

POSTHARVEST LOSSES

I.Z. SARTAJ ¹ and S. EKANAYAKE ²

¹ Central Rice Breeding Station, Batalagoda, Ibbagamuwa;

² Central Agricultural Research Institute, Gannoruwa

Abstract: Although the production of rice has increased in the recent past considerable grain losses amounting to 10-15% are reported to occur throughout postharvest operations namely, harvesting, threshing, drying, storing, milling, marketing and distribution. Genetic characteristics of the variety, environmental conditions prevailing at the time of harvest and methods used for threshing, cleaning and drying contribute to grain losses, and also affect the product quality. Storage at the on-farm level is important as it alleviates the problem of inadequate capacities of centralized storage facilities, and also reduces cost. Efficient storage requires cleanliness, moisture control and protection from birds, rodents and microorganisms. Parboiling is an effective postharvest operation that enables to prevent the loss of nutrients during milling. It is also suitable for salvaging wet and damaged paddy and increasing head rice yields. Improvement of the milling facilities should lead to the improvement of the quality of the final product.

INTRODUCTION

Rice is the staple food in Sri Lanka and provides much of the calorie, protein and other nutrient requirements of the population. Therefore, it is only natural that massive investments were made by the successive governments to raise the rice production to meet the country's growing demand. As a result of expanding the extent under rice cultivation as well as due to the development of improved varieties, rice yields increased significantly in the recent past.

In spite of the rapid growth of rice production considerable losses are reported to occur throughout the production process, and postharvest losses account for a major share of the total loss. These losses occur at harvesting, threshing, drying, storing, marketing

and distribution. A conservative estimate shows that 10-15% of the rice crop harvested in developing countries never reaches the consumer. Postharvest losses of rice associated with the different processes show that percentage loss for individual operations could vary from 1-10% (Table 1).

The most significant grain loss in the postharvest stages occurs during storage, and is caused by improper and inadequate facilities, particularly at farm level. The grain has to be stored because of the seasonal nature of production and the more or less constant rate of requirement by the consumer throughout the year. It has been estimated that approximately 40% of the total paddy produced in the country is available as a marketable surplus soon after harvest. A recent survey conducted in the

Table 1. Postharvest losses of rice

| <i>Operation</i> | <i>Loss (%)</i> |
|------------------|-----------------|
| Harvesting | 1 - 3 |
| Handling | 2 - 7 |
| Threshing | 2 - 6 |
| Drying | 1 - 5 |
| Storage | 2 - 6 |
| Milling | 2 - 10 |

Source: National Academy of Sciences, 1978

Anuradhapura district has revealed that 4-6% of the paddy is lost during storage (Fernando *et al.*, 1988). It is estimated that the losses due to insect damage are in the range of 4-6% of the stored grain (Palipane, 1979). Further, fungi and insects reduce the quality of the produce. For example, aflatoxin produced due to incorrect storing and postharvest processing could be hazardous to human health. The quality of rice also suffers due to 'black grains' caused by a fungus.

The above facts emphasize the importance of postharvest conservation, an area that has received scant attention in the past. This paper discusses some aspects concerning postharvest losses of rice such as pre-harvest and harvesting factors influencing the magnitude of losses, postharvest processing and storage technologies. An attempt is made to cover both quantitative and qualitative aspects of postharvest losses, and to identify areas for research and extension focus in the next decade.

POSTHARVEST LOSSES

Pre-harvest factors

The genetic characteristics of a variety greatly influence the postharvest losses it is likely to incur. Generally, traditional varieties are better adapted to postharvest handling than improved varieties. Before introducing a new variety it is important to pay sufficient attention to characteristics that enable it to show superior postharvest handling qualities. For example, varieties with a low moisture content in the ripe grain can be dried easily and varieties with a thicker seed coat would show reduced damage due to rodents and insects. Shattering is a varietal characteristic that could increase losses during harvest and postharvest stages (Table 2).

Management practices such as crop protection measures adopted also influence the postharvest characteristics. Insect infestation of a maturing crop may increase its vulnerability to postharvest losses, but insecticide residues may reduce the extent of postharvest insect damage.

Table 2. Shattering percentage of some commonly cultivated varieties

| <i>Variety</i> | <i>Shattering (%)</i> |
|----------------|-----------------------|
| Bg 11-11 | 17.8 |
| Bg 12-1 | 9.1 |
| Bg 34-8 | 7.0 |
| Bg 94-1 | 10.0 |
| Bg 380 | 3.6 |
| Bg 90-2 | 5.3 |
| Bg 400-1 | 4.1 |
| Bg 78 | 6.6 |
| Bw 351 | 2.9 |
| Bw 100 | 5.2 |
| Bw 272-8 | 14.0 |

Source: Genetic stock records, Central Rice Breeding Station, Batalagoda, Unpubl.

Harvesting factors

The stage of ripeness at which the crop is harvested could influence the subsequent storage quality of the grain. Generally, harvesting could start before the grain is fully ripe. However, such grain would have a higher moisture content and would deteriorate more quickly than mature grain due to the presence of enzymes. The optimum moisture content under tropical conditions for rice grain at harvest is 21-24%. This point is generally reached 28-32 days after flowering (Jayawardena, 1973; Chandler, 1979). If the crop is allowed to stand in the field after it has reached maturity, considerable losses occur in the field, and the percentage recovery of head (whole grain) rice after milling is also reduced. For instance, if the rice crop is left in the field until the moisture content of the grain is reduced

to 15% the yield reduction could be as high as 20%. This loss could be attributed to a number of factors such as shattering in the field, damage due to birds and rodents, and shattering during harvesting and transport to the threshing floor. Harvesting at the correct stage makes it possible to reduce losses, and also enables to produce high quality milled rice. When a crop is allowed to remain in the field after it is mature, 'sun checking' (cracking of the grain) occurs and the grain breaks during milling. Another disadvantage of late harvesting is that rainfall or dew may cause the semi-dried grains to be re-moistened, resulting in grain cracking. This also leads to low milling yields and recovery of head grain.

Threshing

Traditional methods of threshing such as using animals to trample the sheaves placed on the threshing floor or

the modern equivalent of using tractor wheels may result in grain loss as a certain amount of grain may not be detached from the panicle. This method also allows impurities to become mixed with the grain, which may lead to subsequent storage problems. The use of flails to beat the grain from the stalk may damage the grain. The axial flow paddy threshers that have become increasingly popular may provide an answer to these problems.

Cleaning

Usually, threshed paddy contains sand, small stones, straw, and immature and unfilled grains. The extraneous material has to be removed to produce high quality rice. At the on-farm level this is achieved by sieving manually and winnowing. These methods are far from perfect and generally, the paddy sold is of an inferior quality. Although, mechanization of the cleaning process would provide a solution, subsistence farmers having small holdings cannot afford to purchase cleaning and drying equipment.

Drying

The moisture content in the rice grain at the time of harvest varies from low levels to over 30%. This must be reduced to 13-14% if the rice is to be stored for any length of time and to obtain high head rice recovery. High moisture content leads to rotting of the grain and

reduces the milling quality because of breakage. It also causes discolouration and quality loss due to fermentation and heat damage. Mould attacks and possible aflatoxin production may also cause loss in quantity and quality.

Traditionally, sun-drying of the grain is done by spreading the paddy in a 2-3 cm deep layer. This is periodically turned. At the end of the day, the paddy is heaped and covered for the night to facilitate gradual cooling. This process of intense drying in the sun and cooling in the night causes 'sun checks' and cracks on the rice kernel. In raw-milled rice sun-drying probably is the major cause of the high percentage of broken grain. This method is labour-intensive and depends on having fair weather. In addition, there are losses due to rodents and birds. For best storage and processing results drying should be uniform and slow. In this regard, drying in the shade is better than rapid sun-drying (Table 3). The only disadvantage of this process is that it is very slow.

Mechanical drying involves the use of machinery such as air blowers and heaters. The air is heated and forced through the mass of paddy. During the drying process, rapid removal of surface moisture causes contraction of the outer layers and the high temperature tends to cause expansion. This results in two opposite effects which produce internal stresses in the grain. These stresses cause breakage during milling. The method

Table 3. Effect of time of harvest and method of drying on head rice recovery

| <i>Time of harvest (days after 50% flowering)</i> | <i>H 4</i> | | <i>Ld 66</i> | | <i>Bg 11-11</i> | |
|---|------------|--------------|--------------|--------------|-----------------|--------------|
| | <i>Sun</i> | <i>Shade</i> | <i>Sun</i> | <i>Shade</i> | <i>Sun</i> | <i>Shade</i> |
| 24 | 57.3 | 62.2 | 64.0 | 69.2 | 66.0 | 66.6 |
| 28 | 60.5 | 65.4 | 60.6 | 68.8 | 65.8 | 69.5 |
| 32 | 60.4 | 65.0 | 66.6 | 67.7 | 65.3 | 68.2 |
| 36 | 51.8 | 62.8 | 67.8 | 68.8 | 64.6 | 66.5 |

Source: Jayawardena, 1973

used to overcome this problem is to 'temper' the grain in between drying periods permitting the moisture within the grain to equalize, eliminating the development of stresses within the grain.

Storage

Paddy stored under good conditions for up to 3-4 months or more improves head rice yields of rice, increases grain hardness and causes the starch and protein fractions to become less soluble in water (Juliano, 1979). This 'aged rice' expands more during cooking and absorbs more water than freshly harvested rice, resulting in more flaky cooked rice, a quality much appreciated in Sri Lanka.

Bulk storage of paddy is done in bins or in silos, and requires mechanical handling, aeration and temperature monitoring. Compared to stacking in warehouses bulk storage involves less grain loss over longer periods, and in many situations, costs less to operate. Essential requirements for this method of storage are cleanliness and maintaining a moisture upper limit of 14%.

Paddy may be put in sacks and stacked in warehouses or in the open with protection from the elements. This type of storage is referred to as the flat storage. The sack ensures the safe storage and transport of the contents, protects the produce from decay, divides it into manageable units which can be easily stacked and handled. The division into smaller units also reduces 'bulk effects' such as heating and condensation. The warehouses should have provision for protecting the storage area from high atmospheric humidity. The floor should be protected from dampness, and the entry of rats and birds should be prevented. The storing should be done in such a way to facilitate easy identification and inspection of stocks. Continued vigilance helps in early detection of insect infestation, rodent damage etc.

Improving storage at the on-farm level may help in increasing farmers' incomes not only by reducing qualitative and quantitative losses but also through off-season sale of the produce at higher prices. In addition, improvement of storage at the on-farm level will help to

alleviate the problem of inadequate capacity of state and private sector stores. In improving farm level storage it is preferable, wherever possible, to improve and popularize traditional on-farm storage structures than introduce completely new technology because the former are fabricated from available material at a low cost. Also, the farmers are familiar with the design and operation of traditional storage structures.

Traditional storage structures

'Atuwa', 'bissa', 'waruwa' and 'peha' are the widely adopted traditional storage structures. These have been described by Fernando *et al.* (1988).

The outdoor 'atuwa' is a rectangular structure made of clay supported by a timber frame and is built on a platform raised 1.5 m above ground. The roof is usually covered with straw. Loading and unloading of grain are done through a wooden door provided at the upper edge of the wall.

The outdoor 'bissa' is barrel-shaped and is made of clay or mud, supported by a timber frame. It is also constructed on a raised platform and the roof is made of straw. The loading and unloading operations are carried out by lifting the roof from one side to create a space between roof and wall.

Unlike the other structures the outdoor straw 'bissa' has to be constructed while the paddy is being loaded because the straw wall is supported from inside by the grain mass. When grain is taken out after lifting the roof, the straw wall has to be broken gradually from the upper

edge until it reduces to the new height of the grain mass. Once the structure is completely unloaded it has to be rebuilt.

The outdoor 'waruwa' is cylindrical in shape and the wall is made of straw supported by a timber frame. The structure is built on a platform elevated 1.5 m above the ground. Loading and unloading are carried out by lifting the roof.

The indoor 'peha' is an open basket, made of woven split bamboo. The capacity varies between 200-500 kg. The interior of the basket is normally coated with a thin layer of cowdung prior to filling with grain.

A comparison of these storage structures showed that high grain losses occur in the rectangular 'atuwa' made of clay. This is due to insect and mould infestations because of wetting of walls during rainy weather and exposure of the bulk of grain to the atmosphere favouring insect multiplication. In the 'bissa' and 'waruwa' the grain moisture varied with the ambient relative humidity making grains susceptible to mould damage during wet weather. This shows that straw walls are not good insulation barriers against the diffusion of water vapour. Therefore, these storage structures are less suitable for outdoor on-farm storage than clay-walled structures. Short life span of structures made of straw like 'bissa' is also a clear disadvantage. The clay 'bissa' was found to be the best among the outdoor storage bins. The loss of grain weight of 1.9% (dry basis) in the clay 'bissa' after a storage period of 180 days was, on an average, 26% less than the losses that occurred

in other types of outdoor bins (Fernando *et al.*, 1988).

The performance of the 'bissa' could be further improved by providing an outlet at the bottom, making a hopper bottom floor or construction of a roof where only a section has to be lifted to remove grain. In the traditional 'bissa' the whole roof has to be lifted to remove grain. This tends to damage the wall of the structure. Also, rat guards could be fixed on the pillars carrying the bin. Although, the cost of storage in the 'peha' is low compared to the other types of indoor bins, grain losses during storage due to insect and rodent damage are very high.

Storage insects

Insects infect both paddy and rice in storage and cause considerable damage. *Rhizopertha dominica* (Lesser grain borer), *Sitophilus* spp (Weevil) and *Sitotroga cerealella* (Angoumois grain moth) are the most common insect pests of stored grain. Physical losses apart, insect activity leads to deterioration of quality. Insect infestation also tends to accelerate undesirable chemical changes in the whole grain. Some insects selectively attack the germ, the most nutritious part of the grain. The presence of contaminants such as dust and insect excreta may render it unsuitable for consumption.

Temperature, humidity and moisture within the grain are the most important factors influencing the development of insects in stored grains. The size of the grain, its physical properties such as hardness, composition and nutritive value also influence the development of insects.

The use of insecticides is the most effective management tool for controlling insect pests. Generally, contact action insecticides and fumigants are used on storage pests. Pirimiphos methyl, methacrifos and phoxim have been found to be effective in controlling all three insect pests mentioned above. Malathion is effective only against *Sitophilus oryzae*.

Factors such as mammalian toxicity, residual toxicity and cost-benefits will have to be considered in selecting a suitable insecticide. Control of insect pests can be achieved with good sanitation and the routine use of a low cost insecticide.

Fungi

Among various organisms that affect the quality of rice grain moulds are important, not only due to their ubiquity but also due to their ability to grow quickly and produce toxic compounds hazardous to human health. The invasion of food grains by fungi also results in loss of weight and viability, discolouration, and changes in biochemical and functional properties.

Rice is harvested at grain moisture contents higher than what is safe for storage in order to avoid breakage during threshing. Subsequent drying to reduce it to safer moisture levels, therefore, becomes mandatory. For want of facilities, this is often ignored, and as a result fungal infestation of rice during storage is inevitable. The percentage of 'black grain' in rice caused by the fungus *Curvularia fallus* seems to increase with storage time (Table 4).

Table 4. The effect of storage period on extent of 'black grain' incidence in paddy (var. Bg 90-2)

| <i>Storage time</i> | <i>Black grain (%)</i> |
|---------------------|------------------------|
| 0 | 3.4 |
| 2 weeks | 5.0 |
| 4 weeks | 5.2 |
| 6 weeks | 5.4 |
| 8 weeks | 8.4 |
| 10 weeks | 12.5 |
| 12 weeks | 16.5 |

Source: Breckenridge and Sangarapillai, 1978

PARBOILING

Nearly 70% of the rice consumed in Sri Lanka is parboiled before milling. In the parboiling process, paddy is soaked, steamed and dried before milling. Parboiling is a hydrothermal process that causes gelatinization of the starch within the rice grain followed by its partial retrogradation causing significant changes to its original physical, physico-chemical, cooking and eating properties. Parboiling is done to increase the total and head rice yields of paddy, prevent the loss of nutrients during milling, salvage wet and damaged paddy and also to suit the consumer preferences.

Parboiling has the following advantages: Shelling is easy because the husk is split during parboiling; Added strength acquired by the rice kernel during parboiling helps to reduce the percentage of broken grain (cracks, incomplete grain filling and chalkiness are completely healed during the parboiling process, apparently because of re-alignment and cementing of the grain

constituents after starch gelatinization); Retains vitamins, and minerals and resists insect damage during storage; Loss of solids into the gruel during cooking is less; Withstands over-cooking without becoming pasty; The bran contains 25-30% of oil. Heat treatment of paddy during parboiling destroys to a certain extent the lipase enzyme system responsible for the hydrolysis of oil leading to the development of free fatty acids. Thus the oil is of a superior quality as it has a lower concentration of free fatty acids.

The disadvantages of parboiling are: Heat treatment destroys certain natural antioxidants, therefore, during storage parboiled rice develops rancidity more easily; Takes more time to cook to the same degree of softness than raw rice; Mycotoxins hazardous to human health may develop, because the parboiled paddy retains a high moisture content for a long time; Drying the rice from 45-50% moisture to 14-16% adds to the cost; Hardness of the kernel makes it difficult

to polish and the paddy tends to choke the polisher due to the high oil content in the bran.

Small amounts of paddy may be parboiled at home by boiling in water for 2-3 hours and drying in the sun to a moisture content suitable for storage and milling. The main drawback of this method is that the grain is not hydrated completely. Under insufficient heat treatment incomplete gelatinization occurs resulting in a product characterized by a high percentage of white bellies and poor milling qualities. Also, boiling in water leads to the loss of nutrients, especially B vitamins.

The improved method for parboiling involves the use of different soaking periods for different grain types; 24 hours for short grain types and 48 hours for long and medium grain types. The paddy after soaking is steamed. This technology was developed at the Rice Processing Research and Development Centre, Anuradhapura (Adhikarinayake and Swarnasiri, 1988).

Table 5 gives the time taken and amount of fuel consumed for parboiling using the conventional and improved methods. Fuel consumption was higher in the conventional method because steam has to be generated for both hydration and gelatinization, whereas in the improved method fuel is consumed only to generate steam for gelatinization of starch in hydrated grains. Comparison of the quality of paddy obtained by the two methods of parboiling is given in Table 6 and clearly shows the superiority of the improved method.

MILLING

Milling involves a series of operations commencing with cleaning extraneous matter, removal of the hull and a fraction of the bran layer, and grading of milled rice. Efficient milling enables to give a high recovery rate of rice and an increase in head rice yield (minimize the breakage of grain). Purity of the product and minimizing the cost of the whole operation are also important.

The moisture content of paddy is critical for efficient milling. The optimum moisture content is 14%. It is also important that the grain should be uniform to ensure optimum performance of the milling machine. During the process of polishing the adjustment of the polisher is critical as excessive pressure on the grain would create too much friction and the temperature will rise, resulting in broken grain. Thus, to ensure better recovery of head rice at least three passes through the polisher are recommended. This would, however, add to the operational cost.

The present grading requirements fixed for paddy are 71% milled rice with 30% broken and 3% bran for Grade I raw milled rice, and 71% outturn with 12% broken and 4% bran for parboiled rice. Thus, to improve the quality of the final product, attempts should be made to increase the milled rice outturn, reduce the % broken grain and also increase the degree of polish by at least another 1%.

Table 5. Time taken and amount of fuel consumed for parboiling in conventional and improved methods

| Method | Grain type | Time taken | | | Quantity of firewood consumed (kg) |
|---------------------|------------|--------------|---------------|----------------|------------------------------------|
| | | Soaking (hr) | Boiling (min) | Steaming (min) | |
| Conventional method | Short | - | 70 | - | 11.1 |
| | Medium | - | 74 | - | 14.4 |
| | Long | - | 95 | - | 15.5 |
| Improved method | Short | 24 | - | 53 | 8.5 |
| | Medium | 48 | - | 50 | 8.0 |
| | Long | 48 | - | 70 | 7.5 |

Source: Adhikarinayake and Swarnasiri, 1988

Table 6. Quality of paddy parboiled by improved and conventional methods

| Method | Grain type | Milling yield (%) | Head rice yield (%) | Under parboiled grain (%) |
|---------------------|------------|-------------------|---------------------|---------------------------|
| Conventional method | Short | 67.7 | 4.1 | 92.0 |
| | Medium | 66.5 | 15.4 | 91.5 |
| | Long | 68.2 | 18.0 | 90.1 |
| Improved method | Short | 70.0 | 67.4 | Nil |
| | Medium | 70.2 | 65.6 | Nil |
| | Long | 72.5 | 68.4 | Nil |

Source: Adhikarinayake and Swarnasiri, 1988

Nutrient distribution in milling fractions

The nutrient content varies depending on the degree of milling. Table 7 gives the nutrient distribution in the successive abrasive layers for IR 32 and IR 480-5-9 brown rice (IRRI, 1977). The starch and amylose content of starch increased progressively from the periphery to core in both rices while the other nutrients showed a trend to decrease.

STRATEGIES FOR THE FUTURE

Emphasis should be placed on the development of varieties with low shattering and possessing the ability to repel insects and pests. Farmers should be made aware of the importance of timely harvest in order to reduce losses. Storage of paddy at the farm level should be improved to prevent losses. Improving the existing storage methods would also

Table 7. Nutrient distribution in successive abrasive layers of IR 32 and IR 480-5-9 brown rice

| Nutrient | Variety | Brown rice (0-100) | Milled rice (90-100) | Bran (0-6) | Polish (6-12) | Endosperm | | |
|-------------------|------------|-----------------------|-------------------------|---------------|------------------|-------------------------|------------------|------------------|
| | | | | | | Sub-aleurone (12-20) | Outer (20-30) | Core (30-100) |
| Crude protein (%) | IR 32 | 7.7 | 6.8 | 14.0 | 13.0 | 12.2 | 9.7 | 5.5 |
| | IR 480-5-9 | 11.0 | 10.5 | 13.8 | 18.0 | 21.2 | 16.6 | 7.4 |
| Crude ash (%) | IR 32 | 0.8 | 0.3 | 5.8 | 3.4 | 1.0 | 0.3 | 0.2 |
| | IR 480-5-9 | 1.5 | 0.8 | 11.9 | 6.7 | 1.7 | 0.6 | 0.3 |
| Total P (%) | IR 32 | 0.2 | 0.1 | 1.0 | 0.7 | 0.2 | 0.1 | 0.1 |
| | IR 480-5-9 | 0.4 | 0.2 | 2.6 | 1.6 | 0.4 | 0.1 | 0.1 |
| Crude fat (%) | IR 32 | 3.0 | 0.5 | 20.7 | 12.8 | 3.0 | 0.3 | 0.2 |
| | IR 480-5-9 | 2.7 | 0.4 | 20.9 | 13.7 | 2.9 | 0.3 | 0.1 |

Figures in parentheses are weight fractions in %

Source: IIRI, 1978

help in alleviating the problem of insufficient storage capacity.

Full utilization of the existing paddy storage and milling complexes is important so that their operation would be profitable. This would require the adoption of an efficient maintenance programme.

The parboiling methods used at present should be improved to prevent health hazards arising due to development of mycotoxin.

Studies on the degree of milling which would produce a product that is nutritive as well as acceptable to the consumer is also important.

A system of standards and grades applicable to the local situation should be developed for purposes of purchasing paddy. This should be strictly adhered to since good quality rice cannot be produced from poor quality paddy.

REFERENCES

- Adhikarinayake, T.B. and D.P.C. Swarnasiri. 1988. An improved home level parboiling technique. *Tropical Post Harvest Technologist* 1 (1) : 19-22.
- Breckenridge, C. and V. Sangarapillai. 1978. Study of the incidence of 'black grain' in rice and its effect on quality. *Tropical Agriculturist* 134:43-53.
- Chandler, R.F. 1979. Rice in the tropics. A guide to the development of national programs. International Agricultural Development Service Westview Press, Boulder, Colorado, USA.
- Fernando, M.D., K.B.Palipane and T.B. Adhikarinayake. 1988. Improvement of farm level grain storage methods in Sri Lanka. *Tropical Post Harvest Technologist* 1 (1) : 47-66.
- IRRI. 1978. Annual report for 1977. International Rice Research Institute, P.O.Box 933, Manila, Philippines.
- Jayawardena, S.D.G. 1973. Effect of grain moisture content, time of harvest and method of drying on milling quality of rice. *Tropical Agriculturist* 129: 103-118.
- Juliano, B.O.1979. The chemical basis of rice grain quality. *In* Proceedings of the workshop on chemical aspects of rice grain quality. pp.69-90. International Rice Research Institute, P.O.Box 933, Manila, Philippines.
- National Academy of Sciences. 1978. Postharvest food losses in developing countries. National Academy of Sciences, Washington DC, USA. 206 p.
- Palipane, K.B. 1978. Evaluation of the bissa - An indigenous storage bin. RPRDC Report 5/78. Rice Processing Research and Development Centre, Anuradhapura, Sri Lanka.