Grain Drying in Asia

Proceedings of an International Conference
held at the FAO Regional Office for Asia and the Pacific,
Bangkok, Thailand, 17–20 October 1995

Editors: B.R. Champ, E. Highley, and G.I. Johnson

Sponsored by:
Group for Assistance on Systems relating to Grain After-harvest (GASGA)
Australian Centre for International Agricultural Research (ACIAR)
ASEAN Food Handling Bureau (AFHB)
U.N. Food and Agriculture Organization (FAO)

Australian Centre for International Agricultural Research
Canberra 1996
The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. Its mandate is to help identify agricultural problems in developing countries and to commission collaborative research between Australian and developing country researchers in fields where Australia has a special research competence.

Where trade names are used this constitutes neither endorsement of nor discrimination against any product by the Centre.

**ACIAR PROCEEDINGS**

This series of publications includes the full proceedings of research workshops or symposia organised or supported by ACIAR. Numbers in this series are distributed internationally to selected individuals and scientific institutions.

© Australian Centre for International Agricultural Research, GPO Box 1571, Canberra, ACT 2601.


ISBN 1 86320 179 3

Cover: A low-cost portable grain dryer developed in Vietnam for small farmer households with access to electricity. See pp 308–313.

Pre-press production by Arawang Information Bureau Pty Ltd, Canberra, Australia.
Contents

Welcome Remarks 6
A.Z.M. Obaidullah Khan
FAO Assistant Director General

Keynote Address 8
Dr Narong Chomchalon
FAO Regional Plant Production Officer

Remarks from Conference Sponsors 10
GASGA – J. Faure
ACIAR – G.I. Johnson
AFHB – Koh Siew Hua

Invited Papers 11

Setting the Scene 13
Grain Quality Problems in Asia 15
Bienvenido O. Juliano

Grain Drying in China: Problems and Priorities 23
Ren Yonglin and J. van S. Graver

Problems and Priorities of Grain Drying in Indonesia 31
Hadi K. Purwadaria

The Rice Processing Industry in Malaysia: Problems and Priorities in Grain Drying 38
Rostan A. Ghaffar and Fatimah Mohd. Arshad

Problems and Priorities of Grain Drying in the Philippines 46
Silvestre C. Andales

Problems and Priorities of Grain Drying in Thailand 54
Maitri Naewbanij

Grain Drying in Vietnam: Problems and Priorities 57
Phan Hieu Hien, Nguyen Hung Tam, Truong Vinh, and Nguyen Quang Loc

Perspectives on Drying Problems in the Southeast Asian Region and Results of R&D Projects to Solve Them 67
Dante de Padua

Lack of Incentives as Constraints to Introduction of Efficient Drying Systems 74
Chew Tek Ann

Principles of Grain Drying and Aeration 81
Grain Physical and Thermal Properties Related to Drying and Aeration 83
Chong-Ho Lee and Do Sup Chung

Modelling Moisture Migration in Stored Grains 99
G.R. Thorpe

Analysis of Continuous-flow Grain Dryers 123
F.W. Bakker-Arkema, M.D. Montross, Liu Qiang and D.E. Maier

In-store Drying and Grain Psychrometrics 132
Robert Driscoll

Design of Aeration and Drying Systems 141
Design Parameters for Aeration and In-store Drying Systems 143
C.J.E. Newman

Control Systems for Aeration and Drying of Grain 158
G. Srzednicki
Evaluation of Available Technology  
Socioeconomic Factors as Determinants of Drying Technology Requirements  
*Brian Fegan*

Effect of Drying on Grain Quality  
*Otto R. Kunze*

Small-scale Grain Dryers  
*Justin A. Tumambing*

Use of Continuous-flow Grain Dryers in Thailand  
*Keeradit Bovornusvakool*

Fluidised-bed Paddy Drying  
*Somchart Soponronnarit*

In-bin Grain Drying Systems  
*R. Driscoll and G. Srzednicki*

Renewable Energy Sources for Grain Drying  
*A.C. Hollingdale*

Non-conventional Grain Drying Technology  
*Francis Courtois*

**Contributed Papers**

Grain Drying as a Means of Reducing Harvest Losses  
*Yahya Abawi*

Minimum Daily Temperature as a Predictor of Dewpoint Temperature  
*Yahya Abawi*

Design and Development of a Rotary Semi-fluidised System Dryer for Paddy  
*T.F. Anchiboy and R.E. Manalabe*

Chilled Aeration/Storage of Grain in Southeast Asia  
*F.W. Bakker-Arkema, D.E. Maier, and A. Sebastianelli*

Promoting Grain Storage Technology and Best Practice through Short Courses  
*R.J. Banyer and J.H. Kent*

Rice Hull Furnaces for Paddy Drying: the Philippine Rice Research Institute’s Experience  
*E.U. Bautista, R.E. Aldas, and E.C. Gagelonia*

Drying Maize and Maize Seed in Vietnam  
*Bui Huy Thanh and Le Doan Dien*

Commercialisation of a Mobile Flash Dryer for Farmer Cooperatives  
*Manolito C. Bulaong, Renita Sm. Dela Cruz, and Silvestre C. Andales*

Grain Condition Monitoring and Aeration Control Systems  
*Cao Guanzhi*

Use of Rice Husk Gasification in Grain Drying  
*Chen Zhishun*

The Effects of Drying and Shelling on *Fusarium* spp. Infection and *Fusarium* Toxins Production in Maize  
*O.S. Dharmaputra, H.K. Purwadaria, H. Susilo, and S. Ambarwati*

Drying Simulation: a PC-based, User-orientated Decision Support System for In-store  
*Drying and Aeration of Grains  
V.K. Jindal, R.C. Martinez, and Le Van Diep*

The Current Situation and Prospects for Grain Drying in Northeastern China  
*Ju Jinfeng, Liu FangJiu, Du Shuxiao, and Xu Zengtao*

Grain Drying in India — Problems and Prospects  
*Sone Lal and C.P. Ramam*

Revisiting Sun Drying of Grain: Widely Adopted but Technologically Neglected  
*Reynaldo M. Lantin, Bernabe L. Paita, and Herbert T. Manaligod*
A Low-cost In-store Grain Dryer for Small Farmers
Le Van Ban, Bui Ngoc Hung, and Phan Hieu Hien

The Present Situation and Directions for Development of Grain Drying in China
Li Huojin

The Development of Artificial Drying of Paddy in Malaysia
Loo Kau Fa

Chilled Aeration for Pest Management in Stored Food Grains
D.E. Maier, L.J. Mason, R.A. Rulon, A.C. Strait, and D.J. Zink

Rapid Fluidised-bed Drying: a Successful Postharvest Tool
Yingyod Yingyuenyong

Mechanical Drying, Horizon 2010: an increased Role Predicted
F. Mazaud

Traditional Paddy Drying in Bangladesh and Associated Problems
K.A.M.S.H. Mondal and M.A. Malek

Development of Rice-husk Furnaces for Grain Drying
Nguyen Van Xuan, Truong Vinh, Pham Tuan Anh, and Phan Hieu Hien

Pilot and Commercial Application of Ambient Temperature In-store Drying of Paddy in Northern Thailand
R.J. Parkin

Use of Existing Pig Pens as Drying Bins for Wet Season Paddy Harvest
M.C. Pasikatan, G.C. Salazar, and E.U. Bautista

Case Studies on Moisture Problems in Guyana Brown Rice
D. Permaul

Grain Drying in a Batch Fluidised-bed Dryer
Pham Cong Dung

Development of a Conduction-type Dryer for Paddy
Banshi D. Shukla and Robert E. Stickney

Rice Husk Furnace and Reversible Airflow Grain Dryer
P. Kuizon

Some Socioeconomic Aspects of Plans for Increased Grain Production in Papua New Guinea
Levi B. ToViliran

Development of a Fluidised-bed Dryer for Paddy in Vietnam
Truong Vinh, Phan Hieu Hien, Nguyen Van Xuan, Nguyen Hung Tam, and Vuong Thanh Tien

Rice-husk Gasifier for Heat and Electricity Production for Small to Medium Mills
G. Vaitilingom

Rice Drying Technology in China
Zhao Simong

Heat and Mass Transfer in Grain Bulks of Arbitrary Shape
G.R. Thorpe

An Evaluation of the Returns to Research on Grain Drying and Storage in the Philippines
M.C. Mangabat, J.S. Davis, J.A. Tumambing, P.D. Sayaboc, G.C. Sabio, and C.L. Maranan

Invited Paper

Preservation of Grain with Aeration
D.E. Maier

Conference Summary and Recommendations

International Standards for Agricultural Grain Dryers

Participants
Welcome Remarks

Representatives of GASGA, ACIAR, AFHB, distinguished delegates, my colleagues in FAO, ladies and gentlemen:

It is my pleasure and privilege to welcome you all to the FAO Regional Office for Asia and the Pacific, on behalf of the Director-General of FAO and on my own behalf.

FAO is indeed privileged to be a partner with such distinguished institutions as the Australian Centre for International Agricultural Research (ACIAR), the ASEAN Food Handling Bureau (AFHB), and the Group for Assistance on Systems relating to Grain After-harvest (GASGA). This international conference has been made possible by their collaborative endeavour. The Regional Association for Post Production Technologies in Asia (REAPASIA), catalysed by the FAO Regional Office (RAP), has made a modest contribution towards sponsoring resource persons, as has the Agricultural Engineering Services of FAO Headquarters, using the TCDC/ECDC partnership program.

The preceding three decades and a half, although a period of unprecedented population growth, have seen substantial progress in efforts both to produce food and ensure access to food for all people. Over the past 30 years, the volume of agricultural production has doubled and world agricultural trade has increased threefold. The global per capita availability of food has increased from 2300 kilocalories (9600 kJ) per day in the early sixties to some 2700 kilocalories (11300 kJ) at present, despite an increase of over 2400 million people in the world’s population.

Yet 800 million people in the world today go to bed hungry. As many as 192 million children under the age of five suffer from chronic or acute protein and energy deficiencies.

Current statistics for Asia and the Pacific region are depressing. The region houses two-thirds of the world’s undernourished. One person in five does not have access to sufficient food energy to lead a healthy, active life. Nineteen (19) of this region’s 27 developing countries which are members of FAO are low-income, food-deficit countries.

We must, however, not let such disheartening statistics contain our aspirations, because Asia and the Pacific region has also made real progress. This vast region, home to 70% of the world’s developing population, is not uniformly food insecure. East Asia, including Southeast Asian countries, has made the most rapid improvement worldwide. In two decades, it has halved the numbers of undernourished people, reducing the percentage from 44 to 16% of the total population. South Asia has also made steady, though insufficient gains. It reduced the percentage of undernourished population by a third from 34 to 24%, but could not manage to bring down the absolute numbers of undernourished people, owing to population growth.

Apart from this record of significant achievements, FAO’s study on Agriculture Towards 2010 (AT 2010) suggests that per capita cereal production and agricultural production in general, will continue to grow, though at a lower pace. Cereal self-sufficiency ratios are likely to be little changed at 97% in East Asia and fall slightly from 102 to 97% in South Asia. At these self-sufficiency levels, net cereals imports in 2010 are likely to rise by only 2 million tonnes to 22 million tonnes in East Asia; but may double to 1 million tonnes in South Asia.

This slight to moderate projected import expansion at the end of 20 years will, to an extent, be balanced because import capacity will continue to grow rapidly as in the past. The percentage of export earnings spent on food imports in the group of 26 developing countries in the region declined from 15 to 5% in the past two decades, and will undoubtedly decline further as export earnings expand.
Consequently, East Asia may see the percentage of population chronically undernourished falling from 16 to 6% and the numbers from 252 to 70 million. South Asia will also experience significant progress, though it will not be enough. The percentage of undernourished may be halved to 12%, with the number of undernourished people falling from 271 to 202 million.

Rice, as you know, is not only a staple food in many countries in Asia, it is a way of life. The expanding agricultural economies in some countries are focusing on the international market. Thailand is exporting more than 5 million tonnes of rice this year and Vietnam around 2 million tonnes. Drying is the first step in reducing quantitative and qualitative losses of grain after harvest. A combination of temperature and moisture control is optimal in minimising deterioration during the storage. Since the first is costly, then drying becomes the most cost-effective technique. Technologies are there for drying and storage of grains. Yet there have been relatively few successes in transferring efficient grain drying systems in this region. The scientists assembled here will evaluate the relevant technologies and also the obstacles to their adoption. Let me mention here the changed trade scenario after the Uruguay Agreement. Opportunities for export from Asia will be counterbalanced by international competition. To be an effective player in this competitive environment, quality of grain must be ensured.

Asian countries produce over 90% of the world’s rice, over 85% of its wheat, and over 60% of coarse grains. Dramatic increases in production have not always been matched by similar improvements in postproduction handling. In the context of this conference, it is clear that grain drying is not simply a technical solution to a grain storage problem. If that were so, why is it that literally hundreds of grain dryers have been developed and yet farmers in many countries of the region continue to use the roadsides to dry their grains, under less than optimal conditions?

Technology has perhaps to be reorientated, from hardware solutions to software, knowledge-based solutions. More importantly, the frontier science and technology must be integrated with the local organic and experiential wisdom of farmers.

Adoption of technologies is not enough; the small farmers who till our soils must be empowered to own the technologies. Access to credit or private sector support for the additional resources required is essential for such empowerment.

Participants and observers in the drying conference will, no doubt, deliberate upon available and relevant technologies. What to my mind is critical is the producers’ access to and ownership of your knowledge and expertise.

It is now my honour and privilege to declare this GASGA International Conference on Grain Drying in Asia, officially open.

A.Z.M. Obaidullah Khan
FAO Assistant Director General and Regional Representative for Asia and the Pacific
Keynote Address

Mr A.Z.M. Obaidullah Khan, FAO Assistant Director General and Regional Representative for Asia and the Pacific; distinguished participants; ladies and gentlemen:

It is a privilege and pleasure for me to participate in this International Conference on Grain Drying in Asia and to present the keynote address to the distinguished scientists assembled here.

May I extend a warm welcome to all the distinguished participants, experts, and organisations present at this international conference. As has been mentioned by the FAO Regional Representative, Mr A.Z.M. Obaidullah Khan, this conference has been made possible by the collaboration of four international and regional bodies:

- The Australian Centre for International Agricultural Research (ACIAR);
- The ASEAN Food Handling Bureau (AFHB);
- The Group for Assistance on Systems relating to Grain After-harvest (GASGA); and
- The Food and Agriculture Organization, Regional Office for Asia and the Pacific.

This is a good example of mutual collaboration, where the comparative advantage of each agency has come to the forefront in ensuring a conference of technical excellence.

Never in the history of this region has grain drying taken on such critical importance, as Thailand and her neighbours strive to produce grains for the export markets of the world. In the case of rice, double and even triple cropping is now standard practice to obtain higher yields from the same land. The risk lies in the proximity of these harvests to the wet seasons in the countries involved, and the lack of comprehensive drying facilities to handle wet paddy. The danger of postproduction losses is increased by this intensive production and, in some cases, by the lack of incentives for the farmers to undertake drying procedures.

The socioeconomic environment in which the farmers are operating is as significant as the physical environment in determining whether these technologies are used. In addition, extension and promotion is vital to convince potential users of the value of these technologies before they can be fully transferred into popular use.

As I speak, one of the worst floods on record is causing record damage to Thailand’s agricultural economy. A most serious situation exists, where provinces with at least 8 million rai [ca 6.25 rai = 1 ha] of cultivated land are flooded.

One million tonnes of rice may be lost from an estimate of 21 million tonnes this year. The only bright side of the picture is that prices for rice are expected to rise and that there will be no shortage of irrigation water for the second crop of rice. Last year’s second crop planting was on about 4.1 million rai.

Animal feed production has been affected severely as a result of the damage to maize and soybeans, especially in Sukhothai and Phitsanulok. Maize production may now drop from 3.6 million tonnes, by over 200,000 tonnes. Prices of maize substitutes are increasing and broken rice has reached 7 Baht per kilo, a record price.

This GASGA International Conference on Grain Drying in Asia is very timely. A number of critical factors have been identified in earlier meetings on postharvest technologies. These factors include: the increased importance of the wet season crop in the total output of grains; the shift to more commercial cereal markets in tropical countries, with higher outputs entering the marketing chain; and a growth in the ability of trading countries to discriminate between qualities of grains.
At government level, there is a need to consider policy on the required infrastructure and framework for the farmers, processors, transporters, and marketers, to optimise the postharvest operations for grains.

Research goals in the postharvest sector have included identification of ways and means to protect grains in production, by reduction of postproduction losses. Also, positive technologies to meet the needs of producers and consumers have been sought by identifying critical control points in postharvest operations.

When researchers formulate their objectives they need to consider first the social, economic, political, and administrative framework surrounding the work, as well as the actual economic cost/benefit considerations. These points for consideration were put forward by earlier international seminars held by the same groups assembled here.

It should be clarified during the conference discussions whether the barriers to progress arise from the policy environment, from socioeconomic considerations, or are problems with technical solutions. All of us must redirect our energies to becoming involved in the reframing of policies which may be impeding implementation of sound postproduction practices.

This international conference is an important milestone in the history of postproduction technology. Thai scientists present are ready to participate to the full with international scientists gathered here, to ensure that a complete exchange of technical information takes place, with the goal of improving the quality of grain production in this and other countries, as well as improving international cooperation between the countries represented here.

May I now wish your deliberations every success.

Thank you.

Dr Narong Chomchaloon
Regional Plant Production Officer
FAO
Bangkok
Remarks from Conference Sponsors

GASGA

Mr Chairman, ladies and gentlemen, dear friends and colleagues, at the opening of this international conference, I would like to say a few words about GASGA, the group whose acronym you have seen on the front page of the circulars sent to all participants.

GASGA, the Group for Assistance on Systems relating to Grain After-harvest, is a voluntary association of organisations concerned with donor operations on grain storage, handling, and processing in developing countries.

Those organisations have major involvement in most, if not all, of the following:

- provision of professional advice;
- conduct of field projects; and
- conduct of research and its application in relation to the problems of the postharvest sector of grain production.

The association is essentially technical; it is international in character, but informal and limited in membership, so that its deliberations can take place more readily.

The following organisations are the current members of GASGA:

ACIAR Australian Centre for International Agricultural Research, Canberra, Australia;
CIRAD Centre de Cooperation Internationale en Recherche Agronomique pour le Development, Montpellier, France;
GTZ Gesellschaft für Technische Zusammenarbeit, Eschborn, Germany;
FAO Food and Agriculture Organization of the United Nations, Rome, Italy;
NRI Natural Resources Institute, Chatham, U.K.

GASGA's main objective is to coordinate and disseminate information and advice on postharvest food-crop systems, especially of grains, in order to improve policies, procedures, and efficiency. For this purpose, position papers on basic issues are prepared, such as on mycotoxins, pesticides, and the importance of the postharvest sector for development. Also, executive seminars are organised, and a GASGA newsletter is produced.

The GASGA executive meets annually to review progress in its activities and to consider proposals for future work. In its meeting in Rome in 1994 it was unanimously agreed that grain drying in Asia was becoming crucial due to (a) the expanding agricultural economies of this region; (b) the development of a second harvest of paddy in countries where the rainy season is coming soon after, thus making difficult the traditional sun drying; (c) the cost of artificial drying which needs to be examined in the light of available and newly developed technologies; and (d) the privatisation trend evident in many places thus giving, in principle, more opportunities to producers and operators to benefit more directly from their investment and efforts.

We are therefore very pleased to see that this conference is now a reality, thanks to the support of many, but more particularly from the three organisers, the ASEAN Food Handling Bureau, ACIAR, and FAO, the last two of which, you will recall, are GASGA members.

I wish this conference every success.

J. Faure
CIRAD
ACIAR

FAO Regional Representative Mr Obaidullah Khan, distinguished guests, ladies and gentlemen:

In the past 20 years we have seen many successes in the improvement of grain productivity and quality in Asia; a fortunate legacy of the green revolution and peace. Communities have prospered as a result, and will continue to do so. Land, however, is a finite resource. We are almost at the limit of land area available for agriculture, and water, energy, and other natural resources are becoming scarce.

So precious was rice, my colleagues in the region have told me, that their parents would scold them if they left just one grain in their bowl! Teaching children to eat all of what they are given is an admirable means of reducing postharvest waste—and a great challenge in a television-programmed, consumption-orientated modern society. So too is maximising the quantity and quality of produce available for the plate.

Also here at FAO Headquarters in Bangkok, we yesterday celebrated World Food Day and FAO’s 50th Anniversary with a symposium on the theme ‘Food for All’. The symposium was honoured to be addressed by HRH Princess Maha Chakri Sirindhorn and other distinguished speakers.

Her Royal Highness noted that ‘food for all’ must be translated in ‘nutrition for all’. Quality of food is as much a vital concern as is quantity. Food for all encompasses not only production, but also minimisation of postharvest losses and maximisation of storage life and grain quality.

Grain drying, along with other facets of postharvest technology will continue to play a primary role in garnering the harvest, especially if greenhouse gases and global warming make cropping and harvesting less predictable. Grain drying methods have been part of the technology and social revolution, a hand-in-hand partnership with the green revolution, which has been vital in achieving food for all.

In the coming decades, population growth, land and water availability, and community demand for chemical-free food will challenge our ingenuity further. This meeting sets the scene for directing and progressing one component: grain drying.

In welcoming you on behalf of ACIAR, I would also like to pay tribute to my predecessor in the ACIAR Postharvest Program, Dr Bruce Champ. Under his stewardship, the ACIAR postharvest technology research partnerships in the region have contributed significantly to grain drying options—options that are energy efficient, cost effective, and adaptable.

Modern sophisticated technology, on the one hand, and innovative low-technology alternatives, on the other, have both done much to reduce time and labour per unit yield.

The outcomes we seek—feeding people and livestock, and implementing grain drying technology—are matters of both individual effort and the synergy that comes from working together. What each of us gains from this meeting similarly relies on our individual and combined efforts. Over the next four days we will talk, listen, taste, and smell conference activities and Thai hospitality.

I believe that GASGA’s initiative in organising this conference, and the strong participation in it, reflect HRH Princess Maha Chakri Sirindhorn’s concluding comment at the symposium yesterday. The Princess said:

The greatest advantage is the growing sense of regional and international partnership for development ... a new spirit of technical cooperation among developing countries has emerged. This
stronger sense of empathy and cooperation will strengthen ... efforts to use our resources on a sounder and more sustainable practical basis. In this way, 'Food for All' can indeed become a realistic goal for everyone.

Mr Obaidullah Khan, distinguished participants, thank you for your attention. Enjoy the meeting.

_G.I. Johnson_  
Coordinator  
Postharvest Technology Program

**AFHB**

Mr Khan, Assistant Director General and FAO Regional Representative for Asia and the Pacific, representatives from GASGA, ACIAR, and FAO, ladies and gentlemen:

May I wish all of you a very good morning and a warm welcome to the GASGA International Conference on Grain Drying in Asia.

On behalf of the ASEAN Food Handling Bureau based in Kuala Lumpur, Malaysia, I would like to express our sincere thanks to everyone in this conference who has helped us in organising and in making this conference a success.

It is a privilege for the ASEAN Food Handling Bureau to be on the organising committee with GASGA, ACIAR and the FAO.

As you may be aware, the Bureau is in the process of taking on some new directions itself. These should become clearer by next year. However, we trust our pathways will continue to meet and we can still all work together using the skills which have been built up in the Bureau.

With this, I look forward to sharing and having more fellowship with all of you in the next four days in Bangkok and in this International Conference on Grain Drying in Asia.

_Koh Siew Hua_  
Project Officer
INVITED PAPERS

Setting the Scene
Grain Quality Problems in Asia

Bienvenido O. Juliano*

Abstract

Maintenance of grain quality is the major consideration in postharvest handling of grains. Grain quality is influenced by variety, preharvest environment, and postharvest handling. Grain breeding programs concentrate on varietal improvement, whereas engineers improve postharvest processes to enhance grain quality. Major grain quality problems arise from lack of incentive to farmers, and are manifested in yellow rice, broken, ageing and storage changes, variety mixing and mislabelling, and lack of screening methods to differentiate among rices with similar starch properties and among special rices for rice food products. High aflatoxin level from fungal growth is the major problem for maize and parboiled rice. Fissuring during drying is also a quality problem in maize.

Specific grain properties relevant in drying include moisture content (water activity) and both critical and equilibrium moisture contents, and hull or husk tightness. Delayed drying may result in stackburning of wet grain due to nonenzymic browning and microbial growth and mycotoxin production in maize and parboiled rice. Improper and over-drying may reduce head rice yield and aroma. Rice varieties differ in their critical moisture content (11–16%, below which they fissure readily) and in equilibrium moisture content. Further interdisciplinary research should accelerate the solution of quality problems related to postharvest handling of grain.

Milled rice is the staple food in tropical Asia and is the major source of dietary energy and protein (Juliano 1993). The major nutrient of milled rice is starch (90% of dry matter) followed by protein (8% of dry matter). Rice is consumed mainly as boiled whole grain. Starch occurs as compound starch granules 3–9 μm in size and protein exists as two types of protein bodics 0.5–4 μm in size (Juliano 1985). Milled rice is classified by iodine-colorimetric assay for apparent amylose content (AC) into: waxy, 1–2% milled rice dry basis; very low, 5–10%; low, 10–20%; intermediate, 20–25%; and high, 25–33%. Final starch gelatinisation temperature (GT), wherein 90% of the starch granules swell irreversibly in hot water, is classified as low <70°C, intermediate 70–74°C, and high 74.5–80°C. The AC is the major influence on the texture of cooked rice, with waxy being the softest and most sticky, and high-AC low GT rices the most flaky (Juliano 1995). By contrast most nonwaxy maize varieties have high AC and intermediate GT starch.

* Philippine Rice Research Institute—Los Baños, Phil Drive, University of the Philippines at Los Baños campus, 4031 College, Laguna, Philippines.

Maintenance of grain quality is a major consideration in postharvest handling of grains. Grain quality is influenced by variety, preharvest environment, and postharvest handling (Juliano and Duff 1991a) (Table 1). Although variety is the principal factor contributing to grain quality, good postharvest handling can maintain or even improve it. In countries with marked variability in temperatures during the ripening periods, significant differences in grain quality have been reported within a variety. In tropical Asia, grain physiochemical properties of a variety are relatively constant.

Grain quality denotes different properties to various groups in the postharvest system. To the farmer, grain quality refers to quality of seed for planting and dry grain for consumption, with minimum moisture, microbial deterioration, and spoilage. The miller or trader looks for low moisture, grain size, shape, and translucency, variety integrity, and high total and head (wholegrain) milled rice yield. Market quality is mainly determined by physical properties and variety name, whereas cooking and eating quality is determined by physiochemical properties, particularly AC (Table 2).
Table 1. Effects of environment, processing, and variety on grain quality at different steps in the postharvest system (Juliano and Duff 1991a; Juliano 1993).

<table>
<thead>
<tr>
<th>Postharvest process</th>
<th>Environment</th>
<th>Postharvest handling</th>
<th>Variety</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Growth duration; photoperiod; degree of ripeness; dormancy</td>
</tr>
<tr>
<td>Threshing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Threshability; shattering</td>
</tr>
<tr>
<td>Drying</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Stackburning</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Yellowing</td>
</tr>
<tr>
<td>Mycotoxins</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Hull/husk tightness</td>
</tr>
<tr>
<td>Storage/ageing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Hull tightness, etc.</td>
</tr>
<tr>
<td>Pests</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Hull tightness/content</td>
</tr>
<tr>
<td>Dehulling</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Milling</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Marketing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size and shape</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>Genetically determined</td>
</tr>
<tr>
<td>Degree of milling (whiteness)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Depth of grooves</td>
</tr>
<tr>
<td>Head rice</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Translucency</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Aroma</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Pecky grains</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Stink bug resistance</td>
</tr>
<tr>
<td>Foreign matter</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Shelf life</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Cooking and eating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amylose content</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>Vol. expansion; texture</td>
</tr>
<tr>
<td>Gelatinisation temperature</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>Cooking time; texture</td>
</tr>
<tr>
<td>Gel consistency</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>Cooked rice hardness</td>
</tr>
<tr>
<td>Texture of cooked rice</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Grain elongation</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Nutrition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein content</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Yellow maize</td>
</tr>
<tr>
<td>Vit. A content</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Unsaturated fatty acids</td>
</tr>
<tr>
<td>Oil quality</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Viability: vigour</td>
</tr>
<tr>
<td>Seed</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

Grain breeding programs concentrate on varietal improvement, whereas agricultural engineers look at postharvest processes to enhance grain quality. Grain quality factors important for table rice include grain size, shape, and translucency, colour, total and head milled rice yield, aroma, cooking and eating quality, and nutritional value. These are mainly varietal in nature, but are affected also by preharvest environment and postharvest handling.

Major Grain Quality Problems

Major grain quality problems arise from lack of incentive to farmers to grow better quality rice, and are manifested in yellow rice from stackburning of wet grain, brokens from grain fissuring during drying, ageing, and storage changes, variety mixing and mislabelling in the trade, lack of screening methods to differentiate among rices with similar starch properties, lack of screening methods for special rices for rice food products, and lower protein content in yield trials. High aflatoxin level from microbial growth on wet grain is the major problem for maize and parboiled rice.
Table 2. Rice-grain apparent amylose content (AC) type preferred in various Asian countries (Juliano and Duff 1991b; Juliano and Villareal 1993).

<table>
<thead>
<tr>
<th>Waxy</th>
<th>Low AC</th>
<th>Intermediate AC</th>
<th>High AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laos</td>
<td>China (japonica)</td>
<td>Cambodia</td>
<td>Bangladesh</td>
</tr>
<tr>
<td>Thailand (north)</td>
<td>China-Taiwan (japonica, indica)</td>
<td>China (indica)</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td>India (Basmati)</td>
<td>India</td>
</tr>
<tr>
<td>Korea, South</td>
<td></td>
<td>Indonesia</td>
<td>Pakistan</td>
</tr>
<tr>
<td>Nepal</td>
<td></td>
<td>Malaysia</td>
<td>Philippines</td>
</tr>
<tr>
<td>Thailand (northeast)</td>
<td></td>
<td>Myanmar</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pakistan (Basmati)</td>
<td>Thailand (north, central, south)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Philippines</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thailand (central)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vietnam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a Data from China National Rice Research Institute, Hangzhou.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lack of incentives to farmers

Lack of incentives to the Filipino rice farmer to improve grain quality was reported by Umali and Duff (1990). Given the importance of quality characteristics for creating and stimulating demand, especially among the higher income urban sector, transmission of price and market signals and a greater degree of integration at the farm to wholesale market level will be necessary to improve the farmgate price and to provide incentive to farmers to produce better quality rice. Moreover, improvements in grain quality that do not lower yields will generally benefit all rice consumers by lowering the cost of better quality rice.

Problems related to drying

Drying may be considered as the initial step of ageing. Moisture content (water activity) is the most important criterion for rough rice quality (Roettger 1982; Unnevehr et al. 1992). The traditional photoperiod-sensitive rices have more synchronous flowering and the harvested grains have fewer immature and overdried grains than nonphotoperiod-sensitive rices (Juliano 1993). Dormancy prevents preharvest sprouting of grain (Juliano and Chang 1987). The level of the major aroma principle, 2-acetyl-1-pyrroline (Burgy et al. 1983), in the aromatic variety Hieri planted in 17-24 farmers' fields at Kubokawa, Kochi, Japan during 1993-95 was similar and ranged from 60-200% of the mean value (Fuslimi et al. 1996).

Delayed drying of harvested grain may result in grain deterioration and yellowing through stackburning caused by heating of the wet grain (>20% moisture) through microbial and grain respiration (Phillips et al. 1988, 1989). Yellowing can be simulated by heating grain at 60°C (Yap et al. 1990). Yellow discoloured grains result from a nonenzymic browning type reaction (NRI 1991) and all varieties are affected. The slight cream colouration of aged rice probably involves the same mechanism. Colourless precursor products are first formed before discoloration occurs (NRI 1991). Yellow grains are harder and more translucent than unaffected grains, indicating that mainly wet grains are affected. A prediction equation for stackburning has been calculated by Wrigley et al. (1994).

Protein of yellow rice has lower lysine content than protein of sound grain and had lower net protein utilisation and protein quality in growing rats (Eggum et al. 1984) (Table 3). However, moderately yellow rice does not produce major adverse effects when fed to rats and broiler chicks in nutritionally balanced diets (NRI 1991). Stackburning of maize of less than 12.5% moisture bagged in polypropylene in lieu of jute bags has been reported, nutritionally altering the maize and making it less suitable for milling for food (Tyler 1992). Yellow rice grain is more translucent and has higher head rice yield than white rice grain (Yap et al. 1990).

Aflatoxin produced by the fungus Aspergillus flavus is the major problem in maize because of the practice of delayed drying of the grain (Wicklow 1994). Aflatoxin results in liver disorders and cancer in poultry, pigs, cattle, and man. Surveys in Thailand indicated that aflatoxin contamination of maize was low at harvest and increased during storage (Siricha et al. 1991). Ears were less contaminated by A. flavus and aflatoxin than were the grains. Most contamination started in grains that were damaged by shelling and were not dried properly. A 1990 survey in the Philippines showed that most stocks of the maize entering trade channels were positive for aflatoxin and the levels were higher than those observed on farms (Quitco 1991).
Table 3. Comparison of properties, and of energy and protein utilization in rats, of four yellow milled rices from stackburning of unthreshed panicles plus straw with those of three ordinary milled rices (Eggum et al. 1984; Juliano 1985).

<table>
<thead>
<tr>
<th>Property (at 14% moisture)</th>
<th>Yellow rices</th>
<th>White rices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein (% N × 6.25)</td>
<td>7.4</td>
<td>8.7</td>
</tr>
<tr>
<td>Lysine (g/16 g N)</td>
<td>3.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Amino acid score* (%)</td>
<td>56</td>
<td>64</td>
</tr>
<tr>
<td>Energy content (kJ/g)</td>
<td>15.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Balance data in growing rats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digestible energy (% of intake)</td>
<td>96.0</td>
<td>96.6</td>
</tr>
<tr>
<td>True digestibility (% of N intake)</td>
<td>92.0</td>
<td>98.4</td>
</tr>
<tr>
<td>Biological value (% of absorbed N)</td>
<td>66.4</td>
<td>67.2</td>
</tr>
<tr>
<td>Net protein utilisation (% of N intake)</td>
<td>61.0</td>
<td>66.1</td>
</tr>
<tr>
<td>Protein quality** (%)</td>
<td>52</td>
<td>63</td>
</tr>
</tbody>
</table>

* Based on 5.5% lysine as 100% (WHO 1985).
** Based on amino acid score × TD/100 (FAO 1990).

Hull or husk tightness may be a factor, as A. flavus can readily inoculate the ripening grain. Incidence of aflatoxin in rice in India is higher with incidence of heavy rains (cyclones) during the harvesting season (Tulpule et al. 1982). During the 4-day soaking step of parboiling, sound grain soaked in A. flavus-inoculated water failed to have aflatoxin, suggesting that reported high aflatoxin levels in soaked grain results from contamination of the rice grains before soaking (Yap et al. 1987). All brown rices tested were susceptible and their bran colonised by Aspergillus spp. (Ilag and Juliano 1982). Seed viability is adversely affected by these problems.

Drying should consider the varietal differences in critical moisture content (11–16%) below which the grain fissures upon moisture adsorption (Juliano and Perez 1993) (Table 4). All rices are resistant to fissures at 16% moisture (Juliano et al. 1993). Rough rice is stressed by soaking 1-3 hr in 30°C water before dehulling and milling in a Kett micromill. The Japanese have taken advantage of this phenomenon and adjust moisture content of grain to 15% so that head rice during milling will be high and the milled rice will not fissure during the cold water soaking phase of cooking (Satake 1994), but proper storing of the 15%-moisture rice may be a problem. Above 75% relative humidity, equilibrium moisture content is higher in waxy and low-AC rough rices than in high-AC rough rice (Juliano 1964) (Table 5). Such differences are consistent with the negative correlation of equilibrium water content of brown rice steeped in water at 30°C water with AC (Kongseree and Juliano 1972; Antonio and Juliano 1973), and with the absence of chalky regions (Antonio and Juliano 1973). Among high-AC translucent milled rices, equilibrium water content is higher in low GT than in intermediate GT rices (IRRI 1980). Fissuring is also a major problem in maize drying, because of greater susceptibility of cracked grain to disease and pest infestation.

Low-temperature drying preserves the rice aroma principle, 2-acetyl-1-pyrroline (Itani and Fusilini 1996). Hot-sand flash drying results in parboiling in the wet season, but only drying in the dry season, with improvement of grain translucency and milling quality.

Table 4. Critical moisture contenta for fissures in rough rice of four rices differing in crack resistance; 1990 dry and wet seasons at Los Baños, Laguna, Philippines (Juliano and Perez 1993).

<table>
<thead>
<tr>
<th>Variety or line namea</th>
<th>Critical moisture contentb (% wet basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry season</td>
</tr>
<tr>
<td>CP/SLO 17</td>
<td>&lt;10</td>
</tr>
<tr>
<td>IR60</td>
<td>14</td>
</tr>
<tr>
<td>IR74</td>
<td>15</td>
</tr>
<tr>
<td>IR42</td>
<td>16</td>
</tr>
</tbody>
</table>

a CP/SLO 17 low AC high GT; IR60, IR74, and IR42 high AC low GT.
b Moisture content below which rough rice fissures significantly on soaking for 1-3 hr in 30°C water.
Table 5. Equilibrium moisture content at >75% relative humidity at 27.5°C by desorption and adsorption of four rough rices differing in starch properties (Juliano 1964).

<table>
<thead>
<tr>
<th>Relative humidity (%)</th>
<th>Waxy low GT (Malagkit Sungsong)</th>
<th>Equilibrium moisture content (% wet basis)</th>
<th>Low AC low GT (Taichung 65)</th>
<th>High AC interm. GT (Peta)</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Desorption isotherm</td>
<td></td>
<td>Adsorption isotherm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>96.5</td>
<td>22.3 21.7</td>
<td>20.4 19.6</td>
<td>13.3 13.2</td>
<td>13.0 12.8</td>
<td>0.18**</td>
</tr>
<tr>
<td>84</td>
<td>16.3 16.4</td>
<td>15.8 15.8</td>
<td>15.4 15.6</td>
<td>15.0 14.8</td>
<td>0.13*</td>
</tr>
<tr>
<td>75</td>
<td>14.3 14.1</td>
<td>14.1</td>
<td></td>
<td></td>
<td>0.08ns</td>
</tr>
</tbody>
</table>

a Starting at 5% moisture.

Ageing and storage changes

Physiochemical changes (ageing) occur in the grain during 3–4 months after harvest when stored above 15°C, resulting in higher total and head rice milling yield, greater volume expansion and water absorption during cooking, with less solids in cooking liquid, and a more flaky cooked rice (Juliano 1985, 1994). The milled rice also develops a slight cream colour. Aged rice has a price premium in tropical Asia, particularly for rice products, but ageing reduces the stickiness of japonica rice. Waxy rice also undergoes ageing, and freshly harvested rice is preferred for rice products. Thus, high temperature drying reduces the quality of Japanese waxy rice crackers (Saito et al. 1974). Storage also results in loss of the more volatile components of rice aroma and of vitamins in the grain, particularly vitamin A. Some ageing also occurs during grain drying and probably during grain desiccation in the field. Insect infestation also results in quantitative and quality losses of stored grain (Juliano 1985). Growth of Tribolium castaneum larvae is negatively correlated with AC of rice (Vohra et al. 1980).

The lipids (fat) of rice located in the spherosomes or fat globules begin to decrease after 6 months of storage, while the level of free fatty acids increases (Aibara et al. 1986). Oxidation of the unsaturated fatty acids into carbonyl compounds (aldehydes and ketones) contributes to the stale odour of stored rice, mainly due to hexanal (Juliano 1985). Shelf life of milled rice is shorter than that of rough rice due to fat rancidity.

Viability decreases during storage at ambient temperature, with varietal differences in mean viability periods (Juliano et al. 1990).

Variety mixing and mislabelling

Grain size and shape are mainly varietal characteristics. Variety mixing and mislabelling in the market is common, and variety name in the Philippines is used to denote particular variety types rather than the variety itself (Juliano et al. 1989). Some varieties also have variable translucency, such as IR64 (Perez et al. 1990). Thus, consumers have a variable concept on the grain quality of market samples labelled by specific variety names. Authentic samples are needed to validate data from consumer surveys. Unfortunately, routine variety identification of milled rice is not yet possible (Juliano 1995). With the approval of the GATT Uruguay Round trade agreement mislabelling of cheap imported rice as local rice is a problem being addressed in South Korea.

Texture evaluation of rices with similar starch properties

As many countries achieve self-sufficiency, grain quality has become an important breeding objective (Juliano and Duff 1991b). In the Philippines and most of tropical Asia, the physiochemical properties preferred are intermediate AC and intermediate GT (Juliano and Villarreal 1993) (Table 2). This type has soft cooked rice, with some degree of stickiness. Thus in the Philippines, all varieties released recently have these properties of intermediate AC and GT (Juliano 1996). Current methods for evaluating cooked rice texture are not sensitive enough to differentiate among them. Alternative approaches being pursued are hardness distribution within the cooked grain (surface vs core) and effect of amylopectin staling on cooked-rice hardness. Collaboration among chemists involved in national breeding programs should accelerate the development of such methods, as the problem is now common to most national programs.

The Philippine Rice Research Institute (PhilRice) aims to achieve softer rices, similar to premium upland rices with 18–22% AC (Juliano and Villarreal
1993), by slightly lowering its AC objective from 20–25% to 18–22%. The rice has to be of low GT (for 18–20% AC) and intermediate OT (for 20–22% AC) to have the desired soft texture of freshly cooked rice (Juliano 1996).

Screening methods for special rices

Rapid screening methods for special rices, such as waxy (glutinous) and nonwaxy rices ideal for use in local traditional rice products (Juliano and Hicks 1996), are also important to ensure that such rice types are not eliminated in the breeding program. The local production and availability of wet-milled and dried flour may reverse the trend of substituting maize starch and wheat flour for wet-milled rice in traditionally rice-based products, particularly rice noodles and steamed fermented cakes.

Nutritional value

The reduction of yield and protein content in yield trial plots at PhilRice and IRRI has been attributed to insufficient available nitrogen (N) during the reproductive stage: split application of N fertilizer close to flowering has been recommended (Cassman et al. 1995, unpublished data). Rice is the principal source of protein in the tropical Asian diet (Juliano 1993) and reduction of protein content from the mean value of 7.3% down to as low as 5% would reduce the available protein in Asian diets. Hence, protein level of milled rice should at least be maintained in the new varieties. The grain should also be free of mycotoxins that can cause human cancer. International efforts to improve the level of micronutrients, vitamin A, iron, and zinc in the cereal grain have been initiated, with rice tolerant of low levels of available iron and zinc in rice soils being studied (Bouis 1995). The feasibility of introducing carotenoid biosynthesis in rice endosperm is being explored (Rockefeller Foundation 1993).

Linoleic acid content of rice oil is negatively correlated with temperature during ripening of Japanese rice (Taira et al. 1980).

Need for Interdisciplinary Research

Since most of the problems discussed here involve more than one scientific discipline, the combined inputs of agricultural engineers, biologists, chemists, social scientists, and other scientists in relevant disciplines will accelerate the effective and efficient solving of research problems, considering the limited human and monetary resources available in the region. Regional collaboration should be encouraged inasmuch as the problems are common to the region.

References


Grain Drying in China: Problems and Priorities

Ren Yonglin* and J. van S. Graver†

Abstract

China's annual grain harvest of 425–450 million tonnes (Mt) includes a large proportion (approx. 30 Mt) that is received at high moisture content. Grain drying is the most important factor in minimising postharvest losses, since it directly affects safe storage, transportation, distribution, and processing quality. Currently, considerable losses are incurred annually during storage and transportation of grain, as a result of inadequate drying. This paper outlines the current status of the problem.

The People’s Republic of China (China) is a vast country, with its main grain producing areas situated between latitude 20-50°N and longitude 95-120°E (Fig. 1). Within this area, geographic and climatic conditions vary greatly. This is reflected in the different grains, and varieties of grains, that are grown in China, and accounts directly for the wide range of moisture contents at which these grains are harvested. A diversity of postharvest technologies has been developed to handle and store the different grains produced in the different growing regions. Since 1984, the annual grain harvest has exceeded 400 million tonnes (Mt) and in 1994 it reached a record 450 Mt (Ren 1991). Of this, rice comprises 40-45% of China’s total grain production, with wheat and maize each contributing 22% (Garnaut and Ma 1992).

Geographic Distribution of High Moisture Content Grain

Nationally, about 70% of all grain produced is kept by farmers for food, seed, and stock feed. Of the grain delivered by farmers to depots of the government Grain Handling Bureaux (GHB), approximately 30 Mt are received at high moisture content (Table 1) and must be dried. The grains involved are mainly maize and paddy, with small quantities of soybean and wheat. These grains are produced in three main growing regions (Fig. 1).

Northeast growing region

This region produces approximately 35% of the maize grown in China, which is 55–60% of the region’s total agricultural production. Northeast China is characterised by its low ambient temperatures and a short growing season. These crops are harvested in autumn, a time when the weather is not always favourable for this activity. Days are short with reduced sunshine and there is usually only a short frost-free period before winter. Under such conditions it is very difficult for the crop to dry in the field. This results in a harvest of maize (and soybeans) that is taken in by the farmers at very high moisture content.

Consequently, every year GHB depots in the region receive very large quantities of high moisture content grain. When maize is received at GHB depots, its moisture content (m.c.) is normally between 22 and 30%. Thus, drying this grain to a level that permits safe storage is the principal activity of grain depots during winter and spring, an activity that must be completed before the ambient temperatures rise during summer.

Recently in this region, the area of land planted to paddy has been extended very rapidly. This is because premium rice produced in the region is better than that grown in southern China and has very good consumer acceptance. However, due to the prevailing low ambient temperature, the crop requires a considerably longer growing period than it does in southern China. Consequently, over 90% of the rice produced in the region is harvested at high moisture contents and must be dried before it can be safely stored until the following summer (Zhang 1995).
Table 1. Geographical distribution of high moisture content grain (stored in grain depots).

<table>
<thead>
<tr>
<th>Geographic location</th>
<th>Provinces, cities and regions</th>
<th>Varieties</th>
<th>Quantities (Mt)</th>
<th>Range of moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast (maize belt)</td>
<td>Heilongjiang, Jilin, Liaoning and eastern Inner Mongolia</td>
<td>Maize</td>
<td>18-21</td>
<td>18-30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soybean</td>
<td>1-1.5</td>
<td>14-17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paddy</td>
<td>1-2</td>
<td>17-20</td>
</tr>
<tr>
<td>Centre (wheat belt)</td>
<td>Beijing, Hebei, Shanxi and Shandong</td>
<td>Wheat</td>
<td>0-2</td>
<td>14-18</td>
</tr>
<tr>
<td>South (paddy belt)</td>
<td>Anhui, Jiangsu, Hubei, Jiangxi and Zhejiang</td>
<td>Maize</td>
<td>2.5-4</td>
<td>15-19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paddy</td>
<td>5-10</td>
<td>16-24</td>
</tr>
</tbody>
</table>

Central growing region

This region, which includes the city of Beijing, and Hebei, Shanxi, and Shandong, produces some 50-60% of the maize grown in China. Some 3-6 Mt of the high moisture content grain handled in China is grown in this region. The crop is normally harvested during October and November at an average moisture content of 16%, though it is not unusual for some of the crop to be harvested at up to 19% m.c. In addition, the GHB depots in this region can expect to receive some of the high moisture content grain grown in northeastern China.

Wheat is also grown in this region. The crop is harvested during May and June, a time when the weather is normally hot and dry. However, sometimes prolonged spells of rain may wet the grain before and during the harvest. This can cause the grain to sprout, and may even lead to moulding, which occurs rapidly because of the combination of increased moisture content and high ambient temperatures.

Figure 1. Map of China showing distribution of high moisture content grain.
Southern growing region

Paddy is the main crop produced in this region. Two crops are harvested annually (Wang 1986) in the provinces of Anhui, Jiangsu, Hubei, Jiangxi, and Zhejiang. The second crop is harvested at a time when rain and high ambient relative humidities can be expected, which results in a harvest with moisture contents in the range 16–18%. These may rise to 20–24% in very wet years, causing losses due to moulding and sprouting (Zhuge et al. 1993). On average some 5–10 Mt of high moisture content grain are harvested annually in the region.

On-farm Grain Drying

Due to the small-scale of the farms, farm level mechanisation of postharvest handling of grain is seriously underdeveloped at present. There is a complete absence of mechanical or artificial grain drying methods at the farm level, so that sun drying and natural aeration are the only methods applied to remove moisture from ‘wet’ grain after the harvest. They are applied in the following ways.

In-field drying

In the northeastern and central growing regions, as the crop matures, the grain kernels cease growing and start to dry. At this stage the moisture content of the kernels is still high—around 30–40%. Nevertheless, the crop can be harvested provided proper drying facilities are available. However, traditional grain storage structures are unsuitable for preserving grain at this high moisture content. Thus, the standing crop is left in the field for about a month to dry. Normally, when it has dried to between 15–18% m.c. it is harvested. To hasten the drying process, farmers remove the husks from the cobs when the grain is in the waxy stage. This procedure not only removes moisture but also promotes maturation.

In-crib drying

Cribs built with slatted walls and floors using sorghum canes or reeds to allow easy ventilation are extensively used for drying maize on the cob. The open design allows a good flow of air through the grain, particularly when cribs are sited in the path of the prevailing wind. Such cribs are built with one or more sections, each with a capacity of approximately 6 m³.

Seed drying

Maize on the cob, particularly for use as seed, may be dried in bundles, indoors suspended from rafters of a dwelling, or outdoors from the branches of a tree.

Sun drying

Sun drying is widely practiced and, at present, accounts for 98% of the grain dried by farmers. It is labour intensive, requiring the grain to be spread in a 2–3 cm layer and regularly turned until it has dried to approximately 12–13% m.c. In summer, with favourable weather, this usually takes two days for wheat and indica rice. However, in autumn when the maize and japonica rice are harvested, these grains can be dried to only 14–16% m.c. due to the overcast skies and weak solar radiation (Semple et al. 1992; Xu et al. 1989).

The roadside, concrete or earthen platforms, school sports fields, and even the roof tops of houses may be used for sun drying. Farmers frequently have their own drying yards in the front of their houses. Obviously, the efficiency of sun drying depends on the type and variety of grain being dried, and the locality where it is grown. However at farm level, where it is essential to prevent high moisture content grain from deteriorating, it is still the most rapid method of drying grain currently available. Losses incurred during sun drying amount to about 5% and are due to spillage, careless handling, and consumption by birds, rodents, and domestic poultry (Chi et al. 1992). Where roads are used to dry grain, considerable damage is caused to the highways so that they have to be re-paved prematurely. The costs involved in re-paving roads and highways are very high and thus the practice has been prohibited and other means for grain drying are being promoted.

Grain Drying at Government Grain Depots

Three main grain drying methods are used by the GHBs: sun drying, aeration drying, and mechanical drying. Currently, about 30% of high moisture content grain is mechanically dried, 10–25% of high moisture grain is dried by an aeration method, and the balance is sun dried.

Sun drying

This traditional method of grain drying is still widely used and is applied to 45–55% of the high moisture content grain received by the GHBs. Commonly, high moisture content grain is spread out in a 5–10 cm layer on a yard that may be paved. Most intermediate grain depots have their own drying yards, over which grain is spread and turned every 2–3 hours to ensure uniform drying (Zhang 1988). In the northeastern and central growing regions about 5 days are required to reduce the moisture content of maize by 3–5%.
In the northeastern growing region, the ambient temperatures at the end of winter and the beginning of spring are very low and the relative humidity is comparatively high (Table 2).

Table 2. Ambient temperatures at the end of winter and beginning of spring in the northeastern growing region.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>-12 to -16</td>
<td>70-75</td>
</tr>
<tr>
<td>January</td>
<td>-13 to -17</td>
<td>55-60</td>
</tr>
<tr>
<td>February</td>
<td>-7 to -12</td>
<td>40-50</td>
</tr>
<tr>
<td>March</td>
<td>-3 to -8</td>
<td>60-65</td>
</tr>
</tbody>
</table>

Under such conditions, it is very difficult to sun-dry grain to a moisture content that allows safe storage. Most grain dried in this manner is treated during a short period just before the end of spring. This is an immense task given the quantities of grain involved, particularly as the procedure is heavily dependent on good weather conditions. To complete the task in the short time available, the GHBs must seek assistance from local government agencies to provide sufficient space for the purpose. Roads, school sports fields, other paved public spaces, even airport landing strips have been used to dry high moisture content maize before the temperature rises in spring. Prolonged spells of bad weather increase the risk of losses occurring. Additionally, the handling losses incurred during sun drying can be quite substantial.

Sun drying is labour intensive and makes extensive demands on space, particularly in the case of existing large-scale operations of the centralised storage system in China, where more than 70% of the grain is handled and transported in bags. Although labour is cheap, the expense of sun drying nationwide is considerable, particularly when the costs of the losses incurred are taken into account.

This makes sun drying a very expensive operation. Some local governments have offered farmers incentives to encourage them to undertake sun drying at farm level in an effort to alleviate the problems incurred in the central storage system. However, this has not proven successful because in spring all available farm labour is required to prepare the fields for the next crop.

Mechanical drying

Design and manufacture of mechanical dryers in China commenced in the late 1950s utilising Russian design, theory, and engineering principles. The late 1970s and early 1980s were years of successive bumper crops, which created an immense grain drying problem. This situation produced the impetus to develop and extend the application of mechanical drying, which has since continued rapidly. Nowadays, most grain dryers are designed and manufactured by provincial engineering research and design institutes, or end users.

Three types of grain dryers are commonly used in China: tower dryers, rotary drum dryers, and fluidised-bed dryers (Wang 1988; Zhang 1995).

Tower dryers

Tower dryers are extremely effective where there is a need to dry very ‘wet’ grain. Thus, they are most common in the northeastern growing region, where they are used to dry maize. They are classified as direct or indirect dryers. In the former, the heated gas/air mixture makes direct contact with the grain and consequently has a higher drying and energy efficiency than the latter, where heat exchangers are used. There is, however, a risk of contamination in direct tower dryers and to minimise this risk they are usually fired with anthracite rather than lignite. Coal-fired tower dryers have a capacity in the range of 10-20 t/hour with the ability to remove 8-12% moisture per pass through the dryer. Since there is no risk of contaminating grain when indirect tower dryers are used, no special fuel arrangements are required. However, their energy consumption is greater. An example of this is the steam dryer, in which grain is dried as it falls into a drying chamber over a series of pipes heated by water/steam mixture. This chamber is ventilated by fans that remove hot moist air resulting from the drying process.

Rotary drum dryers

Paddy is commonly dried in rotary drum dryers (Zhao 1996). These are fuelled mainly with paddy husks or coal and operate at high temperatures (grain drying temperatures of 60°C are attained). Their capacity ranges from 5-15 t/hour. Before the grain is fed into the dryer it is cleaned and preheated with hot air recycled from the dryer. Typically, such dryers can reduce grain moisture content by 3% per pass. However, they can increase the number of cracked kernels (Zhu 1988).

Fluidised-bed dryers

Fluidised-bed dryers are popular in the southern growing area for drying paddy (Zhao Simong 1996). These dryers also operate at high temperatures and are fuelled with rice husks or coal. However, grain residence time within fluidised-bed dryers is short—approximately 2 minutes. In addition, because the grain is well mixed with the drying air during the fluidising process, the capacity of such dryers is greater, ranging from 3-15 t/hour. They are capable of reduc-
ing grain moisture content by 3–5% per pass. Typically, a tempering and cooling tower is incorporated into these dryers.

**Aeration drying**

Use of aeration to dry grain commenced in the 1970s when engineering design for this purpose was introduced. Since then its use has spread rapidly. The form of construction required for aeration is simple. It is economic because grain is dried in-store with no extra handling costs. Aeration is used to dry maize in the central growing region and paddy in the southern growing region. Currently 70–80% of the high moisture content maize (approx. 18% m.c.) in the central growing region and 80–85% of the paddy in the southern growing region is dried by aeration. The capital investment in equipment is also lower than that required for mechanical dryers. In addition, aeration has an advantage because there is no appreciable reduction in grain quality. Aerated grain is kept fresh, retains a good colour and remains free from contaminants. Of particular importance with paddy is the increased head rice yield compared with that obtained after mechanical drying.

In the northeastern growing region, aeration is managed with reference to grain moisture content, and ambient temperature and relative humidity. After March aeration fans are operated intermittently, usually from 10:00 am to 3:00 pm when the relative humidity is low. It normally requires 35–80 days of fan operation to reduce maize moisture content from 24 to 14% without use of an additional heat source. This drying system is more economic and has added advantages of better grain quality in terms of reduced fissuring (stress cracks) and absence of mycotoxins.

Aeration is also used in the northeastern growing region as part of a two-stage drying strategy. The first stage involves use of a high temperature mechanical dryer to reduce maize moisture content to approximately 18% during winter. The second stage involves aeration, which commences around mid May.

Aeration is also extensively used in the northeastern and central growing regions to dry bulk maize and paddy stored outdoors. These grain bulks may be horizontally retained within walls of bagged grain or vertically stored in silos made of reed and/or bamboo matting. The horizontal bulks are normally 10 × 10 × 1 m (width × length × height) with a number of ducting systems to aerate the grain from the bottom of the bulk. Matting silos are generally 4–5 m high and 4–5 m in diameter, and have a capacity of 50–70 t. The grain is aerated through a duct 2–3 m long and 0.5–1.0 m in diameter that is positioned centrally at the bottom of the silo.

A number of permanent horizontal storages constructed with in-floor aeration ducts are in use in the southern growing region.

---

**Grain Drying Problems**

In China, minimisation of postharvest losses has always been a key issue in management of stored grain. This is particularly important in a situation where large quantities of high moisture content grain are involved. It is also a matter of concern when crops are wet by rain during the harvest, leading to the presence of mycotoxins (Semple et al. 1992). At present the major postharvest problem confronting the GHBs is a severe shortage of mechanical drying capacity to handle the large quantities of high moisture grain taken into storage. In the absence of mechanical drying, substantial inputs of labour, materials, and money are required to sun dry the crop (particularly maize in the northeastern growing region), and prevent moulding or other damage occurring during storage and distribution.

Before 1990, farmers were able to delay delivery of their grain to government grain depots until January of the year following the harvest and maximum receivable moisture contents were set (maize at 16–20% and paddy at 16–18%). At that time approximately 20 Mt of high moisture content grain would be received into the government grain depots. Thus, on-farm storage of grain could extend for 1–2 months. However, since 1990 the amount of high moisture grain received at the government grain depots has increased rapidly. This can be attributed to:

- introduction of high yielding but late maturing maize varieties;
- successive bumper harvests; and
- a requirement for farmers to deliver grain to storage depots as soon as possible after the harvest.

A combination of these factors means that enormous quantities of very high moisture content grain have to be dried and delivered to the GHBs over a very short period, a task that is virtually impossible given China’s lack of on-farm drying capacity. Thus, the total amount of high moisture grain delivered to the GHBs has risen by 10 Mt compared with the period before 1990. Another important administrative factor influencing delivery of high moisture grain is the policy of imposing only low penalty rates when high moisture grain is delivered to the GHBs.

In the case of maize, the maximum moisture content for grain received into GHBs was raised by 2–5% to facilitate the requirement for early delivery. In practice much of the maize harvest is frozen when it is taken into storage. This is because farmers must wait until the maize is frozen on the cob by low winter temperatures before it can be shelled. Otherwise the grain would be severely damaged by mechanical shelling due to its high moisture content.

Under the existing management system, GHBs now have to procure immense quantities of high moisture content maize within a short period after the
The high moisture content paddy harvests in the southern growing region present a second serious grain drying problem in China. Their average moisture content is lower than that of maize, but the higher ambient temperatures in southern China greatly increase the risk of deterioration. Thus, it is essential to dry the paddy harvest as rapidly as possible (Wang 1988). It has been shown (Zhuge et al. 1993) that a 3–5 day delay in drying paddy adversely affects germination rate, reduces head rice yield and, in indica varieties, produces a significant increase in the number of discoloured grains.

**Grain Drying Priorities**

It is estimated that, by the year 2000, grain production in China could reach an upper limit of 500 Mt (Garnaut and Ma 1992). Should this figure be achieved, the quantity of high moisture content grain produced, and the problems associated with it, would become very difficult to manage in the existing organisational structure. However, grain production has not kept pace with the demand of China’s growing population. The gap between demand and supply has increased in recent years because grain consumption has increased more rapidly than production. To solve this food crisis, a need has been identified to tap new food resources and also to reduce postharvest losses.

China in its ninth Five Year Plan has set national priorities for its grains postharvest industry which include the need to:

- establish effective management of its grain reserves;
- change from bag to bulk handling;
- reduce postharvest losses caused by insects and moulds;
- introduce new, non-polluting, processing methods for flour, oilseeds, rice and soybeans; and
- establish new national standards.

Steps have been taken to improve national grain storage, handling, and distribution ability through the China Grain Distribution and Marketing Project. This project will modernise the operations of the GHBs by providing a large number of bulk grain storage complexes incorporating mechanical grain drying facilities.

Specifications for these mechanical dryers will vary relative to the anticipated capacity of primary and intermediate storage depots at which they will be situated. Small-capacity dryers, to dry grain delivered by farmers, will be installed at primary depots. Large capacity dryers will be installed at intermediate depots where it is anticipated that greater quantities of maize from both farmers and some primary depots will have to be dried.

Investigations have been undertaken to study aspects of drying frozen grain (Liu et al. 1995). Other research that may be relevant was the demonstration that drying methods can affect storability. Maize dried at high temperatures has been shown to have reduced storability, while the effect of previous storage at high moisture contents can also decrease subsequent storability (Marks and Stroshine 1995). Whether this is applicable to high moisture content maize stored at freezing temperatures may have to be investigated further.

Design calculations have been carried out to minimise fissuring during mechanical drying of rice (Bakker-Arkema et al. 1994), and suggestions have been made that paddy losses in southeastern coastal areas of China may be minimised by developing husk fired mechanical dryers (Chi et al. 1992).

Priorities for drying high moisture content grain in China should be examined and established on a holistic systems basis commencing with grain production, harvesting, then proceeding through postharvest storage and handling, and distribution to end users. The major problem throughout the system is the lack of mechanical drying capacity. The requirements at each stage of the system may be broadly divided into hardware and policy (or management) requirements.

Hardware requirements include:

- design and development of mechanical drying systems, and regimes, specifically to accommodate the difficulties associated with drying frozen grain in the northeastern growing region (Dayanghirang et al. 1993; Liu et al. 1995; Ju 1996);
- development of drying regimes that minimise grain fissuring (Sutherland and Ghaly 1982; Kunze 1996);
- design and development of aeration-based drying strategies including computer simulations and control technology (Ghaly 1978; Wilson 1987, 1988, 1990a, 1990b; Wilson and Nguyen 1988; Abawi 1996; Cao and Ha 1996; Newman 1996; Zhao 1996);
- modelling drying regimes (Ghaly et al. 1974; Ghaly and van der Touw 1982; Sutherland and Ghaly 1982; Ghaly and Sutherland 1983, 1984; Driscoll et al. 1987);
- modelling moisture migration in stored grains (Thorpe 1996);
- application of computer based decision support systems for cost effective control of drying processes (Halid et al. 1995).

Policy requirements include:
• modernising farm-level postharvest technology as a means for improving the socioeconomic environment (Xu et al. 1989; Chi et al. 1988, 1992; Zhuge et al. 1993; Fegan 1996; Tumanbing 1996);
• adjustment of prices paid for grain relative to production costs (Zhuge et al. 1993);
• introduction of price penalties for grain delivered at moisture contents exceeding the established limits;
• selection, breeding and introduction of early maturing high-yielding maize (and other grain) varieties that ripen early (prior to the onset of winter in the case of maize).

In the last 15 years China has moved away from a system of agricultural production and marketing based on communes, with rigid central planning and control, to a more decentralised and market-oriented system (Watson 1996). Previous policies emphasised self-sufficiency at all levels. Grain drying, and priorities for grain drying, are currently being addressed as China restructures its grain storage system through the China Grain Distribution and Marketing Project.

Acknowledgments

The authors’ attendance at this conference was supported by the Australian Centre for International Agricultural Research (ACIAR). We thank Fred Bakker-Arkema and Dirk Maier for drawing our attention to a number of publications, and Robert Driscoll and Chris Whittle for their constructive comments during preparation of this paper.

References

Abawi, Y. 1996. Minimum daily temperatures as a predictor of dewpoint temperature. These proceedings.
Cao Guangzhi and Ha Zhenfang 1996. Grain condition detection, analysis, and control system. These proceedings.
Fegan, B. 1996. Socioeconomic factors as determinants of technology requirements. These proceedings.


Tumambing, J. 1996. Small-scale grain dryers. These proceedings.


Zhao Simong 1996. Rice drying technology in China. These proceedings.


Problems and Priorities of Grain Drying in Indonesia

Hadi K. Purwadaria*

Abstract

The current status of grain drying in Indonesia is discussed at various levels: farmers, cooperatives, private millers, collecting traders, feed industries, and seed processors. The performance of various grain drying systems operating in the field is also discussed. In relation to grain processing, constraints to the adoption of mechanical dryers are analysed, and the opportunities for grain drying development in the near future are illustrated.

INDONESIA is a significant grain producer. Output of paddy in 1994 was 46.7 Mt (MOA 1995), and in 1993, 6.6 Mt of maize and 1.7 Mt of soybeans were grown (BPS 1994). All the grain enters a postharvest chain in which drying is one of the key operations.

There are three major groups in Indonesia handling primary grain processing, including drying: the first group is farmers, who dry grain at the first stage from the initial harvested moisture content to about 18–20%; the second is cooperatives, private millers, wholesalers, and feed industries who dry grain at the second stage, from 18–20% to the final moisture content appropriate for storage; and the third group is seed processors, who dry grain from the harvested moisture content (22–25%) to the storage moisture content (12–13%) in a single operation.

In general, the farmers apply sun drying regardless of weather conditions, leading to maximum quality losses of about 4.5% for paddy (IDRC 1989), 8.25% for maize (Purwadaria 1988), and 4.0% for soybean (Purwadaria 1988) because of delay in drying during the wet season. During the wet season, private millers use mechanical dryers, but only as needed to supplement their large (1–2 ha) sun-drying floors. The collecting traders at the provincial capitals, and the feed industries, make use of mechanical dryers for locally purchased grain when its moisture content is higher than their required standard, 12–14%. The seed processors use mechanical dryers both in dry and wet seasons, complemented by the drying floor.

Data on dryer development in Indonesia have been sparse and inaccurate. BPS (Central Bureau of Statistics 1994) reported that the number of dryers increased from 1975 units in 1990 to 7034 units in 1993, but gave no information on the type and the capacity of the dryers. The figures might include the sun-drying floors of private millers. In an effort to characterise dryer development in Indonesia, the author carried out a survey of drying equipment associated with BULOG (National Logistics Agency), the Ministry of Agriculture, Cooperatives and Small Enterprises Development, and the Ministry of Industry in Jakarta, made field observations in South Sumatra and East Java covering various dryer manufacturers and dealers, and reviewed the available literature. Though much time was spent and many worthwhile observations were made and are reviewed here, it should be noted that this paper contains case studies and subjective analyses based on limited interviews. It is the author's hopes that this short report will stimulate a more detailed study by all parties concerned with dryer development in Indonesia, to identify the steps needed to improve implementation of grain drying technology among the various target groups mentioned.

Current Status of Grain Drying in Indonesia

Grain drying at farm level

Farmers commonly sun dry their grain on whatever land they have available, either the field or the yard around their houses. On 60 m² of land, a farmer can sun dry 2.4 t of paddy, which is the average produc-
tion per 0.5 ha in Indonesia. Some farmers who do not have sufficient land for sun drying will sell to collecting traders called ‘penebas’, their mature grain as it stands in the field. The yield will be estimated and agreed to by both parties and the cost of harvesting will be borne by the penebas.

Grain drying at cooperatives

The government has provided the KUD (village unit cooperatives) with milling machines, sun-drying floors, godowns, and mechanical dryers. The distribution of KUD sun-drying floors and mechanical dryers in various provinces in Indonesia is shown in Table 1. The estimate of the total drying capacity is 39,504 tonnes/batch on the total sun drying floor and 10,575 tonnes/batch for all types of mechanical dryers. However, the real numbers of mechanical dryers operating in the field might be less than 5%, leaving the sun-drying floor as by far the primary means of grain drying.

Table 1. Sun-drying floor and mechanical dryers owned by KUD (Village Unit Cooperatives) at various provinces in Indonesia*

<table>
<thead>
<tr>
<th>No.</th>
<th>Province</th>
<th>Sun-drying floor Units</th>
<th>Area, m²</th>
<th>Total capacity (tonnes paddy/batch)</th>
<th>Mechanical dryer, units LISTER</th>
<th>Flat bed diesel oil</th>
<th>Bin dryer</th>
<th>Total capacity (tonnes paddy/batch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Aceh</td>
<td>26</td>
<td>31 200</td>
<td>1 248</td>
<td>12</td>
<td>22</td>
<td>55</td>
<td>320</td>
</tr>
<tr>
<td>2.</td>
<td>North Sumatra</td>
<td>179</td>
<td>116 400</td>
<td>4 656</td>
<td>22</td>
<td>30</td>
<td>18</td>
<td>412.8</td>
</tr>
<tr>
<td>3.</td>
<td>West Sumatra</td>
<td>12</td>
<td>14 400</td>
<td>576</td>
<td>22</td>
<td>20</td>
<td>23</td>
<td>380.8</td>
</tr>
<tr>
<td>4.</td>
<td>Riau</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>160</td>
</tr>
<tr>
<td>5.</td>
<td>Jambi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>169.6</td>
</tr>
<tr>
<td>6.</td>
<td>South Sumatra</td>
<td>58</td>
<td>34 800</td>
<td>1 392</td>
<td>33</td>
<td>30</td>
<td>-</td>
<td>516</td>
</tr>
<tr>
<td>7.</td>
<td>Lampung</td>
<td>8</td>
<td>9 600</td>
<td>384</td>
<td>28</td>
<td>20</td>
<td>39</td>
<td>874.4</td>
</tr>
<tr>
<td>8.</td>
<td>West Java</td>
<td>285</td>
<td>189 000</td>
<td>7 560</td>
<td>69</td>
<td>78</td>
<td>186</td>
<td>1 710.8</td>
</tr>
<tr>
<td>9.</td>
<td>Central Java</td>
<td>120</td>
<td>84 000</td>
<td>3 360</td>
<td>42</td>
<td>50</td>
<td>21</td>
<td>917.6</td>
</tr>
<tr>
<td>10.</td>
<td>Yogyakarta</td>
<td>21</td>
<td>15 000</td>
<td>600</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>11.</td>
<td>East Java</td>
<td>354</td>
<td>234 000</td>
<td>9 360</td>
<td>40</td>
<td>50</td>
<td>91</td>
<td>1 095.6</td>
</tr>
<tr>
<td>12.</td>
<td>Bali</td>
<td>38</td>
<td>27 000</td>
<td>1 080</td>
<td>6</td>
<td>-</td>
<td>12</td>
<td>271.2</td>
</tr>
<tr>
<td>13.</td>
<td>West Nusa Tenggara</td>
<td>89</td>
<td>60 600</td>
<td>2 424</td>
<td>43</td>
<td>30</td>
<td>71</td>
<td>844.4</td>
</tr>
<tr>
<td>14.</td>
<td>East Nusa Tenggara</td>
<td>70</td>
<td>42 000</td>
<td>1 680</td>
<td>-</td>
<td>20</td>
<td>40</td>
<td>144</td>
</tr>
<tr>
<td>15.</td>
<td>West Kalimantan</td>
<td>3</td>
<td>3 600</td>
<td>144</td>
<td>59</td>
<td>30</td>
<td>29</td>
<td>874.4</td>
</tr>
<tr>
<td>16.</td>
<td>Central Kalimantan</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>17.</td>
<td>South Kalimantan</td>
<td>4</td>
<td>4 860</td>
<td>192</td>
<td>3</td>
<td>30</td>
<td>37</td>
<td>215.2</td>
</tr>
<tr>
<td>18.</td>
<td>North Kalimantan</td>
<td>8</td>
<td>9 600</td>
<td>384</td>
<td>25</td>
<td>20</td>
<td>21</td>
<td>413.6</td>
</tr>
<tr>
<td>19.</td>
<td>South Sulawesi</td>
<td>164</td>
<td>111 600</td>
<td>4 464</td>
<td>39</td>
<td>50</td>
<td>117</td>
<td>945.2</td>
</tr>
<tr>
<td>20.</td>
<td>South East Sulawesi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>270</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>39 504</td>
<td>465</td>
<td>500</td>
<td>889</td>
<td>10 575.6</td>
</tr>
</tbody>
</table>

Capacity of sun-drying floor 0.04 tonnes paddy/m², LISTER 12 tonnes paddy/batch, flat bed dryer 1.6 tonnes paddy/batch (diesel oil) and 4 tonnes/batch (paddy husk), bin dryer 90 tonnes paddy/batch.


Grain drying and seed processors

The seed processors use mechanical dryers in conjunction with the sun-drying floor. The largest rice seed supplier—a public company—its main station in West Java, which produces 14 000 t rice seed/year has 14 units of flat bed dryers with a total capacity of 148 t paddy/batch and 6 units of circulating dryer with a total capacity of 60 t paddy/batch. In addition to the mechanical dryers, the seed processor uses sun-drying floor with an area of 2 ha. About 75% of the total seeds produced are processed through the mechanical dryers.

Grain drying at other commercial operations

Various mechanical dryers are used by the private millers and the collecting traders, but their function is to complement sun drying, especially in the wet season. Whilst the area of the sun-drying floor at the pri-
Vale millers could be estimated (Table 2), data on the numbers of mechanical dryers are not available. A rough estimate is that less than 10% of the rice-milling capacity has passed through mechanical dryers. Most of the mechanical dryers are purchased by the large-scale rice millers with a capacity of 1200 t/year or higher. This figure was obtained by taking the average capacity for the large-scale milling machines in Table 2. An IDRC-sponsored study by IPB (IDRC 1988) reported that an optimal scale for KUD rice milling was 2600 t of paddy plus 1000 t of maize per year when it had a mechanical dryer with 10 t grain/batch capacity, a sun-drying floor with an area of 1000 m², and a milling machine with a capacity of 5 t/hour.

Some feed industries receive locally produced maize and use large-capacity mechanical dryers such as 70 t/hour continuous dryers of U.S. origin (Table 3). Others purchase most of their supply from imported maize already at 12% moisture content (m.c.), and thus do not dry. Imported maize in 1993 reached about 1.1 Mt compared to 6.6 Mt of locally produced maize. The feed industries, in general, are making concentrate while the poultry shops or the poultry farmers add more ground maize to produce the final formulation for feeding chickens. The poultry shops and farmers obtain their maize from the collecting traders, or directly from the farmers who sun dry it. A major feed company has five branches in the big cities in Indonesia—Medan, North Sumatra; Bandar Lampung, Lampung; Jakarta; Semarang, Central Java; and Surabaya, East Java—and operates five units of continuous dryer, each of 70 t/hour capacity, and drying maize at up to 100-200 000 t/year/unit.

Types of mechanical dryers

Commercial mechanical dryers in operation, and their performance, are listed in Table 3, and compared with the pit dryer adopted by maize farmers (ACPHP 1988) and sun drying. The rate of sun drying (0.3–0.5% m.c. dry basis/hour) is lower than all mechanical drying (1.1–1.9% m.c. dry basis/hour) but, except for the 70 t/hour continuous dryer (Rp 4.0/ kg), the cost of sun drying (Rp 7.5–9.0/kg) remains competitive with that of mechanical drying (Rp 6.4–13.4/kg). The imported Japanese-made dryers were obtained through a Japanese grant, while Taiwan and U.S.-made dryers were purchased commercially. One dealer confided that he had sold 25 units of a Taiwanese circulating dryer with a 6 t/batch capacity at East Java and West Nusa Tenggara in 1994–1995. More recently, a 5 t/hour fluidised-bed dryer was imported from Thailand and set up at one of the DOLOG technical units in Aceh. Its performance has yet to be documented.

The locally manufactured mechanical dryers commonly come as flat bed (Fig. 1), circulating (Fig. 2), and continuous-flow (Fig. 3) types. In general, the manufacturers produce mechanical dryers only to order while primarily engaged in the manufacture of other agricultural machinery such as hand tractors, threshers, rice milling units, and food and wood processing equipment. One manufacturer of a 15 t batch circulating type dryer in East Java claimed that it sold only 9 units in 1988–1989. Another, in South Sumatra, reported of selling 11 units of a 5 t/hour continuous dryer for agricultural products in 1993–1995. Two of the units were used for paddy and maize drying, while the others were for coffee beans and black pepper. At least five manufacturers and three workshops are capable of manufacturing dryers: PT Agrindo, PT Meco Inoxprima, CV Alpha Omega, and PT Adh Isi Setia Utama Jaya at Surabaya, East Java; CV Gunung Indah at Lumajang, East Java; PT Maju Bersama and PT New Ruhaak at Jakarta; and Lukman at Palembang, South Sumatra.

Some other types of mechanical dryer are being introduced (Table 4) such as the solar collector (Trim and Gordon 1991; Damardji et al. 1991), and the low temperature in bin drying system (CDAE 1995). Two mechanical dryers implemented at the KUD, the flat bed dryer using paddy husks as fuel and the Lister are no longer used, due to technical and cost disadvantages (IDRC 1988).

Table 2. Number of rice millers and their milling capacity in Indonesia, 1993

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of milling machine</th>
<th>Units</th>
<th>Milling capacity (tonnes/year)</th>
<th>Estimated area of sun-drying floor</th>
<th>Size (m²)</th>
<th>Total area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Large scale, &gt;0.5 tonnes/hr</td>
<td>1518</td>
<td>2 047 335</td>
<td>1 200–20 000</td>
<td>955</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Small scale, &lt;0.5 tonnes/hr</td>
<td>40 663</td>
<td>21 005 622</td>
<td>200–1 200</td>
<td>1 220</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Compact rice milling unit &lt;0.5 tonnes/hr</td>
<td>26 035</td>
<td>12 903 324</td>
<td>200–400</td>
<td>781</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Polisher &lt;0.3 tonnes/hr</td>
<td>182</td>
<td>62 547</td>
<td>200–400</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Huller &lt;0.3 tonnes/hr</td>
<td>63</td>
<td>29 425</td>
<td>200–400</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Engelberg &lt;0.3 tonnes/hr</td>
<td>6 328</td>
<td>1 488 419</td>
<td>200–400</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>37 536 672</td>
<td></td>
<td></td>
<td>3 154</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Performances of sun-drying floor and various mechanical dryers in commercial operation in Indonesia.

<table>
<thead>
<tr>
<th>Items</th>
<th>Sun-drying floor</th>
<th>Flat bed, diesel oil</th>
<th>Pit dryer</th>
<th>Circulating dryer</th>
<th>Continuous dryer, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paddy</td>
<td>Cob</td>
<td>Shelled</td>
<td>Paddy</td>
<td>Shelled</td>
</tr>
<tr>
<td>Commodity</td>
<td>Paddy</td>
<td>Maize</td>
<td>Paddy</td>
<td>Paddy</td>
<td>Paddy</td>
</tr>
<tr>
<td>Capacity, tonnes/batch</td>
<td>0.04 (t/m²)</td>
<td>15</td>
<td>1</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Initial moisture content</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% w.b.</td>
<td>25</td>
<td>20</td>
<td>30</td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>% d.b.</td>
<td>33</td>
<td>25</td>
<td>43</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Final moisture content</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% w.b.</td>
<td>14</td>
<td>12</td>
<td>17.5</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>% d.b.</td>
<td>16</td>
<td>14</td>
<td>21</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Drying temperature, °C</td>
<td>42</td>
<td>41</td>
<td>65</td>
<td>78</td>
<td>40</td>
</tr>
<tr>
<td>Drying time, hrs</td>
<td>16–24 (dry season)</td>
<td>15</td>
<td>13</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>24–32 (wet season)</td>
<td></td>
<td></td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Drying rate, % d.b./hr</td>
<td>0.3–0.5</td>
<td>0.7</td>
<td>1.7</td>
<td>1.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Fuel consumption, L diesel oil/tonnes water removed</td>
<td>–</td>
<td>138</td>
<td>61 kg maize cob/t</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Drying cost, Rp/kg*</td>
<td>7.5–9.0</td>
<td>13.4</td>
<td>12</td>
<td>7.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Cent $US/kg</td>
<td>0.33–0.39</td>
<td>0.59</td>
<td>0.53</td>
<td>0.30</td>
<td>0.39</td>
</tr>
</tbody>
</table>

1 Cent $US = Rp 22.80  
*not including the investment cost

Figure 1. Flat-bed batch dryer of 10 t capacity at a seed processor in West Java. (below)

Figure 2. Two units of a 15 t/batch circulating dryer in East Java. (right)
Figure 3. Cascading continuous-flow dryer of 5 t/hour throughput, used for drying rice and coffee beans in South Sumatra.

Table 4. Performances of various mechanical dryers from experimental results.

<table>
<thead>
<tr>
<th>Items</th>
<th>LISTER b</th>
<th>Flat bed, paddy husk a</th>
<th>Solar collector b</th>
<th>LT-IBDS c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commodity</td>
<td>Paddy</td>
<td>Paddy</td>
<td>Paddy</td>
<td>Paddy</td>
</tr>
<tr>
<td>Capacity, tonnes/batch</td>
<td>11</td>
<td>4</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Initial moisture content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% w.b.</td>
<td>24</td>
<td>24</td>
<td>25</td>
<td>22.5</td>
</tr>
<tr>
<td>% d.b.</td>
<td>31</td>
<td>31</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>Final moisture content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% w.b.</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>% d.b.</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Drying temperature, °C</td>
<td>38</td>
<td>38</td>
<td>45- day, 35 night</td>
<td>36</td>
</tr>
<tr>
<td>Drying time, hours</td>
<td>21</td>
<td>21</td>
<td>50</td>
<td>94</td>
</tr>
<tr>
<td>Drying rate, % d.b./hr</td>
<td>0.7</td>
<td>0.7</td>
<td>0.34</td>
<td>0.16</td>
</tr>
<tr>
<td>Fuel consumption, L diesel oil/</td>
<td>96</td>
<td>52 litres diesel oil</td>
<td>9</td>
<td>128</td>
</tr>
<tr>
<td>tonnes water removed</td>
<td></td>
<td>107 kg paddy husk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying cost, Rp/kg</td>
<td>9.0</td>
<td>9.4</td>
<td>16.4</td>
<td>18.7</td>
</tr>
<tr>
<td>Cent US$/kg d</td>
<td>0.39</td>
<td>0.41</td>
<td>0.72</td>
<td>0.82</td>
</tr>
</tbody>
</table>

L-T-IBDS = Low Temperature In-Bin Drying System

a IDRC, 1988; b Trim and Gordon, 1991; c Damardjati et al., 1991; d CDAE, 1995; and d not including the investment cost.
Problems in Implementing Mechanical Drying

No incentive for farmers to dry grain

Most farmers sell their paddy immediately after harvesting and threshing. The harvested moisture content of the paddy in the dry season is about 20–23% wet basis (w.b.) and in wet season is about 24–30% w.b. Soybean and maize farmers are forced to sun dry their produce, since soybean should be threshed and maize shelled only at 17~18% m.c. (w.b.). However, farmers rarely complete the second stage of drying from 17–18% to 14% m.c. (w.b.).

The present situation is exemplified in Figure 4. Currently, BULOG does not interfere in paddy purchasing and buys only milled rice. Thus, the market standard overrules the government standard referring only to the moisture content and impurities levels.

During the wet season harvest in February–April 1995, the price of paddy at 27% m.c. (w.b.) (37% d.b.) and 6% impurities was Rp 410/kg (Fig. 4, point A). On the other hand, the price at 23% m.c. (w.b.) (30% d.b.) and 4% impurities was Rp 540/kg (point B).

![Figure 4. Diagram explaining market standards and price differentials for paddy in 1995.](image)

**Taking 1 tonne of paddy, the incentive calculation goes as follows**

A: Value of 1 tonne paddy = Rp 410 000

B: Weight loss due to removal of moisture content

\[
37\% \text{ d.b.} - 30\% \text{ d.b.}/100\% \times (1 - 0.27) \times 1 \text{ t} = 0.05 \text{ t}
\]

Weight loss due to reduction of impurities =

\[
6\% - 4\%/100\% \times 1 \text{ t} = 0.02 \text{ t}
\]

Remaining weight of paddy =

\[
1 - 0.05 - 0.02 = 0.93 \times 930 \text{ kg}
\]

Value of remaining paddy =

\[
930 \times \text{Rp} 450/\text{kg} = \text{Rp} 418 500
\]

Farmers will gain Rp 8500/t when they dry and clean paddy from A to B but taking into account the minimum cost of sun drying, which is Rp 7500/t (Table 3), the effort is hardly worthwhile.

In the dry season of July–September 1995, the price of paddy increased to Rp550/kg at 23% m.c. (w.b.) (30% d.b.) and 4% impurities (point B) and Rp575/kg at 20% m.c. (w.b.) (25% d.b.) and 3% impurities (point C).

**More competitive investment for sun-drying floors**

At the village level, where the cooperatives and the private millers are located, land remains relatively cheap. For example, in the Lumajang district, East Java, where a workshop manufactures 15 t/batch mechanical dryers at a selling price of Rp40 million and a dealer offers 6 t/batch imported dryers for Rp30 million, an entrepreneur can purchase 0.5 ha of land, meaning 150-200 t/batch, at Rp40 million. Land purchase is even more attractive, since land increases in value in the long term rather than depreciating. Furthermore, the entrepreneur can submit the land title as collateral to the bank to obtain credit. No bank will take a mechanical dryer as credit collateral.

**Influence of weather on sun drying for some rice belt areas**

Land prices are not so attractive in the urban areas such as Karawang district, the rice belt area of West Java—the largest rice-producing province in Indonesia—where the price of 0.5 ha block could be as high as Rp250–300 million.
Nevertheless, looking at the average rainfall distribution through the year (Fig. 5), one can understand the justification for wide use of sun drying, since the only months with average rainfall above 200 mm are January (330 mm) and February (240 mm). The peak harvest in the wet season comes in March–April, when average rainfall is below 200 mm/month.

![Rainfall Distribution](image)

**Figure 5.** Annual distribution of average rainfall at Karawang, West Java.

**Priorities for the Future**

The following are recommendations for future development of grain drying systems in Indonesia.

1. A multipurpose mechanical dryer for grains and other estate crops such as black pepper, coffee, and cacao beans will likely capture more sales than a single purpose grain dryer.

2. Batch dryers with a capacity above 10 t/batch, or continuous dryers with a capacity of at least 5 t/hour, are recommended since the target groups are the seed processors, large-scale millers, and the wholesalers.

3. Urban areas should be the target for marketing dryers. Here land and/or labour are expensive.

4. The performance of the fluidised-bed dryer recently introduced should be assessed and compared with other mechanical dryers in use.

**References**

ACPHP (ASEAN Crops Post Harvest Programme) 1988. Analysis of the acceptability of the maize pit dryer at the village level in Yogyakarta, Indonesia. ACPHP-IPBMOC-BULOG.


The Rice Processing Industry in Malaysia: Problems and Priorities in Grain Drying

Roslan A. Ghaffar and Fatimah Mohd. Arshad*

Abstract

This paper discusses the evolution of paddy and rice policy in Malaysia since the 1960s and its impact on the drying sector. The major policies that have direct bearings on the drying sector are: minimum support price, LPN's (National Paddy and Rice Authority) involvement in marketing and milling of paddy and rice price control. The interventionist policy has resulted in the declining role of the private sector, direct transfer to farmers and millers, and overall milling inefficiency. A shift in policy in 1993 — to deregulate selected price of rice and corporatisation of LPN — is expected to improve the drying and milling sector in the future. Several priority areas for further development of the rice-processing industry are suggested.

A study made in 1988 by the World Bank concluded that Malaysia's rice was noncompetitive in price and quality. This conclusion reflected a multitude of structural problems underlying the industry. For more than two decades (until January 1993, when the price of super quality rice was floated) the paddy and rice sector was subject to price control, from farm through to retail levels. As shown by Fatimah (1995), the prices supported are much higher than the world prices making Malaysian rice noncompetitive with that of her neighbours. Quality defects in rice are a function of both technical and economic factors. Technically, poor quality of rice is attributable to improper drying and handling of paddy. This situation is aggravated by the paddy pricing system at the farm level which does not provide enough incentive for farmers to dry paddy (Chew and Fatimah 1987; Chew and Ghaffar 1985). In fact, it has been shown that it is more profitable for farmers to sell wet paddy to the rice millers, particularly to LPN (National Paddy and Rice Authority) complexes. As concluded by Fredericks and Mercader (1983), although postharvest losses for rice due to drying per se range from 1 to 5%, a significant portion of the losses incurred in storage and milling is related to drying. Improper drying, particularly during the wet season, contributes to losses due to rotting and downgrading of the quality of milled rice, as characterised by a high percentage of brokens, discolouration, and mould infestation. It is assessed that at the current estimate of 5% losses, MYR47 million worth of rice is wasted annually (during October 1995, ca 2.40 Malaysian Ringgit (MYR) = US$1). Clearly, drying is a significant function in determining the quality of rice and hence economic return and level of efficiency of the industry. This paper seeks to review the current status, problems, and priorities in paddy drying in Malaysia. The approach of the paper is as follows. The next section traces policy development in the paddy drying sector before January 1993 when the government decided to remove price control on super grade rice while maintaining control of the prices for premium and standard grades (LPN 1995). This is followed by a brief discussion on changes in paddy and rice policy particularly following deregulation of the prices of selected rice and the corporatisation of LPN on 7 July 1994. The last section discusses the implications of the new restructuring policy for the paddy drying sector.

* Faculty of Economics and Management, Universiti Pertanian Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
Paddy and Rice Policy in Malaysia

The development of the paddy drying and milling sectors is closely aligned with government policy. One of the earliest market interventions took the form of introduction of a guaranteed minimum price (GMP) for paddy of MYR15 per pikul (1 pikul = 60.5 kg) in 1949, to provide incentives to producers. The GMP has never been revised downwards, only upwards. In 1973, the name was changed to the minimum support price (MSP) and its objective has been expanded to include the need to provide producers with a high return and to protect consumers from the vagaries of the world rice market. As will be shown later, this pricing policy has contributed to the current structure of the processing sector.

In the 1950s, the processing sector was operating in an open economy, but in the early 1960s the government decided to intervene. The paddy processing sector was perceived as being monopolistic, and a cause of peasant indebtedness and poverty. Attempts to break the monopoly initially took the form of government owned mills and 'co-operativisation' of the mills (Tan Siew Huey 1987). Under this policy, the establishment of cooperative rice milling societies (CRMS) was encouraged, to provide small-scale milling services for milling paddy into rice to be consumed by the producers themselves, and to function as marketing agents for the members.

Between 1961 and 1963, the CRMS were given monopoly powers in some parts of the country. However, in the areas where the private market was well developed and there were close links between paddy dealers and private millers, there was considerable resistance to these moves. The policy was sharply criticised by the private sector and it was discontinued because it ran counter to the government's commitment to free enterprise (Fredericks and Wells 1983). At their peak, the CRMS took only about 4% of total paddy production (Vokes 1978).

By mid-1960s it was recognised that the cooperatives had failed to undermine the dominance of private traders in the paddy market. The private mills persevered in the market by offering better terms than the CRMS. The CRMS could not compete, as they were severely handicapped in their efforts by shortages of funds and expertise. The government attributed this failure to market imperfection and concluded that, rather than an increase in competition, greater regulation of the market was needed.

During the mid-1960s, the government embarked on the self-sufficiency in rice production program through increases in yields and an expansion of double-cropping. The failure of the cooperatives to provide a viable alternative to the private market and the need to ensure adequate processing capacity to cope with the expected increase in production led the government to introduce market regulations and invest in paddy and rice-processing plants.

A key step in the direction of greater market regulation was taken with the formation of the Paddy and Rice Marketing Board (PRMB) in 1966. The PRMB set up two types of schemes: regulatory and trading. The regulatory schemes involved the licensing of all paddy buyers and the enforcement of the conditions of the license. In its trading schemes, the PRMB undertook buying, selling, and milling of paddy. By 1972, PRMB schemes covered nearly 90% of the paddy land in West Malaysia (Selvadurai 1972). Despite this, PRMB could not change the fundamental structure of the paddy market. In 1978, the National Paddy and Rice Authority (LPN, Lembaga Padi dan Beras Negara) was established to provide a more coordinated and effective interventionist policy. LPN was charged with the responsibility of ensuring 'fair' prices for both farmers and consumers, and of achieving self-sufficiency in paddy production.

The formation of LPN marked an important turning point in the history of the paddy industry. Two major market interventions were made after it was set up. Firstly, rice price and import controls were introduced in May 1974 to protect consumers from sharp price increases in times of shortages. Secondly, the government, through LPN, entered the paddy processing sector, competing directly with the private mills.

The government’s decision to play an active role in processing was based on the recommendation of a 1969 FAO study of the milling industry (U Thet Zin 1969). The study revealed the inability of existing mills to produce good quality rice and the serious milling losses to farmers and the economy. The study recommended that regulatory controls be imposed to improve the milling industry.

The government’s involvement in paddy processing was also prompted by the need to ensure adequate drying facilities to handle the off-season crops, which were to expand rapidly, particularly in the Muda Agricultural Development Authority (MADA) and Kemubu Agricultural Development Authority (KADA) schemes. The expected increase in paddy output resulting from double cropping would require adequate support in the form of drying, milling, and storage facilities. Given the large capital outlay needed to purchase dryers, it was assumed few private millers would be able to take in the off-season crop. The government then decided to build drying and milling facilities in the major producing areas. By 1980, LPN had established 28 integrated milling complexes (Table 1). To ensure that its mills were being used to full capacity and to protect farmers' interest, LPN became a buyer of last resort.
Table 1. Number of LPN integrated complexes by date completed*

<table>
<thead>
<tr>
<th>Year completed</th>
<th>Number</th>
<th>Cumulative total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1970</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>1970</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>1971</td>
<td>5b</td>
<td>11</td>
</tr>
<tr>
<td>1972</td>
<td>4c</td>
<td>15</td>
</tr>
<tr>
<td>1974</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>1975</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>1976</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>1981</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>1982</td>
<td>1</td>
<td>31</td>
</tr>
</tbody>
</table>

*Refers to drying, milling, and storage installations with 10,000 t/season capacity.

In the mid-1980s, the self-sufficiency target was reduced to 55–65% under the National Agricultural Policy (NAP) formulated in 1984 (MOA 1994). The same level was maintained in the 1993 NAP (MOA 1994). The reduction in the self-sufficiency target was in response to worldwide production and the increase in the country's purchasing power to import cheaper rice (Fatimah 1995). The continuous increase in fertilizer prices in the world market led the government to expand support to paddy producers' income through two major strategies: direct subsidies in the form of fertilizer and cash, and continued direct involvement in rice milling and marketing. Under the fertilizer subsidy scheme, farmers owning less than 2.4 ha of paddy land were given free fertilizers. The value of this subsidy amounted to about MYR231 per hectare, or about 33% of the cost of production per ha (Chamhuri 1985). The objective of the fertilizer subsidy scheme was to reduce the costs of production to farmers, increase farm incomes, improve and modernise paddy cultivation practices so as to boost paddy yields and total production to meet the self-sufficiency target.

This subsidy could be invested only in authorised banks. The farmers were in full support of the scheme but protested about the amount. In 1982 the subsidy was increased to MYR10 per pikul in the form of cash, and in 1990 to MYR15 per pikul. Thus, the effective price of paddy to farmers increased from MYR28 to MYR32 per pikul to a new range of MYR43 to MYR47 per pikul. The cash subsidy (which was given out in the form of coupons) is claimable from LPN or authorised banks, provided the farmers sell their paddy to authorised agents only. This arrangement has directed the flow of paddy from unlicensed traders (including millers) to authorised agents and LPN drying complexes. By 1985, the share of paddy handled by LPN had increased to 46% (compared with about 20% in the 1970s) (LPN 1991).

Combine harvesters were introduced in the 1970s, to cater for the increase in paddy production due to the rapid expansion of double-cropping areas in the mid-1960s. With harvesters, the harvesting time for paddy was reduced from 30 to about 15 days. The effects of the combine harvesters on the handling and drying of paddy were not anticipated. Until the late 1980s, paddy was handled manually, with the grain packed in gunny sacks and transported to the mills using lorries. Loading and unloading of paddy were done manually.

The introduction of the harvester affected the technical efficiency of the mills, particularly the LPN complexes. It was seen that the complexes were not able to cope with the intensive flow of paddy within a shorter time period (before combine harvesters were introduced the buying period stretched over about 30 days). The LPN complexes were designed to cope with a smaller intake of paddy spread over a longer period. This lag in handling technology explains the significant postharvest losses incurred by the LPN complexes in the mid-1980s. This problem was further aggravated by the policy stand of LPN as 'the buyer of last resort' which forced LPN to accept all deliveries regardless of its own drying or storing capacity and the quality of the paddy delivered by the farmers.

To rectify the problem and reduce the intake cost, LPN has invested in a bulk receival system, and grain coolers and dryers in some of its complexes (Table 2). According to LPN (1995) the system enhances the paddy intake operation and reduces the handling cost. The LSU drying and cooling system has proven to be able to increase drying capacity. DryerMaster, a computerised system designed to monitor the wet paddy content, has also proven effective. Overall, LPN found that the system brings positive results—it reduces operating costs (particularly electricity and petrol costs) and avoids overdrying of paddy (LPN 1995).
The three major policy instruments that have direct implications for the paddy drying sector are: minimum support price (MSP), LPN direct involvement in paddy marketing and processing, and rice price control. A brief discussion follows, on the impact of these policies on the drying sector.

**Declining role of private mills**

As pointed out by Tan Siew Huey (1987), the involvement of LPN in the processing sector, especially when excess capacity already existed in the private mills, naturally crowded out these mills. In 1983, the private mills had a total capacity to mill 1,988,064 t of paddy while LPN’s capacity amounted to 369,600 t. Before the formation of LPN in 1973, the private mills were purchasing almost 90% of the paddy sold by the farmers. By the mid-1980s, this proportion had dropped to half. The result was that the private processors were using about one-third of their capacity. Unfortunately, there are no data available on the number of private mills and their capacity in the late 1980s and early 1990s. However, a study made by LPN in 1986 on the private mills in Kedah/Perlis indicated that, in 1985, excess capacity was still a serious problem. During that year the annual rated drying capacity of the private mills was estimated at 952,187 t, but the amount of paddy purchased amounted to only 418,027 t, suggesting a utilisation rate of facilities of 43% (LPN 1986). In terms of milling capacity, their utilisation rate was about 51% (rated milling capacity was estimated at 812,135 t/year).

During the early part of 1985, LPN complexes were buying more paddy than they could mill. In order to cope with the heavy inflow of paddy to LPN complexes, the milling capacity was increased from 369,900 t/year in 1983 to 428,720 t/year in 1994. As shown in Table 3, the amount of paddy purchased by LPN is far in excess of its drying and milling capacities. Hence, LPN has to rely on the private sector to dry and mill its excess paddy. On average, LPN mills about 76% of the paddy purchased from farmers, while the rest is sent to the private millers under the grinding scheme either for further drying or milling. As will be shown later, this policy has resulted in an unintended direct transfer to the miller.

In view of the unavailability of data concerning the current capacity of the private mills, it would be difficult to estimate the current extent of excess capacity. However, if one assumes that the capacity has not changed (an assumption which is supported by LPN), it would appear that the problem of underutilisation of the private mills has somewhat ameliorated. In 1994, the utilisation rate for private mills stood at 51%.

There is evidence that the private mill sector is static in numbers and growth (Tan Siew Huey 1987), a situation attributed to poor prospects of higher returns. Their margin has been fixed by LPN through the MSP of paddy and the rice ceiling price policy. In the last 20 years, the MSP has been revised upwards three times while processing cost has almost doubled. Hence, the margin of private miller has been squeezed so much so that it has been reported that some have to resort to rice adulteration and mixing to maintain an adequate return. As will be shown in the next section, the declining role of private mills led to a decline in milling efficiency.

**Drying subsidy to growers and millers**

LPN’s paddy buying practices and pricing (and deduction system) subsidised farmers’ and millers’ incomes. As in other ASEAN countries, the paddy sold in Malaysia is subjected to penalties in the form of deductions from the price for wet and dirty paddy. This is to ensure that only high quality paddy enters the next stage of processing — milling. The deduction rates were linear, whereas the drying cost per unit increases sharply at higher moisture contents. The private millers are generally stringent in the quality of paddy they accept for processing as this will impinge on their processing margin. LPN, due to its social obligation, could not adopt the same policy, instead it had to buy all paddy offered to it regardless of its capacity to handle it, or its quality. In short, LPN functioned as a buyer of last resort. It has been shown that LPN’s deduction rates were so lenient as to encourage farmers to sell wet paddy. In effect, Chew and Fatimah (1987) showed that the farmers received a hidden subsidy for not drying their paddy grain. LPN was then stuck with a large influx of wet

---

**Table 2. Number and types of dryers and mills at LPN complexes, 1988–1994.**

<table>
<thead>
<tr>
<th>Dryers (units)</th>
<th>Mill (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSU FBD/IBD Predryer</td>
<td></td>
</tr>
<tr>
<td>1988 49 142 90 30</td>
<td></td>
</tr>
<tr>
<td>1989 49 142 90 30</td>
<td></td>
</tr>
<tr>
<td>1990 49 142 90 30</td>
<td></td>
</tr>
<tr>
<td>1991 49 142 90 30</td>
<td></td>
</tr>
<tr>
<td>1992 49 142 90 30</td>
<td></td>
</tr>
<tr>
<td>1993 49 142 90 30</td>
<td></td>
</tr>
<tr>
<td>1994 49 147 90 30</td>
<td></td>
</tr>
</tbody>
</table>

Note:Rated drying capacity of LPN complexes was 7861 t per day between 1988–91, increasing to 8567 t/day between 1992–94.

Source: Lembaga Padi dan Beras Negara (LPN), Malaysia.