Rice Grain Marketing and Quality Issues

SELECTED PAPERS FROM THE International Rice Research Conference

IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE
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Contents

Foreword

Preface
C.L. Yap

Trends and patterns in Asian rice consumption 1
B. Duff

Assessing rice quality characteristics and prices in selected international markets 23
M. Kaosa-ard and B.O. Juliano

Consumer demand for rice grain quality 37
Z.F. Toquero

Parboiling and consumer demand for parboiled rice in South Asia 47
N.H. Choudhury

Rice grain quality as an emerging priority in national rice breeding programs 55
B.O. Juliano and B. Duff

Research priorities for improving rice grain quality 65
IRRI and national rice research programs continue to work to raise the yield frontier and reduce production costs. As rice supplies increase to meet demand, and as incomes rise in many developing countries, rice consumers become increasingly concerned with factors that influence the chemical and physical characteristics of the rice grain they buy. Those grain quality preferences affect the prices they are willing to pay.

Selective breeding for preferred qualities in particular market areas could be a mechanism to return more of the benefits of improved quality rice (with the higher market price it commands) to the farmer, rather than only to the processor or trader. This is particularly true for irrigated rice, the source of the bulk of the rice in the market.

One session of the 1990 International Rice Research Conference cosponsored by IRRI and the Rural Development Administration, Republic of Korea, focused specifically on grain quality and consumer preferences for particular characteristics of rice in different markets. This book contains the research papers presented in that session. Dr. B. O. Juliano was the technical editor; Dr. L. R. Pollard and Mrs. G. Argosino, the publication editors.

Klaus Lampe
Director General
Rice quality and marketing are important and controversial subjects. “Rice quality” refers to many aspects ranging from moisture content, chalkiness, and proportion of brokens to shape, length, width, and eating characteristics. Different countries have their own measures of quality and systems of control, but such measures and systems of control lack uniformity among countries. Even what constitutes brokens, as opposed to head rice, varies.

This lack of uniformity makes international trade in rice more difficult and less transparent. It creates areas of dispute, of concern as well as uncertainty. Planning for national supply is fraught with pitfalls. Supply is often affected by global availabilities. While we say demand for rice is likely to increase, we do not know the type and quality of rice consumers will want.

This lack of uniformity belies considerable efforts to bring about the acceptance of some international standard of quality. Standardization of national grading systems as a means of facilitating world trade in rice has been one of the primary objectives pursued by FAO’s Intergovernmental Group on Rice since its inception in the mid-1950s. As early as 1958, the Group produced a model system for grading in international trade and introduced standard definitions of terms for adoption by national governments. This was revised in 1972 to reflect new developments in production and milling techniques. The revised model, developed in collaboration with national experts and government representatives from 41 countries, remains in use today.

To keep up with new developments, however, the Codex Alimentarius Commission, a joint FAO-WHO body, has embarked on further work in this area. A draft of a proposed international standard for rice has been prepared and submitted to governments for their comments. On the national level, FAO has implemented a number of projects geared toward improving quality and marketing. The projects range from research to the development of parboiling factories and the rehabilitation of existing milling facilities.

Despite these efforts, considerable work remains to be done.

Over the last decade, there has been a dramatic turnaround in the demand for different types of rice, especially in the international market. Increased demand from the Near East has created a premium market for high-quality rice. At the same time, the
emerging importance of Africa in the international market for rice has increased the demand for rice with a large proportion of brokens. Since the mid-1970s, international demand for broken rice has tripled.

At the same time, there has been a downward slide in the market for some types of rice. A prime example is the international market for medium-round grains (japonica). The international demand for parboiled rice also has declined, as some main buyers adopted policies to restrict imports.

Rapid changes in consumer demand due to changes in taste and income have led to similar shifts on the national level. In the Republic of Korea, for example, a rise in consumer income has led to a fall in per capita consumption of rice. That, in conjunction with higher production, has reduced pressure on rice supplies overall. This has led to a revival in demand and to increased production of the lower yielding varieties of traditionally preferred japonica rice.

Work needed in the area of quality and marketing is not confined to improving actual quality. It includes monitoring changes in demand in order to fine-tune supply. It requires improving the data base on rice demand by type and quality: knowing the type and quality of rice demanded is as important as knowing the total quantity needed, or supplied. This forms the essential basis for determining the production needed of the different types of rice, as well as the investments needed in processing or milling facilities.

Currently available data on rice do not provide a good basis for judgment. Rice statistics, at best, classify rice into long, medium, or short; husked, milled, and rough; parboiled or white. But with individual countries holding different concepts of what constitutes long, medium, and short, only very approximate estimates can be derived. Equally important characteristics, such as amylose content—which, in fact, is a prime determining factor for consumer preference—are usually not reflected in classification systems. Using such a limited data base makes for poor analysis of demand trends in a market as selective as the rice market.

This focus on trends in consumer demand for rice and rice quality, and on the policy issues surrounding these trends comes at an appropriate time. It is to be hoped that the knowledge and interest generated here will provide further stimulus to work in these areas, and help raise the research priority on the qualities of rice of the different varieties to be developed.

C. L. Yap, Secretary
Intergovernmental Group on Rice,
Basic Foodstuffs Service Commodities
and Trade Division
FAO, Rome
With the exception of the highest income countries, per capita rice consumption in Asia over the last 30 yr has been stable, or has increased only moderately. Total consumption continues to grow in close correlation with population and income growth. Rice supply, personal income, urbanization, and the availability and price of dietary substitutes are key determinants of diversity in Asian diets, including the quality of the rice consumed. The relative prices of rice, wheat, maize, and coarse grains also impact the composition of Asian diets. The factor that affects overall demand the most continues to be population growth, particularly in the poorest countries where rice constitutes the most important component of the diet.

Since 1960, rice research has concentrated, rightly, on supply side factors. Shifts in demand have been so closely linked with population growth that the consequences of not increasing production were self-evident. While this scenario has changed relatively little over the last three decades, there is some evidence of increasing diversification in Asian diets. In addition, in higher income countries such as Japan, both total and per capita intake of rice has declined as other commodities are being substituted in the diet. One issue at the forefront of current research on rice supply and demand is assessing the net impact of changing incomes coupled with rising population on overall and per capita rice consumption.

This report has three objectives: 1) to examine the role of rice in the diets of Asian consumers; 2) to evaluate trends in rice consumption over the last 30 yr; and 3) to evaluate the role of income in expenditures for rice and assess the probable impact.

Simple economics of food consumption

A much researched and well-documented finding is that as incomes increase, significant changes occur in dietary patterns (Bouis 1990, Marks and Yetley 1988). As incomes increase, consumers are able to substitute more preferred for less preferred foods in the diet, and shifts in food demand occur. The implicit assumption is that consumers desire to improve the quality of their diets.
In general, as incomes rise, direct consumption of coarse grains falls continuously; intake of rice and wheat rises, peaks, and falls; and consumption of meat rises slowly, reaching a maximum only at high incomes. These relationships are illustrated in Figure 1.

Marks and Yetley partitioned the estimated relationships into different income stages, which they used as a basis for classifying countries and income groups within countries by the composition of their food demand patterns. Stage I defines the range dominated by consumption of coarse grains. Stage II encompasses the range within which consumption of rice-wheat is growing most rapidly and replacing coarse grains. In stage III, rice-wheat consumption reaches a peak and meat consumption is increasing. Throughout stage IV, the share of rice and wheat declines. In stage V, meat consumption reaches a maximum. Throughout stage VI, there is a continuous decline in consumption of rice, wheat, and meat.

FAO’s recommended dietary allowance (RDA) for daily per capita caloric (energy) intake is often used as a measure of nutritional adequacy. Figure 2 was derived by dividing the RDA by observed daily caloric intake over a range of income levels. The intersection of the coarse grains curve with the rice-wheat curve occurs at approximately 100% RDA. In other words, when consumption of coarse grains and rice-wheat are at equal proportions in the diet, consumers are receiving adequate calories. Imposing Marks and Yetley’s stages on Figure 2, we find that in stage I, incomes from $200 to $1300 correspond to 60-100% RDA. In stage II, incomes from $1300 to $2300 correspond to 100-110% RDA. In stage III, incomes from $2300 to $3100 correspond to 110-130% RDA.

![Diagram](image)

1. Percentage of wheat and rice, coarse grains, and meat in the diet, by income.
Flinn and Unnevehr (1985) observed that the widespread problem of malnutrition is not just a problem of food availability; it is also a problem of income and income distribution. Rice is a major source of income in rural Asia, as well as a key component of private expenditure. Increased productivity in the rice sector can reduce malnutrition by increasing the incomes of the poorest segments of society and by stabilizing prices and increasing the availability of rice to consumers.

**Rice in Asian diets**

Rice occupies a unique position in many nations because of its importance in traditional diets. In most Asian countries, it is the largest single source of calories (Fig. 3). In the Philippines, for example, rice and rice products contribute 56.2% of total energy, 42.9% of total protein, and 29.8% of total iron in the average diet in 1982 (FNRI 1984). The importance of rice in meeting basic nutritional requirements is greatest for rural and poor consumers. Rice accounts for up to 70% of total energy and protein intake for the lowest quartile of all income-earning households. Similar findings are reported for other countries (Flinn and Unnevehr 1985).

To assess national and regional changes in rice consumption, we constructed a data base to be used in evaluating patterns and trends across countries and over time (Appendix Tables 1-11). The data were compiled from USDA, FAO, IMF, and individual country series.
3. Rice calorie contribution 1986, by country, in actual and percentage contribution to daily diet.

Per capita cereal (rice, wheat, and coarse grains) consumption patterns for the 11 countries included in the data base are diverse (Table 1). Consumption has fallen in six countries and increased in five. In share of total cereals consumed, rice remains dominant (>60%) in six countries and constitutes a very high proportion in all countries.

Table 1. Composite cereal consumption in selected Asian countries, 1960 and 1988.\(^a\)

<table>
<thead>
<tr>
<th>Country</th>
<th>1980 Cereal consumption (kg/capita)</th>
<th>1980 Rice (%)</th>
<th>1988 Cereal consumption (kg/capita)</th>
<th>1988 Rice (%)</th>
<th>Change(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>190</td>
<td>98</td>
<td>184</td>
<td>83</td>
<td>-</td>
</tr>
<tr>
<td>China</td>
<td>145</td>
<td>48</td>
<td>233</td>
<td>47</td>
<td>++</td>
</tr>
<tr>
<td>India</td>
<td>168</td>
<td>48</td>
<td>180</td>
<td>45</td>
<td>+</td>
</tr>
<tr>
<td>Indonesia</td>
<td>147</td>
<td>81</td>
<td>185</td>
<td>87</td>
<td>++</td>
</tr>
<tr>
<td>Japan</td>
<td>197</td>
<td>64</td>
<td>177</td>
<td>43</td>
<td>--</td>
</tr>
<tr>
<td>Korea (ROK)</td>
<td>190</td>
<td>66</td>
<td>198</td>
<td>66</td>
<td>+</td>
</tr>
<tr>
<td>Nepal</td>
<td>235(^c)</td>
<td>51</td>
<td>182</td>
<td>48</td>
<td>--</td>
</tr>
<tr>
<td>Pakistan</td>
<td>180</td>
<td>13</td>
<td>173</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Philippines</td>
<td>136</td>
<td>67</td>
<td>165</td>
<td>64</td>
<td>++</td>
</tr>
<tr>
<td>Taiwan, China</td>
<td>191</td>
<td>85</td>
<td>146</td>
<td>58</td>
<td>---</td>
</tr>
<tr>
<td>Thailand</td>
<td>180</td>
<td>99</td>
<td>159</td>
<td>96</td>
<td>--</td>
</tr>
</tbody>
</table>

\(^a\)Data derived from Appendix Tables 1-11. \(^b\)Symbols indicate direction and relative amount of change. \(^c\)Data for 1964.
except Pakistan. Bangladesh, Japan, and Taiwan, China, exhibit declining total cereal intake. Japan and Taiwan also show substantial declines in the share of rice in aggregate consumption.

Total and per capita rice consumption present a mixed picture. With the exception of Japan and Taiwan, total consumption has increased. Per capita consumption, however, has declined in some countries, risen in others, and remained relatively stable in still others (Fig. 4). The reasons are diverse.

In Bangladesh, wheat consumption has increased to make wheat a significant part of the diet. Wheat production expanded rapidly during the 1970s (Fig. 5), and a favorable rice/wheat price ratio favored consumption of wheat. Average overall cereal consumption was maintained in the range of 175-185 kg/capita from 1960 to 1988. Per capita rice consumption declined throughout the 1960s, and stabilized at 150-160 kg in the 1980s. Total demand continues to increase in close harmony with population growth.

In China, per capita consumption of both rice and wheat increased significantly throughout the period from 1960 to 1985, with the sharpest growth beginning in 1980; per capita consumption plateaued in the late 1980s (Fig. 6). Direct consumption demand for coarse grains fell after 1980. There is little evidence of substitution between rice and wheat at the national level during this period, with rice contributing a near constant 47% to total cereal consumption. Wheat and rice prices were maintained at a near constant ratio from 1960 to 1988.

![Rice consumption (kg/capita)](image)

5. Per capita rice and wheat consumption and their prices in Bangladesh, 1960-88.

In India, aggregate cereal consumption has increased substantially over the last three decades (Fig. 7). Wheat consumption increased 250%, rice consumption 85%. India, however, incurred little change in per capita rice consumption. Rice production during the period grew slowly. In contrast, per capita wheat consumption during the period nearly doubled, reflecting the widespread adoption of improved wheat production technology and the consequent impact on yields and prices.

Indonesia has shown rapid increases in both per capita and total consumption of rice, particularly since the mid-1970s. The successful introduction of high-yielding rice technologies coupled with supportive government policies was largely responsible. Indonesia is principally a rice-eating nation: in 1988, rice constituted 87% of per capita cereal consumption, an average of 158 kg/person.

In Japan and Taiwan, incomes have increased sharply over the last 15 yr. Both per capita and total rice consumption fell rapidly as consumers switched dietary expenditures to meat, fruits, and vegetables. In Japan, substitution of lower cost wheat products also may have eroded rice consumption (Table 2). The data indicate a moderate increase in wheat consumption over the period, partly the result of a favorable rice/wheat price relationship beginning in 1970.

In the Republic of Korea, incomes have increased rapidly. Unlike the Japanese, however, Koreans for many years have consumed a mixture of rice and barley (a coarse grain) as the starchy staple in their diets. As incomes increased, consumers have substituted more rice for barley. Coarse grain consumption declined nearly 40% during a period when rice and wheat consumption was rising (Appendix Table 6).

Table 2. Cereal consumption patterns in Japan, 1960 to 1988.\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total (t × 10^6)</th>
<th>Per capita (kg)</th>
<th>Price (yen)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice</td>
<td>Wheat</td>
<td>Coarse grains</td>
</tr>
<tr>
<td>1960</td>
<td>11.9</td>
<td>3.8</td>
<td>1.9</td>
</tr>
<tr>
<td>1965</td>
<td>11.8</td>
<td>4.5</td>
<td>1.7</td>
</tr>
<tr>
<td>1970</td>
<td>11.7</td>
<td>5.0</td>
<td>1.8</td>
</tr>
<tr>
<td>1975</td>
<td>10.7</td>
<td>5.7</td>
<td>2.2</td>
</tr>
<tr>
<td>1980</td>
<td>10.1</td>
<td>5.9</td>
<td>3.1</td>
</tr>
<tr>
<td>1985</td>
<td>10.1</td>
<td>6.1</td>
<td>3.5</td>
</tr>
<tr>
<td>1988</td>
<td>9.5</td>
<td>5.8</td>
<td>4.0</td>
</tr>
</tbody>
</table>

\(^a\)Data derived from Appendix Table 5.

The data for Nepal are difficult to interpret, particularly the high coarse grain consumption indicated during the 1960s. A clear decline in per capita rice consumption beginning in 1976 (Appendix Table 7) is only partially compensated by increased consumption of wheat. Per capita intake of all cereals exhibits a slightly declining trend during the 1980s.

Pakistan is primarily a wheat-consuming nation. Much of the country’s aromatic Basmati rice is exported; the remainder, in combination with coarse rice, represents only 12-13% of total cereal consumption.

In the Philippines, total rice consumption expanded parallel with population growth and moderate increases in income. Per capita consumption has remained relatively flat (Fig. 4). Annual per capita milled rice consumption was estimated at about 96 kg in 1960, rising to about 105 kg in 1988.

Thailand had one of the highest per capita rice consumption levels in the world during the 1960s and early 1970s. Per capita consumption has declined steadily since 1975; during the same period, domestic rice production stagnated and economic growth began to accelerate. One explanation for high consumption levels during the early years may be an overstatement of consumption during periods when rice leakages occurred across Thailand’s borders into neighboring Malaysia. This requires further investigation.

It is clear that the level and pattern of rice consumption in Asia differ for each country and are changing over time. During the last 30 yr, individual consumption has increased in some countries, declined in others, and remained unchanged in still others. Some changes are partially predictable. Consumption theory indicates we should anticipate an even greater softening in rice demand in Japan and Taiwan. A similar scenario will likely emerge in Korea during the 1990s. However, these three countries represent only about 10% of the total rice demand in the region. For those countries where rice is the principal component of the diet and where income growth is low or stagnant, average rice consumption will remain high and possibly increase into the next century.
Income and the demand for rice

Economists use a time-tested tool to evaluate the impact of income changes on consumption: the concept of income elasticity of demand. Simply stated, income elasticity represents the change (positive or negative) in demand (consumption) for a commodity, which results from a given change in income. For example, if income increases 10%, what is the percentage change in the demand for a commodity? If the resulting estimates of income elasticity are positive and greater than 1, consumption of the commodity will increase at a rate greater than the rate of increase in income. If the estimate lies between 0 and 1, consumption of the commodity will increase, but at a rate less than growth in income. If the estimate is negative, consumption of the commodity will decline with increases in income. Declining consumption illustrates the case of an inferior good. The alternative outcomes are summarized as:

<table>
<thead>
<tr>
<th>Income (Y)</th>
<th>Elasticity</th>
<th>Demand for commodity (X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing</td>
<td>&gt;1</td>
<td>Increases faster than Y</td>
</tr>
<tr>
<td>Increasing</td>
<td>&gt;0 - &lt;1</td>
<td>Increases slower than Y</td>
</tr>
<tr>
<td>Increasing</td>
<td>&lt;0</td>
<td>Declining</td>
</tr>
</tbody>
</table>

Population growth and changes in real income are the most important factors affecting growth in demand for rice. We used an econometric system that incorporated the cross-section time series data contained in Appendix Tables 1-11 to develop estimates of the income elasticity of demand for rice for each country and for each year since 1960 (Huang et al 1990).

Japan, Taiwan, Malaysia, Singapore, and Thailand have negative elasticities, indicating that growth in per capita rice demand is declining over time (Table 3). These

<p>| Table 3. income elasticities for rice in selected Asian countries, 1961-88. |</p>
<table>
<thead>
<tr>
<th>-----------------------------</th>
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<tbody>
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<td></td>
<td></td>
</tr>
<tr>
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<td>-.334</td>
<td>-.404</td>
<td>-.478</td>
<td>-.535</td>
<td>-.564</td>
<td>-.591</td>
</tr>
<tr>
<td>Japan</td>
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<td>-.340</td>
<td>-.440</td>
<td>-.477</td>
<td>-.502</td>
<td>-.517</td>
<td>-.530</td>
</tr>
<tr>
<td>Singapore</td>
<td>-.284</td>
<td>-.264</td>
<td>-.390</td>
<td>-.441</td>
<td>-.488</td>
<td>-.503</td>
<td>-.522</td>
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<tr>
<td>Malaysia</td>
<td>-.047</td>
<td>-.103</td>
<td>-.157</td>
<td>-.193</td>
<td>-.335</td>
<td>-.350</td>
<td>-.349</td>
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<tr>
<td>Thailand</td>
<td>.191</td>
<td>.071</td>
<td>-.110</td>
<td>-.166</td>
<td>-.239</td>
<td>-.267</td>
<td>-.328</td>
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<td>Group II countries</td>
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</tr>
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<td>India</td>
<td>.254</td>
<td>.252</td>
<td>.248</td>
<td>.256</td>
<td>.226</td>
<td>.225</td>
<td>.237</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>.129</td>
<td>.120</td>
<td>.121</td>
<td>.126</td>
<td>.115</td>
<td>.123</td>
<td>.125</td>
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<tr>
<td>Korea</td>
<td>.150</td>
<td>.157</td>
<td>.164</td>
<td>.170</td>
<td>.173</td>
<td>.174</td>
<td>.174</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>China</td>
<td>.370</td>
<td>.350</td>
<td>.333</td>
<td>.325</td>
<td>.315</td>
<td>.303</td>
<td>.299</td>
</tr>
<tr>
<td>Philippines</td>
<td>.344</td>
<td>.337</td>
<td>.331</td>
<td>.330</td>
<td>.321</td>
<td>.327</td>
<td>.324</td>
</tr>
<tr>
<td>Indonesia</td>
<td>-</td>
<td>-</td>
<td>.581</td>
<td>.540</td>
<td>.470</td>
<td>.488</td>
<td>.466</td>
</tr>
<tr>
<td>Burma</td>
<td>.495</td>
<td>.487</td>
<td>.475</td>
<td>.491</td>
<td>.477</td>
<td>.477</td>
<td>.463</td>
</tr>
</tbody>
</table>
elasticities also have become more negative since 1960, indicating that as incomes rise, expenditures for rice are declining at an increasing rate.

The elasticities in Myanmar, China, Indonesia, and the Philippines are positive, relatively large, and have been relatively stable. There is some evidence of a slow decline in the elasticities for China and Indonesia during the 1980s. Myanmar and Nepal exhibit relatively large and increasing coefficients, indicating a decline in real per capita consumption expenditures (declining real incomes), with an increasing percentage of real income being spent on rice.

Elasticities in Korea are low but have increased slowly. As Korean incomes have increased, a portion of additional income is used to purchase additional rice to replace barley as a component of the rice-barley mixture. When this substitution process is complete, the income elasticity of rice may decline as other commodities are substituted for rice in Korean diets.

Although five countries demonstrate a declining expenditure for rice, they represent less than 10% of total rice consumption for the Asian region.

From this analysis, we conclude that rice is not an inferior good, that income elasticities in countries consuming the greatest share of rice will remain positive throughout the 1990s, and that substantial increases in rice production will be required to meet rising consumption requirements well into the 20th century.

Challenges for rice research

Rice supply prospects for the 1990s and into the 21st century are not expected to be strong. The land frontier in most Asian countries is essentially closed. Crop area planted to rice did not grow throughout the 1980s. Much of the easy progress associated with Green Revolution technology has been realized. Despite the enthusiasm within the research community, at this point both the probability and possibility of raising the rice yield frontier remains uncertain. Coupled with these technical concerns are the reduced budgets available to public research, decreasing investments in irrigation and in public infrastructure, and declining political and financial support for the policy mechanisms necessary to nurture and maintain viable food systems.

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Notes

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### Appendix Table 1. Cereal consumption and prices in Bangladesh, 1960-88.

<table>
<thead>
<tr>
<th>Year</th>
<th>Consumption (kg/capita)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rice</td>
<td>Wheat</td>
</tr>
<tr>
<td>1960</td>
<td>189.69</td>
<td>0.55</td>
</tr>
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<sup>a</sup>Private consumption expenditure derived from IMF (1989). PCE is an estimate of private consumption expenditure, in contrast to per capita total income, which includes government expenditure. <sup>b</sup>Cereal prices expressed in taka/kg.
Appendix Table 2. Cereal consumption and prices in China, 1960-88.

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<sup>a</sup>Estimates of private consumption expenditures based on "The Development of China" (1949-1989) rather than on IMF data. <sup>b</sup>Expressed in yuan/kg.
### Appendix Table 3. Cereal consumption and prices in India, 1960-88.

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<sup>a</sup>Private consumption expenditures derived from IMF (1989). <sup>b</sup>Expressed in rupee/kg.
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\(^a\)Private consumption expenditures derived from IMF (1989). \(^b\)Expressed in rupiah/kg.
Appendix Table 5. Cereal consumption and prices in Japan, 1960-88.

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<sup>a</sup> Private consumption expenditures derived from IMF (1989). <sup>b</sup>Expressed in yen/kg.
Appendix Table 6. Cereal consumption and prices in Republic of Korea, 1960-88.

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<sup>a</sup>Private consumption expenditures derived from IMF (1989).<sup>b</sup>Expressed in won/kg.

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<sup>a</sup>Private consumption expenditures derived from IMF (1989).  
<sup>b</sup>Expressed in rupee/kg.
Appendix Table 8. Cereal consumption and prices in Pakistan, 1960-88.

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<sup>a</sup>Private consumption expenditures derived from IMF (1989). <sup>b</sup>Expressed in rupee/kg.
### Appendix Table 9. Cereal consumption and prices in the Philippines, 1960-88.

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<sup>a</sup>Private consumption expenditures derived from IMF (1989).<sup>b</sup>Expressed in peso/kg.
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<sup>a</sup>Private consumption expenditures derived from IMF (1989). <sup>b</sup>Expressed in NT$/kg.

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<sup>a</sup>Private consumption expenditures derived from IMF (1989).  
<sup>b</sup>Expressed in baht/kg.
Assessing rice quality characteristics and prices in selected international markets

M. Kaosa-ard and B. O. Juliano

The relationship between rice price and quality characteristics was examined in three selected high-income markets: Hong Kong; Bonn, Germany; and Rome, Italy. Rice samples taken from major retail outlets were analyzed for physicochemical properties at IRRI. The quality characteristic variables included in the hedonic function were obtained from interviews with traders, millers, and supermarket managers in each market. In the traditional rice-consuming economies of Hong Kong and Italy, quality characteristics are important considerations. In Hong Kong, indica rice is preferred and higher prices are paid for rice with relatively long grain, higher percentage of head rice, and flaky but soft texture. In Rome, japonica rice is preferred. In contrast to East Asian consumers, Italians prefer chalky grains and relatively harder gel. In both markets, the types of outlets are important factors influencing prices. In Bonn, a traditionally nonrice-consuming market, only one physical quality, percentage of head rice, was statistically significant. In this market, processing level, lot size, and packing type are important considerations.

As per capita incomes in rice-consuming countries rise and as yield constraints are overcome, grain quality becomes more and more important in both traditional exporting and importing countries. For traditional exporters, good grain quality is essential to sustain traditional markets and to penetrate new high-income and high-technology markets. For traditional importers about to attain rice production self-sufficiency, good grain quality not only improves the welfare of local consumers but also provides an assurance that emerging surpluses will find a rewarding market.

Aside from the positive welfare effects derived by consumers in rice-producing and -consuming countries, Monke and Pearson (1987) argued that substantial price differences between different qualities imply nonperfect substitution, and that technological changes that improve rice quality may yield high gross returns. Improving the grain quality characteristics of genetic sources or varieties could reduce processing costs and directly increase returns to farmers.

The test of whether the quality characteristics of a variety will yield an additional price premium was the primary objective of this study. Three markets were examined:
Hong Kong; Bonn, Germany; and Rome, Italy. Details of the quality characteristics of the rice samples analyzed are described in a companion paper (Juliano et al 1990).

**Grain quality characteristics**

**Rice standards**
Traditionally, rice growers and exporters establish certain criteria to grade their commodities. The most common involve such physical properties as length of grain, degree of milling, percentage of brokens, proportion of damaged grain, colored grain, moisture level, and impurities.

Only a few countries export high standard rice (Australia, Surinam, Thailand, Uruguay, and the United States). Only Thailand and the United States are major suppliers in the high standard market. In Thailand, 100% A, B, C, and 5% rice are considered high standard rice. U.S. No. 2 is considered the high-quality rice in the United States.

Rice standards do not fully explain price variations. According to the Thai rice standard, U.S. No. 2 and Thai 100% C are equivalents. But Thai 100% C rice received 92% of the CIF Rotterdam price received by U.S. No. 2 in the tight-market situation in 1981, and fell to 50-60% of U.S. No. 2 between 1982 and 1985 (Efferson 1985).

Many factors can be cited to explain this price differential for the period covered by Efferson’s study. The 1981 U.S. Farm Act was one major reason; cleanliness (absence of impurities), another. In industrialized countries such as the United States and Australia, where rice growing, processing, and transporting are highly mechanized, a continuous processing and packing system ensures the absence of foreign matter. In Asian exporting countries, where the processing, packing, and transporting system is partly manual, standards on foreign matter are less strictly observed.

In Thailand, rice of higher grade is taxed at a higher rate, and rice standards are checked for tax purposes. Under the Thai system, percentage brokens and kernel length are considered more important than the absence of impurities. As Thai rice exporters have increased their share of the high-income markets, more attention has been given to cleanliness; only exporters who strictly observe the cleanliness standard can penetrate into high-income rice markets.

Other quality criteria, such as cooking quality, that are not incorporated into rice standards also contribute to price differentials.

**Cooking quality**
People from different regions have different tastes and preferences. The Japanese prefer short-grain japonica rice that is soft and relatively sticky when cooked. Thais favor well-milled, long-grain indica rice that is soft but flaky when cooked. In many traditional rice markets (India, Pakistan, Thailand), fragrant rices fetch the highest prices. In nontraditional markets (such as those in the West), fragrant rice is considered...
spoiled or contaminated (Efferson 1985). Consumers in Bangladesh, Nigeria, and Liberia are said to prefer parboiled rice. Those in the Middle East prefer rice pilaf, treated with butter or vegetable oil (Eve 1973).

What consumers consider good rice depends partly on historical and sociocultural factors. A top-quality rice in one region may be considered low-quality in another. Consumer preferences for cooking quality need to be incorporated into the concept “good quality rice.”

It is possible to translate consumer preference for cooking quality into measurable chemical properties. Cooking quality depends on a number of characteristics: amylose content, gelatinization temperature, gel consistency, grain elongation, and aroma.

**Apparent amylose content.** Apparent amylose content is a major determinant of eating and cooking quality. It directly affects water absorption and volume expansion during cooking. Rices with high amylose content have high volume expansion (not necessarily elongation) and a high degree of flakiness. Tenderness and stickiness of cooked rice inversely correlate with amylose content. When cooked, rices with high amylose content are relatively dry, separate, and less tender. They also become hard upon cooling. Low-amylose (10-20%) rices become moist and sticky when cooked (e.g., most japonica varieties).

U.S. long-grain rices with amylose content between 23 and 26% are considered intermediate-amylose varieties. The amylose content of Thai rices ranges from a low 12% to a high 31%. The amylose content of traded Thai rices has never been measured. Basmati rices have higher amylose content than Thai fragrant rice (22.7% for Basmati 370 and 23% for Basmati 6129, less than 20% for Khao Dawk Mali 105).

**Gelatinization temperature.** Gelatinization temperature is the water temperature at which starch granules begin to swell irreversibly. An alkali test is used to measure gelatinization temperature. Alkali spreading values of 1-2 are indicators of high gelatinization temperature; 3, high intermediate; 4-5, intermediate (70-74 °C); and 6-7, low (<70 °C).

This property is expected to become increasingly important where quick cooking is desired (e.g., in the production of instant or minute rice). IRRI’s breeding strategy has focused on intermediate gelatinization temperature. U.S. long-grain rices usually have intermediate gelatinization temperatures, the medium- and short-grain varieties usually have low gelatinization temperatures.

**Gel consistency.** Rices of similar amylose content can be differentiated according to tenderness measured through gel consistency. Within the same amylose group, cooked rice with softer gel consistency is more tender. The method used by Cagampang et al (1973) to measure gel consistency classifies rices into the following three groups:
- Hard gel consistency (26-40 mm)
- Medium gel consistency (41-60 mm)
- Soft gel consistency (61-100 mm).

**Grain elongation and aroma.** For some special ethnic markets, grain elongation and aroma are important cooking qualities.
Sources of rice quality improvement and returns

In an earlier study of rice quality in Thailand, Kaosa-ard (1985) identified sources of quality improvements and losses. Table 1 summarizes the traditional and emerging quality criteria, classified by source of quality improvement or loss. The traditional criteria for grading rice involves physical appearance. Because rice is also sold in high-income markets where hygiene standards are high, absence of foreign matter, length of shelf life, and packaging techniques have emerged as new criteria.

Among the physical criteria, percentage brokens is affected by a number of factors: variety, preharvest and postharvest handling, etc. Shape and age are derived only from varietal characteristics. Aroma, a result of site and genotype interaction, is also a varietal attribute. Improved high-yielding varieties produce rice with increased incidence of chalkiness. Translucency and colorlessness, two properties usually found in

Table 1. Traditional and emerging quality criteria and sources of quality improvement.\(^a\)

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<th>Site or site × genotype interaction</th>
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\(^a\) + = quality improvement; – = quality loss.
traditional varieties, have reemerged as significant criteria as more and more hectarage is planted to high-yielding varieties.

Knowledge of consumer preference for cooking quality has been based on observed transactions and expert judgment, rather than on systematic evaluation. As rice is increasingly consumed in nontraditional rice markets in Europe, Africa, and North and South America, chemical properties represent a first approximation of preferred cooking qualities.

Varietal improvement may further enhance many aspects of quality. Because varietal improvement is long-term, rice traders have resorted to processing techniques as a short-term solution for achieving a desired quality standard. For example, a sorter can help remove colored grains. Mechanical equipment may be used to separate broken from head rice. Returns to processing costs probably constitute a large proportion of current market prices. Improvement in chemical properties may reduce processing costs and reroute the returns from processors to farmers.

Recent advertisements and marketing gimmicks are claimed to affect nontraditional consumer preferences. In nontraditional, high-income urban markets, factors such as packaging, services, and utilities accompanying a particular sales outlet (e.g., parking, airconditioning, etc.) could also affect a consumer’s willingness to pay a particular price for a product.

The term “rice standards” refers to those characters related to traditional criteria; the term “rice quality” includes cooking quality. While it is possible to have an international comparison for standards, high or low quality must be discussed in the context of a particular market.

Conceptual framework

The instrument used to relate market price and quality characteristics of rice is the hedonic regression, which states a general relationship as (Lucas 1975)

\[ P_i = P(X_{i1}, \ldots, X_{ij}, e_i) \]

where \( P_i \) is observed price of commodity \( i \), \( X_{ij} \) is characteristic \( j \) in commodity \( i \), and \( e_i \) is disturbance term. Note that this hedonic function is neither a demand nor a supply function. As Rosen (1974) has shown, the hedonic price curve represents the equilibria of the consumer’s bid curve and the supplier’s offer curve. He suggested a two-stage least square if a demand or a supply structure is to be reflected.

There is no a priori rule about the inclusion of quality characteristics (Tabor 1988), but characteristics included should be observable and economically relevant to consumers. This makes the use of expert information for specification of the inclusion list necessary.

In this study, both linear and logarithmic functions (\( P_i = \beta X_{ij} \)) are used. The linear specification is generally acceptable if the characteristics measured are objective and continuous in nature. These properties are well met by the commodity of this study—rice. Inclusion of a characteristic for each market depended on the information obtained from interviews.
The Hong Kong market

Hong Kong imports almost all of its rice. Since 1965, the volume of Hong Kong rice imports has been around 360,000 t/yr, despite a population increase. The three major sources of rice supplies to Hong Kong are Thailand (50%), China (33%), and Australia (17%).

Consumer preference

Hong Kong consumption of rice is estimated at 70 kg/head per yr. A large proportion is consumed by foreign visitors and tourists.

Hong Kong consumers prefer long, slender, well-milled, and soft-textured rice. Thai rice is well-known in Hong Kong for its flavor and, recently, for its fragrance. Thai rice supplied to Hong Kong is generally of very high standard: it is more carefully selected and milled than rice supplied elsewhere.

The Chinese rice consumed in Hong Kong is mostly 10% long-grain rice called See Mew. The high-amylose Chinese rice is particularly suitable for the fried rice served in restaurants.

Australian rice is preferred for its softness. The long-grain Inga variety constituted about 75% of total Australian supplies; the short-grain Calrose variety, 15%. The balance is brokens. American rice is less preferred because of its higher price.

As incomes steadily increased, more and more Hong Kong consumers shifted from higher to lower amylose rices. Hong Kong traders blend rice of different origins to achieve the desired cooking quality. Because Australian and Thai rices are harvested at different times, the two are said to be complementary: a fresh-season crop from Thailand may be blended with a last-season crop from Australia (and vice versa) to maintain the desired cooking quality.

Sample collection

Samples collected from three retailers (10 samples), three supermarkets (40 samples), and three wholesalers (43 samples) were shipped by air to IRRI during December 1987 (a cool season) to avoid further physical deterioration.

Grain characteristics

Table 2 shows the physicochemical characteristics of the Hong Kong rice samples. Rices sold in Hong Kong have soft texture, 20% amylose on average, and soft gel (over 50 mm). By conventional standards, most are of high quality, exhibiting more than 95% head rice with less than 1% chalky and damaged grains.

One striking difference in the quality of rice from different origins is in amylose content. On the average, it is highest for Chinese rice (24.7%) and lowest for Thai rice (17.8%). The fragrant rice from Thailand has amylose content as low as 14%. Thai and Australian rices tend to have very soft gel.
Table 2. Physicochemical characteristics of rice samples from three international markets.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hong Kong</th>
<th>Bonn</th>
<th>Rome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>6.4</td>
<td>0.8</td>
<td>7.4</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>2.1</td>
<td>0.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Length/width ratio</td>
<td>3.1</td>
<td>0.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Head rice percentage</td>
<td>95.6</td>
<td>4.4</td>
<td>88.5</td>
</tr>
<tr>
<td>Translucency (%)</td>
<td>98.7</td>
<td></td>
<td>75.3</td>
</tr>
<tr>
<td>Kett whiteness (%)</td>
<td>42.9</td>
<td>1.6</td>
<td>30.2</td>
</tr>
<tr>
<td>Chroma meter L* value</td>
<td>74.6</td>
<td>0.7</td>
<td>56.3</td>
</tr>
<tr>
<td>Chalky grains (%)</td>
<td>0.3</td>
<td>0.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Damaged grains (%)</td>
<td>0.3</td>
<td>0.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Alkali spreading value</td>
<td>6.4</td>
<td>0.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Apparent amylose (%)</td>
<td>20.0</td>
<td>4.2</td>
<td>23.4</td>
</tr>
<tr>
<td>Gel consistency* (mm)</td>
<td>53.6</td>
<td>17.4</td>
<td>47.4</td>
</tr>
<tr>
<td>Gel consistency** (mm)</td>
<td>67.3</td>
<td>21.6</td>
<td>65.4</td>
</tr>
<tr>
<td>(Sample size)</td>
<td>(93)</td>
<td></td>
<td>(82)</td>
</tr>
</tbody>
</table>

*aSource: surveyed samples. b100-mg test. c90-mg test.

Price variations

A preliminary survey showed that prices differed substantially with outlet type (wholesale, retail, and supermarket). The data from samples collected confirmed this observation. Retail shops, on the average, offered rice at lower prices than supermarkets, but much higher than did wholesalers. Within the same supermarket chain, the price of rice of the same brand differed among outlets; the prices of different brands in two competing supermarkets in the same location were more similar. Price variations at the supermarket level correlated with distribution outlets. A well-distributed brand may have a wider price dispersion. This finding suggested using a weighting procedure in the regression analysis.

Pure Chinese rice, a hard-textured type, commanded the lowest price; bagged rice of mixed origins was the most expensive.

Impact of market and quality characteristics on prices

Interviews with Hong Kong traders, wholesalers, and distributors suggested that percentage head rice, length, milling degree, and soft texture are important quality variables.

Two sets of regressions were run on the Hong Kong samples. The first regression comprised the whole sample. In the second regression, the total number of observations was reduced from 93 to 68 because some supermarket samples were of the same brand and packing, and the mean values of prices and sample characteristics were used. A set of dummy variables representing sales outlets was also added to this equation. Soft texture was approximated by gel consistency. Both linear and log model were tried. Both equations were weighted by the inverse of the square root of the market share of each observation.
Preliminary results suggested that milling degree was not statistically significant, and it was dropped from the equation. Head rice percentage correlated with length of rice, and head rice percentage was dropped from the equation to avoid a multicollinearity problem.

The best-fit equations are presented in Table 3. The linear model seems to provide a marginally higher $R^2$. The equation suggests that a marketing margin of retail prices over wholesale prices should be HK$1.50 for supermarkets and HK$1.289 for small retail shops. An increase of 1 mm in rice length will result in a price increment of 18 cents/kg; a 1-mm greater value in gel consistency (softer gel) will increase price by 1 cent. Together, these variables explained about 85% of the price variations found in the Hong Kong market. The log model suggests that the price elasticity of rice length is 0.225%; that of gel consistency, 0.148%.

The second set of regressions consisted only of observations obtained from supermarkets. At the supermarket level, the quality characteristics suggested by a supermarket manager and by importers are statistically significant: Hong Kong consumers prefer long-grain, fluffy, but soft rice. The premium for an increase in head rice percentage at the supermarket level is 6 cents/kg; for soft gel consistency (a measurement of tenderness), it is 17 cents. A 1% increase in amylose content raises the price 9 cents. Together, these attributes explain 75% of the price variations at the supermarket level.

The log model suggests a higher price elasticity with respect to head rice than to apparent amylose or gel consistency. It can be concluded that in this high-income, traditionally rice-consuming market, cooking quality is an important consideration.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Linear</th>
<th>Log</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>SE</td>
</tr>
<tr>
<td><strong>All samples</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.847</td>
<td>0.334</td>
</tr>
<tr>
<td>Length</td>
<td>0.177</td>
<td>0.801</td>
</tr>
<tr>
<td>Gel consistency$^a$</td>
<td>0.009</td>
<td>0.002</td>
</tr>
<tr>
<td>Retailers</td>
<td>1.289</td>
<td>0.112</td>
</tr>
<tr>
<td>Supermarkets</td>
<td>1.500</td>
<td>0.093</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.8529</td>
<td></td>
</tr>
<tr>
<td>F value</td>
<td>98.083</td>
<td></td>
</tr>
<tr>
<td>(degrees of freedom)</td>
<td>(4, 63)</td>
<td></td>
</tr>
<tr>
<td><strong>Supermarket samples</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>3.426</td>
<td>1.353</td>
</tr>
<tr>
<td>Gel consistency$^a$</td>
<td>0.17</td>
<td>−0.004</td>
</tr>
<tr>
<td>Head rice</td>
<td>0.058</td>
<td>0.013</td>
</tr>
<tr>
<td>Amylose</td>
<td>0.089</td>
<td>0.024</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.757</td>
<td></td>
</tr>
<tr>
<td>F value</td>
<td>18.699</td>
<td></td>
</tr>
<tr>
<td>(degrees of freedom)</td>
<td>(3, 14)</td>
<td></td>
</tr>
</tbody>
</table>

$^a$90 mg rice.
The Bonn market

Rice consumption in the Federal Republic of Germany is around 2 kg/person per yr. The country imports around 170,000 t of rice and exports between 30,000 and 40,000 t annually. The major suppliers are the United States, Thailand, and Surinam.

The total value of retail sales is around 300 million Deutschemarks (DM)/yr. Of the rice marketed, 15% is japonica varieties (mostly used for dessert dishes). The remaining 85% is indica varieties imported mainly from the United States, Thailand, and Surinam. In the indica market, the combined market share of two American firms producing high-quality rice was about 30%. These firms also pack their rice in high-quality packing materials. The larger market shares (about 55%) are held by large chain stores and distributors that sell rice of lesser quality. The remaining 15% is shared by two millers producing medium-quality products.

By local regulation, rice distributors must specify the percentage brokens in the containers. There are three standards: the spitzen (5% brokens), standard (15% brokens), and household (25% brokens). In the market segment supplied by discount or chain stores, 50% of the rice sold was spitzen quality, 10% standard quality, and 40% household quality.

The high- and medium-quality rice suppliers generally distribute spitzen quality rice. A few brands market 100% whole kernel rice, but their market shares are negligible.

Rice sold in this market is mostly packed in 500-g lots. “Boil-in-Bag,” one of the more popular types of packaging, refers to packing of rice in perforated plastic bags. The rice can be cooked in the bag. This type of packing facilitates both cooking and cleaning activities.

Consumer preference

German consumers were said to prefer easy-cooking rice. Length of grain and degree of milling, the quality desired by East Asian rice consumers, are not considered important rice characteristics. German consumers were thought to be more interested in flaky rice of relatively hard texture. Some traders felt that such a preference has been fostered by advertisements of a U.S. brand that suggest that good rice “never sticks.” Others claimed that German consumers do not care about the “taste” of rice. They are more interested in price. Interviews with traders also suggested that customers have little knowledge about the local grading system (i.e., percentage brokens), and have only vague awareness that whole grain and spitzen are of superior quality. German customers are said to be more price-conscious than quality-conscious.

Physicochemical characteristics of German rice samples

The physicochemical characteristics of long-grain rice samples are presented in Table 2. In general, rice sold in Germany has a much lower percentage head rice, higher amylose (23% on average), and slightly harder gel consistency than the Hong Kong samples. Even the amylose content of the short-grain samples is higher than that of the Hong Kong samples of indica rice.
Price variation

Prices of packaged rice in Germany vary according to grade, processing level, grain type, packing type, and lot size. Whole grain and spitzen quality commanded much higher prices than standard and household rice. Both whole grain and spitzen rice are generally brand name products; standard and household rice usually bear the name of discounters. Packing types also appear to have a significant impact on prices. Precooked and parboiled rice derived 60-230% higher price margins than regular raw rice.

Impact of grain quality on prices

The independent variables specified for the hedonic functions of the German samples include processing (brown, milled, parboiled, or precooked), packing type (double or single packing), amylose content, and gel consistency. The observations were weighted by the inverse of the square root of market share by brand. The results are presented in Table 4. Both linear and log functions were tried; the log function provided a better fit.

On the basis of the linear model, lot size, packing type, and degree of processing are the factors found to influence prices in Bonn supermarkets. Double packing fetches DM 0.62 above single packing. Smaller lot size (500 g) commanded a DM 0.56 higher premium. Milled rice cost DM 0.80 less than brown rice (all brown rice samples happened to be whole grain). Parboiled or precooked rice obtained DM 0.19 more than raw milled rice. Percentage head rice was the only statistically significant quality characteristic, but its impact was small. A 1% increase in head rice would yield DM 0.011 more. The log model predicts that a 1% increase in head rice would increase price by 0.06%. Cooking qualities specified for this model (amylose and gel consistency) were not important factors.

Table 4. Impact of quality characteristics on retail prices of rice in Bonn supermarkets (weighted OLS).\(^a\)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Coefficient</th>
<th>SE</th>
<th>t value</th>
<th>Coefficient</th>
<th>SE</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.474</td>
<td>0.504</td>
<td>0.941</td>
<td>0.609</td>
<td>0.281</td>
<td>−2.462</td>
</tr>
<tr>
<td>% head rice</td>
<td>0.011</td>
<td>0.006</td>
<td>2.020</td>
<td>0.246</td>
<td>0.063</td>
<td>3.936</td>
</tr>
<tr>
<td>Lot size</td>
<td>0.561</td>
<td>0.271</td>
<td>2.075</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Double packing</td>
<td>0.624</td>
<td>0.219</td>
<td>2.852</td>
<td>0.366</td>
<td>0.073</td>
<td>5.051</td>
</tr>
<tr>
<td>Brown rice</td>
<td>0.800</td>
<td>0.211</td>
<td>3.788</td>
<td>0.339</td>
<td>0.076</td>
<td>4.413</td>
</tr>
<tr>
<td>Parboiled rice</td>
<td>0.189</td>
<td>0.388</td>
<td>0.488</td>
<td>0.128</td>
<td>0.144</td>
<td>0.889</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjusted R(^2)</th>
<th>0.416</th>
<th>0.4884</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>11.112</td>
<td>12.297</td>
</tr>
<tr>
<td>(degrees of freedom)</td>
<td>(5, 66)</td>
<td>(6, 65)</td>
</tr>
</tbody>
</table>

\(^a\)Weighted by the inverse of square root of the market share of each brand. ns = not statistically significant.
The Rome market

Italy is the largest rice producer and exporter in the European Community. It produces slightly more than 1 million t of rice/yr and exports about 700,000 t annually. The rice grown in Italy is japonica varieties—the preferred type in southern Europe, including the south of France, Spain, and Portugal. Because nonrice-producing countries in North Europe primarily demand indica rices, the surplus output of Italy enters the north European countries as “milk rice” for sweet dishes. The remaining output has to find markets outside the northern European region, mainly in Jordan and Lebanon. Italian millers also import brown rice for further milling and processing for the European Community market.

Rice is sold in large supermarkets, chain stores, suburban small supermarkets, and specialty food stores (alimentari) and food markets.

Rice sold in all outlets is mostly packed in transparent plastic bags. Compared with the Federal Republic of Germany, packing is less fancy in Italy. The variety and milling degree (undermilled, milled, and very well milled) are usually specified.

Consumer preference

Interviews with rice experts, local millers, and packers revealed that the preferences of Italian consumers differ from those of northern European consumers; Italians are accustomed to the home-grown japonica varieties. Italian consumers are said to have a good knowledge of “delicious” varieties. Camaroli, for example, is considered a choice variety. According to a rice expert, good rice is not supposed to be too hard or too soft, but leaning toward the hard.

An interesting feature of Italian preferences is that, in contrast to consumers in other regions, Italian consumers were said to prefer more chalky varieties. Nonchalky rice is usually exported. The slender shape preferred in the Hong Kong market is not considered a superior characteristic in Italy.

Price variation

Prices of Italian rice samples differed according to market outlet, grain type, lot size, and packing. Imported indica rices are subject to high levies, and hence, higher market prices. Locally produced rice is packed in plastic bags or thin cardboard boxes.

Physicochemical characteristics of Italian rice

Table 2 provides information on the physicochemical characteristics of Italian rice. Japonica varieties sold in Italian markets have higher amylose content and harder gel than indica varieties sold in the Hong Kong market.

Impact of quality characteristics on price

Quality characteristics specified as important quality attributes by traders in Italy (chalkiness and cooking qualities like amylose and gel consistency) were included in the regression, with market outlets, grain, and packing type entered as dummy
Table 5. Impact of quality and marketing attributes on price of Rome rice samples, May 1988.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Linear Coefficient</th>
<th>SE</th>
<th>t value</th>
<th>Linear Coefficient</th>
<th>SE</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2700.20</td>
<td>403.28</td>
<td>6.70</td>
<td>8.29</td>
<td>0.41</td>
<td>20.15</td>
</tr>
<tr>
<td>Alimentari\textsuperscript{a}</td>
<td>1415.39</td>
<td>288.57</td>
<td>4.90</td>
<td>0.59</td>
<td>0.12</td>
<td>4.71</td>
</tr>
<tr>
<td>Supermarkets\textsuperscript{a}</td>
<td>425.37</td>
<td>243.59</td>
<td>1.75</td>
<td>0.18</td>
<td>0.11</td>
<td>1.69</td>
</tr>
<tr>
<td>Japonica</td>
<td>-653.55</td>
<td>284.63</td>
<td>-2.30</td>
<td>0.22</td>
<td>0.13</td>
<td>-1.75</td>
</tr>
<tr>
<td>Double packing</td>
<td>1443.10</td>
<td>358.80</td>
<td>4.02</td>
<td>0.39</td>
<td>0.19</td>
<td>2.02</td>
</tr>
<tr>
<td>Chalkiness</td>
<td>11.60</td>
<td>9.17</td>
<td>1.27</td>
<td>0.02</td>
<td>0.20</td>
<td>1.12</td>
</tr>
<tr>
<td>Gel consistency</td>
<td>-9.90</td>
<td>4.38</td>
<td>-2.26</td>
<td>-0.18</td>
<td>0.10</td>
<td>-1.75</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.77</td>
<td></td>
<td></td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>47.47</td>
<td></td>
<td></td>
<td>15.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(degrees of freedom)</td>
<td>(6, 76)</td>
<td></td>
<td></td>
<td>(6, 73)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}Dummy variable.

variables. Since market shares of each brand could not be obtained, the regressions were not weighted. The regressions were corrected for heteroscedasticity problem.

All variables specified have the expected signs: more chalky rices commanded a higher price; double packing was 1,443 Italian liras higher per kg than single packing; japonica varieties commanded 654 liras less than indica varieties; rice in specialty food stores (alimentari) and supermarkets was 1,415 and 425 liras more costly than rice bought in the food market (Table 5).

The log model suggests that the price elasticity of chalkiness (in absolute value) is lower than that of gel consistency. A 1% increase in chalkiness will yield an additional price premium of 0.02%; increasing gel consistency by 1% reduces price by 0.18%. As in the results from other international markets, marketing variables (such as distribution channel and packing type) commanded high price premiums.

The Italian consumers favor harder rice texture.

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Notes

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Consumer demand for rice grain quality

Z. F. Toquero

This paper summarizes the results of the domestic component of the IDRC Rice Grain Quality project in Bangladesh, Indonesia, Malaysia, Philippines, and Thailand. Results from the country studies highlight the wide variation in consumer demand for quality characteristics and the economic values attached to each attribute across countries, regions, rural and urban areas, income groups, and seasons. In general, rice consumers in urban areas and those with higher incomes are more discriminating, consider more quality characteristics, and attach higher implicit prices to these attributes than to rural consumers and those with lower incomes. The physical and chemical characteristics considered relevant by consumers were color, shape, foreign matter content, percent head rice, amylose content, and alkali spreading value. It is evident that rice should be treated as a heterogeneous good and that its quality characteristics should be specified precisely, to clarify the commodity-demand relationship.

The multicountry Rice Grain Quality project funded by the International Development Research Centre is designed to assess an optimal strategy for rice grain quality improvement. Its purpose is to estimate the implicit values for rice grain characteristics, using market price as a measure of consumer preferences under budget constraints within the international and domestic markets. It also examines variations in consumer tastes across regions, between rural and urban markets, among rice variety groups, and among income classes. The international component covers the rice markets of Hong Kong, Thailand, and the European Community (EC) (Kaosa-ard and Juliano 1991). The domestic component involves five Asian countries: Bangladesh, Indonesia, Malaysia, the Philippines, and Thailand.

This paper summarizes the results of the country studies included in the domestic component. Due to the wide variation in orientation and scope of the different country studies, data on some topical issues surrounding hedonic pricing were not available for some countries.

The hedonic model used in the project assumes that the utility of a good such as rice is a function of its characteristics or attributes, including its physico-chemical characteristics, and its cooking and eating qualities, such that
\[ P_r = \sum_{j=1}^{m} X_{rj} P_{rj} \]

where \( P_r \) = market price of rice, \( X_{rj} \) = quantity of characteristic \( j \) in one unit of rice, and \( P_{rj} \) = implicit value of characteristic \( j \).

Using the ordinary least square (OLS) regression of observed market prices on measures of quality, the independent variables \( (X_{rj}) \) explain the variance in price of rice while the estimated coefficients \( (P_{rj}) \) measure the implicit value of each characteristic.

**Bangladesh**

The Bangladesh component was done by Choudhury et al (1989) in four administrative regions of Bangladesh: Dhaka, Rajshahi, Khulna, and Chittagong.

**Consumer preference**

High-income consumers generally preferred fine-grade rice which is soft and non-sticky when cooked. Low-income consumers preferred coarse rice which is non-sticky and hard when cooked. Parboiled rice is preferred to raw rice, although raw rice is also consumed in some Bangladesh districts.

**Price variation**

The price of rice was significantly higher in urban markets ($0.24-$0.52/kg) than in rural markets ($0.24-$0.42/kg). In urban markets, the highest price was in Chittagong ($0.36/kg) and the lowest in Khulna ($0.32/kg). In rural markets, the price in Dhaka was significantly higher than in Khulna and Rajshahi. The price difference among regions was largely due to differences in income and, to a lesser degree, to grain properties.

The season in which rice is grown also affects its market price. For example, rice grown in the aman season (May-October) is sold at a comparatively lower price in the early months of the year but at a much higher price later. This happens mostly for fine-grade rice. Age of rice after harvest also influences its market price: prices are lower for freshly harvested rice and higher for aged rice.

**Implicit prices for quality characteristics**

Percent yellow grain, cooking time, and imbibition ratio were the most significant characteristics affecting the price of raw rice (Table 1). Consumers of raw rice preferred less yellow grain, shorter cooking time, and greater volume expansion. This was especially important to rural consumers because of the enhanced feeling of satiation after consuming a given volume of rice.

More variables significantly affected the price of parboiled rice sold in urban markets than that of rice sold in rural markets. They included 1,000-grain weight, grain shape, moisture content, cooking time, and imbibition ratio. The 1,000-grain weight, an intrinsic character related to the coarseness of grain, is a negative determinant of price. One unit increase in the coarseness of parboiled rice translated into a 0.123%
price reduction in urban markets and a 0.074% reduction in rural markets. Moisture content and cooking time also pulled down the price of parboiled rice in urban markets.

Both urban and rural consumers of parboiled rice expressed preference for slender grains. Urban consumers were willing to pay 1.034% more for every unit increase in grain shape (L/B ratio); rural consumers were willing to pay 1.504% more.

**Indonesia**

The Indonesian component involved three major urban centers: Jakarta, Medan, and Ujung Pandang (Damardjati and Oka 1989).

**Consumer preference**

Indonesia exhibits wide variability in consumer taste, preference, and consumption patterns, largely because of the archipelagic nature of the country. Consumers in Sumatra and Sulawesi prefer nonsticky cooked rice that hardens when cooked. Consumers in Java prefer sticky and soft-cooked rice. Poor rural Indonesians who live in upland rainfed areas eat more nonrice staples, such as corn, cassava, and sweet potato; poor people in the lowland wet areas consume more rice.

Jakarta exhibited high consumer heterogeneity probably as a result of the diverse backgrounds and origins of its population. Consumer preferences for specific quality characteristics varied widely.
Price variation
Average price per kilogram was $0.29. The highest price was $0.31/kg in Medan; the lowest, $0.29/kg in Jakarta. A wide range of prices in all three areas indicates the wide range of rice quality characteristics offered in the markets.

Implicit prices for quality characteristics
The Jakarta market exhibited the most physicochemical characteristics that significantly affected price (Table 2). This suggests that rice quality carries more weight in the buying decisions of Jakarta consumers, and that they are willing to pay more for local rice than are consumers in other cities.

In Medan, the characteristics that significantly affected price included degree of milling, alkali spreading value, softness, and brand name. Head rice recovery, amylose content, and brand name mattered most in Ujung Pandang.

In all three areas, brand name (i.e., modern or traditional varieties) affected price the most. Jakarta consumers expressed preferences for improved or modern varieties, which are sticky when cooked. Medan consumers also wanted rices that are sticky when cooked, but they preferred traditional varieties. Ujung Pandang consumers preferred modern varieties that are sticky when cooked, but the majority purchased modern varieties that produce hard cooked rice.

Malaysia
This discussion draws heavily on the study by Wong et al. (1989) conducted in Malaysian regions of rice surplus production (Kedah), rice deficit (Johor), and urbanization (Kuala Lumpur).

Table 2. Regression of price on selected physicochemical characteristics of rice in urban areas, Indonesia, 1987\(^a\) (Damardjati and Oka 1989).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Medan</th>
<th>Ujung Pandang</th>
<th>Jakarta</th>
<th>All cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whiteness (%)</td>
<td>-6.796</td>
<td>21.193</td>
<td>457.240</td>
<td>67.494</td>
</tr>
<tr>
<td>Chalkiness (%)</td>
<td>-29.966</td>
<td>9.456</td>
<td>-18.106</td>
<td>-1.677</td>
</tr>
<tr>
<td>Milling degree (%)</td>
<td>270.560</td>
<td>-41.373</td>
<td>-171.380</td>
<td>-142.610</td>
</tr>
<tr>
<td>Head rice (%)</td>
<td>20.036</td>
<td>88.965</td>
<td>116.530</td>
<td>100.600</td>
</tr>
<tr>
<td>Yellow and damaged grain (%)</td>
<td>-10.483</td>
<td>-4.863</td>
<td>-58.924</td>
<td>-31.634</td>
</tr>
<tr>
<td>Amylose content (%)</td>
<td>-8.154</td>
<td>-193.870</td>
<td>135.120</td>
<td>196.670</td>
</tr>
<tr>
<td>Alkali spreading value</td>
<td>1.415</td>
<td>13.894</td>
<td>34.856</td>
<td>19.637</td>
</tr>
<tr>
<td>Softness (consistency/ stickiness)</td>
<td>-95.137</td>
<td>-77.636</td>
<td>-61.892</td>
<td>-133.160</td>
</tr>
<tr>
<td>Brand name dummy</td>
<td>81.168</td>
<td>118.780</td>
<td>34.538</td>
<td>70.611</td>
</tr>
<tr>
<td>Constant</td>
<td>-675.950</td>
<td>836.470</td>
<td>-1333.100</td>
<td>-102.720</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.6282</td>
<td>0.6522</td>
<td>0.4786</td>
<td>0.4134</td>
</tr>
<tr>
<td>R-adj</td>
<td>0.5874</td>
<td>0.6162</td>
<td>0.4612</td>
<td>0.4019</td>
</tr>
</tbody>
</table>

\(^{a}\) Regression equation is in semi-log form; price of rice was used as independent variable. Significance is at the 5% level.
Characteristics of the rice market
Malaysia does not have a typical Asian rice-based economy. Rice production contributes only 1% to the gross domestic product and 5% to total agricultural value added (World Bank 1988). The rice industry is characterized by pervasive government intervention, not only through pricing policies but through a wide spectrum of regulatory measures. Rice is a controlled commodity; prices are institutionally determined and have remained virtually unchanged since 1974.

Among the three regions, Kuala Lumpur had the highest price of rice per kilogram ($0.49) and Kedah the lowest ($0.37). Better quality rice (on the basis of whiteness, head rice, translucency, and damaged grains) was found in Kuala Lumpur and Johor; that of poorer quality in Kedah. Rices sold in Kuala Lumpur and Johor were slender, with intermediate amylose content and medium alkali spreading value. Rices sold in Kedah were medium-shaped, with high amylose content and medium alkali spreading value.

More high-priced and better quality rices were found in urban than in rural markets. Urban markets sold rices with intermediate amylose content, rural markets sold rices with high amylose content. Both markets sold rice with medium alkali spreading value.

Implicit prices for quality characteristics
Percent head rice and grain shape were the most significant variables that directly affected the price of milled rice in four out of five market locations (Table 3). In all areas, the magnitude of the coefficients for percent head rice dwarfed those of the other significant variables. Amylose content was a significant price determinant in all urban markets; chalkiness and damaged grains were significant variables in only two market locations.

More quality variables significantly affected price in the surplus production area of Kedah (Table 4). In Kuala Lumpur, only head rice, grain shape, and apparent amylose content were significant. In Johor retail markets, head rice, chalkiness, and shape were the significant determinants of price.

Table 3. Stepwise regression of price on selected physicochemical characteristics of milled rice in retail markets, by area of Malaysia, 1987-88 (Wong et al. 1989).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Kedah</th>
<th>Kuala Lumpur</th>
<th>Johor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
<td>Urban</td>
</tr>
<tr>
<td>Head rice (%)</td>
<td>0.005**</td>
<td>0.003*</td>
<td>0.006*</td>
</tr>
<tr>
<td>Chalkiness (%)</td>
<td>–0.004*</td>
<td></td>
<td>–0.017**</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>0.113**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>0.182**</td>
<td>0.113**</td>
<td>0.513**</td>
</tr>
<tr>
<td>Damaged grains (%)</td>
<td>–0.010**</td>
<td>–0.012**</td>
<td>–0.033**</td>
</tr>
<tr>
<td>Amylose content (%)</td>
<td>–0.016**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.821</td>
<td>–0.037</td>
<td>–0.077</td>
</tr>
<tr>
<td>R²</td>
<td>0.715</td>
<td>0.590</td>
<td>0.685</td>
</tr>
</tbody>
</table>

** = significant at 1% level; * = significant at 5% level.
Table 4. Stepwise regression of price on selected physicochemical characteristics of milled rice in retail markets, by region in Malaysia, 1987-88 (Wong et al. 1989).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Kedah (surplus)</th>
<th>Kuala Lumpur (metropolitan)</th>
<th>Johor (deficit)</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head rice (%)</td>
<td>0.008**</td>
<td>0.006**</td>
<td>0.003**</td>
<td>0.003**</td>
</tr>
<tr>
<td>Whiteness (%)</td>
<td>0.004**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chalkiness (%)</td>
<td>−0.007**</td>
<td>−0.006**</td>
<td>−0.007**</td>
<td></td>
</tr>
<tr>
<td>Length (mm)</td>
<td>0.123**</td>
<td>0.513**</td>
<td>0.497**</td>
<td>0.448**</td>
</tr>
<tr>
<td>Shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damaged grains (%)</td>
<td>−0.011**</td>
<td>0.497**</td>
<td>−0.011**</td>
<td></td>
</tr>
<tr>
<td>Amylose content (%)</td>
<td>−0.033**</td>
<td>−0.033**</td>
<td>−0.006**</td>
<td></td>
</tr>
</tbody>
</table>

** = significant at the 1% level, * = significant at the 5% level.

The Philippines

This section summarizes the results of a consumer study by Abansi et al. (1988) covering selected rural markets of Nueva Ecija and urban markets of Manila, and a retail study by Maranan et al. (1989) covering major urban and rural markets of Manila and Nueva Ecija in Luzon, Cebu City and Iloilo in Visayas, and Davao City and Cotabato in Mindanao.

Price variation

At the national level, glutinous (waxy) varieties commanded the highest average price per kilogram ($0.52), followed by traditional varieties ($0.36), modern varieties ($0.31), and rice issued by the National Food Authority ($0.30).

Glutinous rice exhibited a very wide range of prices, from a low of $0.24/kg to a high of $1.36/kg. This was due to the inclusion in this category of both low-priced ordinary nonaromatic varieties and the high-priced special black or violet colored tapol varieties. Tapol is usually bought in small quantities and mixed with white glutinous varieties to enhance the color and flavor of some snack foods.

The traditional varieties category was also a mixture of low-priced ordinary upland varieties with poor eating qualities and expensive special upland varieties (e.g., Milagrosa, Sampaguita, and Dinorado) with distinctive flavor.

Implicit prices for quality characteristics

The Philippine component examined the impact of rice quality on prices among variety groups, among income classes, and between rural and urban markets (Table 5).

Implicit prices for quality among variety groups. Regardless of variety groups, rice consumers preferred bold, short-grained rice with low levels of impurity or damaged kernels (Maranan et al. 1989).

Preferences for whiteness and apparent amylose content differed among variety groups. Consumers of modern varieties preferred whiter rice, and were willing to pay higher prices for them. Buyers of glutinous rice would pay higher prices for colored
Table 5. Mean implicit value of rice quality characteristics for different income groups and urban and rural consumers, Manila and Nueva Ecija, Philippines, 1987 (Abansi et al 1990).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value (₱/unit)</th>
<th>Income group</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low  Medium  High</td>
<td>Urban  Rural</td>
</tr>
<tr>
<td>Whiteness (%)</td>
<td>0.01 0.01 4.03</td>
<td>0.02 0.03</td>
<td></td>
</tr>
<tr>
<td>Translucency (%)</td>
<td>– – –</td>
<td>– – –</td>
<td></td>
</tr>
<tr>
<td>Length (mm)</td>
<td>0.16 4.23 –0.44</td>
<td>–0.33 0.02</td>
<td></td>
</tr>
<tr>
<td>Foreign matter (%)</td>
<td>4.03 4.03 –0.14</td>
<td>–0.10 4.02</td>
<td></td>
</tr>
<tr>
<td>Head rice (%)</td>
<td>0.01 0.01 0.02</td>
<td>0.01 0.01</td>
<td></td>
</tr>
<tr>
<td>Apparent amylose content</td>
<td>0.08 0.02 –0.17</td>
<td>–0.08 0.08</td>
<td></td>
</tr>
<tr>
<td>Alkali spreading value</td>
<td>0.07 0.15 0.39</td>
<td>0.25 0.12</td>
<td></td>
</tr>
</tbody>
</table>

*Less than one centavo (US$1 = ₱20.57).

grains. This inconsistency can be attributed to the inclusion of the high-priced black to purple-colored tapol in the glutinous variety category.

Consumers of traditional varieties preferred low-amylose rice, which is moist, sticky, and tender when cooked. Consumers of modern varieties preferred high-amylose rice, which is dry, less tender, and flaky when cooked. This unexpected preference among consumers of modern varieties could be due to the inclusion of IR42 and IR60 in this category. These varieties have high amylose content but are considered fancy or special varieties and command higher prices.

Implicit prices for quality between urban and rural consumers. Significant differences in quantity and characteristic demanded by urban and rural consumers were found (Abansi et al 1988). Rural households consumed more rice (about 49 kg/mo) than their urban counterparts (37 kg/mo), but rural expenditure for rice was 10% lower than that of urban consumers. It can be surmised that rural households purchase cheaper rice, implying a difference in demand for quality between rural and urban consumers.

Of the physical or sensory characteristics, only preferred grain shape showed no significant difference between rural and urban consumers. Rices sold in the urban market were whiter, more translucent, and contained less foreign matter than those sold in rural markets.

Both urban and rural consumers considered percent head rice, foreign matter content, apparent amylose content, and alkali spreading value significant variables affecting the price of rice. However, the magnitude of the effect of each attribute differed between the two groups, and the economic value attached by each group to each characteristic varied. Except for amylose content, urban consumers attached higher implicit value to rice characteristics than did rural consumers (Table 5).

Both groups were willing to pay higher prices for relatively clean rice with high head rice percentage and high alkali spreading value. Urban consumers (who are usually busy) were willing to pay $0.005 for each percent reduction in foreign matter. In terms
of alkali spreading value, both urban and rural consumers preferred rice with lower cooking temperature and shorter cooking time. This was expected. Urban consumers are mostly white- or blue-collar workers who place a premium on their time. Rural consumers are mostly farmers whose time is also valuable, especially during peak labor months.

Urban consumers preferred rice with low to intermediate apparent amylose content (i.e., moist and tender when cooked, does not harden upon cooling). Rural consumers were willing to sacrifice moistness and softness for greater volume expansion, to feed a large family with less rice.

Monthly income was the only variable considered by urban consumers to significantly affect price. This implies that the desire of this group for better grade rice is translated into effective demand as purchasing power increases. Among rural consumers, age and educational attainment were significant positive determinants of price. There was no significant relationship between rural income and price perhaps because more than 70% of the rural consumers had low per capita income. The price variation between rice grades and varieties was too small to produce a definite and significant relationship.

**Implicit prices for quality among income levels.** Results of Abansi’s study indicate that consumers with higher incomes are more discriminating. High-income consumers bought rice with higher quality characteristics and attached higher implicit prices to these attributes than did low- and medium-income consumers (Table 5).

Low-income consumers preferred cleaner, high-amylose rice with high volume expansion. Medium-income consumers preferred short-grained rice with less foreign matter and shorter cooking time. High-income consumers preferred short-grained traditional varieties with high head rice recovery, less impurities, and short cooking time.

For all income levels, location was the only significant variable among the socioeconomic characteristics considered. This suggests that consumers at all income levels paid higher prices for rice in urban markets than they did in rural markets.

**Thailand**

The Thailand study was conducted in the major rice-producing provinces Bangkok, Chiang Mai, and Khon Kaen by Sriswadilek et al (1989).

**Consumer preference**

Two main groups of rice are consumed domestically in Thailand: nonglutinous and glutinous. Because of ethnic groupings and culture, nonglutinous rice is preferred by a majority of the people in the central and southern part of the country, and glutinous rice is commonly preferred in the north and northeast. The quality characteristics of nonglutinous rice sold in the central, north, and northeast are very similar. The quality characteristics of glutinous rice are the same in the north and the northeast.
Rice packed in plastic bags has become very popular, especially in Bangkok, because of its convenience.

**Characteristics of rice sold in the market**
Nonglutinous rice was more expensive ($0.31-$0.36/kg) than glutinous rice ($0.25-$0.26/kg). Nonglutinous rice contained fewer defective grains than glutinous rice. Nonglutinous rices have intermediate apparent amylose content; glutinous rice is waxy. Both quality groups possess high alkali spreading value.

**Implicit prices for quality characteristics**
More quality characteristics significantly affected the price of nonglutinous rice than that of glutinous rice. The significant negative determinants of nonglutinous rice price were broken grains, chalkiness, defective grains, and apparent amylose content: nonglutinous rice consumers were willing to pay higher prices for every unit reduction in these characteristics. The significant positive determinants of nonglutinous rice price were length, elongation ratio, and aroma (Table 6).

Packing was a significant variable for nonglutinous rice sold in Bangkok markets, but was not significant when pooled with results from Chiang Mai and Khon Kaen markets.

Only two quality variables—brokens and packaging—significantly affected the price of glutinous rice. Percent nonglutinous and alkali spreading value had negative relationships with price.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Nonglutinous</th>
<th>Glutinous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Round 1</td>
<td>Round 2</td>
</tr>
<tr>
<td>Constant</td>
<td>6.40</td>
<td>2.46</td>
</tr>
<tr>
<td>Whiteness (%)</td>
<td>–0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Broken grains (%)</td>
<td>–0.01**</td>
<td>–0.01**</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td></td>
<td>–0.10</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>0.46*</td>
<td>0.73**</td>
</tr>
<tr>
<td>Chalkiness (%)</td>
<td>–0.02**</td>
<td>–0.02**</td>
</tr>
<tr>
<td>Defective grains (%)</td>
<td>–0.14**</td>
<td>–0.05*</td>
</tr>
<tr>
<td>Glutinous rice % (other)</td>
<td>–0.07</td>
<td>–0.02</td>
</tr>
<tr>
<td>Nonglutinous (%)</td>
<td></td>
<td>–0.01</td>
</tr>
<tr>
<td>Apparent amylose content (%)</td>
<td>–0.07**</td>
<td>–0.04**</td>
</tr>
<tr>
<td>Alkali spreading value</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>Elongation ratio</td>
<td>0.31</td>
<td>0.86*</td>
</tr>
<tr>
<td>Aroma</td>
<td>0.28**</td>
<td>–0.39**</td>
</tr>
<tr>
<td>Packaging</td>
<td>0.18</td>
<td>0.19</td>
</tr>
<tr>
<td>Summary</td>
<td>363</td>
<td>412</td>
</tr>
<tr>
<td>R²</td>
<td>0.50</td>
<td>0.31</td>
</tr>
<tr>
<td>F</td>
<td>32.16**</td>
<td>16.51**</td>
</tr>
</tbody>
</table>

*Significant at the 1% (**) and 5% (*) levels.
Conclusion

In general, urban rice consumers and those with higher incomes were more discriminating, considered more quality characteristics, and attached higher implicit prices to those attributes than were rural, lower income consumers. The physical and chemical characteristics considered relevant by consumers were color, shape, foreign matter content, percent head rice, amyllose content, and alkali spread.

The results of different country studies underscore the potential usefulness of the hedonic approach in examining consumer tastes and preferences through estimations of implicit prices for different quality characteristics. Identification of the physico-chemical attributes valued by consumers would help identify the equity and efficiency issues that would result from potential economic, engineering, and genetic solutions to achieving the quality characteristics demanded in domestic and world markets.

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Notes

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Parboiling is the pregelatinization of the rice grain within its hull. More than 50% of the rice produced in South Asia is parboiled. The process involves soaking the rice to saturation, steaming the grain (without much volume expansion), and drying the steamed rice to around 14% moisture. Parboiling changes the grain properties, makes the grain harder, and gives a higher milling outturn than raw rice. A characteristic color and smell are developed. Parboiled rice takes longer to cook than raw rice, and the cooked rice is harder and fluffier. Parboiled rice retains more proteins, vitamins, and minerals during milling and loses fewer solids than raw rice during cooking. The parboiling process may be accomplished by traditional, improved, or modern methods. The traditional method is used mainly for grain for home consumption, the improved method primarily for trade. Modern processing systems produce milled rice of excellent quality, but are not yet widely used because of high investment costs. In South Asia, consumer demand for parboiled rice quality does not vary much from country to country. Grain size and shape, appearance of milled rice, translucency, amber color of milled rice, percentage broken grains, and cooked rice hardness and fluffiness influence consumer preferences.

Parboiling is a hydrothermal treatment of rice that pregelatinizes the grain within its hull. It is not known when, where, or why this practice began, but it is known to have existed in ancient India (Ramiah 1937). Parboiling may have been introduced to avoid breakage during milling and to make freshly harvested rice less sticky when cooked. Another advantage, improvement of nutritional quality, was unplanned.

About 20% of the rice produced worldwide, and more than 50% of all rice produced in South Asia, is parboiled (Bhattacharya 1985). Bangladesh produced 15.5 million t of cleaned rice in 1987-88 (BBS 1989); more than 90% of it was parboiled. Consumers in 56 of the 64 districts of that country traditionally have preferred parboiled rice (Fig. 1).

About 60% of the total rice production in India is parboiled, predominantly in Kerala, Tamil Nadu, Orissa, Assam, Bihar, and West Bengal States (Pillaiyar, 1990,

Sri Lanka is also a parboiled-rice consuming country, with more than 60% of its rice parboiled (Ekanayaka, 1990, pers. comm.; Fernando, 1990, pers. comm.). The people of Western, Sabaragammuwa, Wayamva, Central, North Central, and Northeast Provinces consume parboiled rice.

In Nepal, parboiled rice is consumed by the people living on the border with India. No more than 25% of the country’s rice is parboiled.

Of the relatively low amount of rice consumed in Pakistan, only 8% is parboiled.

The descendants of Indian immigrants in West Africa and the Caribbean use parboiled rice. Parboiling has been practiced on a commercial scale in the United States, Italy, and Guyana since 1940 (Matz 1959).
Parboiling process

Parboiling involves three steps: soaking rough rice, steaming soaked rice, and drying steamed rice (Fig. 2). The process can be accomplished by various methods (Ali and Ojha 1976, Bhattacharya 1985).

In South Asia, the traditional method is used predominantly to parboil rice for domestic use. More than 70% of the rice is processed by this method. The improved method is used by commercial millers who process rice for traders who buy raw rice from the market and sell milled rice to the consumer. About 20% is processed by this method. Modern parboiling and milling systems were introduced a few years ago, but are not widely popular because of their large capacity and high initial cost. Not more than 10% of the parboiled rice is processed by this method.

Ali and Ojha (1976) estimated that the cost of parboiling and drying using modern and conventional methods were similar. Pillaiyar (1990, pers. comm.) reported that the modern method costs more than the traditional method.

Traditional method

Farmers in rural areas of Bangladesh, India, Nepal, and Sri Lanka soak rice at ambient temperature. Soaking time differs, depending on the age of the rice, but is usually overnight. Aged rice is soaked longer than freshly harvested rice. The soaked rice is put inside an earthen or metal pot and heated in an oven. About 25% of the grains remain immersed in water inside the pot. That water boils and generates steam. The grains that are immersed are parboiled by the boiling water, those above the water level are parboiled by the steam generated. Parboiling ends when the husks of the top grains in the pot open. The parboiled rice is then dried in the sun and milled in huller mills.

Improved method

Commercial rice traders process rice by placing it in a parboiling kettle with a cone-shaped bottom (Fig. 2). Steam is passed through the grains for a few minutes. The heated grains are then removed through the bottom of the drum to a tank and soaked overnight. The soaking water absorbs heat from the grains and remains warm for several hours, enhancing water absorption.

The soaked rough rice is transferred back to the drums and steamed for a few minutes, until the hull opens. The grains are spread on a cement floor to dry under the sun, and are milled in huller mills.

**Modern methods**

Some modern parboiling methods include the Central Food Technological Research Institute (CFTRI) process, the Jadavpur University process, the improved process in Thailand, the Avorio process, the crystal rice process, and the rice conversion process. The first two methods are more generally practiced in South Asia. Rice is soaked at high temperature (60-62 °C) for 3-4 h. The water is drained off and the soaked rice steamed under partial pressure for 2-5 min. The rice is dried in a mechanical dryer. The parboiled rice is husked by a low power disk huller or a rubber roller and milled by a cone-type polisher.

**Changes during parboiling**

Changes in the properties of rice during parboiling have been described by Ali and Ojha (1976) and Bhattacharya (1985). Milled parboiled rice is slightly shorter and broader than milled raw rice. It is glassy, translucent, and shiny. The grain is more compact and harder. Chalkiness and opaqueness disappear without a change in grain density.

Parboiling affects milling quality (Ali and Ojha 1976). The hull is easier to remove but, because the grain becomes harder after parboiling, a longer time or greater force is needed to mill it. This greater energy requirement is one disadvantage of parboiling.

Head rice recovery improves dramatically. If rice is properly soaked, steamed, and dried, breakage can be reduced to almost zero. Broken grains that are found in milled parboiled rice result mostly from improper drying, although incomplete steaming may also result in breakage.

The cooking properties of parboiled rice are different. Water uptake is slower than with raw rice, and it takes longer to cook parboiled rice to the same degree of softness. Parboiled rice can absorb more water without disintegrating, resulting in greater volume expansion. The cooked rice is firm, fluffy, and nonsticky. Parboiled rice expands less in length and more in breadth, giving it a coarser look than cooked raw rice.

Cooked parboiled rice has a better chewing quality because of its hard texture. This chewiness is preferred by parboiled rice consumers, but people who prefer cooked raw rice find parboiled rice too firm to mix with curry. In preference tests, parboiled rice is considered acceptable or superior, even by raw rice consumers.

The nutritional quality of parboiled rice is higher than that of raw rice. Vitamins have diffused inward, escaping loss during milling. More vitamins are retained during cooking. The mineral content of parboiled rice is higher than that of raw rice. In vitro protein digestibility also increases, although Eggum et al (1977) reported lower digestibility of parboiled rice protein than of raw rice protein by rats in in vivo tests.
Consumer demand

Consumer preferences for a particular rice grade depend on both intrinsic and acquired qualities (Table 1). Consumer demand for either raw or parboiled rice depends first on size, shape, and appearance, then on cooking property and taste. Milled parboiled rice is translucent, bright, and shiny. Its characteristic color and smell are preferred properties.

Consumer demand is reflected by price. The higher the price, the greater the demand. In a survey in Bangladesh to determine the influence of grain properties on market price, grain size and shape, broken grains, appearance, and cooked rice hardness and fluffiness influenced consumer demand (Choudhury et al 1989). Consumer demand for different qualities of parboiled rice does not appear to vary much among South Asian countries, although data on consumer preference is meager. Most of the information available comes from casual personal communication and observation.

Bangladesh

Parboiled rice in Bangladesh is predominantly processed in traditional systems, followed by improved systems. Very little rice is processed in modern mills (Afsar, 1990, pers. comm.; Haque et al 1985). The milled rice produced by the traditional systems has acceptable quality, but is not well liked by consumers because of its dull properties.

Table 1. Some rice properties that influence consumer preference.  

<table>
<thead>
<tr>
<th>Grain characteristic</th>
<th>Expected influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance score</td>
<td>+</td>
</tr>
<tr>
<td>Brightness score</td>
<td>+</td>
</tr>
<tr>
<td>Polish score</td>
<td>+</td>
</tr>
<tr>
<td>Chalkiness score</td>
<td>–</td>
</tr>
<tr>
<td>Length (L) (mm)</td>
<td>+</td>
</tr>
<tr>
<td>Breadth (B) (mm)</td>
<td>–</td>
</tr>
<tr>
<td>L/B ratio</td>
<td>+</td>
</tr>
<tr>
<td>1,000-grain wt (g)</td>
<td>–</td>
</tr>
<tr>
<td>Weight/length</td>
<td>–</td>
</tr>
<tr>
<td>Contrasting grains (%)</td>
<td>–</td>
</tr>
<tr>
<td>Yellow grains (%)</td>
<td>–</td>
</tr>
<tr>
<td>Brokens (%)</td>
<td>–</td>
</tr>
<tr>
<td>Damaged grains (%)</td>
<td>–</td>
</tr>
<tr>
<td>Black or pecky grains (no./100 g)</td>
<td>–</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>–</td>
</tr>
<tr>
<td>Alkali spreading value</td>
<td>–</td>
</tr>
<tr>
<td>Equilibrium water content</td>
<td>–</td>
</tr>
<tr>
<td>Gel consistency (mm)</td>
<td>+/-</td>
</tr>
<tr>
<td>Amylose (%)</td>
<td>+</td>
</tr>
<tr>
<td>Cooking time (min)</td>
<td>–</td>
</tr>
<tr>
<td>Elongation ratio</td>
<td>+</td>
</tr>
<tr>
<td>Imbibition ratio</td>
<td>+</td>
</tr>
</tbody>
</table>

color (Table 2). Even so, farmers process their own rice this way, to use family labor. The improved rice mills produce the better quality milled rice preferred by retail consumers. Although the modern rice mills produce the best quality milled rice, it is not as acceptable as the rice from improved rice mills because the rice from modern mills has an unpopular deep amber color.

The influence of grain properties on consumer demand in Bangladesh is shown in Table 3 (Afsar, 1990, pers. comm.; Choudhury et al 1989). Grain size and shape influence consumer demand most. Appearance and translucency of parboiled rice are important. Broken grains, amber color, and cooked rice fluffiness and hardness also influence consumer demand. Color is more important in parboiled rice than in raw rice.

India
About 60% of the total rice production in India is parboiled. The traditional processing system predominates, although some rice is processed in modern rice mills. The best quality rice is produced by the traditional system and is best-liked by consumers (Table 2).

Information on the influence of the different grain properties on consumer demand in India shown in Table 3 was supplied by Pillaiyar (1990, pers. comm.). Grain size and shape influence consumer preference for parboiled rice least. Broken grains, grain translucency, and cooked rice hardness have great influence on consumer preference. Amber color of parboiled grain and cooked rice fluffiness have little influence.

Pakistan
In Pakistan, parboiled rice is processed mostly by the improved traditional method. No more than 10% of processed rice comes from modern rice mills. The quality of rice produced in the modern rice mills is better than that produced in the traditional mills (Table 2). People also prefer rice processed by modern mills.

Information on the influence of different grain properties on consumer preference in Pakistan shown in Table 3 was supplied by the Rice Research Institute in Punjab (RRIP, 1990, pers. comm.). Grain size and shape and cooked rice fluffiness influenced

<table>
<thead>
<tr>
<th>Country</th>
<th>Traditional</th>
<th>Improved</th>
<th>Modern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quality</td>
<td>Preference</td>
<td>Quality</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>India</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3. Influence of rice quality characteristics on consumer preference.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Quality characteristic</th>
<th>Bangladesh Raw</th>
<th>Parboiled</th>
<th>India Raw</th>
<th>Parboiled</th>
<th>Pakistan Raw</th>
<th>Parboiled</th>
<th>Sri Lanka Raw</th>
<th>Parboiled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size and shape</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Broken</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Appearance</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Translucency</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Amber color</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cooked rice</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fluffiness</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>


consumer preference the most. Grain appearance and translucency influence preference for parboiled rice more than that for raw rice. Broken grains and cooked rice hardness have the least influence. The amber color of parboiled grain influences consumer preference.

**Sri Lanka**

Most parboiled rice in Sri Lanka is processed by traditional and improved methods. Some rice is processed by modern rice mills. The best quality is produced in the modern rice mills and is most liked by the people (Table 2). The traditional system produces rice with acceptable quality, although the quality produced in the improved mills is better.

The information on the influence of grain properties on consumer preference given in Table 3 was supplied by Fernando (1990 pers. comm.) and Ekanayake (1990, pers. comm.). Grain size and shape, broken grains, appearance, and amber color have the most influence on consumer preference for both raw and parboiled rice. Grain translucency and cooked rice fluffiness have the least influence.

**Nepal**

Many people in Nepal consume parboiled rice, but detailed information about parboiling systems and consumer preference could not be obtained. It appears that most of the parboiled rice is processed by the traditional method.

**References cited**


Notes

Author’s address: N. H. Choudhury, Grain Quality and Nutrition Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh.

Citation information: International Rice Research Institute (1991) Rice grain marketing and quality issues. P.O. Box 933, Manila, Philippines.
Rice grain quality as an emerging priority in national rice breeding programs

B. O. Juliano and B. Duff

Grain quality includes not only the traditional physical and visual properties of the rice grain but also cooked rice texture as indexed by apparent amylose content, alkali spreading value (index of gelatinization temperature), gel consistency, actual texture measurement of cooked grain, and protein content (nutritional value). Texture measurement is done primarily to verify amylose classification, but instrument methods are not sensitive enough to differentiate cooked rice within the same amylose type, as do sensory evaluation and processing. Consumer demand studies show wide diversity in grain quality characteristics preferred. They are useful in setting priorities in a grain quality breeding program. A 1990 survey verified that grain quality is one of the major objectives, if not the major objective of national rice breeding programs in countries that are self-sufficient in rice production. Rice grain quality may be affected by variety, environment, and processing. Many national programs have characterized the grain quality of popular varieties and their germplasm collection entries. Asian food scientists have been characterizing the properties of varieties most suitable for traditional rice products, to improve product quality and shelf life and to provide value added and employment in the rural areas. Mutants and transgenic rices obtained from biotechnology may also need to be screened for possible alteration of grain quality. Strong national programs are expected to play a major role in research related to grain quality evaluation as IRRI shifts its research emphasis from grain quality to the biochemistry of the rice plant, including the grain.

Physical and visual properties of the rice grain—grain size and shape, head rice, translucency—traditionally have been integral objectives of national rice breeding programs. The use of varietal parents of diverse cooking and eating qualities in the breeding programs of the 1960s led to chemical screening for apparent amylose content (Juliano et al 1981b), alkali spreading value, or starch gelatinization temperature (Little et al 1958), gel consistency (Cagampang et al 1973), and protein content (Juliano 1982). Cooked rice texture is assessed, using sensory and instrument methods, to verify chemical tests (Juliano et al 1981a, 1984).
Table 1. Priority given to grain quality, yield potential, and other plant properties in some national rice breeding programs. IRRI, 1990.

<table>
<thead>
<tr>
<th>Country</th>
<th>Grain quality</th>
<th>Yield potential</th>
<th>Resistance</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Disease</td>
<td>Insects</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>China</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Taiwan, China</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Japan (Super Rice Program)</td>
<td>1.5</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Korea (Suwon)</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Korea (Milyang)</td>
<td>6</td>
<td>3.5</td>
<td>3.5</td>
<td>1</td>
</tr>
<tr>
<td>Madagascar</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Malaysia (overall)</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grain quality</td>
<td>3</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Myanmar</td>
<td>2.5</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Philippines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Upland</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Thailand</td>
<td>2.5</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>USA</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>33.5</td>
<td>38.5</td>
<td>19.5</td>
<td>12</td>
</tr>
</tbody>
</table>

*aHighest number indicates highest priority.  
*bImprovement of cultural practices.
As increasing numbers of rice-producing countries attain self-sufficiency, grain quality has become an important rice breeding objective in national research programs (Table 1). Only yield and disease and pest resistance had higher priority than grain quality in 10 countries surveyed.

Because many promising lines have highly similar starch properties, amylose content cannot be used as a quality index. Methods measuring texture characteristics of cooked rice had to be used to index quality. But current instrument methods are not as sensitive as sensory tests (Del Mundo et al 1989). Paired samples differing in sensory evaluation of cooked rice texture are given in Table 2.

Rice grain quality can be affected by variety, environment, and processing (Juliano and Duff 1989) (Table 3). Environmental and handling conditions during ripening, harvest, postharvest, and processing can enhance or impair grain quality. Processing also increases the price of rice.

### Consumer demand and quality studies

Rice demand and consumption patterns are extremely diverse and dynamic. Over the last 30 yr, per capita rice consumption has declined in Japan, Taiwan, Singapore, Malaysia, and Thailand (Huang et al 1990). Consumption has increased in China, Indonesia, Korea, and the Philippines. Per capita consumption in India and Pakistan has remained nearly constant. As total expenditure levels increase, consumption shifts include substitution of rice for coarse grains (Korea), of wheat for rice (Bangladesh), and higher- for lower-quality rice.

Growth in income only partially explains the change in rice consumption. Structural transformation and urbanization raise the opportunity cost of labor, making preparation of traditional foods costly and time-consuming (Bouis 1990). Urban families in

### Table 2. Examples of pairs of rices within the same amylose-gelatinization temperature type that differ in sensory texture measurements.

<table>
<thead>
<tr>
<th>Amylose-gelatinization temperature type</th>
<th>Variety name</th>
<th>Texture of cooked rice and source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate amylose and intermediate GT</td>
<td>C4-63 and IR64 Lemont and Newbonnet</td>
<td>IRRI: IR64 is softer US: differences in thickness and processing behavior</td>
</tr>
<tr>
<td>Low amylose and low GT</td>
<td>Akibare (japonica) and Milyang 29 (indica/japonica)</td>
<td>Korea: japonica rice is softer</td>
</tr>
<tr>
<td>Waxy and low GT</td>
<td>Mochigorne and Calmochi Malagkit Sungsong and IR29 Japonica and indica Niaw San Pahtawng and RD6</td>
<td>US: Calmochi is inferior for cakes IRRI: IR29 is less tacky Taiwan, China: japonica is more sticky but less tender than indica Thailand: RD6 is softer</td>
</tr>
</tbody>
</table>
Table 3. Effects of environment, processing, and variety on rice grain qualities\(^a\) (Juliano and Duff 1989).

<table>
<thead>
<tr>
<th>Postharvest process or grain property</th>
<th>Environment</th>
<th>Processing</th>
<th>Varietal effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>+</td>
<td>+</td>
<td>Growth duration, photoperiod, degree of ripening, dormancy</td>
</tr>
<tr>
<td>Threshing</td>
<td>+</td>
<td>+</td>
<td>Threshability, shattering</td>
</tr>
<tr>
<td>Drying</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Yellowing</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Storage/aging</td>
<td>+</td>
<td>+</td>
<td>Waxy ages less than nonwaxy does.</td>
</tr>
<tr>
<td>Parboiling</td>
<td>+</td>
<td>+</td>
<td>Gelatinization temperature</td>
</tr>
<tr>
<td>Pecky grain</td>
<td>+</td>
<td>+</td>
<td>Stink-bug resistance</td>
</tr>
<tr>
<td>Dehulling</td>
<td>0</td>
<td>+</td>
<td>Hull tightness and content</td>
</tr>
<tr>
<td>Milling</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Consumer demand</td>
<td></td>
<td></td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Size and shape</td>
<td>+</td>
<td>0</td>
<td>Genetically determined</td>
</tr>
<tr>
<td>Degree of milling (whiteness)</td>
<td>+</td>
<td>+</td>
<td>Depth of grooves</td>
</tr>
<tr>
<td>Head rice</td>
<td>+</td>
<td>+</td>
<td>Crack resistance</td>
</tr>
<tr>
<td>Translucency</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Aroma</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Foreign matter</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Shelf life</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Cooking and eating qualities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amylose content(^b)</td>
<td>+</td>
<td>0</td>
<td>Volume expansion and texture</td>
</tr>
<tr>
<td>Gelatinization temperature(^c)</td>
<td>+</td>
<td>0</td>
<td>Cooking time</td>
</tr>
<tr>
<td>Gel consistency(^d)</td>
<td>+</td>
<td>0</td>
<td>Cooked rice hardness</td>
</tr>
<tr>
<td>Texture of cooked rice</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Grain elongation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

\(^a\) with effect: 0 = no effect. \(^b\) Colorimetric iodine assay: waxy 0-2%, low 10-20%, intermediate 20-25%, and high >25% dry basis. \(^c\) Indexed by alkali spreading value: low 6-7, intermediate 4-5, high-intermediate 3, and high 2. \(^d\) Soft 61-100 mm, medium 41-60 mm, and hard 25-40 mm.

which both spouses work and spend significant periods commuting have more demand for convenience foods. The result has been increased demand for prepared foods, including convenience packing. Over time, urbanization increases the proportion of wheat products in the diet, while consumption of traditional rice dishes declines. Improved communications and enhanced marketing infrastructure strengthen the demonstration effect resulting from adoption of convenience food patterns and may affect the composition of both urban and rural diets.

Increasing commercialization of semisubsistence agriculture also will produce more diversified diets, as farm families acquire increased purchasing power to buy a broader range of both traditional and nontraditional foods in the market.

Consumer demand studies are useful in verifying the relative importance or priority given various rice grain properties in a breeding program. Unnevehr et al (1985) applied the hedonic model to quantify consumer demand for rice grain quality characteristics (Juliano and Gonzales 1989); that has been verified in studies of more extensive retail markets of raw rice in Southeast Asia (AGPHP 1989) and Madagascar.
(Andrianilana et al 1990), parboiled rice in Bangladesh (Choudhury et al 1989), and rice in international markets (Hongkong, Rome, and Bonn) (Juliano et al 1990a). Now breeding and research efforts can be devoted to more economically important grain properties.

Many national programs have characterized the grain quality of their popular rice varieties and germplasm collection entries. In China, for example, 100 varieties of superior quality rice recommended in 24 provinces and varieties cultivated in more than 6,600 ha have been characterized. The 25,000 entries in the China rice germplasm bank are also being analyzed. Standards for high grain quality were approved by the Chinese Ministry of Agriculture in 1988 (Y. K. Luo, pers. comm.). Variety samples from 46 countries are also analyzed periodically at IRRI (Juliano and Pascual 1980). Preferences for grain quality types are summarized in Table 4. IRRI chemists also have completed analyses of amylase content and gelatinization temperature of about 30,000 entries in the International Rice Germplasm Center (IRGC).

Instrumentation for rice grain quality assessment has produced color measuring units, such as the Minolta Chroma Meter CR-110, Riken-Sanno Rice meter for grain translucency, and near-infrared reflectance spectrosopes for amylase/amylopectin (Satake 1989a, Bean et al 1990), and the Japanese quality rating of milled rice (Satake 1989b). The applicability of the Japanese machines to tropical rice needs to be verified.

Table 4. Preferred apparent amylase rice type in some rice-producing countries that contribute 0.1% or more to total world rice production. IRRI, 1990.

<table>
<thead>
<tr>
<th>Countries expressing preference for indicated amylase rice type</th>
<th>Waxy</th>
<th>Low</th>
<th>Intermediate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laos, Thailand (north)</td>
<td>China (japonica)</td>
<td>Cambodia</td>
<td>Bangladesh</td>
<td></td>
</tr>
<tr>
<td>Thailand (north)</td>
<td>Taiwan, China (japonica)</td>
<td>China (japonica)</td>
<td>China (indica)</td>
<td></td>
</tr>
<tr>
<td>China (japonica)</td>
<td>Japan</td>
<td>India (Basmati)</td>
<td>India (coarse)</td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td>Indonesia</td>
<td>Malaysia</td>
<td>Pakistan (coarse)</td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>Myanmar</td>
<td>Pakistan (Basmati)</td>
<td>Philippines</td>
<td></td>
</tr>
<tr>
<td>Thailand (northeast)</td>
<td>Thailand (central)</td>
<td>Philippines</td>
<td>Sri Lanka</td>
<td></td>
</tr>
<tr>
<td>Armenia</td>
<td>Vietnam</td>
<td>Thailand (north, central, south)</td>
<td>Thailand (north, central, south)</td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>Brazil (upland)</td>
<td>Cuba</td>
<td>Brazil (upland)</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Spain</td>
<td>Italy</td>
<td>Cuba</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>USA (short, medium)</td>
<td>Ivory Coast</td>
<td>Italy</td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td>USSR</td>
<td>Liberia</td>
<td>Ivory Coast</td>
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<td>Guinea</td>
<td>Indonesia</td>
<td>Madagascar</td>
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<td>Peru</td>
<td>Nepal</td>
<td>Nigeria</td>
<td>Madagascar</td>
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<tr>
<td>Brazil (irrigated)</td>
<td>Philippines</td>
<td>USA (long)</td>
<td>Nigeria</td>
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</table>

aData from China National Rice Research Institute. bData from International Institute of Tropical Agriculture.
International trade

World trade in rice is less than 5% of total production, and the export market is highly competitive. Nontraditional exporting countries have difficulty entering. For example, Thai jasmine rice (Khao Dawk Mali type) is the premium rice in Hong Kong (Juliano et al 1990a) and annually, 100,000 t are exported to the U.S. Now, Australia and the U.S. have developed similar long-grain, low-amylose, aromatic ices that compare with jasmine rice.

The International Organization for Standardization (ISO 1988) recently adopted standard rice specifications and an FAO Codex Alimentarius committee is meeting in Washington, D.C., in October 1990 to consider international standards for rice. Recent collaborative studies on variety identification have demonstrated the applicability to rice quality differentiation of reversed-phase, high-performance liquid chromatography of acetic acid extracts of brown rice (Hussain et al 1989); prolamin (alcohol-soluble protein) (Lookhart et al 1987); and glutelin (alkali-soluble protein) of milled rice (Huebner et al 1990) and polyacrylamide gel electrophoresis in aluminum lactate buffer of acetic acid extracts of brown rice (Hussain et al 1989). The prolamin method successfully differentiates U.S. and Thai rices (Anonymous 1989). Analysis of the aroma principle 2-acetyl-1-pyrroline (Buttery et al 1983) has been used to verify the authenticity of the Basmati label on imported rice samples in the U.S.

Quality of rice products

National programs have been studying ways to improve the quality and shelf life of traditional and new rice products, to generate income and employment in the rural area and to increase rice consumption (Hirao 1990, Husain and Husin 1988, Imai 1990, Juliano and Hicks 1990, Maneepun 1987, PhilRice 1989, Yokoo 1990). Methods used to screen for table quality are also applicable to evaluating parboiled rice (Unnikrishnan and Bhattacharya 1987, Biswas and Juliano 1988) and processed rice products (Juliano and Hicks 1990). The use of 20% gelatinized starch in place of wheat gluten as binder for bread without wheat (Satin 1988) follows the same principle as that of surface-gelatinized rice batter balls for noodle extrusion (Juliano 1985).

The International Rice Commission 17th Session, Goiania, Brazil, 4-9 Feb 1990, recommended further development work that will ensure consumer acceptance and promote utilization of processed rice products. The IUFOS/Technical Advisory Committee of the CGIAR/International Agricultural Research Centers Symposium on Crop Utilization 11-13 Dec 1989 strongly recommended that international agricultural research centers give equivalent consideration to qualities of utility as is given to desirable agronomic characters. IRRI plans to do some work on processed rice product quality (varietal suitability) as part of its postharvest project.
Nutritional value

New mutants, transgenic plants, and lines from wide crosses being generated in breeding programs should also be checked for desirable and undesirable grain characters. For example, transgenic plants with the trypsin inhibitor gene may also have this protein in the embryo and aleurone layer (maternal tissue) of the grain. Incorporation of the maize Y1 (endosperm ß-carotene) gene (Buckner and Robertson 1990) or the tomato phytoene (provitamin A carotenoid) gene (Cheung and Kawata 1990) into rice grain would help reduce the incidence of vitamin A deficiency in Asia (vitamin A is also considered an anticancer agent) (Ziegler 1989). However, a nonpigmented precursor is needed to reduce consumer objection to yellow-endosperm rice.

The starch digestion rate of cooked milled rices measured by glycemic index is inversely affected by amylose content (Juliano and Goddard 1986, Juliano et al 1989) and is further reduced by parboiling and noodle extrusion (Panlasigui 1989, Juliano et al 1989). The amylose extender mutant of IR36 has more than 40% amylose and 0.5% higher lysine content in its protein (Juliano et al 1990b). Given its very high amylose content, it may be ideal for the production of extruded rice noodles. This mutant may also have a lower glycemic index than IR36. Differences in glycemic index between low-amylose and waxy rices are not significant (Juliano and Goddard 1986, Jiraratsatit et al 1987).

With the demonstrated hypocholesterolemic effect shown in hamsters (Kahlon et al 1990) and preliminary results in humans (Gerhardt and Gallo 1989), demand for and consumption of stabilized full-fat rice bran have increased dramatically in the U.S. Any impact in Asia awaits improvement of the purity of locally processed rice bran, freeing it from hull contamination.

Role of national programs

Second-generation problems of rice grain quality are more complicated than previous ones, and require differentiation among lines with similar starch properties. More sensitive screening methods for cooked rice texture are needed. Many national rice and food science research programs are advanced enough to take the lead in grain quality research. This has been a key factor in the successful symbiotic relationship in grain quality research by national programs, IRRI, and advanced institutions. Grain quality research at IRRI is planned to terminate by December 1992, in order to emphasize biochemistry. National programs must now evaluate their role in grain quality research.

Conclusion

National programs have increased efforts in breeding for rice grain quality, and projects now include characterization of important varieties and selected germplasm entries.
Grain quality problems, however, have become more complicated as screening has shifted from physical/visual properties to physicochemical properties (amylose content, etc.) and to texture properties of cooked rice.

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Notes

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Knowledge of preferences for rice grain quality in various countries is important to rice breeders and national breeding programs. The considerable knowledge available on the high quality rices of different countries should be correlated with a data base on the physicochemical properties of milled rice, including length-to-width ratio. IRRI has information on the physicochemical properties of milled rice of popularly grown varieties in about 60 countries. This should be expanded into a data base that includes quality characteristics of popular varieties grown in national programs.

Classification of varieties as indicas or japonicas on the basis of grain dimensions and physicochemical properties of milled rice is no longer reliable. The classification into six groups on the basis of allelic combinations at 14 isozyme loci as suggested by Glaszmann (J. C. Glaszmann, Isozymes and classification of Asian rice varieties. Theor. Appl. Genet. 74:21-30 [1987]) is more useful for breeders. Javanicas and tropical upland rices belong to group 6, along with japonicas. Intergroup crosses show sterility and restriction to recombination. The group to which the parents being used in a grain quality improvement program belong should be considered, to avoid hybrid sterility and intergroup barriers to recombination.

Bottlenecks to grain quality improvement in national programs include:
- Multiplicity of breeding objectives.
- Lack of infrastructure for grain quality evaluation.
- Lack of well-defined selection criteria.

The consumer demand study using the hedonic model should identify the grain properties for which consumers will pay a premium price. In countries where the range of amylose content of breeding lines is already narrow, the cooked rice texture method may no longer be sensitive for screening for texture differences. Genetic diversity for amylose content should be encouraged.

For improving the milling yields and head rice recovery, special attention should be paid to crack resistance and increased tolerance for moisture absorption stress. Milling yields could also be improved through selection for lower hull weight. Hulling percentage in different varieties varies from 14 to 28%.
Aroma is an important quality characteristic of high-quality rices. In most countries, aromatic rices command higher prices on the domestic market. In the international markets, Basmati and Jasmine rices command premium prices. Demand for the Jasmine rices of Thailand has been increasing steadily. No high-yielding aromatic varieties have been developed so far. This may be due to the low priority given this trait in breeding programs, and to problems of intergroup incompatibility. Basmati and many aromatic rices belong to group 5. Crosses of group 5 varieties with improved indicas belonging to group 1 do not yield good progenies. Efforts should be made to identify aromatic rices that belong to group 1, to use as donors for aroma. Khao Dawk Mali from Thailand is one such variety with potential as a parent.

International standards for rice grain classification are important. The FAO/WHO Codex Alimentarius Commission study nearing completion should be welcomed by national programs.

Priority research areas for multinational collaborative research on rice grain quality should be identified by national grain quality research teams.

(Prepared by G. S. Khush [moderator] and B. O. Juliano [rapporteur], on the basis of concluding discussions)