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BY

J. CHARLTON, M.Sc., A.I.C.,
Agricultural Chemist, Burma.

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The Prevention of Nuisances Caused by the Parboiling of Paddy.

(*Received for publication on 16th February 1923.*)

INTRODUCTORY.

In Burma the practice of parboiling paddy is to some extent a localized one. It is only in Lower Burma that parboiling is an important industry. In Upper Burma, parboiling is almost unknown and therefore a short explanation of the process is essential.

In the process of parboiling, paddy (unhusked rice grains) is steeped in water in tanks, usually of cement, for periods up to three or four days. The water is then run off and the paddy transferred to vertical iron cylinders or cauldrons through which one or more steam pipes are placed vertically, these pipes being pierced with small holes at intervals along their length within the cylinders. Steam is blown into the paddy until the husk slightly dehisces, the steaming operation being then regarded as complete. The paddy is then allowed to fall out of the cylinders by removing a large trap door at the bottom and is either spread on the ground to dry in the sun or is dried by mechanical means. When thoroughly dry, the paddy is milled in the usual way.

The appearance of the rice so treated differs markedly from that of ordinary white rice. Whereas white rice is opaque, parboiled rice is translucent. A distinction should be drawn between two varieties of parboiled rice, *viz.*, *mill-char* and half-boiled rice. *Mill-char* is parboiled rice which has been completely steeped and steamed and is therefore almost transparent; half-boiled rice has not been so thoroughly subjected to the action of water and steam and is therefore not so transparent, white bellies of opaque starch usually being present in large amount. The explanation given by millers is to the effect that in the steeping operation water penetrates the rice grains and, when subsequently heated for a short time by steam to 100°C., the starch is partly gelatinized. If the steeping operation is incomplete, white bellies of opaque starch remain in the interior of the rice grains.

In the steeping operation, either cold or hot water may be used. Some millers prefer hot water because they are of opinion that a better colour of parboiled rice is obtained by this means. Others maintain exactly the opposite view. By using hot water the length of steeping is reduced and hence at busy periods, hot water is used by practically all millers. No definite rules regarding temperature of steeping water and length of steeping required have hitherto been laid down.

Definite rules regarding the amount of steam necessary to parboil a given amount of paddy cannot be given. The concensus of opinion of millers is that the longer the steepage, the less is the steaming required. The time given is necessarily a compromise since grains near the steam pipes are thoroughly parboiled while those at the edge of the cylinder get much less steam.

Small millers almost invariably dry the parboiled paddy in the sun. European millers also utilize this method in addition to artificial drying. The small millers usually have no artificial drying plant and are therefore entirely dependent upon fine weather for drying. It frequently happens that wet weather occurs while paddy is steeping. At such times, particularly if the paddy has been steeping for much more than twenty-four hours, foul odours emanate from the steeping tanks. Even worse results when this paddy is steamed, the foul odours being carried by the wind to considerable distances. Many mills being in municipal limits, the parboiling industry has become a public nuisance in the wet season. The cause of the nuisance was easily traced to putrefactive bacteria in the steeping tanks.

Objects of parboiling. Various reasons are given. It is stated by people who eat this variety that parboiled rice is more sustaining than white rice. Coringee coolies who are large consumers state that after a meal of parboiled rice they can work throughout a whole shift of eight hours without a further meal. If white rice were substituted they could not do this.

Parboiled rice is preferred on account of its taste. It is stated that when cooked it remains sweet for a longer period than white rice, and if subsequently warmed up, the flavour is less adversely affected than that of white rice similarly treated.

Although parboiled rice has been partially cooked, it is not so easy to prepare for food as white rice.

An advantage for parboiled rice is claimed inasmuch as it interferes less with digestive powers than white rice.

It is certain that the milling losses are reduced by this process. Breakage is greatly diminished. Partly because of this reduced breakage, the profits to the miller are increased by parboiling.

In Burma the last reason probably accounts for the great increase in the number of parboiling mills since 1917. Practically all the parboiled rice is exported. On the other hand, in India, particularly in Bengal, the preparation of parboiled rice is a home industry, the work being carried out by women in the villages and not in mills. In brief, whereas parboiling is an ancient practice usually carried out in the home in India, in Burma it quite recently became an industry, the markets being chiefly India and Ceylon. The question of nuisances is therefore much more serious in Burma than in India. This is clearly demonstrated by the following official figures :—

Export of parboiled rice from Burma.

	Tons
1919-20	371,170
1920-21	294,351
1921-22	380,973

At the request of the Director of Public Health, Burma, I took up the question of parboiling nuisances in March 1921. The subject matter of this paper has already been reported to the above officer at intervals up to the present time.

The Director of Public Health raised the following points :—

1. Are the bacteria causing the nuisance essential to the process ?
2. If not, how can they best be suppressed ?

Note. According to information received, the paddy in the steeping tanks will not germinate however long it may be left under water.

3. The discharge of the steeping water into drains, borrow pits or land around the mills causes nuisances.
   Sterilizing this waste water by boiling was suggested.
4. Suggestions have been made to change the steeping water at intervals, *e.g.*, every twenty-four hours.

Note. The increased bulk of waste water would be a disadvantage.

Not having seen the process of parboiling, it was first necessary to visit mills where parboiling was in operation. Accordingly in March 1921 I visited Prome where there are four parboiling mills in municipal limits. It was decided to carry out a few experiments while there on lines suggested by the Director of Public Health (see above), but these were only in the nature of preliminary experiments, subsequent work being carried out in the laboratory and in Messrs Steel Bros.' mill, Upper Pazoondaung, Rangoon.

Preliminary investigation at Prome.

No bacteriological laboratory was available at any time throughout the whole investigation but this was not regarded as a serious handicap.

For the work in Prome, mills having comparatively small steeping tanks were chosen as being more economical for experimental work. Trials of the following were made :—

1. Chlorination of the steeping water.
2. Steeping at high temperature.
3. Changing the steeping water at intervals.

Chlorination.

Bleaching powder containing over 25 per cent. available chlorine was used. An *intermediate* tank would have been very useful for mixing purposes but this was not available. The bleaching powder was therefore mixed into a thin paste with water, diluted considerably and portions were added to the water entering the steeping tank at intervals so that the chlorine was fairly equally distributed throughout the whole volume of the steeping water. It was found that, if the chlorine solution was added to the steeping tank when full of water, stirring for very long periods failed to carry down the chlorine to the bottom of the tanks, which are usually six feet deep.

Various doses of chlorine were given using cold water. (Table I.)

TABLE I.

Chlorination of steeping water. (Steeping water not changed.)

Chlorine dose in parts per million	Temperature of steeping water (original)	REMARKS
2·5	34°C.	Bad in two days.
5·0	33°C.	„ „ „ „
11·2	34°C.	„ „ „ „
15·0	34°C.	„ „ „ „
20·0	33°C.	„ „ „ „

The chlorine dose is calculated on the volume of steeping water used in this and subsequent experiments.

In all cases, even with a heavy dose of chlorine equal to $20/10^6$, no free chlorine could be detected after one hour. The chlorine was undoubtedly used up in oxidising organic matter instead of killing the micro-organisms.

After a lapse of two days, no advantage over unchlorinated samples was discernible.

It was therefore decided to repeat the chlorination daily, running off the old steeping water before recharging. Experiments were tried with both cold and hot steeping water. (Table II.) The chlorine dose is the average daily dose and was kept as nearly constant as possible.

TABLE II.

Chlorination of steeping water. (Water changed daily.)

Average daily chlorine dose in parts per million	Temperature of steeping water (original)	REMARKS
3·8	34°C.	No improvement upon the ordinary method after two days.
10·0	34°C.	Slight improvement.
18·8	30°C.	Paddy perfectly fresh for four days. Strong smell of bleaching powder.
10·8	50°C.	Unsatisfactory.

Very large doses of chlorine were necessary to keep the paddy fresh. With hot water $10{\cdot}8/10^6$ of chlorine failed to give a good result. A similar dose with cold water gave a slightly better result than untreated paddy. Until a very heavy dose of nearly $20/10^6$ of chlorine was given, paddy could not be kept fresh for four days. Germination of the paddy occurred to some extent under these conditions. A strong smell of bleaching powder was noticed when no free chlorine could be detected chemically. This was very objectionable. The method also involved changing the steeping water which is a disadvantage when using chemical methods of sterilization. In addition, such large doses of chlorine are necessary to keep the paddy fresh that the expense of treating paddy on the large scale would be prohibitive.

Steeping at high temperature.

A small cement tank, measuring about 8′ × 4′ × 6′, fitted with a 1½″ steam pipe (pressure 90—100 lb.) was available. The steam pipe reached within one foot of the bottom of the tank and pointed vertically downwards. It was my intention to try to maintain the paddy while steeping at 60°C. for several days. The tank was charged with paddy and water in the usual way, the temperature of the water being 34°C. Steam was blown in until the temperature at the top of the tank near the steam pipe was 70°C. The bottom of the tank even near the steam pipe remained persistently cold, although a large amount of the paddy near the steam pipe was actually cooked. It became clear that such a crude method as blowing steam into the paddy could not possibly prove satisfactory for the purpose in view unless elaborate and expensive mechanical stirrers were fitted.

The problem of steeping at high temperature therefore required further study and a different method of application.

Changing the steeping water.

Three different steeping tanks were chosen, the water in these being changed every six, twelve and twenty-four hours respectively. (The last of these was not carried out in Prome but in Rangoon.)

Changing the water was found to improve matters very considerably up to the fourth day of steepage. (Table III.) By the end of the third day, however, germination was noticeable. Millers have stated that this would cause a loss in milling. In the vast majority of mills in Burma adequate water supply for changing the steeping water even every twenty-four hours is not at present available, so that it is at present quite impossible to put the method into operation. Again, the increased bulk of waste water from the mills would lead to a further nuisance since they have no proper method of disposal of waste water. Boiling waste water is much too expensive to be attempted, and since re-infection would occur immediately, success by such a method is by no means assured.

TABLE III.

Changing the steeping water at intervals.

Water changed at intervals of	Condition of paddy after					Temperature limits
	one day	two days	three days	four days	five days	
6 hours	Good	Good	Good. Fair amount of germination.	Fair	Bad	29—33°C.
12 hours	Good	Fair.	Fair. Fair amount of germination.	Fair	Very bad	28—34°C.
24 hours	Good	Fair to good	Fair	Fair, germination noticeable.	Very bad	29—34°C.

While experimenting with changing the steeping water, it appeared possible that the improved result as regards odour was due to aeration on changing the water. It is possible that by this means anaerobic bacteria were largely suppressed. Experiments were therefore designed to examine this possibility.

FURTHER EXPERIMENTS FOR THE SUPPRESSION OF NUISANCES.

Aerobic steeping of paddy.

Five ordinary kerosine tins were filled with equal weights of paddy and water, the volume being kept constant throughout the experiment by adding more water as required. Two of the tins were kept in a water bath at 40°C., two in another water bath at 30°C., while the fifth was allowed to stand at room temperature as a blank experiment. Air was pumped through the paddy in one of the tins kept at 40°C. and through one kept at 30°C. Aeration was accomplished by means of a good cycle pump and was repeated at intervals of one hour for about one minute on each of these occasions.

Differences in the rate of production of bad odours were clearly shown (Table IV). Aerobic steeping considerably delayed the production of foul smells but germination considerably increased. No germination occurred in the paddy subjected to anaerobic conditions, *i.e.*, the blank experiment.

TABLE IV.

Aerobic versus anaerobic steeping of paddy.

Condition after	30°C.		40°C.		Room temperature (25°C.—35°C.)
	Aerobic	Anaerobic	Aerobic	Anaerobic	Anaerobic
1 day	Good	Good	Good	Good	Good
2 days	Good	Fair	Good	Bad	Bad
3 days	Good	Bad	Good	Bad	Bad
4 days	Quite good	Bad	Fair	Bad	Bad

It was not possible at this time to find the hydrogen ion concentration of the steeping water. Acidities were done but no definite conclusions could be drawn from these results. The aerobic steeping samples showed a variable acidity, sometimes greater, sometimes less than the anaerobic samples.

The above result was subsequently confirmed on the semi-large scale in the mill. Although nuisances could be suppressed for about four days by blowing air through the steeping paddy, a very high percentage of germination occurred. The question of germination therefore demanded further investigation.

Germination of paddy when steeping.

Three flasks A, B and C of about one and a half litres' capacity were almost filled with paddy, water being then added so as to completely cover the paddy. The flasks were kept out of doors under ordinary shade conditions, being therefore subjected to a maximum temperature of 110°F. and a minimum of 70°F.

In A the water was not changed throughout the experiment.

In B the water was changed every twenty-four hours.

In C the water was changed every twelve hours.

When the water was drained off, the acidity was taken, using phenolphthalein as indicator. Acidity is expressed as the number of cubic centimetres of Normal KOH required to neutralize 100 c.c. of the steeping water. (Table V.) The non-volatile acidity, (b), was determined by gently boiling about 30 c.c. of the liquid, 10 c.c. of which was then cooled and titrated. The hydrogen ion concentration was not determined.

TABLE V.

Acid developed in steeping water when changed at intervals.

		24 hours	48 hours	72 hours	96 hours	120 hours	144 hours	168 hours
A	(a)	..	..	..		..	..	17·40
	(b)	..	..	..	..	..	..	16·08
B	(a)	1·14	1·25	1·20	1·44	2·04	2·64	2·94
	(b)	0·33	0·84	0·88	..	1·56	1·98	2·40
C	(a)	0·84	0·84	0·96	1·02	1·20	1·20	1·32
	(b)	Neutral	0·18	0·27	..	0·72	0·84	0·72

(a) Total acidity.
(b) Non-volatile acidity.
Acidity=Number of c. c. of N.KOH required to neutralize 100 c. c. of steeping water.

After seventy-two hours, germination was noticed in B and C. After ninety-six hours, the paddy in B had germinated even more noticeably while in C almost all grains seemed to have germinated. Germination in no case proceeded very far, but to an extent disliked by millers. After

seven days the percentage germination was determined in each of the flasks and was as follows :—

A	nil
B	30·0%
C	76·0%

It appears, therefore, that the more acid the medium, the less is germination likely to occur. The fact that the paddy daily becomes more favourable to the action of acid forming micro-organisms when treated in this manner is clearly shown by the increasing amounts of acid formed in a given time.

A. Wilson [1] has stated that germination of grains is due to the lactic acid bacteria. He states that anything inimical to the bacteria, though harmless to enzymes, prevents germination taking place.

Addition of pure lactic acid would therefore be expected to increase the tendency to germinate. Accordingly paddy was steeped for seven days in lactic, acetic acid, etc., the acid solutions being changed every twenty-four hours to ensure that the paddy was always in a medium of approximately the same concentration. In another series the acid steeping liquids were not changed throughout the experiment. The percentage of germination in each case was determined (Table VI). The experiment with bleaching powder was carried out to determine whether disinfectants suppressing bacteria (lactic acid bacteria included) also suppress germination.

Acidity is expressed as the number of c.c. of Normal KOH required to neutralize 100 c. c. of the steeping solution.

[1] Wilson, A. *Jour. Amer. Chem. Soc.*, 1904, 26, 289.

TABLE VI.

Germination in seven days' steeping, steeping in acids, etc., of varying concentration.

	LACTIC ACID			ACETIC ACID			SULPHUR DIOXIDE (AS ACID CALCIUM SULPHITE)			BLEACHING POWDER		
	% Acid (by volume)	Acidity	% Germination	% Acid (by volume)	Acidity	% Germination	% Acid	Acidity	% Germination	Chlorine dose (parts per million)	Acidity	% Germination
1	0·05	0·15	32·5	0·11	1·25	52	...	0·20	1·5	3·0	Neutral	57·00
2	0·10	0·50	48·5	0·22	3·20	6	...	0·35	1·5	6·0	"	66·00
3	0·15	1·00	40·0	0·33	5·10	nil	...	0·45	0·5	9·0	"	60·00
4	0·20	1·40	51·0	0·44	7·10	nil	...	0·70	nil	12·0	"	54·00
5	0·25	1·90	28·0	0·55	9·15	nil	...	1·15	nil	15·0	"	55·00
6	0·30	2·30	13·5	0·66	10·80	nil	...	2·75	nil	18·0	"	58·00
7	0·50	4·40*	nil	1·11	20·20*	nil	...	0·80*	nil	20·0	*"	1·50
8	1·00	8·35*	nil	2·22	39·50*	nil	...	2·20*	nil	40·0	*"	2·25
9	1·30	13·80*	nil	3·33	59·35*	nil	...	4·65*	nil	60·0	*"	2·00

* Original acidity only. Acidity = Number of c. c. of N.KOH required to neutralize 100 c. c. of solution.

In experiments Nos. 1–6, the steeping water was changed every twenty-four hours; in Nos. 7–9 it was not changed throughout the experiment. With increasing concentrations of lactic acid in Nos. 1–6 there is a tendency for germination to diminish; acetic and sulphurous acids behave similarly. With increasing doses of chlorine in Nos. 1–6 in which there is an increased suppression of all bacteria, there is no decrease in germination. Under these conditions, it is therefore likely that lactic acid bacteria are not responsible for germination. The fact that conditions are not made really favourable for germination, the paddy being covered by water (acidified, etc.), should be remembered.

Hence in order to suppress germination when steeping paddy, high acidity and anaerobic conditions are desirable.

STEEPING IN DILUTE ACIDS TO PREVENT DEVELOPMENT OF BACTERIA.

In experiments on germination of paddy, it was found that dilute acids, in addition to preventing germination, prevented the production of obnoxious odours. The acids used included lactic, acetic, sulphuric, sulphurous, formic, hydrochloric, citric, tartaric and boric acids. From the point of view of cost, sulphuric, hydrochloric and sulphurous (as acid calcium sulphite) were most suitable. Paddy was therefore steeped in various concentrations of these acids for seven days and the steeping water microscopically examined after that time. (Table VII.)

TABLE VII.

Microscopic flora of acidified steeping water after steeping for seven days.

HYDROCHLORIC ACID.

Concentration	Odour	Microscopic appearance
0·020 N.	Bad	Long rods and streptococci. Long rods by far the more numerous.
0·025 N.	Bad	As 0·020 N.
0·030 N.	Bad	Fewer organisms than above.
0·035 N.	Unpleasant	Very few organisms.
0·040 N.	Good	Bacteria very few indeed.
0·045 N.	Good	Yeasts only.
0·050 N.	Good	Yeasts only.

TABLE VII—*concld.*

SULPHURIC ACID.

Concentration	Odour	Microscopic appearance
0·020 N.	Bad	Very mixed culture of bacteria with certain very long forms.
0·025 N.	Bad	Similar to 0·020 N.
0·030 N.	Bad	As above.
0·035 N.	Fair	As above.
0·040 N.	Good	Mixed culture of yeasts and bacteria (with very long rods).
0·045 N.	Good	Practically entirely yeasts.
0·050 N.	Good	Practically entirely yeasts.

SULPHUR DIOXIDE (as acid calcium sulphite).

% SO_2	Concentration (calculated)	Odour	Microscopic appearance
0·0830	0·0260 N.	Bad	Yeasts absent. Many bacteria, mostly short rods.
0·0925	0·0290 N.	Bad	Bacteria numerous—long and short rods.
0·1040	0·0325 N.	Bad	As for 0·0925 per cent. but more moulds.
0·1190	0·0372 N.	Good	Bacteria and moulds in fairly equal numbers.
0·1390	0·0434 N.	Good	Very many moulds and yeasts. Badly infected with bacteria.
0·1660	0·0520 N.	Good	Little of anything. Few yeasts and moulds.

With hydrochloric and sulphuric acids when the concentration was less than 0·035N., either bacteria only or bacteria and yeasts were obtained. At concentrations of 0·045N. or higher, only yeasts and moulds developed. Sulphurous acid (in the form of acid calcium sulphite) behaves similarly to the stronger acids. In no case did obnoxious odours develop within one week when the original acidity was 0·045N. Bacteria were absent from such steeping solutions. As soon as the acidity falls sufficiently low, bacteria appear and simultaneously bad odours arise. Therefore bacteria cause the obnoxious smells.

The best results as regards the finished rice were obtained with acid calcium sulphite. The bleaching effect of the sulphur dioxide gave a rice free from all trace of blackening of the grain. Since acid calcium sulphite is usually supplied as a liquid containing about 4 per cent. sulphur dioxide, transport for long distances would be a very serious item. Accordingly at my request the Burma Chemical Industries Ltd. produced a calcium sulphite sludge containing up to 40 per cent. SO_2. Experiments with this sludge were made, acidifying with sulphuric acid to liberate the sulphur dioxide. It was found that excellent results could be obtained with the following proportions of sludge and sulphuric acid :—

I. 0·03% SO_2 (as sludge)+0·36% H_2SO_4. Acidity=0·055 N.
II. 0·06% SO_2 (as sludge)+0·36% H_2SO_4. Acidity=0·045 N.

The sludge contained excess of lime to keep it stable. This lime, together with the hardness of the water, caused a certain amount of loss of sulphuric acid.

As was expected, the sludge behaved in exactly the same way as sulphurous acid, the effect of the sulphur dioxide being marked after seven days' steeping. Whereas paddy which had been steeped in 0·045 sulphuric acid for this period had lost its good colour, the sulphite treated sample remained excellent. It is not to be supposed that there is much benefit by treating paddy with sulphite when the steeping period does not exceed two to three days. In such cases the difference in colour of the final product is negligible.

The above results were tested practically in the mill from 13th to 20th February, 1922. The following steeping solution was decided upon :—

0·03% SO_2 (as sludge) + 0·18% H_2SO_4.

since it was considered that if bad odours could be suppressed for about four days, this would be adequate inpractice.

Steeping paddy in dilute sulphuric acid of pH 4·0 should suppress nuisances, but such a steeping solution very soon gives off the most obnoxious odours. Actually it was found that a solution of pH 1·4 —pH 1·7 was necessary to keep sweet for seven days. This is owing to the fact that the solution is unbuffered. In such cases the amount of acid present is as important as the hydrogen ion concentration. In addition, it is cheaper to add more acid than to buffer the solution. The solution used in the mill, *viz.*, 0·03% SO_2+0.18%H_2SO_4, was found to have a hydrogen ion concentration pH=1·7.

Since different mills steep at different temperatures, it was decided to run the large scale test at two different temperatures, *viz.*, 50°C. (122°F.) and 30°C (86°F.), as nearly as possible. Two large iron tanks had been fitted up for mixing the sludge and sulphuric acid. Steam was laid on for mixing purposes and for bringing to the required temperature. The liquid could be run by gravity to any steeping tank required.

Every steeping tank in the mill was charged with the acid liquid during the test so that a fair estimate of the value of the process could be obtained. During the week, about 17,000 baskets of paddy were so treated, the amount of parboiled rice from this being approximately =260 tons. The following conclusions were drawn :—

(1) No offensive odour was developed in steeping, boiling or in any other stage of the process. It was difficult to realize that the mill was working the parboiling process.

(2) Hot or cold steeping made no difference as regards odours.

(3) The finished parboiled rice was free from odour of any sort, good or bad.

(4) The colour of the finished rice from the cold steepage tanks was slightly better than that from the hot steepage tanks. This is partly due to the fact that loss of sulphur dioxide is greater at the higher temperature.

(5) The colour of the finished rice from cement steeping tanks was better than that from iron tanks.

(6) Breakage in milling was less than for any week during the previous six weeks.

Defects of the process.

(1) The acid solution rapidly attacks iron tanks, piping, etc., particularly when hot. Very special precautions will require to be taken to avoid this.

(2) The sulphuric acid is dangerous to handle particularly with the class of labour employed in such mills.

Acidification of the steeping water with sulphuric acid having proved successful in preventing bad smells, an alternative method not involving the addition of strong acids was very desirable. The handling of sulphuric acid by mill coolies involves a certain amount of risk, and hence if a method which is simpler in operation can be found it is to be preferred.

Lactic acid when added to the steeping water in concentrations of 0·5% (about) was perfectly satisfactory in preventing bad smells. If therefore the ordinary soil bacteria which are always present in enormous numbers in the grain could be utilized to develop lactic acid, it was considered that a satisfactory method could perhaps be evolved. Accordingly this work was tested along two separate lines :—

(*a*) Using acid water from previous steeping operations.
(Steeping at ordinary temperatures—35°C.—36°C.)

(*b*) Steeping at high temperatures (55°C. and higher).

In (*a*), the evil smelling acid water was thoroughly boiled with live steam to boil off the obnoxious compounds, leaving only non-volatile, and therefore chiefly lactic, acid in solution. It may at once be said that this method resulted in complete failure. It proved impossible to boil off the bad smelling compounds and even after about ten experiments in which the same steeping water had been used, boiling on each occasion before using for the next paddy, no real improvement was noticed. No foul smelling compounds must therefore be allowed to arise at all, or the water is permanently spoiled for further use.

It has long been known that at 55°C. and higher, only lactic acid bacteria thrive well in sugar solutions. This fact is made use of in the distilling industry. By keeping a sugar solution at 55°C. for a certain length of time, lactic acid bacteria develop a certain acidity and in this acid liquid ordinary saprophytic bacteria cannot develop, whereas yeasts, moulds and other higher organisms can. On testing this method, it was found that no obnoxious odour was evolved from paddy steeping at 55°C. until about five days had elapsed. At 60°C. this did not occur in a week. Similarly at 70°C. and at 80°C., the latter being tested for two days' steeping only, for reasons to be given later. The above temperatures are far in excess of those used by mills, although upon occasion some use steeping water at 60°C.

When water at 60°C, is added to the paddy, however, the mean temperature falls at once below the temperature necessary to prevent the bad odours arising (55°C. to 60°C.). Whether the use of such hot water at 70°C.—80°C. was practicable or not as regards quality of the finished rice remained to be proved, particularly as regards colour of the rice, breakage in milling, etc.

Breakage in milling.

Duplicate experiments steeping paddy at temperatures from 35°C. to 80°C. were carried out. In one series, ordinary tap water was employed, while in the other a solution containing 0·03 per cent. sulphur dioxide and 0·18 per cent. sulphuric acid was used. Results are given in Table VIII.

The figures so obtained were determined as follows :—

A series of experiments was carried out with paddy which had been steeped for four days at room temperature, *i.e.*, the usual time given in mills. The soaked paddy was then steamed for various periods from 5–40 minutes to determine the optimum time of steaming. The shortest time to give good results was found to be twelve and a half minutes, this time therefore being adopted in all cases.

Similarly the length of time necessary to hand-mill the paddy was determined and found to be twelve minutes. This length of time was therefore adopted as standard. In this case, however, it should be pointed out that milling for a longer period was not found to alter the percentage breakage materially, merely to polish the rice a little more.

TABLE VIII.

Breakage in milling. Percentage breakage when steeping at various temperatures (sun drying the parboiled rice).

Steeping for—	3 hours	6 hours	9 hours	12 hours	15 hours	18 hours	21 hours	One day		Two days		Three days		Seven days	
	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Acidified	Blank	Acidified	Blank	Acidified	Blank	Acidified
Temperature 35°C.	..	..	..	..	..	..	..	60·6	57·0	23·0	41·6	39·7	24·4	45·8	32·9
45°C.	..	..	..	99·2	..	96·3	..	65·2	90·7	35·2	49·1	18·0	7·1	38·3	33·6
55°C.	..	92·0	42·2	39·0	74·1	35·0	27·6	30·1	24·6	43·5	20·7	32·4	25·6	14·4	33·5
60°C.	..	99·9	44·8	9·5	13·9	4·0	10·4	20·6	46·3	37·1	52·8	61·4	61·3	89·8	77·9
70°C.	..	92·2	4·4	16·3	13·9	20·2	19·2	21·6	29·8	31·9	32·6	42·9	31·3	34·6	52·4
80°C.	99·8	97·5	4·2	7·3	24·9	6·3	5·8	8·0	5·5	*9·4	*7·9	..	..	..	..

*Grain soft and sticky.

The percentage breakage was determined by taking a minimum 2,000 grains as sample, broken grains being separated. On the supposition that each grain on breaking gives two halves, the number of broken grains was divided by two and the percentage broken calculated. This is easily explained in a specific instance :—

In a certain sample suppose there are 2,000 whole *plus* broken pieces.

Let . . . . 1500 = whole grains
500 = broken grains

$$\therefore \text{ breakage} = 100\left\{\frac{\frac{500}{2}}{1500+\frac{500}{2}}\right\}$$
$$= 14{\cdot}3 \text{ per cent.}$$

The above is not the method employed in the mills but has been found to approximate very closely, and what is more important, it is a more stringent test. In the mills the method is to take 100 c.c. of a sample, separate the broken grains and determine their volume. The number of c.c. of broken grains gives the percentage breakage direct.

In a number of samples determined by both methods, breakage was as follows :—

	Laboratory method Per cent.	Mill method Per cent.
1	39·7	35·0
2	24·4	24·0
3	60·8	53·0
4	61·0	59·0
5	8·0	7·8

In general it was found that in good samples of 10 per cent. breakage or less the two methods gave practically identical results. When the breakage is large, the laboratory method gives the higher figure, as in fact, it invariably does. The reason for the divergence, small or great, is due to the fact that when rice breaks it may break into more than two pieces. When the breakage is small the grain usually breaks into two pieces; whereas if the breakage is large, it breaks into a great number.

For reasons given later, care must be exercised in drawing conclusions from the figures given in Table VIII, but the following appeared valid :—

(1) The minimum length of steepage for certain good results is as follows :—

35°C.	3 days.
45°C.	3 days.
55°C.	21 hours.
60°C	12 hours.
70°C.	9 hours
80°C.	9 hours.

(2) The best and most consistently good results are obtained by steeping at high temperatures, *e.g.*, 70°C.

There are many results which are apparently incorrect or out of place. This is due to a factor which in the first place was overlooked.

Colour of the finished rice.

It is well known that prolonged steeping gives the rice a brown colour which is apt to affect the selling value adversely. From earlier work it appeared that this was due to bacterial action, but in the present series of experiments this was ruled out by steeping at 80°C. at which temperature, although bacteria were present, they were present in such small numbers that they could not be responsible. Staining began to occur after approximately the following lengths of steepage :—

Steeping temperature	Blank	Acidified
35°C. . . .	Quite good up to 6-7 days.	Quite good up to 6-7 days.
45°C. . . .	Quite good up to 6-7 days.	Quite good up to 6-7 days.
55°C. . . .	Fair up to 6-7 days.	Fair up to 6-7 days.
60°C. . . .	Good for 3 days. Fairly brown in 7 days.	Good for 3 days. Fairly brown in 7 days.
70°C. . . .	Quite good for 2 days. Fair for 3 days. Brown in 7 days.	Quite good for 2 days. Fair for 3 days. Brown in 7 days.
80°C. . . .	Good for 12 hours. Brown in 18 hours.	Good for 12 hours. Brown in 18 hours.

The discoloration of the grain is therefore a chemical staining as it is increased regularly with increase of temperature. It cannot be due to bacteria as these decrease in number as the temperature rises above 70°C., whereas discoloration increases regularly with increase of temperature above 70°C.

It is therefore apparent that the best quality of parboiled rice can be produced by steeping at 80°C. for nine to twelve hours. Prolonged steeping, *i.e.*, two days at 80°C. caused the grains to gelatinise and clump together. This does not occur within twenty-four hours, however, and is only just becoming serious after two days.

Acidity developed at high temperatures to eradicate foul odours.

It was a matter for surprise to find that even at 80°C. bacteria were present and could produce acidity in the steeping water. The rate of production of acid at temperatures from 35°C. to 80°C. was determined in terms of hydrogen ion concentration. Results are given in Table IX.

TABLE IX.

Hydrogen ion concentration of steeping liquid (pH), steeping at various temperatures.

Steeping for	3 hours	6 hours	9 hours	12 hours	15 hours	18 hours	21 hours	One day		Two days		Three days		Seven days	
	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Acidified	Blank	Acidified	Blank	Acidified	Blank	Acidified
35°C.	..	..	..	..	..	..	..	*5·2 †7·6	1·8	*4·2 †4·2	1·9	..	..	*4·0 †4·0	2·1
45°C.	..	..	..	*6·5 †7·8	..	*6·4 †7·3	..	*5·2 †6·8	1·8	*4·2 †4·2	1·7	*4·0 †4·0	1·8	*4·0 †4·0	3·4
55°C.	..	*6·4 †7·9	*6·0 †7·5	*6·4 †7·5	*5·6 †5·7	5·0 †5·0	*4·2 †4·2	4·2 †4·0	1·8	*4·0 †4·1	1·7	*4·1 †4·0	2·8	*4·1 †4·0	3·5
60°C.	..	*7·0 †7·9	*6·6 †7·3	*4·2 †4·1	*4·2 †4·1	*4·2 †4·2	*4·2 †4·2	*4·2 †4·2	2·0	*4·1 †4·1	2·1	*4·1 †4·0	2·6	*4·1 †4·1	3·5
70°C.	..	*6·6 †7·4	*5·2 †5·3	*4·2 †4·2	*4·2 †4·2	*4·0 †4·1	*4·0 †4·0	*4·0 †4·1	2·0	*4·0 †4·0	2·6	*4·0 †4·0	2·8	*4·0 †4·0	3·6
80°C.	*7·5 †7·7	*7·2 †7·6	*6·8 †7·2	*6·5 †6·8	*6·0 †6·6	*6·0 †6·8	*6·4 †6·8	*6·0 †5·8	2·6	*5·0 †5·0	3·9	..	..	..	..

* Before boiling.
† After boiling.

It was found that within a week, no matter what the temperature, the steeping water attained a certain constant intensity of acid (about pH 4·2 to pH 4·0). No appreciable change of hydrogen ion concentration took place after boiling the liquid for some time so as to get rid of volatile acids when the liquid had attained pH 4·2 to pH 4·0. In the early period of steeping, boiling the solution certainly did alter the hydrogen ion concentration, the difference being due to carbon dioxide in solution. It appears likely therefore that in all cases, no matter what the temperature of steepage, lactic acid is the acid ultimately formed in greatest amount. The evil smelling compounds have no noticeable effect on the hydrogen ion concentration.

Accepting the supposition that acidity in the steeping water is due to lactic acid, the problem is considerably narrowed. By steeping paddy at 60°C. or higher until the hydrogen ion concentration =pH 4·0, such a solution should be proof against bad smells for a considerable time. Thus from Table IX, by steeping as follows :—

At	55°C,	for 21 hours.
"	60°C.	" 12 "
"	70°C.	" 12 "
"	80°C.	" more than 2 days.

these solutions should be proof against bad odours for a moderately long period. This was found to be the case, but a more thorough test was performed.

Samples of paddy were steeped at various temperatures for varying periods until they had developed a certain amount of acid. They were then allowed to stand under ordinary conditions of temperature, etc., the time being noted before they began to evolve bad odours. Results are given in Table X.

TABLE X.

Acidity developed at high temperatures for the prevention of bad odours from steeping paddy.

Temperature of steeping		Length of exposure to high temperature (in hours)								Remarks
		3	6	9	12	15	18	21	24	
55°C.	pH developed .	..	..	..	..	..	..	..	..	In the case of exposures of 18 hours and upwards odour only very slightly offensive after four days.
	Good for :— .	2 days .	2 days .	2 days .	2 days .	2 days .	3 days .	3 days .	3 days .	
60°C.	pH developed .	7·5	7·0	6·6	4·2	4·2	4·2	4·2	4·2	In the case of exposures of twelve hours and upwards odour only very slightly offensive after four days.
	Good for :— .	(Bad in 24 hours)	(Bad in 24 hours)	2 days .	2 days .	3 days .	3 days .	3 days .	3½ days	
70°C.	pH developed .	..	6·6	5·2	4·2	4·2	4·1	4·0	4·0	After four days only very slightest odour in all cases.
	Good for :— .	..	3½ days	3½ days	3½ days	3½ days	3½ days	3½ days	3½ days	
80°C.	pH developed .	..	6·4	6·0	6·4	5·6	5·6	..	..	Not so good as 70°C. probably because less acid is developed at 80°C.
	Good for :— .	2 days .	2 days .	2 days .	2 days .	2 days .	2 days .	2 days .	2 days .	

By steeping at 55°C. for eighteen hours, no bad odour was developed for three days; similarly at 60°C. for fifteen hours, no bad odour was noticed in three days; at 70°C. for six hours, for three and a half days; while at 80°C. exposures from three to twenty-four hours prevented bad odours for only two days.

These results were exactly as anticipated. In those cases where lactic acid is developed quickest (70°C.), such solutions are best in *keeping* qualities.

In the above experiment, the solutions were all quickly cooled down to room temperature after exposure to the high temperature noted. In practice this would not be the case, since large bulks of steeping paddy would cool more slowly. Therefore better results are to be expected from the mills. A solution proof against smells for four days, however, would practically get rid of the parboiling nuisance.

Use of the steeping water continuously.

Owing to the shortage of water in many parboiling mills it would be a great advantage if the water could be used again and again, provided that bad odours were not evolved, that the breakage in milling would not be increased and that the rice remained of good colour and quality.

Having proved that good quality parboiled rice could be obtained by steeping paddy for twelve hours at 60°C., it was determined to try using this water again and again, adding only such water as was necessary to cover the grain since some is absorbed by the paddy and is therefore lost. The water was not boiled or specially treated in any way.

By this means it was found that excellent samples could be produced by continuous steeping at 55°C. to 80°C. The percentage breakage in these samples is given in Table XI. A slight odour was discernible in the steeping water at the end of eleven steepings in the case of 55°C. and 60°C. but none could be noticed in the higher temperature samples. There is therefore no sound argument against using the same water continuously, provided that the temperature of water is not allowed to fall below 60°C. It is to be noted also that the percentage breakage so produced is very small.

TABLE XI.

Continuous use of the steeping water. Percentage breakage in milling.

Number of times steeping water used	55°C.	60°C.	70°C.	80°C.
1 . . .	46·4	49·9	11·0	11·0
2 . . .	8·3	2·7	3·1	3·2
3 . . .	63·4	10·8	13·3	13·8
4 . . .	6·1	4·5	3·8	3 9
5 . . .	36·8	14·7	8·0	10·0
6 . . .	2·0	5·6	4·5	3·9
7 . . .	34·0	20·0	13·8	11·1
8 . . .	28·8	3·4	12·5	3·1
9 . . .	62·3	9·2	12·6	11·8
10 . . .	6·0	4·5	7·3	4·5
11 . . .	42·5	8·3	5·2	24·9
Average . .	30·6	12·1	8·6	9·2
% water recovered.	76·9	78·7	74·0	70·1

REMARKS. 55°C. Slight smell after eleven operations.
60°C. Ditto.
70°C. & 80°C. } Absolutely free from bad odour.
In all cases rice was of first class quality.

The fact that from 70—80 per cent. of the steeping water can be recovered is of the greatest importance to parboilers in Burma, especially in view of the fact that bad odours do not arise when steeping is carried out in this way.

Inspection of the percentage breakage figures also reveals a curious phenomenon. Alternate figures are good and bad (or not so good) respectively. The poorer results were obtained by putting out the

parboiled paddy to dry in the sun *immediately after parboiling at* 7 A.M. The good results were all from paddies parboiled at 7 P. M., these samples being left thinly spread out in the laboratory overnight before being thoroughly dried in the sun next morning.

There is therefore strong argument to support the statement that the greatest cause of a parboiled paddy breaking when milling is due to too rapid drying in the sun (or similarly by artificial methods). To prove this point a further series of experiments was undertaken. In this series twelve equal amounts of the same sample of paddy were steeped in the same incubator at the same time for three days at 45°C., *i.e.*, the experiment was very similar to ordinary condition in the mills using moderately warm water. All samples were parboiled at 7 A.M., but six were dried as usual in the sun while the other six were allowed to dry slowly in the laboratory for two days without any artificial external heat being applied. Figures for the breakage are given in Table XII.

TABLE XII.

Percentage breakage in milling. Sun drying versus air drying (steeping at 45°C. for three days).

	Sun dried	Air dried
1	14·5	5·5
2	24·0	6·2
3	30·2	6·4.
4	39·9	6·9
5	51 1	7·6
6	54·3	8·4
Average	35·8	6·8

The cause of breakage is undoubtedly shown to be dependent upon the method of drying. The close agreement between the figures for the air dried sample and the widely inconsistent values for the sun dried sample may be explained by the fact that the plates on which the paddy was dried were slightly concave. Hence the paddy on the opposite edges received different amounts of the sun's rays. In the laboratory with air drying this would not occur.

This explanation falls into line with the fact often noticed by the millers, *viz.*, that breakage is worst during the first six weeks of the year in Lower Burma. At this time the sky is generally clear and drying of the paddy is very rapidly done. Hence the breakage must be increased unless special precautions are taken.

The figures given in Table VIII are therefore not reliable but are useful because they show what may happen in a mill where sun drying is used. Amelioration may be practised by so arranging the parboiling that the paddy escapes the rays of the sun in the hottest part of the day and by *very frequently* turning the paddy over.

It was therefore necessary to repeat the determination of the percentage breakage of the parboiled paddy when steeped for various periods at temperatures 35°C. to 80°C., the paddy in this instance being dried inside the laboratory for two days. No artificial heat was applied, the paddy being merely spread out in thin layers on iron plates and occasionally turned over. It was found that even on wet days the paddy became dry enough to mill in this time. Results are given in Table XIII.

TABLE XIII.

Percentage breakage when steeping at various temperatures (parboiled paddy dried in the shade).

Steeping for	6 hours	9 hours	12 hours	15 hours	18 hours	21 hours	24 hours		Two days		Three days		Four days		Seven days	
Temperature	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Acidified	Blank	Acidified	Blank	Acidified	Blank	Acidified	Blank	Acidified
35°C.	..	..	..	..	..	..	9·7	13·8	14·8	9·0	12·0	4·5	9·5	6·0	19·4	9·6
45°C.	..	..	..	..	..	..	9·4	6·0	12·5	7·7	11·8	6·0	7·7	5·7	15·3	6·0
55°C.	6·2	3·3	2·8	2·0	1·6	2·1	2·5	6·5	3·3	8·1	3·3	7·6	..	..	5·5	6·8
60°C.	8·3	3·0	4·8	2·7	3·4	4·9	2·7	2·3	4·8	6·7	3·1	3·4	..	..	6·9	8·7
70°C.	8·2	6·3	4·2	3·4	2·1	2·2	1·3	2·2	1·5	1·4	2·2	1·7	..	..	2·7	5·8
80°C.	3·6	2·9	1·1	2·0	4·4	2·1	8·7	13·4	*4·6	*19·7	..	..	..	..	..	..

* Grain soft and sticky.

Considering only the samples which were not acidified, the average breakage for the whole of the figures given is as follows :—

	Per cent. breakage.
80°C.	3·70
70°C.	3.40
60°C.	4·46
55°C.	3·26
45°C.	11·34
35°C.	13·10

The above figures include unsuitable times of steepage but are at least indicative of the fact that steeping at temperatures over 55°C. is to be preferred.

In general it may be said that the artificially acidified water increases the breakage in steeping at 55°C. and higher, while at lower temperatures it reduces breakage. Hence the bacteria causing nuisances probably cause a small amount of the breakage which results when milling.

The difficulty in determining breakage is due to the differing climatic conditions from day to day. All samples should have been dried at the same time to obtain strictly relative figures, but this desirable condition is not attainable without several very large incubators and abundant space for drying. Hence the method adopted was a compromise, but it is believed that drying for forty-eight hours was slightly more than sufficient in all cases, overdrying being a lesser evil than underdrying, since on storing, wet rice both loses weight and is badly attacked by moulds.

THE HOT STEEPING PROCESS ON THE LARGE SCALE.

At Messrs. Steel Bros.' Upper Pazoondaung mill, Rangoon, 22nd November to 4th December 1922.

The point at issue was to find the best all round method of mixing paddy and hot water so that the final temperature at the coldest portion of the steeping tanks was 140°F. minimum. From results previously obtained in the laboratory, I was confident that if this could be obtained in practice, a solution ideal in every way would result. It should be clearly understood that although by this means a steeping tank five or six feet deep records a temperature of about 180°F. at the top and 140°F. at the bottom, the top portion will not be oversteeped. In practice, provided that gelatinization does not occur, it is not possible to oversteep paddy for the process of parboiling.

In the first place, attempts were made to feed the hot water to the bottom of the tanks through perforated pipes so that equalization of temperature would follow automatically. The experiments were carried out in Messrs. Steel Bros.' Upper Pazoondaung mill, Rangoon, using

the ordinary steeping tanks. These tanks are of cement or iron and have a gentle slope towards the outlet cock so that they can be thoroughly drained. To prevent loss of paddy when running water to waste, a large screen strengthened by a steel frame is used. The area of the holes in this screen is larger than the diameter of the waste pipe.

PERFORATED PIPES ALONG BOTTOM OF TANKS.

1. *Single pipe along tanks six feet wide* (Figure 1).

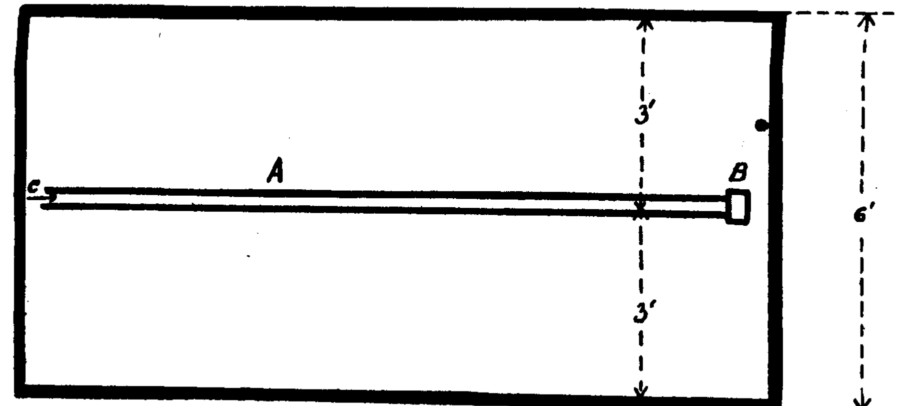

Figure I

A Pipe with ¼" circular holes bored underneath at 3" distance apart along bottom of tank Diameter of pipe = 2"

B Plug

C Hot water (180°F) inlet

This pipe had quarter inch circular holes bored along its underside at three inches distance between each hole along its entire length.

(a) Tank No. 16.

Details. This tank is made of iron, size 6′ × 6′ × 6′, capacity about 250 baskets of paddy. The central pipe was at first raised about six inches above the bottom of the tank.

Time to fill	40 minutes.
Average temperature of entering water	193°F.
Maximum temperature at the bottom (obtained by runnings)	110°F.
Rate of cooling at the top	6°F. per hour (initially).
Duration of steeping	12 hours.
Duration of steaming	20 to 15 minutes.

The paddy from the tank was steamed in separate lots, particular attention being paid to see that there were no signs of understeeping from the lower layers. This procedure was also followed in all tests to be subsequently described.

Results appeared to be quite satisfactory but it was not considered that a temperature of 110°F. at the bottom was the best that could be attained. During the steeping test a rough measure of the distribution of the heat was obtained by pushing long iron rods about half an inch in diameter to the bottom of the steeping tank. On quickly withdrawing these it was found that the lower twelve inches remained quite cold, especially at a distance of more than two feet from the central water pipe.

(b) Tank No. 10.

Details. This tank is of cement, size 15′ × 5′ × 5′, capacity about 325 baskets of paddy. The hot water pipe was arranged exactly as in (a) above.

Time to fill	1 hour
Average temperature of entering water	181°F.
Duration of steeping	12 hours.
Duration of steaming	20 to 15 minutes.

As in the previous test, it was found that the bottom portion of the tank remained cold. It was therefore decided to alter the system of piping.

2. *Two pipes along bottom of tanks arranged to give even distribution of water.* (Figure II.)

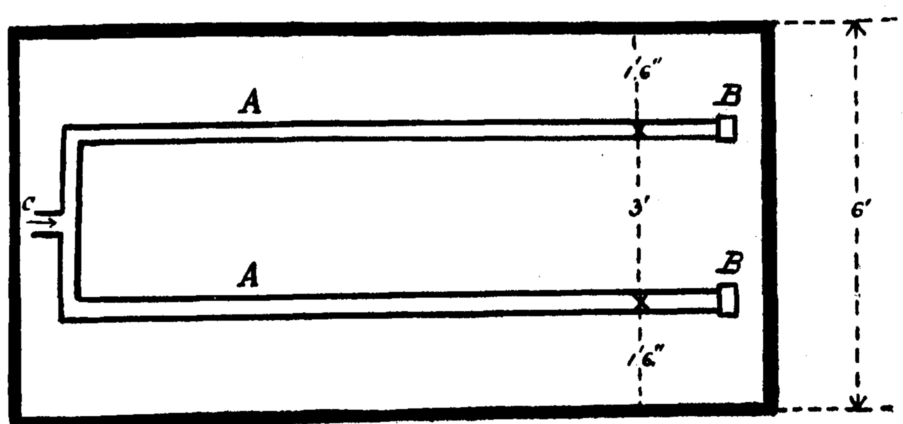

Figure II

A Pipes with ¼″ circular holes bored underneath at 3″ distance apart along bottom of tank. Diameter of pipe = 2″

B Plugs

C Hot water (180°F) inlet.

With the tanks used, the pipes were so arranged that the maximum distance of any part of the bottom of the tank from a source of hot water was 1′ 6″. The pipes were within half an inch of the bottom of the tank.

(a) Tank No. 16.

Details. Average temperature of entering water	190°F.
Time to fill	70 minutes.
Duration of steeping	54 to 72 hours.
Duration of steaming	15 minutes.

In this case it was not possible to parboil after twelve hours as the mill was shut down over week end. It was therefore decided to run the tank as a test to see what time would elapse before bad odours arose—

After 24 hours	perfectly fresh.
" 48 "	very good, acid smell.
" 56 "	unpleasant.
" 72 "	foul.

The results were therefore unsatisfactory. Milling samples were uniformly good except as regards odour.

(b) Tank No. 16.

Details.

Average temperature of entering water	192°F.
Time to fill	75 minutes.
Duration of steeping	9 hours.

When the waste cock was opened to run off the water, it was found that the outlet cock was blocked. The waste water ran off so slowly that I decided to repeat the experiment.

(c) Tank No. 10.

Details.

Average temperature of entering water	190°F.
Time to fill	70 minutes.
Duration of steeping	9 hours.
Duration of steaming	20 minutes.

Even from the lower layers, milling results were excellent in spite of the fact that the duration of steeping was only nine hours.

Although fairly good results had been achieved with the various systems of perforated piping, in no case had the water at the bottom of the tanks been sufficiently hot to ensure uniform results. The idea occurred to the author that cold water from the bottom of the steeping tanks could be withdrawn by means of a pump, steam injector, etc., and discharged to the top of the tanks. Using a steam injector this would also heat the water and a more uniform temperature should thereby be obtained. Complicated and expensive systems of piping inside the tanks would also be unnecessary. Accordingly a steam injector was fitted to the waste cock of tank No. 16 for the purpose.

Circulation of hot water by means of a steam injector.

Tank No. 16.

Details.

Average temperature of entering water	189°F.
Time to fill	70 minutes.
Circulating with injector	60 minutes.
Duration of steeping	12 hours
Duration of steaming	18 to 15 minutes.

By means of introducing iron rods and running samples to waste it was obvious that results were better than in previous experiments. The tank being made of iron, it was easy to make rough tests by the hand on the outside of the tank. At a distance of about six inches from the bottom, the tank was too hot to bear touching for more than a few seconds.

Milling results were uniformly good including samples from the lowest layers of paddy.

Tank No. 16 formed one of a compact block of four exactly similar iron tanks lying so close together that the water from any given tank could be pumped into any other desired tank by means of the steam injector. It was therefore possible to pump the water from previous steeping operations into another tank of paddy in order to steep again, adding only such fresh hot water as was necessary to make up loss occasioned by absorption. A test of continuous use of the same steeping water was therefore easily possible in this particular block of tanks. The tanks were numbered 16, 17, 18 and 19.

Continuous use of steeping water.

First steeping. This experiment was in Tank No. 16 described immediately above.

Second steeping—

Tank No. 18.

Details. Waste water from Tank No. 16 was pumped into a charge of paddy in Tank No. 18 by means of the steam injector. Hot water at 180°F. up to usual requirements was added.

Average temperature at the top of the tank	180°F.
Time to fill	4 hours.
Duration of steeping	12 hours.

Milling samples were all excellent.

Third steeping—

Tank No. 16.

Details. Water from No. 18 was blown back into a charge of fresh paddy in Tank No. 16 as previously described.

Duration of steeping	9 hours.

Milling samples were excellent.

Fourth steeping—

Tank No. 18.

Details. Water from No. 16 was again blown back into No. 18 and circulated until the temperature at the top was 180°F.

Duration of steeping	6 hours.

Different layers of paddy were steamed and milled separately and it was found that even from the bottom of the tank, milling samples were as free from white bellies as is usually the case with ordinary steeping. The fact that steeping was successfully cut down to six hours is extremely important.

Even had it not been previously shown, it now became obvious that the solution of the problem lay in obtaining a temperature of 140°F. minimum at the bottom of the steeping tanks. The simplest way of doing this was to run off the cold water from the lower layers and to replace it by water at 180°F. at the top of the tanks at an equal rate. As soon as the temperature of the waste water reached 140°F. the tanks could be left full.

It was not possible to test this latest method so completely as desired because of pressure of other work. For this reason it was decided to run only two tanks and to leave them until the smell of the paddy became objectionable, this being a more stringent test than merely taking milling samples. In addition, the maximum temperature obtained from runnings from the waste cocks in any previous test was 130°F. Hence if 140°F. could be obtained, an improvement in results was certain.

Hot steeping ensuring a minimum temperature of 140°F.

(a) *Tank No. 16.*

Details.

Average temperature of entering water	179°F.
Time to fill	55 minutes.

The waste cock was then opened and water at 180°F. added to the top of the tank as quickly as necessary to keep the tank full.

Running from waste (1″ diameter)	85 minutes.
Maximum temperature of runnings	145°F.
Volume of water used	twice normal (approximately).

After standing for three days the paddy was acid but entirely free from foul odours.

(b) *Tank No. 1.*

Details. This is a cement tank of irregular shape, capacity about 300 baskets of paddy.

Average temperature of entering water	193°F.
Time to fill (ordinary)	60 minutes.
Running from waste ($1\frac{1}{2}$″ diameter)	35 minutes
Maximum temperature of runnings	147°F.
Volume of water used	twice normal (approximately).

After standing for three days, this tank was also entirely free from bad odours. Observation could not extend to a longer period by the author, but the manager of the mill stated that the contents remained sweet for about four days.

In this experiment, the temperature of water added was 193°F. By the time the tank was finally left full, a small amount of paddy near the inlet at the top had become glutinous. It was apparent that a temperature of 180°F. only is quite adequate for the purpose in view and that this temperature gives an ample margin of safety.

Recommended method for mills.

The largest steeping tank in use determines the size of boiling tanks, etc., required. Boiling tanks should be in duplicate and each should be of such a capacity that the largest steeping tank can be twice filled with water from one charge of a boiling tank. Since the steeping tanks contain paddy, boiling tanks should therefore be approximately equal in volume to the largest steeping tank. A sump to trap waste water for

further use should be provided and this sump should be about half the size of the largest steeping tank.

Let maximum size of any steeping tank	1,000 gallons
∴ Charge of paddy	115 baskets
Size of boiling tanks (each)	1,000 gallons
Size of sump	500 gallons

and *pro-rata*. A sketch of suggested layout is given (Figure III), but obviously wide variations to suit existing installations of steeping tanks are allowable without loss of efficiency.

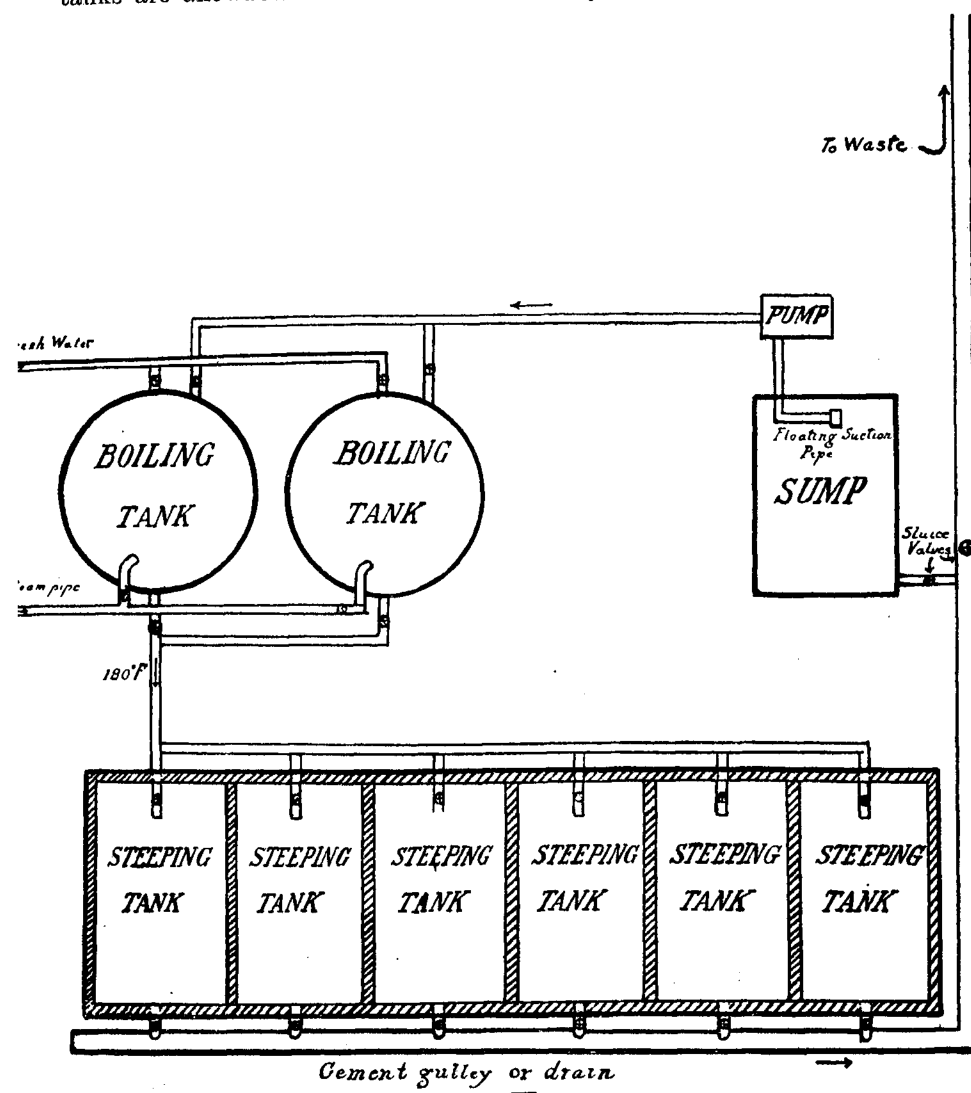

Figure III

In actual use, the contents of a boiling tank at a temperature of 180°F. should be discharged into a steeping tank filled with paddy as usual, water being run from the outlet cock when full. This is continued until the temperature of the runnings attains 140°F. at least or until twice the normal volume of water has been used. The waste water from the steeping tanks should be collected in the sump and pumped back to the boiling tanks as early as possible for further use. The sooner this waste water is again heated to 180°F., the better.

While one boiling tank is being discharged, the other should be heated by steam up to 180°F.

A bye-pass controlled by a large valve should be provided in the drain so that waste water may be discharged instead of passing to the sump, should it not be advisable to again use the water after many operations.

A floating suction is not an essential to the sump. It is quite obvious that, in the majority of cases, the improved method is capable of adaptation without alteration to existing plant. Necessary additions include the sump, pump and, in certain cases, boiling tanks.

Messrs. Steel Bros. Ltd., have now converted a portion of their Dawbong mill and the whole of their Lower Pazoondaung mill to the process. Several thousands of tons of parboiled rice have already been produced by the method to the entire satisfaction of the firm. This result has been attained with newly harvested paddy which by the ordinary steeping method requires four days' steeping. By the new method, thirty-six hours' steeping is adequate.

Analysis of the same variety of parboiled rice produced by ordinary steeping, hot steeping or acid steeping, gives no very definite conclusions (Table XIV). The greatest care in drawing the sample is required, and from a large number of analyses, in addition to those given in Table XIV, the author considers that the greatest caution should be exercised in drawing conclusions. It is, however, safe to say that the change in chemical composition occasioned by hot steeping is small compared with the variation in paddies of different strains.

TABLE XIV.

Composition of milled parboiled rices, Rangoon.

GRAMS PER 100 GRAMS AIR DRY RICES.

Treatment	Moisture	Ether extract	Albuminoids	Soluble carbohydrates	Woody fibre	Ash	Nitrogen: Total	Nitrogen: Albuminoids	Phosphoric acid (P_2O_5)	Potash
Ordinary . . .	14·71	0·71	6·25	77·35	0·16	0·82	1·02	1·00	0·38	0·10
Acidified with H_2SO_4 and sulphite sludge.	14·28	0·66	6·25	77·86	0·17	0·78	1·00	1·00	0·37	0·10
Hot steeping . .	14·39	0·59	6·44	77·72	0·15	0·71	*1·02	*1·03	0·36	0·10

GRAMS PER 100 GRAMS DRY MATTER.

Treatment	Ether Extract	Albuminoids	Soluble carbohydrates	Woody fibre	Ash	Nitrogen: Total	Nitrogen: Albuminoids	Phosphoric acid	Potash
Ordinary . . .	0·83	7·33	90·70	0·18	0·96	1·20	1·17	0·45	0·12
Acidified with H_2SO_4 and sulphite sludge.	0·77	7·29	90·84	0·19	0·91	1·17	1·17	0·43	0·12
Hot steeping . .	0·69	7·52	90·69	0·17	0·93	*1·19	*1·20	0·42	0·12

* Repeated and obtained exactly same result. Presumably nitrate is absent and both total and albuminoid percentages = 1·025 (air-dry).

Conclusions.

A method of steeping paddy for parboiling is described for which the following claims are made :—

1. The duration of steeping can be cut down to one-third or less of that required by the old method.
2. Provided that steeping does not exceed twenty-four hours' duration before replacing the steeping water, such water can be used repeatedly for steeping without any ill effect whatsoever.
3. In case of breakdown in the mill, unexpected rains, etc., the paddy in steep remains sweet for at least three days. (For this purpose it is essential that the coldest portion of the steeping tank should attain at least 140°F.)
4. Breakage in milling is not increased.
5. The colour of the parboiled rice obtained, particularly when the duration of steeping does not exceed twenty-four hours, is the best attainable in practice.
6. A very considerable economy of steeping water is effected (about 70 per cent.).
7. Output from a given number of steeping tanks can be greatly increased.
8. The majority of parboiling mills can be adapted to the process at almost insignificant expense.

Summary.

1. To prevent the nuisances caused by the parboiling of paddy two steeping methods may be employed :—

(*a*) Acidification of the steeping water.

(*b*) Steeping at temperatures initially not lower than 60°C. at the coldest portion of the steeping tanks.

The latter method is to be preferred for many reasons.

2. Anaerobic bacteria are chiefly responsible for the nuisances.

3. Germination of paddy in the steeping tanks is encouraged by low acidity and aeration.

4. Breakage in milling of parboiled rice is chiefly due to too rapid drying.

5. Loss of good colour of parboiled rice occurs after steeping for too long or after steeping at too high temperatures. Adequate steeping can be given in such periods that no loss of good colour occurs.

6. The steeping water may be used continuously in the manner described without ill effect and without causing nuisances.

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