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Tropical Agricultural Research Vol. 11 1999, 308-323

An Assessment of Effect of Rice Quality Characteristics on Market Prices: A Hedonic Pricing Model

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ABSTRACT. *Profitability of rice farming in Sri Lanka has been declining and local rice would face severe competition with trade liberalization. Improvement of both yield and quality of rice may be necessary to ensure profitability in rice farming. Quality improvements in rice require details of consumer preferences for different physical characteristics. Objective of this research is to assess the consumer preference for physical quality characteristics of rice. Hundred and ninety four rice samples were collected from four cities and their physical characteristics were measured in a laboratory. The data were used to estimate three regression models.*

Head rice percentage and impurities, respectively, affect price of rice positively and negatively. Whiteness affects the price negatively only for raw rice. Length and shape affect the price only in raw rice. The highest marginal effect on price is attributed to brand name, samba, in parboiled rice. Chalkiness negatively affects the price of parboiled rice. There are significant differences in preferences for quality characteristics in parboiled and raw rice. Therefore, breeders should incorporate relevant characteristics separately for parboiled and raw rice. Certain quality characteristics are determined by post harvest handling and processing. Therefore, coordination between breeders and rice processors is necessary to assure quality.

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INTRODUCTION

Rice production in Sri Lanka showed a remarkable increase during the past four decades due to provision of irrigation water, improved varieties, better cultural practices and increased agrochemical applications (Gunatilake and Ahmed, 1996). Despite the improvements in productivity, profitability of rice farming showed significant declines in recent times (Weerahewa and Abeygunawardena, 1989, Department of Agriculture, 1998). Per ha yield of rice also has reached a plateau indicating a need for a biotechnological revolution (Gunatilake and Ahmed, 1996). This situation may be aggravated further due to trade liberalization. Rice farmers will have to face intense competition with imported rice coming from Asian countries, which have comparative cost advantages. Developing rice varieties, which capture better market prices in addition to higher yields, may ensure profitability and help coping-up with this situation.

Rice breeders have emphasized yield as their main breeding objective in the past. The grain quality has been given a secondary importance. The free and subsidized rice ration system which existed in Sri Lanka was not conducive for creating an effective demand for better quality rice. The higher proportion of population, which received free and subsidized rice ration, was compelled to consume whatever rice was given to them. Thus, free rice rations have contributed to general disregard for quality of rice. However, from the beginning of 1978 the proportion of the population receiving free or subsidized rice rations was reduced to a minimum. This resulted in more rice being purchased in the open market. The recent increases in per capita incomes together with the above described other developments have created a growing consumer demand for physical purity as well as for better intrinsic quality in rice (Kotagama and Kumara, 1996).

Breeding research is often carried-out by government research institutes. Unlike market institutes, government agencies are not subjected to the checks and balances and feed back reactions of the market. This leads to government failures such as internalities and private goals, redundant and rising costs, derived externalities and distributional inequity (Wolf, 1986). As a result of these failures research outcomes, which are not market-driven, may not be useful for farmers. Nevertheless, since research outcomes are quasi-public goods, markets will under-provide such goods. Therefore, government agencies will have to generate research information, under most circumstances. One way to reduce government failures in breeding research is to carry out well designed market research and use the findings of such research for long-term planning. Although sensory evaluations by laboratory and consumer panels give some indications on important criteria for rice quality, they do not necessarily reflect the consumer preferences. Rice breeders can target attributes that are preferred by consumers in breeding programs by identifying the quality characteristics valued by consumers. The objective of this research is to identify the consumer preferences for grain quality characteristics of rice so that rice breeders can use the findings for their long-term planning.

Kotagama and Kumara (1996) have conducted a study on the economics of rice grain quality in Sri Lanka using a hedonic price model. Their findings suggest that percentage head rice, shape of milled rice and aroma of cooked rice are positively related, while the grain length and gloss of cooked rice are negatively related to the price. Although this study has contributed to the literature as a pioneering study conducted in Sri Lanka, it has collected 31 samples of rice from only the Kandy market. Therefore, generalizability of the findings for the whole island may be limited. The present study uses a representative sample covering different regions. Also the Kotagama and Kumara (1996) study has not separated the rice quality characteristics for parboiled and raw rice. The present study assesses the rice quality characteristics separately for the two types. Moreover, the present study examines the incremental contribution of the brand name to the price, which has not been studied earlier.

THEORY

Among the relevant previous studies, Dhrymes (1967) and Ladd and Suvannunt (1976) developed the basic theoretical framework on demand for consumer goods characteristics. Cowling and Rayner (1970) extended the basic theory model to include brand names in addition to quality characteristics. Brorsen *et al.* (1984) applied the theoretical model for bid/acceptance rice market in the USA. Toquero (1991) provides a summary of rice quality characteristics studies conducted in Asia. The basic theory says that consumers buy different products because they provide utility. The utility provided by a product depends upon the product characteristics. The total amount of utility a consumer enjoys from his purchase of products depends upon the total amount of product characteristics purchased. At the equilibrium the price paid by consumer equals the sum of marginal monetary values of the product characteristics. The marginal monetary value of the product characteristic is the product of the marginal unit of characteristic in the commodity and the marginal implicit prices of the characteristic (Ladd and Suvannunt, 1976). In order to show this relationship, which is the theoretical foundation for this research, let us consider consumer utility maximization. Assume a consumer purchases n products and that each product has certain characteristics denoted by x_j. The products and the characteristics are indexed by i and j, respectively.

(1) $U = (x)$

Where U is utility and x is a vector of the total of the characteristics provided by all the products. The x depends on the quantity of each product consumed (q_i) as well as the quantity of x in each product (x_{ij}). Note that some products provide certain characteristics which are not provided by other products. This possibility is assumed away for the simplicity in this exposition. Since total quantity of x depends upon quantities of the ith product the utility function can be re-written as:

2) $U = (x(q))$

Where q is a vector of all the products consumed by the consumer. It is assumed that the consumer can vary only the q_i's. The magnitudes of the x_{ij}'s are exogenous to the consumer because their magnitudes are determined intrinsic quality of the product.

The consumer is assumed to maximize equation (2) subject to the budget constraint

(3) $\sum_i p_i q_i = I$

where p_i is the fixed price paid for the ith product, and I is the consumer's fixed money income. The consumer selects the values of the q_i that maximizes the Lagrangian:

(4) $L = U(x(q)) - \lambda(\sum_i p_i q_i - I)$

The consumer is viewed as selecting the combination of products that provide the combination of product characteristics, which maximize utility. Choices of product quantities are based on the availability of different characteristics in the products. Differentiation of the Lagrangian with respect to the quantity of ith product (q_i) results the first order condition:

(5) $$\partial L / \partial q_i = \sum_j (\partial U / \partial X_{ij})(\partial X_{ij} / \partial q_i) - \lambda p_i = 0$$

The Lagrangian multiplier (λ) in the above expression is the marginal utility of money income. Substituting this relationship and solving for the price yields:

(6) $$p_i = \sum_i (\partial X_{ij} / \partial q_i)[(\partial U / \partial X_{ij}) / (\partial U / \partial I)]$$

The marginal yield of the jth product characteristic in the ith product is given by $\partial X_{ij}/\partial q_j$. For example, it may be the amount of head rice in a kg of rice. In the bracketed terms, $\partial U/\partial X_{ij}$ is the marginal utility of the jth product characteristic, and $\partial U/\partial I$ is the marginal utility of income. Their ratio is the marginal rate of substitution between income and the jth product characteristic. By equation (3), income equals total expenditure (E). Therefore, the bracketed term can be interpreted as the marginal rate of substitution between expenditure and the jth product characteristic, that is, as the implicit or imputed price paid for the jth product characteristic. Therefore, equation (6) can be written as:

(7) $$P = a + \sum_j \beta_j x_j + \varepsilon$$

Equation 7 can be converted to a stochastic regression equation by adding a random error term and a constant.

(8) $$P_i = \sum_j (\partial X_i / \partial q_i)(\partial E / \partial X_{ij})$$

Where

P	= the market price of the rice sample
$\partial x_j / \partial q_i = x_j$	=the amount of characteristic of j in the rice sample
$\partial \varepsilon / \partial x_j = \beta_j$	= the implicit value of characteristics j
a	= intercept term and
ε	= random error

Equation (8) was estimated using the data collected from different markets to assess the impact of quality characteristics on price of rice.

DATA

Samples of differently priced rice were purchased from randomly selected retailers including super markets, co-operative shops and groceries from four selected cities. The retail markets were selected to reflect the full range of preferences displayed by different income classes. Number of samples collected from each city is given in Table 1. All the samples from each city were purchased within a day to minimize price variation other than due to quality. Sample collection was completed within consecutive five days in November 1995.

Table 1. Distribution of the sample.

City	Number of samples	
	Parboil rice	Raw rice
Colombo	32	15
Kurunegala	35	15
Kandy	36	16
Matara	13	32

Collected rice samples were analyzed in laboratory for physicochemical characteristics. The physical characteristics measured were whiteness, percentage head rice, grain length, grain shape (the ratio of grain length to width), chalkiness (percentage of chalky grains), moisture level and impurities. These characteristics depend on post harvest operations, storage conditions and the variety. The only chemical characteristics, alkali spreading value, was used as a measure of the gelatinization temperature which is partly associated with the amylose content. This characteristic is the major determinant of the cooking quality. The Table 2 shows the expected relationships of different characteristics to price of rice. These expectations are based on observed Sri Lankan market demand and standards used in screening rice varieties at Rice Research and Development Institute (RRDI). Kotagama and Kumara (1996) have made the same hypotheses on rice quality characteristics and the price.

Table 2. Rice grain quality characteristics.

Characteristics (measure)	Expected relationship to price
Whiteness (% of pure white)	+
Head rice (% of unbroken grain)	+
Length (mm)	-
Shape (Ratio length/width)	-
Moisture (%)	-
Chalkiness (% of chalk grain)	-
Impurity (%)	-
Alkali spreading value	-

Whiteness

Whiteness reflects the degree of polishing of rice. Since Sri Lankan consumers are assumed to prefer highly polished rice this variable is expected to have positive relationship with price of rice.

Head rice

RRDI screens rice varieties for higher head rice percentage and it is assumed that head rice percentage to have a positive relationship with price.

Length and shape

Normally rice is categorized into Samba and Nadu type based on shape of grain. Since rice with short round grains are categorized as Samba type, which receive higher prices in the market, these two variables are expected to have a negative relationship with price.

Chalkiness

Chalkiness is measured using visual rating of the chalky proportion of the rice. RRDI screens rice varieties for less chalkiness. Therefore, chalkiness is expected to be negatively related to higher price.

Gelatinization temperature (GT)

Gelatinization temperature determines the time required for cooking. GT is measured by the alkali-spreading value. The rice with intermediate GT are expected to be preferred over low GT, because most traditional varieties have intermediate GT. Since the alkali spread measure is inversely correlated with GT this variable is expected to have negative relationship with price.

Impurities and moisture content

These two variable are expected to have negative relationships with price because of obvious consumer dislike for impurities and colour changes with high moisture contents.

RESULTS AND DISCUSSION

Tables 3 and 4 show the physio-chemical characteristics of parboiled and raw rice, respectively, sold in the market. Most of the physio-chemical characteristics of rice sold in the markets fall in the range of laboratory measurements reported in grain quality evaluation, except for head rice percentage and chalkiness (see Appendix for details of grain quality evaluation). Thus, measured quality characteristics indicate that commercial rice milling does not change the quality of rice significantly from those under laboratory conditions. Head rice percentage of rice sold in the market range from 60% to 98% in parboiled rice and from 24% to 86% in raw rice. These values are much higher percentages than the reported values in laboratory evaluation. In general, head rice percentage in laboratory evaluation range from 60% to 70% in parboiled rice and 20% to 60% in raw rice. These striking differences in head rice percentages are because rice millers remove broken grain to some extent before sending the rice to the market. Parboiled rice in the market shows higher level of chalkiness indicating that parboiling techniques are poor in terms of reducing chalkiness. Most rice varieties show zero percentage of chalkiness for parboiled rice under laboratory conditions.

Table 3. Characteristics of parboiled rice sold in the market.

Characteristics	Mean	SD	Variance	Minimum	Maximum
Price	22.11	5.81	33.71	14.50	65.00
Moisture	15.80	0.83	0.69	12.90	17.50
Head rice	83.31	7.89	62.30	60.50	98.40
Impurity	1.56	1.46	2.14	0.10	6.50
Whiteness	25.76	5.41	29.30	10.30	36.30
Gelatinization temperature	4.28	1.23	1.51	2.00	7.00
Length (mm)	4.47	1.12	1.26	3.70	6.70
Shape	1.90	0.42	0.18	1.60	3.00
Chalkiness	15.90	17.33	300.34	30.00	80.00
Sample size	116				

Three regression models were fitted for parboiled rice, raw rice and for pooled data. For each regression model an initial OLS regression was fitted in order to identify the data problems and violation of assumptions. Preliminary results for the parboiled rice indicate R^2 and adjusted R^2 values of 0.53 and 0.49. These values indicate acceptable level of goodness of fit for cross sectional data. The R^2 indicates that the regression model explains 53% of the variation in price. The difference between the two R^2 values show that there is adequate number of observation in the model given the number of independent variables. Examination of the correlation matrix indicated that

Table 4. Characteristics of raw rice sold in market.

Characteristics	Mean	SD	Variance	Minimum	Maximum
Price	17.55	2.00	4.02	14.00	24.00
Moisture	15.62	0.63	0.40	13.70	16.60
Head rice	62.97	13.37	178.65	53.90	86.10
Impurity	0.89	0.96	0.92	0.10	5.00
Whiteness	29.71	9.54	90.97	15.30	46.40
Gelatinization temperature	4.00	2.45	5.98	1.00	7.00
Length (mm)	5.73	0.50	0.25	3.50	6.60
Shape	2.38	0.28	0.00	1.60	2.90
Chalkiness	68.55	18.66	348.44	30.00	95.00
Sample size	77				

only length and shape variables have a correlation coefficient greater than 0.8. This indicates presence of some collinearity. However, the condition numbers indicate that there is no severe multicollinearity. Durbun-Watson statistic is 1.97 and that indicates the auto-correlation is not a problem in the model. However, Glejser test for herteroscedasticity gave a Chi-square value of 19.29 against the critical value of 16.92 at 9 degrees of freedom. This result indicates the presence of heteroscedasticity. Therefore, maximum likelihood estimation was made in order to correct for heteroscedasticity using HET command in Shazam program. The maximum likelihood procedure does not provide a goodness of fit measure similar to R^2. Available measures indicate a 0.52 value of squared correlation between observed and predicted values and -300. 8 value of the log of the likelihood function. The detail results of the final regression model for parboiled rice is given in Table 5.

As shown by Cowling and Rayner (1970) the brand name also affects the price of a commodity, in addition to the quality characteristics. Therefore, in addition to the eight characteristics described above a dummy variable was included to represent the brand name. One was assigned for Samba and zero was assigned for Nadu. Of the nine independent variables included in the model, only four were significant indicating expected relationships. These are impurity, head rice percentage, chalkiness and brand name. Since the

Table 5. Results of the regression model for price of parboiled rice.

Characteristics	Coefficient	Standard error	T-ratio	P-value
Moisture (%)	0.16354	0.4156	0.3935	0.694
Head rice (%)	0.82507 E-01	0.477 E-01	1.727	0.084*
Impurity (%)	-0.57473	0.2510	-2.290	0.022**
Whiteness (%)	-0.86484 E-01	0.6870 E-01	-1.259	0.208
Gelatinisation temperature	0.16917	0.2358	0.7174	0.473
Length (mm)	0.73476	1.107	0.6639	0.507
Shape (l/w)	-1.7657	2.470	-0.7148	0.475
Chalkiness (%)	-0.37268 E-01	0.1814 E-01	-2.055	0.040**
Samba	7.1881	1.175	6.117	0.00**
Intercept	12.041	7.828	1.538	0.124
R^2		0.5316		
R^{-2}		0.4919		

** and * indicates significance level of 0.05 and 0.1 respectively.

chalkiness and head rice percentage are determined by variety to some extent, rice breeders can incorporate these characteristics into new varieties. Impurity is determined by post-harvest handling. Since the presence of impurities and low head rice percentage reduces the price, careful post harvest handling may lead to marginal price gains.

Whiteness, GT, length and shape do not show statistically significant relationship to the price. Whiteness may be important only in raw rice. Since consumers cannot directly observe GT, it may not show a significant relationship to the price. It is sometimes argued that the short length and round shape cause the higher price of Samba rice. However, according to the results, rather than length and shape, the brand name has a greater marginal impact on the price. After isolating the effect of quality characteristics, when brand name changes from Nadu type to Samba type, price increases by Rs. 7.18 per kg of rice on average. This implies that high price for short round grain rice is due to its brand name rather than due to the grain length or shape. Samba rice processing involves steaming while Nadu generally goes through parboiling. Therefore, capturing the higher price can be enhanced at the processing stage rather than breeding stage. Breeders can also incorporate other important characteristics to rice varieties which can be processed to produce Samba. However, the information on market share of Samba is necessary in order to determine the degree of emphasise for improvements in potential Samba varieties in future breeding programs.

The preliminary run of the regression model for raw rice provided R^2 value of 48% and adjusted R^2 value of 42%. The Durbin-Watson statistics falls in the non conclusive region. Both Glejser and Breusch-Pegan-Godfrey tests indicate presence of heteroscedasticity. Therefore, a heteroscedastic model using the maximum likelihood method was estimated. The fitted model has the squared correlation between observed and predicted value of 0.48 and a -134.6 log of the likelihood function. The results of this model are given in Table 6. Similar to the previous results, head rice percentage and impurities show significant positive and negative relationships to the price, respectively. Chalkiness does not show a significant effect on the price of raw rice. Whiteness, shows a statistically significant negative relationship to the price. Although the finding is in contradiction with the expectation, results may indicate that consumers are aware of the fact that highly polished rice is less nutritious. In contrast to the results for parboiled rice, length and shape show negative and positive relationship to the price, respectively. These results indicate that the consumers do not prefer long grains and bulky grains of raw rice. Their preference for thin grains might be reflecting the mimicking of preference for Basmati rice. Thus, there are significant differences of consumer preferences for characteristics between raw and parboiled rice. Therefore, the information on market shares of these two types is necessary for sound policy making at breeders' level.

The last model was fitted combining data for parboiled and raw rice. The objective of estimating the pooled model is to check whether there is any difference in the impacts of quality characteristics when the two types are put together. The pooled model represents the theoretical model presented earlier when consumers purchase both raw and parboiled rice. Also this pooled model can be used to check whether the cities and different markets show different preferences. The pooled model showed a higher R^2 value of 0.6% with an adjusted R^2 of 0.58. Durbin-Watson statistics is close to 2 and that indicates autocorrelation is not a problem. Glejser test result indicates the presence of heteroscedasticity. Therefore, a heteroscedastic model was estimated using maximum likelihood method. Dummy variable analysis for the different types of market outlets and different cities showed that these variables do not have a significant relationship to the market price. Therefore,

Table 6. Regression results for price of raw rice.

Characteristics	Coefficient	Standard error	T-ratio	P-value
Moisture (%)	-0.18701	0.2685	-0.6965	0.486
Head rice (%)	0.24606 E-01	0.1305 E-01	1.885	0.059*
Impurity (%)	-0.39018	0.1645	-2.372	0.018**
Whiteness (%)	-0.53276 E-01	0.2778 E-01	-1.917	0.055*
Gelatinisation temperature	0.16001	0.1056	1.515	0.130
Length (mm)	-2.6041	0.7953	-3.274	0.001**
Shape (l/w)	4.7747	1.418	3.367	0.001**
Chalkiness (%)	-0.93145 E-02	0.9151 E-02	-1.018	0.309
Intercept	24.388	4.525	5.389	0.00**
R^2		48.77		
R^{-2}		42.75		

** and * indicates significance level of 0.05 and 0.1 respectively.

Table 7. Regression results for pooled data.

Characteristics	Coefficient	Standard error	T-ratio	P-value
Moisture (%)	0.10802 E-01	0.2685	0.4127 E-01	0.967
Head rice (%)	0.36282 E-01	0.1812 E-01	2.003	0.045**
Impurity (%)	-0.68207	0.1522	-0.4481	0.00**
Whiteness (%)	-0.54444 E-01	0.3252 E-01	-1.674	0.094*
Gelatinisation temperature	0.14438	0.1192	1.211	0.226
Length (mm)	-0.33429	0.7008	-0.4770	0.633
Shape (l/w)	0.53013	1.464	0.3621	0.717
Chalkiness (%)	-0.22803 E-01	0.1053 E-01	-2.166	0.030**
Samba	6.4646	1.097	5.895	0.00**
Nadu	-0.81167	0.7455	-1.089	0.276
Intercept	18.836	4.528	4.160	0.00**
R^2			60.39	
R^{-2}			58.20	

** and * indicates significance level of 0.05 and 0.1 respectively.

these variables were excluded from the final model. The results of the pooled model are given in Table 7. Two dummy variables were used for Samba and Nadu in addition to the quality characteristics in the final model. In the case of Samba, one was assigned for Samba and zero was assigned otherwise. A similarly defined dummy variable was used for Nadu. The results show that head rice, impurity, chalkiness and brand name samba were statistically significant with the expected sign. Thus, the results of the pooled model are similar to the results for the parboiled rice model, except for the significant negative effect of whiteness in the pooled model.

CONCLUSIONS AND POLICY IMPLICATIONS

Despite the marked increases of rice productivity achieved during the last four decades, profitability of rice farming showed significant declines in recent times. Rice farmers' situation may deteriorate further when faced with severe competition of imported rice due to trade liberalization. One possible way to cope up with this situation is to produce high quality rice, which capture higher market prices. Rice breeders and processors should know the qualities preferred by consumers in order to produce high quality rice for the market. Random samples of rice were collected from four cities and their quality characteristics were measured in laboratories. Three regression models were fitted for parboiled rice, raw rice and for pooled data.

The results indicate positive impact of the head rice percentage and the negative impact of impurities. These are common to all three models. Chalkiness shows a negative impact in the models for parboiled rice and for pooled data. Whiteness percentage shows a negative relationship with price only for raw rice. GT and moisture content do not affect the price as shown by all three models. In contrast to the generally held belief that the length and shape are important determinants of the price of rice, the result of the parboiled and pooled models suggest that these variable do not affect the price. However, both length and shape determine consumer preferences in raw rice. Another important finding of this research is that a brand name carries the highest marginal imputed price of the parboiled rice. This finding is consistent in both parboiled and pooled models.

There are some significant policy implications arising from the findings. First, there are significant differences in rice quality characteristics preferred by consumers for raw and parboiled rice. Since the difference between these two types is due to rice processing, breeders should be aware of the market share of the two types in planning future breeding programs.

Second, some of the characteristics which affect consumer preferences depend on the variety, while others depend on the post harvest-handling and processing. Therefore, both breeding and processing sectors should use the information generated by this research in order to improve quality of rice. Third, the brand name carries a high weight in determining the market price of parboiled rice. Breeders can therefore incorporate the other desirable quality characters for the rice varieties, which have the potential to be processed as Samba. However, the emphasis of such a program should also depend on the market share for Samba.

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APPENDICES

Appendix 1. Laboratory measurements reported in grain quality evaluation of rice.

	Parboil	Raw rice
Moisture (%)	15-17	15-17
Head rice (%)	60-70	20-60
Impurity (%)	0	0
Whiteness (%)	20-40	20-40
Gelatinisation temperature	1-7	1-7
Length (mm)	3.7-6.9	3.5-6.7
Shape	1.6-3.6	1.6-3.6
Chalkiness (%)	0	40-60
Impurity (%)	1	1