems to differ in their reaction products from each other due to the differentiation of the physical state of these two preparations.

Of these reaction products, the distribution of dextrin, maltose and glucose were also determined by Wiley's method[1]; the reducing sugars in

(1) Wiley, "Agricultural Analysis" (1897) Vol. III, p. 288.

the products are removed by fermentation with yeast, and dextrin and maltose were determined separately. The results are as follows:

	Boiled rice		Mochi	
	By diastase	By saliva	By diastase	By saliva
Dextrin	37	38	35	37
Maltose	30	62	46	63
Glucose	23	—	12	—

As will be seen in this table, when saliva acted on both boiled rice and mochi, maltose and dextrin were formed, and with diastase some glucose was noticed as a reaction product. Mochi is easily converted by diastase into maltose; but in boiled rice conversion of the starch into simpler sugar takes place.

When foods with saliva come into the stomach their digestion was said to proceed in an acidic medium of the gastric juice which usually shows $P_H=1.7$, and therefore, the chemical changes in the constituents of boiled rice and of mochi by diastase and by saliva were investigated under conditions similar to the fluid of the digestion organ, namely at $P_H=1.7$, using KCl—HCl for buffer. The results are shown in the following table.

	Diastase		Saliva	
	$P_H=1.7-2.3$	$P_H=7.8$	$P_H=1.7$	$P_H=6.2-6.5$
Mochi	1.6	23	0.9	19
Boiled rice	1.1	19	0.8	15
Starch	—	50	0.4	28

The numbers indicate the percentage of reducing sugars calculated as d-glucose.

The action of diastase and saliva on the starch of boiled rice and mochi proceeded in a little acid side, $P_H=6\sim7$ to form simpler sugars but no action was observed in an acidic medium such as $P_H=1.7$.

Discussion. As a whole, the action of water on starch at 105°C. will result to produce soluble sugars by hydrolysis, and the beating of rice starch with a wooden pestle in presence of water will also promote in some

degree the hydrolysis of the starch, converting it into soluble polysaccharides and reducing sugars. When diastase or saliva acts on mochi and boiled rice, the formation of soluble polysaccharides and reducing sugars is much more intensive.. The chemical change of the starch in rice by cooking with boiled water and trituration resembles, in some respects, the germination of rice seeds ; the difference is that the velocity in the conversion of starch into soluble sugars is greater in the former, but the conversion of starch into carbon dioxide and water takes place in the latter.

When comparing the action of amylase which occurred in diastase or saliva in boiled rice and mochi, the latter is more affected by the enzyme.

In closing, the writer would like to offer her hearty thanks to Professor S. Komatsu of Kyoto Imperial University, for the experiments were performed under his kind direction and never failing encouragement.

April, 1930. Laboratory of Organic- & Bio-Chemistry,
Kyoto Imperial University.