DESIGN AND FABRICATION OF AN IMPROVED PARBOILING TECHNIQUE TO PROCESS QUALITY PARBOILING RICE AT HOUSEHOLD LEVEL

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Introduction

Rice (*Oryza sativa*) belongs to the Graminae family, which is entirely non-allergenic and gluten-free. Rice is one of the leading food crops of the world and is second to wheat in terms of area harvested and provides more calories per hectare than any other cereal crops (Surajit de Datta, 1981). It is the staple food of over half of the world's population (Ali and Pandya, 1974). About 90% of the world's rice is produced and consumed in Asia

Rice constitutes a major staple food in Sri Lanka, India, Bangladesh, Vietnam and Korea etc. Rice is one of the major agriculture commodities produced in Sri Lanka. Rice is the single most important crop occupying 34 % of the total cultivated area in Sri Lanka. On average 560,000 ha are cultivated during *Maha* and 310,000 ha during *Yala* making the average annual extent sown with rice to about 870,000 ha. About 1.8 million farm families are engaged in paddy cultivation in Sri Lanka. Sri Lanka currently produces 2.7 million tonnes of rough rice annually and satisfies around 95% of the domestic requirement. Rice plays an important role in the nutrition of the average Sri Lankan, as it provides 45% of calories and 40% of the protein requirement and constitutes 68% of the total cereal consumption (Raveendranath, 2003).

Removal of Inert material (cleaning), parboiling, hulling, polishing, grading, packing are the necessary steps in rice production. Parboiling is an age-old process in many parts of Asia, Africa, and to a limited extent in some European countries and America. Parboiling is the hydrothermal treatment of rice that gelatinizes the grain within its hull. It involves hydrating the grains by soaking in water followed by steaming to gelatinize the starch with in the grain endosperm and drying to moisture content suitable for storage and milling (Rao and Juliano, 1970). As a result of starch granules of the grain getting gelatinized, cracks are disappeared and also in this process the gelatinized starch and disrupted protein bodies expand and fill the air spaces in the endosperm thus improving translucency of the parboiled rice. Therefore, the percentage of grain breakage during milling can be significantly reduced because of parboiling, nutritional losses can be minimized and resistance to insect infestation during storage can be increased (Champa *et al.*, 2003).

A number of traditional and modern processing techniques have been used to parboil paddy around the world. In indigenous method soaking and steaming are done at the same time, therefore the temperature control is difficult.

Parboiling is an essential process to convert paddy into rice. At present in Sri Lanka, paddy is parboiled at household level mainly by boiling the paddy in water for 2 to 3 h in a vessel. In this process, soaking and steaming are done at the same time, therefore, the bottom layer of paddy is steamed more than top, and meanwhile control is difficult. However, the main drawback of this traditional parboiling method is that the grains do not get hydrated completely and also since there is insufficient heat treatment for complete gelatinization, un parboiled paddy are resulting with a high percentage of white belies and poor milling qualities. Boiling of grains in water for a long period of time may cause water soluble nutrients, especially vitamins, to dissolve in the boiling water which results high nutrient losses (Vellanki *et al*., 1978).Therefore, there was a necessity to design and develop a reliable, effective parboiling technique at low cost possible to over come the problem faced in the traditional parboiling techniques and improves the parboiling process at household level.

The broad objective of the study was to design an effective and low cost parboiling vessel suitable for household level. The specific objectives were introducing a cheap and reliable parboiling technique for household usage to overcome the problems faced in the traditional parboiling techniques, encourage the peoples to adopt parboiling process at household level, reduce the parboiling and milling losses and improve the nutritional quality of the parboiled rice.

MATERIALS AND METHODS

This research was carried out at the Division of Agriculture Engineering, Faculty of Agriculture, Eastern University, Sri Lanka during the period of October to December, 2004.

MATERIALS

18 gauge metal sheet, 12 gauge flat iron strip, paddy (BG-94-1), thermometer (0-200 °C), Moisture can, Electronic balance and convection oven were used in designing and testing and evaluating the different component of the parboiling vessel.

DESIGN METHODLOGY

Design of steam diverter

18 gauge metal sheet was used to fabricate steam diverter because the gauge was considered as to give enough strength for the operation. Diameter and length of the main diverter were 5 cm and 60 cm, respectively and diameter and length of the branches of the diverted were 2 cm and 15 cm, respectively. The branches were made on the main diverter at 5 cm spacing at right angle in spiral arrangement and small holes were made on the bottom plate of steam diverter to allow enough steam to parboil the bottom layer of paddy. Small holes were also made on the main and branches of the steam diverter as much as possible to divert the steam evenly throughout parboiling chamber (Fig. 1 and Fig. 2).

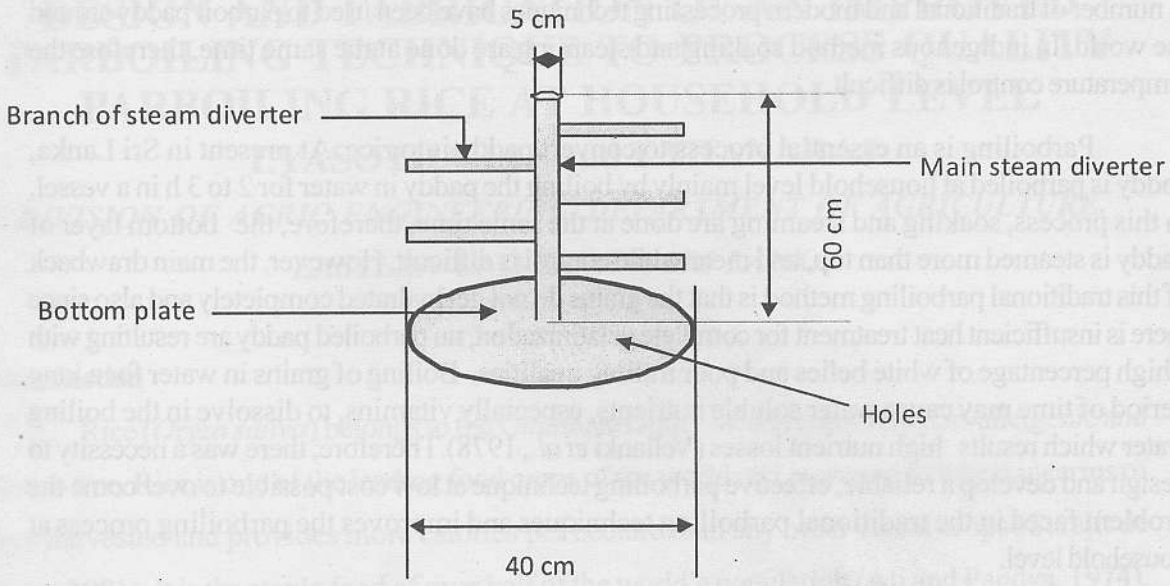

Fig. 1: Side view of steam diverter

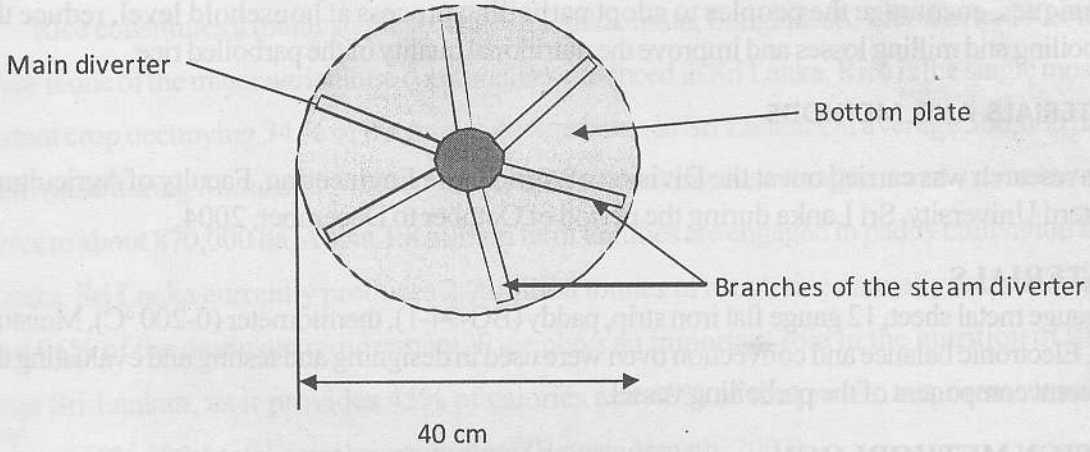

Fig. 2: Top view of steam diverter

Design of parboiling chamber

Parboiling chamber was fabricated using 18 gauge metal sheet at the dimension of 60 cm diameter and 130 cm height. Total volume of parboiling chamber was 0.075 m^3, which was determined using the bulk density of paddy. According to the volume, the parboiling chamber had the capacity to hold 40 kg of soaked paddy. Metal rings were made using flat iron and fixed in the top and bottom of parboiling chamber to give additional strength.

A 15 x 10 cm dimension door was made at the bottom of the parboiling chamber to down load the parboiled paddy. A slush gate was made to close this door completely during the parboiling process. Porous bottom plate of the steam diverter was the bottom of the parboiling chamber and top was completely covered using cover plate made up of metal sheet during parboiling process (Fig. 3).

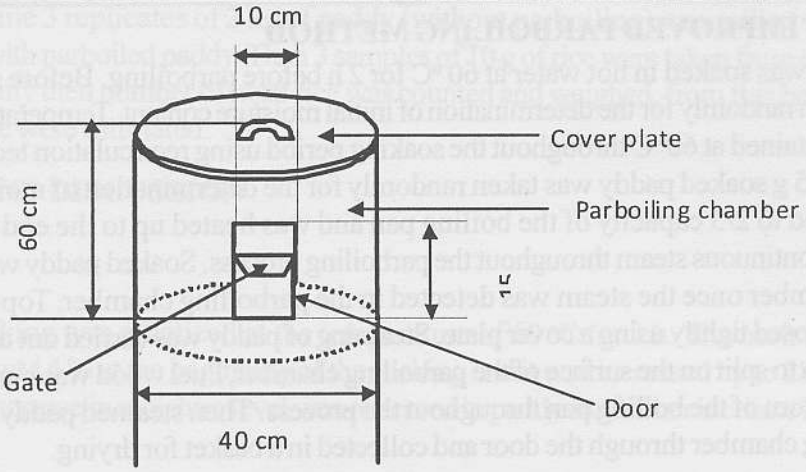

Fig.3: Parboiling chamber

Design of boiling pan

Boiling pan was firmly welded to the bottom of the parboiling chamber, which was also made up using the 18 gauge metal sheet. Length and diameter of boiling pan was 30 cm and 40 cm, respectively. The capacity of the boiling pan was 37.5 l. It was determined that capacity of the water was enough to give steam throughout the parboiling process.

Design of top cover

Top cover was also made using 18 gauge metal sheet. Diameter was 40 cm and a handle was fixed at the top for easy handling.

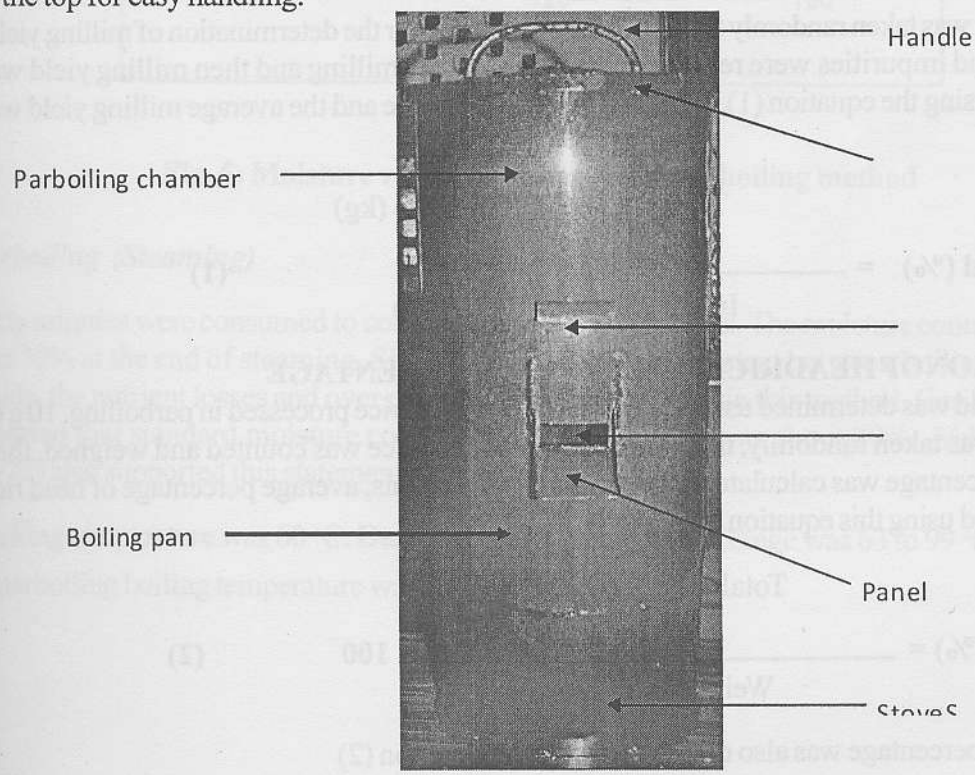

Fig.4: Improved parboiling vessel

TESTING OF IMPROVED PARBOILING METHOD

40 kg of paddy was soaked in hot water at 60 °C for 2 h before parboiling. Before soaking 5 g of paddy was taken randomly for the determination of initial moisture content. Temperature of soaking water was maintained at 60 °C throughout the soaking period using recirculation technique, at the end of soaking 5 g soaked paddy was taken randomly for the determination of moisture content. Water was filled to 2/3 capacity of the boiling pan and was heated up to the end of parboiling process to get continuous steam throughout the parboiling process. Soaked paddy was filled in the parboiling chamber once the steam was detected in the parboiling chamber. Top of parboiling chamber was closed tightly using a cover plate. Steaming of paddy was carried out until the hull of the grains began to split on the surface of the parboiling chamber, Fuel wood was burnt in the stove made at the bottom of the boiling pan throughout the process. Then steamed paddy was removed from parboiling chamber through the door and collected in a basket for drying.

(a) Drying

Parboiled paddy was dried under direct sun for about 48 h to bring down the moisture content to about 14 %. During the drying process, samples were taken randomly in 1 h interval for the determination of moisture content and also temperature difference was recorded throughout the drying period.

(b) Milling

Then paddy was milled to remove hulls and was cleaned to get pure rice. Milled rice was weighed and total milling yield, head rice yield and broken rice percentage were calculated. Then grading was done according these parameters.

DETERMINATION OF MILLING YIEID

2 kg of paddy was taken randomly from the parboiled paddy for the determination of milling yield. Then husk and impurities were removed from the rice after milling and then milling yield was determined using the equation (1). Three replicates were made and the average milling yield was considered.

$$\text{Milling yield (\%)} = \frac{\text{Total weight of milled rice (kg)}}{\text{Initial weight of paddy (kg)}} \times 100 \qquad (1)$$

DETENATIONOF HEADRICE AND BROKEN PERCENTAGE

Head rice yield was determined using the total weight of head rice processed in parboiling. 10 g of milled rice was taken randomly, then total number of head rice was counted and weighed, then head rice percentage was calculated for each sample. From this, average percentage of head rice was calculated using this equation (2)

$$\text{Head Rice (\%)} = \frac{\text{Total weight of head rice (kg)}}{\text{Weight of milled rice (kg)}} \times 100 \qquad (2)$$

Broken rice percentage was also calculated using the equation (2)

At the same time 3 replicates of 2 kg of paddy (without parboiling) was milled to compare the milling yield with parboiled paddy. Then 3 samples of 10 g of rice were taken from each milled rice sample randomly then number of head rice was counted and weighed, from this head rice, broken rice percentage were estimated.

RESULTS AND DISCUSSION

Soaking

Hot water soaking was practiced at the temperature of 60 °C for 3 h. The moisture content of paddy was about 14 % at the beginning of the soaking and it was increased up to 28%. There is no considerable increase in moisture level was observed in paddy for further increase in soaking time (Fig. 5).

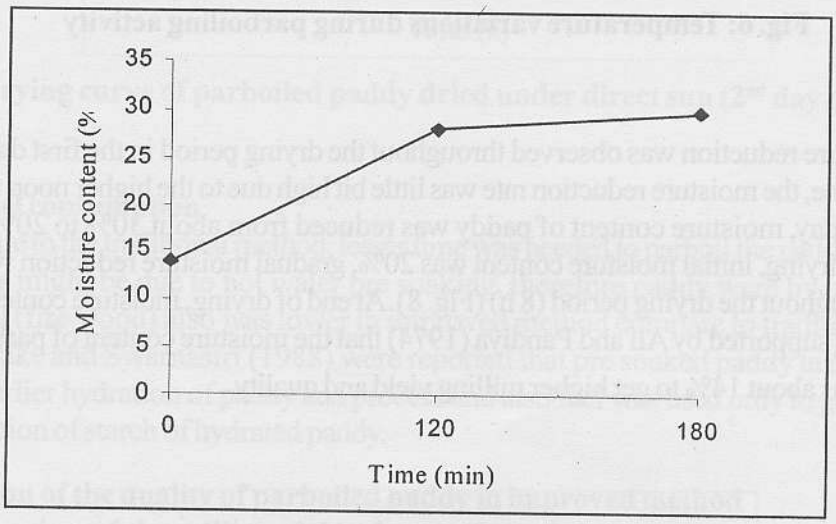

Fig. 5: Moisture variation in improved parboiling method

Parboiling (Steaming)

Sixty minutes were consumed to complete the steaming process. The moisture content of paddy was 30% at the end of steaming. Since there was no direct contact between boiling water and paddy, the nutrient losses and over parboiling were minimized in this method. Garibaldi (1974) reported that standard moisture content of parboiled paddy was about 30%. Vellanki *et al.*, (1978) also supported this statement.

Soaking temperature was 60 °C. During steaming, temperature range was 63 to 99 °C and at end of parboiling boiling temperature was 110 °C (Fig. 6).

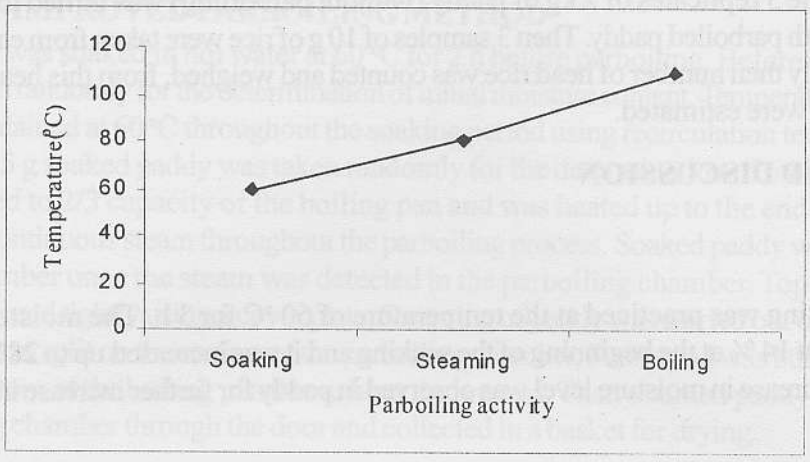

Fig. 6: Temperature variations during parboiling activity

Drying

Gradual moisture reduction was observed throughout the drying period in the first day. However, during noon time, the moisture reduction rate was little bit high due to the higher noon temperature. During the 1st day, moisture content of paddy was reduced from about 30% to 20% (Fig. 7). In second day of drying, initial moisture content was 20%, gradual moisture reduction was observed with time throughout the drying period (8 h) (Fig. 8). At end of drying, moisture content was about 14%. This was supported by Ali and Pandiya (1974) that the moisture content of parboiled paddy after drying was about 14% to get higher milling yield and quality.

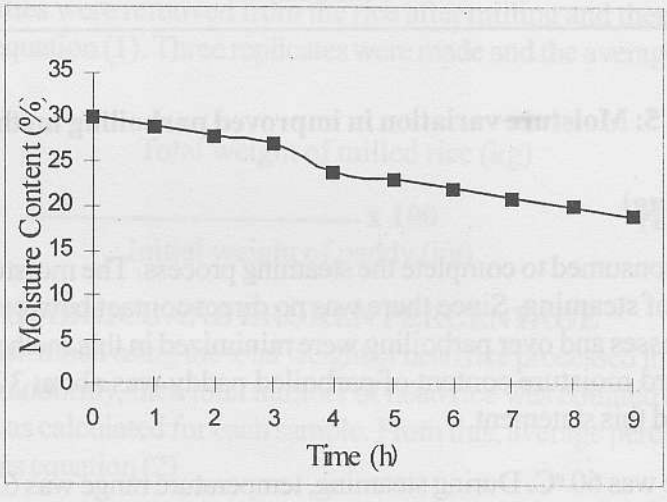

Fig. 7: Drying curve of parboiled paddy dried under direct sun (1st day of drying)

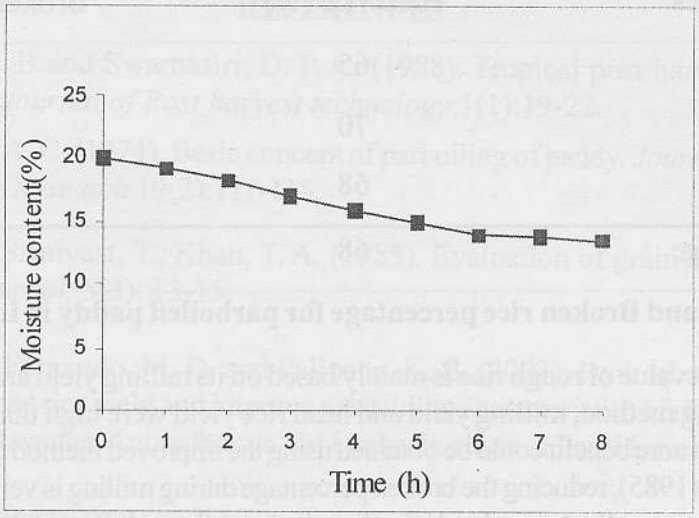

Fig. 8: Drying curve of parboiled paddy dried under direct sun (2nd day of drying)

Time and fuel consumption

When compare to the traditional method, lesser time was needed to parboil the paddy in improved method. This might be due to hot water pre soaking, therefore paddy were hydrated already. Usage of fuel (fire wood) also was lower in improved method compare to traditional method. Adhikarinayake and Swarnasiri (1988) were reported that pre soaked paddy taken lower fuel because of earlier hydration of paddy and process and also fuel was used only to generate steam for gelatinization of starch of hydrated paddy.

Determination of the quality of parboiled paddy in improved method

(a) Determination of the milling yield of parboiled paddy in improved method

Average milling yield was calculated as 58%. It was considered as higher milling rate than that of other method. Because in traditional method, milling yield were less than 50% (Table 1).

(b) Determination of head rice yield and broken percentage

Head rice yield was calculated as 68 % and average broken rice percentage was calculated as 32 %(Table 2). Head rice yields also increased by about 25-35 % than that of traditional methods.

Samples	Milling yield (%)
1	60
2	58
3	54
Average	58

Table 1: Milling yield of parboiled paddy in improved method

Samples	Head rice (%)	Broken rice (%)
1	65	35
2	70	30
3	68	32
Average	68	32

Table 4.2: Head and Broken rice percentage for parboiled paddy in improved method

The market value of rough rice is mainly based on its milling yield and head rice yield. In mproved parboiling method, milling yield and head rice yield were high than that of traditional method. Therefore, more benefit could be obtained using the improved method (Table 2). According to Bhashyam *et al.*, (1985), reducing the broken percentage during milling is very important because the market value is normally determined based on the head rice yield, market value of the broken rice is only 30-50% of the value of head rice.

Conclusions

The following conclusion were drawn from this study,

i. Milling yield obtained in improved parboiling techniques was 58 % and about 10 % higher than that of traditional methods.
ii. About 68 % of head rice and 32 % of broken percentage were obtained in improved method. The head rice yield is higher than that of traditional methods (38 %).
iii. Fuel consumption of parboiling was reduced by about 43% in improved parboiling technique, because improved parboiling method needed only about 4 kg of fuel wood while traditional method needed about 7 kg.
iv. About 33% of head rice yield and about 67% of broken rice were obtained in milling of raw rice without parboiling. Therefore, the broken percentage was reduced by parboiling process.

Recommendation

It could be recommended that improved parboiling vessel is more suitable for rural household level people for efficient parboiling and also which gives more benefit to the farmer including higher milling yield.

Suggestions for future research

i. I suggest that, the hole size in steam diverter is not enough to distribute the steam evenly to the top parts of the parboiling chamber. Therefore, holes size should be increased on top of the steam diverter.
ii. Tightness of top cover with Parboiling chamber is not enough. Therefore, it should be tighten with rubber seal.
iii. The handle of top cover should be covered with rubber to easy handling.

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