CHAPTER 2

RICE HUSK

2.1 Rice Husk

Rice husk is one of the important biomass material. It is a ligno-cellulosic agricultural waste which has an energy value of about 2900-4500 Kcal/Kg which is about 41% of the fuel value of bituminuous coal. The relative low energy density of rice husk may seem unattractive compared to other ligno-cellulosic agriculture wastes such bagasse, coconut husk, etc. However, with the accumulative amount of non-biodegradable rice husk which remains unutilized for part of the years, coupled with increase paddy acreage and high yields of double cropping, the resource potential for rice husk as a source of energy is immense.

Due to its physical and chemical characteristics such as lowbulkdensity, abrasive character, poor nutritive value and high silica content, only a small amount ofRHis being utilized. Traditionally, in a large part of the world disposing of these RH isby burning either in heaps at or near the rice mill, orby selling them in small quantities to people who burn the husks for their heating value. Movement of the husk to any great distance from themillis usually prohibitive due to the very low bulk density of thematerial. In some countries the rice husk is burned to generate industrial process heat, but the combustion efficiency in conventional burner is low and the large quantity of low-value ash thus produced becomes another disposal problem. The more common practice is open-field burning and incorporation of the ash in to the soil. Open field burning causes serious air pollution problems, hence is faced with increasing opposition both by the public and by government agencies.

2.2 Physical and Chemical Characteristics of Rice Husk

Rice husk is a ligno-cellulosic agricultural waste which hasan energy balue of about 2900-4500 Kcal/Kg which is about 41% of the fuel value of bituminuous coal. The relatively low energy density of rice husk may seem unattractive compared to other ligno-cellulosic agricultural wastes such as bagasse, coconut husk, etc. However , with the accumulative amounts of non-biodegradable rice husk which remains unutilized for the past years, coupled with increased paddy acreage and high yields of double cropping, the resource potential for rice husk as a source of energy is immense.

Percentage of Husk

Percentages of husk in paddy vary widely, but 20% can be taken as a fair average. Some varieties in Italy show percentages as low as 14%, while varieties in other countries reach as high as 26 or 27%. In Alor Setar, Malaysia, the analysis of two local paddy varieties showed percentages 18.1 and 22.59% respectively, and these could be milled, in subsequent lots, in the same mill. Fraps reported that Japanese paddy contained 17.9% husk, Honduras paddy contained 20.98% husk,and Blue Rose paddy contained 17.9% husk. It is easier to visualize wide differences in widely separated countrieswith different varieties and climatology than to accept wide variations in adjacent fields.

In some countries,particularly those that harvest a form of stalk rice, the term "husk" is sometimes thought of to include all dockage that is brought to the mill from the paddy field. In this case there is a disproportionate amount of straw. To illustrate, an analysis in Sri lanka showed 26% husk, which was really 22% husk, the balance being straw and other dockage. The accuracy of testing depends on techniques of collection, pre-cleaning and milling; the other variable is the consequence of local terminology.

Attempts are currently being made to increase the weight of paddy wihtout increasing the weight of husk. Plant breeders expect that in the future husk proportions will be less than 15%

Analysis of Husk

Analyses of husks are variable by type and variety. There are many characteristics in which the paddy was shelled. Rubber - roll shellers yield about 1% more rice. The epidermis (silver skin),when shelled with a disc (stone), stays with the husk percentage; when shelled in a rubber roll, the analysis shows a higher rice outturn and thence a higher bran outturn. An analysis shows less silica and more cellulose for a disc-shelled sample, and more silica and less cellulose for a rubber-roll-shelled sample. Similarly, in disc shelling the rice germ is trapped inside the grain, and this affects fat and protein analyses, as well as fuel values.

Table 2.1 shows a tabulation by Houston of analyses of hull over a hundred-year period. A tabulation of husk analysis, partially overlapping Houston's but containing more easily comparable data, appears at table 2.2.

Analyses of rice husk have also been made from the standpoint of its characteristics for use as fuel. A tabulation of these analyses appears in table 2.3.

2.3 Rice Husk Production in Thailand

The average production of rice in Thailand is around 20 million tons per annum with a corresponding amount of around 5 million tons of rice husk. Taking the value of 3000 kcal/kg as the heating value of rice husk, this represents a significant amount of energy i.e. 10 million barrels of oil if it can be effectively utilized.

The amount of rice husk per unit weight of paddy would depend on the milling efficiency. The average figure determined by Niyom and others [ ]was 222.20 kg. per ton of paddy. However the survey of 158 sample rice mills in the present study revealed the yield of rice husk in a range between 200 to 325 kg. per ton of paddy. The yield of rice husk was found to be virtually independent of the milling capacity, with the overall average yield of 261.36 kg. per ton of paddy (see table 2.4). The small difference between this yield and the yield determinedbyNiyom and others may be due to the difference in

TABLE 2.1

Composition of rice hull (% by weight)

H_2O	Crude Protein	Crude Fat	Nitrogen-Free Extract	Crude Fiber	Ash	Pentosans	Cellulose	Other	Year
9.7	3.4	1.4	27.0	42.8	15.7	...	...		1871
8.27	2.87	0.85	34.99	38.15	13.85	...	...		1889
8.97	3.50	0.49	37.86	41.89	18.29	17.24	...		1904
10.0	3.7	1.4	32.3	...	...	...	38.1		1907
8.5	3.6	0.9	29.4	39.1	18.6	18.14	...		1916
6.62, 6.12	2.56, 2.69	0.50, 0.86	...	35.99, 36.08	18.70, 20.10	18.17, 18.14	...		1916
...	4.4	1.6	35.5	4.15	17.1	...	...		1919
11.04	1.7	0.4	28.95	...	...	...	43.12		1920
...	5.95	2.22	38.97	31.71	21.13	...	...	1.76 starch	1924
9.2	7.26	0.90	...	...	18.0	...	65.00[b]		1926
8.80	...	0.89	...	...	17.80	...	34.34	46.97 lignin	1926
9.3	3.3	1.1	34.0	35.4	16.9	...	...		19[illegible]
11.35	3.90	1.27	25.83	40.22	17.43	...	...		1[illegible]
9.8-11.00	2.94-3.62	0.8-1.20	24.70-27.90	...	15.68-18.24	...	41.10-42.90		1[illegible]
7.7, 6.8	1.8, 2.0	0.6, 0.6	32.7, 30.0	35.0, 38.9	22.3, 21.7	...	...		15[illegible]
9.03	1.79	0.44	25.79	40.67	22.29	...	...		1940
8.25	...	...	...	...	21.30	20.90	...		1943
3.74	6.06	1.33[a]	27.25	...	17.03	16.94	35.48		1943
8.1	3.0	0.9	...	...	18.5	18.1	39.1		1944
8.1	3.1	0.9	28.9	40.1	18.9	...	...		1946
...	...	...	...	...	13.6	...	43.7	39.2 lignin	1947
...	2.86	0.92	...	38.43	21.41	19.32	...		1949
8.49	3.56	0.93	29.36	...	18.59	...	...		
8.3	2.88	3.5[a]	...	...	22.6	26.0	42.2	19.2 lignin	1950
9.23	6.38	0.65	31.58	31.30	...	...	39.05		1952
0.0	...	...	...	...	19.03-29.04	...	...		1953
10.0	2.00	1.20[a]	...	...	17.60	21.95	41.22	32.88 lignin	1953
10.23	1.94	0.52	29.6	...	18.33	...	39.39		1954
8.0	3.0	0.8	28.4	40.7	...	...	...		1956
...	1.75	2.98	26.05	44.81	24.16	...	...		1962
8-11	2-3	0.5-1	25-30	36-45	22-24	...	...		1964
0.0	1.8-2.6	0.56, 0.81	29.9, 30.8	44.5, 46.3	21.2-24.0	...	...		1969
0.0	2.18-4.84	0.38-0.78	26.0-34.1	47.28-49.92	15.27-20.32	...	...		1970
2.4-11.35	1.7-7.26	0.38-2.98	24.7-38.79	31.71-49.92	13.16-29.04	16.94-21.95	34.34-43.8	21.4-46.97	Range

[a]Alcohol extract. [b]Cellulose plus pectin.

TABLE 2.2

Composition of rice husk
(% by weight)

Investigator	Description	year	Moisture	Ash	Protein	Fat	Fiber	N.F.E.	Insoluble
Auriol	50 S. variety Vietnam		10.23	18.32	1.94	0.52	39.39	29.60	17.64
Borasio	Neruvialong	1928	10.50	15.68	3.62	1.20	41.10	27.9	14.50
	Tolmino	1928	10.00	18.24	2.94	0.88	42.40	25.54	17.50
	Originario	1928	10.30	18.20	3.10	0.90	42.80	24.20	17.20
	Originario	1928	9.80	17.80	3.00	0.95	42.10	26.35	16.70
	Maratelli	1928	11.00	16.10	2.98	1.10	42.90	25.92	15.50
Browne	not known	1904	8.97	18.29	3.50	0.49	41.89	27.86	17.24
Fontillas	not known	1941		24.91	2.19	2.69	49.22	20.67	
Fraps	minimum	1916	6.11	14.83	1.78	0.54	31.43	24.56	13.69
	maximum	1916	10.95	22.00	5.00	1.98	46.37	36.83	20.84
	average	1916	8.49	18.59	3.56	0.93	39.05	29.38	17.52
Grist	not known	1959	9.02	17.14	3.27	1.18	35.68	33.71	
Joachim	Ceylon	1928	11.35	17.43	3.90	1.26	40.22	25.83	
Morrison	not known	1956		19.1	3.0	0.8	40.7	28.4	
Morse	California	1965	7.08	25.51	2.37	0.24	42.23		
Possenti	Italian	1941	10.3	18.2					
Reed	minimum	1917	5.00	16 4	1.75	0.51	36.57	15.27	
	maximum	1917	9.69	22.03	4.12	1.31	46.82	20.98	
	average	1917	7.91	19.54	2.66	0.80	41.29	18.58	
Ross	not known	1889	8.27	13.85	2.89	0.85	38.15	34.99	
Wise	Hondourus	1916	6.62	18.70	2.56	0.50	35.99		
	Japan	1916	6.12	20.10	2.69	0.86	36.08		

TABLE 2.3
Fuel-related characteristics of rice husk

Investigator	basis	year	Heating Value K cal/Kg	Heating Value Btu/lb	Ash	Moisture	Carbon	Silica	Hydrogen	Nitrogen	Sulfur	Oxygen	Volatile Matter	Fixed Carbon
Agnew #1	dry	1972		6958	18.1								65 0	16.9
Agnew #2	dry	1972		6530										
Beagle		1968		6389	1913	5.72	39.71		5.01	0.46	0.07	29 90		
Beagle	dry	1968		6777	20.29	0	42.12		5.31	0.49	0.07	31.72		
Fontillas					24.91									
Greaves Cotton		1975		6165										
Grist		1959		6000	17.14	9.02								
Maheshwari — IR8	dry	1974	3090		17.4	3.56	39.26		4.99	1.99	0.10		68.6	14.0
Patnai	dry	1974	3560		15.8	3.56	38.92		5.10	2.17	0.12		69.3	14.9
Paoman	dry	1974	3065		18.6	3.56	38.19		4.67	1.52	0.11		68.7	12.7
Dular	dry	1974	3560		16.5	3.56	38.51		4.88	1.82	0.10		67.6	15.9
Basmati	dry	1974	2980		16.5	3.56	38.68		5.08	2.09	0.10		66.6	16.9
Nelson		1950			22.6	8.3		95.8						
Possenti		1941	3300											
Power Gas		1950		6340	21.7								60.9	17.4
Ricegrow. — Char		1970				2.8	55.8	37.05						
Rodgers #1		1936		6074										
Rodgers #2		1936		6152										
Spilling		1970	2900	5500	23.0									
Thai A863		1922	3619		18.7	9.1	40.0		5.0	0.30			56.4	15.8
Thai A864		1922				1.1	2.2		0.2					
Tucker		1952		6274					5.0	0.32				
Tulio		1972		6708		9.8								

rice varieties.

From the yield figures, the total amount of rice husk produced in 1980 was readily determined to be 4.54 million tons, distribution in various regions is shown in table 2.5. The average amount of rice husk for each rice mill would be about 115 tons. Based on the average heating value of 3,880 kcal/kg. (on dry basis) and an average moisture content of 9% , the total energy of 4.54 million tons of rice husk would be equal to 1,916 million liters of crude oil, assuming the heating value of crude oil to be 9,193 kcal/litre. For an average rice mill the availavle rice huskenergy would be equal to 4.85×10^4 liters of crude oil. At the cost of about U.S.$28 per barrel, the energy of rice husk of an average rice mill would theoretically have an economic value of U.S.$ 8,487.5 per year. However, the actual ceonomic value would depend on the amount of rice husks which can actually be utilized. The fugure of U. S.$ 8,487.5 per year merely indicates the economic potential of rice husk.

The supply of rice husk follows the operation pattern of rice mills. The operation period of rice mills varics from 4 to 8 months depending on the supply of paddy and the amount of paddy stored for milling during off-rice season. Large rice mills generally tend to operate longer than smaller rice mills. However, the reverse is found in the southern region. The discontinuity of rice husk supply would be a major constraint of its use as fuel for other industries and as industrial raw materials.

Table 2.5 Regional Distribution of Rice Husks in 1980

Region	Number of Rice Mill	Rice Production ($x10^6$ ton)	Rice Husk ($x10^6$ ton)
Northern	9,420	4.86	1.27
North-Eastern	20,444	5.81	1.52
Central	4,975	5.54	1.45
Southern	4,631	1.15	0.30
Total	39,470	17.4	4.54

2.4 Rice Husk Utilization

For large rice mills using steam engines large than 30 hp., the major use of rice husk is fuel for their own consumtion. Assuming a mechanical conversion efficiency of 30% and a boiler efficiency of 40%, the average milling energy requirement was determined to be 19,000 kcal per ton of paddy which is equivalent to 15.6% of the rice husks produceed that would be consumed in the rice milling operation. Information obtained from the sample rice mill using rice husk for their steam engine showed figures between 15% and 25%. The deviation may be due to variation in the efficiency of the steam engines and boilers.

Utilization of rice husk as fuel in other industries is limited by its bulkiness as indicated by its density of only about 106 kg/m^3. Uses other than fuel are also constrained by the transportation cost.

At present, only a small quantity is used for firing claybricks and for concentrating palm syrup. As packaging material, they are utilized to protect eggs from damage during handling and transportation. They are also used as "insulator" to help delay the melting of ice. In brick making, husks are added to decrease the unit weight and make the heating process easier. Utilization of rice husks as soil conditioner in flower beds and for making bean sprouts, by keeping the bean moist, are also known in Thailand but the quatities used are relatively small. Other utilizations include uses as poultry litter and as a filling material, in the form of husk ash.

The amount of rice husks used as fuel, in 1980, was estimated at about 0.7 million tons (9) which accounted for only 15% of the total amount produced. Quantities used for other purpose would, therefore, appear to be insignificantly small. Consequently, a very large amount of rice husks would still remain unused, and thus, have to be disposed of. The figures would vary depending on seasonal variation of the supply and demand of rice husks. On some occasions, rice husks could be sold at prices ranging from 25 to 250* baths per ton. It thus appears that the price of rice husks is relatively very cheap compared to those of other fuels.

In Thailand, rice milling operation uses steam engines, diesel engines, or electric modtors. Due to its economy of scale, the steam engine is normally the choice for rice mills which require over 30 hp (greater than 20 tons/day capacity) Small and medium rice mills would prefer electric motors if the public supply were available. In the absence of electricity supply, and diesel engine was the only option.

There is no available data on the number of rice mills for each energy option and it was not possible in the present study to survey all existing rice mills. Consequently, the distribution of rice mills according to their energy sources was therefore determined on the basis of a limited survey of only 158 sample rice mills. Of the total 158 rice mills surveyed, 116 mills (73.42%) used diesel engine, 18 mills (11.39%) used steam engine, and 24 mills (15.19%) used electricity (see Table 2.6). Assuming there was no change in the distribution of rice mills according to thier power rating,

Table 2.6 Energy Use Patterns of Surveyed Rice Mills

Size of Rice Mill	Type of Energy Uses		
	Diesel Oil	Rice Husks	Electricity
Large	3 (11.11)	18 (66.67)	6 (22.22)
Medium	26 (78.79)	-	7 (21.21)
Small	87 (88.78)	-	11 (11.22)
Total	116	18	24

Figures in parenthesis are percent

the rice mills with power rating lower than 30 hp would account for 92.77% of the total number of rice mills (see table 2.7)

Of the 27 large rice mills selected for the survey, only 3 mills used diesel engines and another 6 mills used electric motor. (see Table 2.8). For medium and small rice mills, diesel engine was widely used but electric motor was preferable if public supply was available.

Based on the figures obtained from the survey, the number of rice mills using diesel engine was found to be 116. The diesel oil consumption per ton of paddy ranged from 8.38 to 10.79 liters. Using an average figures of 9.42 liters and assuming an efficiency of 25% for the diesel engine, the energy requirement would be about 21,650 kcal/ton.

The total demand for diesel oil for fice milling operation would depend on the amount of rice output. If the diesel engine rice mills contributes to about 73.42% of the total output (see table 2.9), then the total consumption of diesel oil, in 1980, is about 115 million liters, or a total value of about 831 million bahts* on the current market peice of 7.23 baths*/lt.

*Appoximately 23 baths equal 1 U.S.dollar

From the survey result, it is apparent that the milling porcess for in rice mill with capacity starting from 100 kwiens/day can be classified into 2 types, ie. milling of parboiled rice and milling of white rice. Rice mill for parboiled rice consumes a lot of energy due to energy required

Table 2.7 Number of Registered Rice Mills in Each Region According to their Horse Power in 1978

Region.	Horse Power of Engine		
	0-30	31-60	Over 60
Northern	7,256	388	319
North-Eastern	15,684	360	181
Central	3,499	627	409
Southern	4,329	75	39
Total	30,768 (92.77)	1,450 (4.37)	948 (2.86)

Figures in parenthesis are percents.

Table 2.8 Productions of One-Ton Rice Milling Rate in Surveyed Rice Mills

Size of Rice Mill	Products of One-Ton Paddy Milling (kg)			
	Rice Husks	Rice (1st and 2nd grades)	Broken Rice	Rice Bran
Large	259.23	603.29	47.78	89.70
Medium	262.82	604.23	46.41	86.54
Small	262.04	605.48	43.73	88.75
Average	261.36 (26.14)	604.33 (60.43)	45.97 (4.60)	88.33 (8.83)

Figures in parenthesis are percents.

Table 2.9 Regional Distribution of Survey Rice Mills According to Their Energy Use Patterns.

Region	Type of Energy Uses		
	Diesel Oil	Rice Husks	Electricity
Northern	30	5	5
North-Eastern	51	5	15
Central	16	7	2
Southern	19	1	2
Total	116 (73.42)	18 (11.39)	24 (15.19)

Figures in parenthesis are percents.

for the milling process as well as for the parboiling process. Rice mill for white rice consumes much less energy since energy is required only for milling process.

Energy consumption in the rice mill can be classified into two categories:

1. Heat Energy
2. Electrical energy

Heat Energy Consumption in The Rice Mill

Heat energy consumed in the rice mill is obtained from husk which is the by-product of milling process. Milling of each ton of paddy yields approximately 220 Kg. of husk. The obtained husk can be used as fuel for the boiler to produce steam for various processes required in the rice mill. Heat energy consumption can be classified according to the types of milling as follows:

Rice Mill for Parboiled Rice

The following processes for this type of rice mill consume heat energy from steam:

a. Soaking Process

Steam is utilized to heat soaking water to reach the temperature of approximately 70 - 80 C for soaking paddy to increase the moisture content in the paddy from 16% to 50%

b. Steaming Process

Steam is utilized to steam the properly soaked paddy to abtain the fusion of starch granules of the paddy which reduces cracks in the paddy grain.

c. Drying Process

Heat energy from the steam is utilized to reduce the moisture content of the steamed paddy grain to about 14% so that the grain becomes suitable for milling.

c. Milling Process

Steam is suplied to the steam engine to drive the milling machine (some rice mill may also use electrical energy for parts of this process or for the entire process).

In genedralj, this type of rice mill will have inadequate supply of husk. Therefore, addition amount of husk must be purchased at the price of 150 bahts/ton which includes the husk transportation cost to the rice mill. Some rice mill will solve the problem of inadequate supply of husk by reducing heat energy consumption in the milling process by replacing it with electrical energy or drying the paddy by sun drying method.

Rice Mill for White Rice

This type of mill utilizes only steam supply for the steam engine to drive the milling machine. Therefore, the husk leftover will be approximately 20-25%. If electrical energy is also employed to drive the milling machine, there will be husk leftover of approximately 30-35% of the total amount of husk obtained from the milling. The leftover will be sold to other industries such as parboiled rice mill, brickyard, and distilleries at the price of 20-35 baths per ton. In the case of some rice mills located in remote areas with inconvenient communication or without other industries nearby that can consume husk as fuel, the remaining husk will be worthless and cause problem in ridding effort by dumping somewhere else or by burning into ash.

Since this type of rice mill has excessive amount of husk and the remaining husk is sold at such a low price that cannot cover the labor cost to load it to the truck, therefore, this type of rice mill pays no attention to saving measure for heat energy.