9th JIRCAS International Symposium 2002 – 'Value-Addition to Agricultural Products', 94–98

Grain quality from harvest to market

*Joseph F. Rickman**

Agricultural Engineering Unit, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines.

Abstract

Quantitative and qualitative losses of grain after harvest in developing countries can amount to 20–25% of the total market value of the crop. Asian farmers face quality issues at every link in the postharvest chain. On farm, mechanical threshing causes grain discoloration, and improper drying and water relations of the grain can lead to substantial losses. Grain breakage during milling is another cause of loss. In countries in Southeast Asia, the average head rice yields from commercial mills are 63% and can be as low as 53% from village-level milling. The presentation of predominantly low-grade rice in the marketplace severely affects the returns to farmers. The solution to improving grain and seed quality across the region lies in teaching farmers, millers, and postharvest practitioners to see and manage the postharvest chain as a complete system from harvest to market. This will entail the use of quality monitoring equipment such as moisture meters and milling color charts, and the introduction of storage systems that preserve grain quality. The performance of rice mills will need to be improved, and training provided to farmers to show them how a focus on quality at all stages will improve the prices they obtain at market. Finally, the people working in the postharvest area who can improve its performance must have access to up-to-date knowledge and training.

Introduction

POSTHARVEST grain losses across all developing countries have been conservatively estimated at 10–15% and when combined with quality losses could represent a total loss in value of 25–50% in dollar value at market. These losses result in lower returns to farmers, higher prices for consumers and greater pressure on the environment as farmers try to produce more to compensate. Because of these losses, postharvest activity can have a significant impact on the livelihoods of rice farmers. The poor and smallholder farmers are often the most affected as they have the least access to knowledge and to equipment for processing and safely storing grain. These farmers not only lose the most grain through spoilage, but also are often forced to sell their products immediately after harvest, which limits their options for access to markets and reduces their bargaining power.

Postharvest losses occur in terms of both grain quality and quantity. These losses occur mainly through spoilage and wastage at the farm level, and reduced milling yields and grain quality when processed. High moisture content is the most important factor influencing the deterioration of stored grain and seed. If moisture content could be maintained at a sufficiently low level, grain and seed could be stored for many years with little adverse effect. While temperature is inextricably linked to moisture in determining the rate at which grain deterioration occurs, it is often not economic or feasible to modify or control temperature in Asian countries. Rodents also cause grain deterioration and it has been estimated that rodents eat or spoil as much as 2% of the total world grain production. Losses of 6–15% have been recorded during storage in Bangladesh and China. Birds too invade grain stores and, apart from the physical losses through feeding, they decrease the quality through physical contamination.

The International Rice Research Institute (IRRI) has been studying postharvest systems in Bangladesh, Cambodia, the Philippines and Indonesia—ascertaining the problems and trying to develop simple, low cost and appropriate solutions. Through these developments, IRRI believes that it can have a significant, positive impact on the livelihoods of poor rice farmers and their communities.

* Email address: <j.rickman@cgiar.org>.

Quality issues for farmers

QUALITY issues confront Asian farmers in all phases of the postharvest system. They face quality issues on the farm itself during threshing, drying and storing. When they have their rice milled, quality issues arise in the milling process. And finally, quality issues emerge in the markets into which the rice is eventually sold.

On the farm

Mechanical threshing results in grain discoloration

The incidence of grain discoloration is now being reported widely from many countries in Asia. In these countries, contract threshers have now replaced village and hand threshing. This has led to extended periods, often 3–4 days, between cutting and threshing. When panicles are left wet in piles, or grain is stored at higher moisture contents (above 16–17%), yellowing of grain has become a major problem. Market studies are showing a large percentage of the grain (9–10%) is discolored and there is a strong correlation between yellowing and price.

Drying

Sun drying is still the most popular means of drying grain and seed in Asia. Sun drying causes greater grain fissuring and subsequent breakage during milling. Sun drying also causes viability problems with seed. Problems occur when the grain has been overheated or been re-wetted during the drying stage—by rain, for example. Temperatures above 50°C are often recorded on cement drying pads and rarely are air and grain temperatures monitored during the drying process. Also, the grain layer often is too deep (10–15 cm), and not turned regularly enough or tempered during the drying process.

In other situations, when panicles are dried in the field, grain is often being over-dried to less than 10%. This results in grain shattering in the field, losses during transport and grain breakage during threshing. Shattering and transport losses of 5% after field drying have been recorded in Cambodia.

Moisture equilibration

Studies in Cambodia and the Philippines have shown the extent to which rice grain equilibrates with its surrounding environment during storage. With relative humidity levels often above 70% during the wet season, changes in grain and seed moisture content of 2–3% have been recorded during storage in the wet season. Seed viability reduces substantially after 6 months of storage. In many Asian countries, grain and seed are being taken out of storage and re-dried during the storage period. This is very common in Bangladesh and Cambodia and could be avoided by the use of appropriate storage systems. Farmers in the Philippines do not re-dry their grain but acknowledge that up 4% of their grain is lost or damaged from moisture incursion during farm storage.

During milling

Milling and head rice yields in village and domestic rice mills are low in most of the region. Studies from Indonesia, the Philippines and Cambodia show the average milling yield for these countries is 63% for commercial mills and as low as 53% for village mills (Table 1). Head rice yields vary from 20–40% on a paddy basis. These low yields are a result of poor quality paddy coming into the mills, as well as inappropriate or poorly maintained and operated mill equipment. Very few mills have the means to measure either grain moisture content of the paddy or the degree of milling of processed grain.

In the market

Grain quality in the market, as depicted by price, is highly variable and it does not always follow national standards. In the Philippines, for example, laboratory analysis of more than 200 samples taken from large retail outlets showed that 80% of the rice in these markets is off grade and only 2% of the samples met a standard above the lowest national grade. In Indonesia

Table 1. Rice mill yields for Cambodia, Indonesia and Philippines.

	Theoretical yield	Indonesia	Philippines	Cambodia	Cambodia (village)
Capacity (t/hour)		0.75	0.73	1.35	0.2
Husk (%)	19	26	24	24	31
Brown rice (%)	82	74	75	76	69
Bran (%)	8	11	8	11	16
Milled rice (%)	72	63	63	65	53
Head rice (%)	55	46	38	40	
Broken kernels (%)	17	17	27	25	

and the Philippines, there was a very strong correlation between the price and the yellowness of the grain as seen by the naked eye, the amount of chalkiness and the percentage of broken kernels. In Cambodia, price is more dependent on the variety, the percentage of broken kernels and the chalkiness. Whiteness was not such a concern.

The solution

THE solution to improving grain and seed quality across the region is to teach farmers, millers and postharvest practitioners to manage the postharvest process as a complete system from harvest to market. Farmers, millers and postharvest practitioners often lack knowledge of cause and effect in regard to grain quality.

IRRI is addressing these issues by studying the postharvest system as a whole and looking for cost-effective interventions that will help reduce some of the problems. IRRI is developing low-cost monitoring equipment, testing sealed storage systems, developing grain quality training materials and is looking to form a postharvest consortium across countries in the region that are facing similar problems.

Monitoring equipment

Moisture meters

Grain moisture content is the most important factor in maintaining grain quality, yet very few farmers or millers have access to a working moisture meter. Studies with Thai rice farmers showed a variability of 3–5% in grain moisture evaluation by their traditional means of testing (a calibrated tooth or noise) and the actual moisture content as measured by a resistance-type moisture meter. The present cost of a moisture meter is approximately US$200 and this is beyond the scope of most farmers and small millers. Where meters have been donated or purchased, they tend to stay locked in a cupboard or are not used because of lack of knowledge, batteries or operator's manual.

IRRI is in the process of developing a low-cost, resistance-type moisture meter in collaboration with a Chinese company. The target price is US$20 with accuracy within 1–2%. The meter will be specifically designed for measuring moisture content of paddy or rough rice.

Milling color chart

Market studies in the region have highlighted that rice is often over-milled, which reduces the head rice recovery and decreases the total value of the rice crop. Over-milling occurs because very few mills have a whiteness meter or any means other than visual inspection to determine the degree of milling. Because whiteness meters are expensive (US$5000–6000) they are used only in very large commercial mills. The whiteness meter gives a reflective reading of whiteness, indexed from 0 to 100. The indexed number that is often quoted as an acceptable guideline for whiteness is the 'whiteness of brown rice +20'.

IRRI is in the process of developing a milling degree color chart based on the actual color seen by the naked eye. The first color standard used in this study was taken from the Commission Internationale de l'Eclairage (CIE; International Commission on Illumination) color model and used the CIELAB system. This system distinguishes color on the basis of light and dark, red and green, and blue and yellow, and indicates these values on three axes: L, a, and b. These colors can then be expressed in an algorithm that is called the Hunter whiteness. All of these colors are visible to a varying degree on a rice kernel. The b color coordinate has been closely correlated with the quality (price) of rice in the market.

Results showed a very strong correlation between the Hunter whiteness, whiteness from the Satake whiteness meter ($r^2 = 0.93$) and milling degree. Unfortunately the L, a, b coordinates as determined by a colorimeter and expressed by a computer could not give the necessary difference in color when processed by a printing press. A second model based on the RGB (CMY) color model is now being developed. The process is a subtractive model using cyan, magenta and yellow colors. The process was created to print continuous tone images like photographs. The rice images appear very realistic and overcome the problems of trying to use solid colors. The milling color chart will be verified for variety differences, milling degree and discoloration. The estimated cost will be US$2.00 per sheet.

Storage systems

Sealed or hermetic grain storage has proven to be a very effective means of controlling grain moisture variation and insects during grain storage periods. By restricting the air movement between the outside atmosphere and the grain, initial grain moisture levels are maintained and insects controlled by a lack of oxygen. Recent technological advances in plastic manufacturing have led to the development of polyvinyl chloride (PVC) liners that provide the required durability to climate, gas permeability and physical properties that enable airtight storage for extended periods of time.

Studies conducted by IRRI have evaluated commercial plastic envelopes (e.g. Volcani cubes, grain cocoons) and local sealed systems for small farmers based on recycled containers and drums. These studies found that:

- grain moisture levels did not increase significantly (Figure 1)

- there was a significant reduction in insects
- seed viability was maintained for more than 12 months—seed viability in the unsealed, ambient environment dropped after approximately 6 months of storage (Figure 2)
- hermetic storage did not reduce milling recovery or head rice yield, compared to the grain stored in the artificially cooled environment
- rat and bird damage was non-existent
- intermittent opening of the plastic commercial storage bags replenished oxygen inside the stored grain, which on one occasion led to rapid re-infestation of grain with the lesser grain borer (*Rhyzopertha dominica*), which pierced the plastic liner.

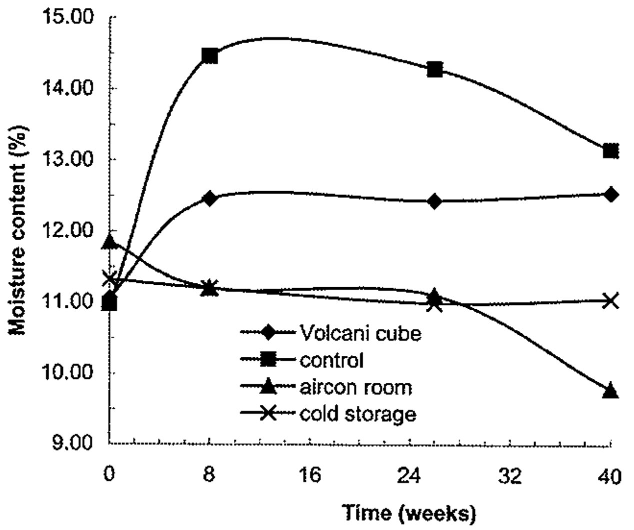

Figure 1. Change in grain moisture content of four different storage systems.

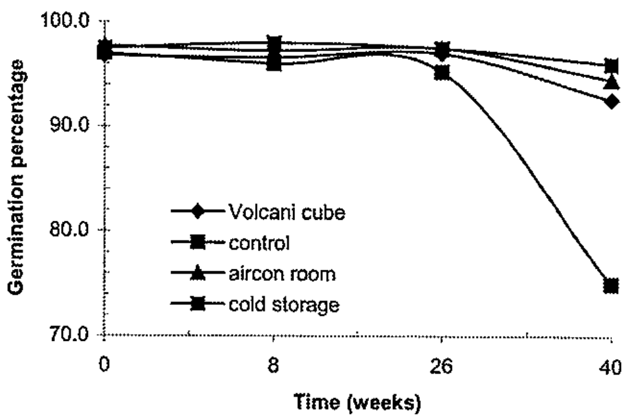

Figure 2. Change in germination of four different storage systems.

On-farm hermetic storage trials were conducted in Bangladesh, Indonesia and Cambodia in collaboration with partner organizations. Preliminary results show an improvement of between 30 and 70% in germination of seed stored by farmers for a 7-month period using hermetic storage compared to the traditional storage method.

Rice milling

Performance evaluation of rice mills has proven to be a useful means of establishing intervention opportunities to improve milling recovery and head rice yield. The evaluation requires the processing of a known quantity of rice through a mill that is being operated at a steady state. During the milling process, all products and by-products are collected and weighed. By analyzing rice samples from before and after each mechanical operation, the cleaning, husking, paddy separation and hull aspiration efficiencies can be determined.

Many of the problems identified were similar in all countries where evaluations have been undertaken. Some of the causes of reduced milling yields and head rice recovery were:

- millers did not monitor grain moisture during storage and milling
- poor paddy cleaning resulted in high levels of foreign matter and cracked kernels in the paddy
- poor paddy separation resulted in low separation efficiency
- rubber rolls were used beyond their design life, were not interchanged and not re-faced
- milling stones were not re-faced on a regular basis
- over-milling caused damage during the polishing process
- lack of evaluation tools such as a moisture meter and milling degree meter for quality evaluation.

As detailed earlier, IRRI is developing low-cost evaluation tools. A priority for training must be to train people to perform rice mill performance evaluations and interpret the results in terms of grain quality improvement.

Market

Evaluation of rice quality in local markets has provided information as to where and how rice quality in the postproduction sector can be improved. Overall findings from market surveys have found that:

- rice standards written on the bag rarely meet the national standards
- price is not always related to variety
- price in all countries is related to percentage of broken kernels and chalkiness
- yellowness is often more important than whiteness.

Training has been developed that provides farmers with guidance on how a grain quality focus throughout the postharvest system can improve the price obtained at market for the harvest.

Knowledge dissemination

THE people working in the postharvest area who can improve the situation must have access to up-to-date knowledge and training. The intermediaries, those people who have jobs to advise and assist the primary workers, must also have access to this knowledge and training. Any 'knowledge gap' limits options for the workers and their efficiency, which ultimately has negative affects on household incomes, nutrition, health, education and the environment.

Field observations (Bell et al. 2000) confirm that there are many knowledge gaps among key players in postproduction with respect to maintaining grain quality, and there is a real challenge of how information can be appropriately packaged and distributed to the end users.

IRRI has developed and presented 'Rice Quality' training courses in Myanmar, Cambodia and the Philippines. These courses consider both crop production and postproduction aspects of grain quality. A participatory learning approach is used and students are taught how to evaluate grain from local markets and test the performance of local rice mills. These courses are also used as a means of sharing standards and experiences from other countries. An online, 'e-learning' version of the course has been developed and trialled in India. This e-learning course is available from IRRI at:

http://www.knowledgebank.irri.org

IRRI is also looking at establishing a rice-based postharvest consortium across the region. Countries such as Bangladesh, Myanmar, Laos, Cambodia, Indonesia and the Philippines face similar problems and all have expressed a desire to be involved. The consortium would be a forum where experiences could be exchanged and a means of improving the transfer of postharvest technology within the region.

Bibliography

Bakker, R.R., Jarcia, E.A., Jawili, M.C.E., Billate, R.D., Barredo, I.R., de Padua, D.B. and Mangaoang, C.C. 2003. Assessment of milled rice quality in the Philippines retail market. In: Proceedings of the 20th ASEAN/2nd APEC Seminar on Post-harvest Technology, Chiang Mai, Thailand, September 2001 (in press).

Bell, M.A., Bakker, R.R., de Padua, D.B. and Rickman, J. 2000. Rice quality management—principles and some lessons, In: Johnson, G.I., Le Van To, Nguyen Duy Doc and Webb, M.C., ed., Quality assurance in agricultural produce. ACIAR Proceedings No. 100. Canberra, Australian Centre for International Agricultural Research, ACIAR, Canberra, 255–263.

Bell, M.A. and Dawe, D. 1998. Increasing the impact of engineering in agricultural and rural development. IRRI Discussion Paper Series No. 30. Los Baños, Philippines International Rice Research Institute.

De Datta, S.K. 1981. Principles and practices of rice production. New York, John Wiley and Sons.

Rickman, J.F., Som Bunna, Poa Sinath and Meas Pyseth 2000. Rice milling in Cambodia, In: Johnson, G.I., Le Van To, Nguyen Duy Doc and Webb, M.C., ed., Quality assurance in agricultural produce. ACIAR Proceedings No. 100. Canberra, Australian Centre for International Agricultural Research, 520–522.