Paddy Husk Fuel Block

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ABSTRACT. *Paddy husk is a major agricultural by-product in Sri Lanka and a large quantity of paddy husk is being disposed causing atmospheric and water pollution. To reduce the environmental effect as well as to utilize the husk as an effective energy source, conversion of paddy husk into an appropriate form is very important. This study focused on making paddy husk blocks using an available binding agent. Three natural extracts were tested for their binding properties and Neolitsea spp. leaf extract was selected as the binding agent due to its high abundance, underutilization and high binding ability. Several ratios of leaf extracts were tested and mixtures were compressed in a wooden mould under hand pressure to form blocks. After sun drying, blocks were tested for their combustion efficiency of material, burning rate and temperature of the exhaust gas. Extract from 50 g of leaves was mixed with 300 g of husk to make one fuel block which gave satisfactory binding properties and burning characteristics, as well as enough strength for handling. These fuel blocks were evaluated in a simple furnace and in a domestic stove that is used for firewood.*

Since the block is rectangular in shape by burning a single side, approximately uniform burning rate was achieved. For that air passage was facilitated only through that single side of the block. In addition, it improves the combustion efficiency of block due to sufficient retention time and reduces the dust problem of raw husk. The results reveal that paddy husk can be utilized as a source of energy in block form in an effective manner.

INTRODUCTION

Paddy husk, the leafy outer covering of the seed, is about 20-25% of the total weight. It is the most abundant agricultural residue in the world (Ong'or, 2006) and is estimated to be around 80 million tons per year (Jain *et al.,* 1996). The average annual rice production in Sri Lanka is about 2,600,000 mt (Anon, 2006) and the annual husk amount being produced in the country is about 572000 mt.

Rice producing countries including Sri Lanka have the challenging problem of utilizing or disposing of this low value by-product. The major problems of disposing or using husk are associated with the woody abrasive nature, low nutrient properties, resistance to weathering, low bulk density, small particle sizes and high ash contents. It cannot be used as an animal feed due to its low content of total digestible nutrients. Husk is not acceptable as a fertilizer due to high C:N ratio, and high cellulose and lignin contents.

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However, it has been successfully used in many applications such as a soil conditioner and mulch, a fuel in furnace, an insulating and a packaging material, fillers for plastic industry, a cleaning agent for iron and steel, a raw material in manufacture of cement (Jain *et al.*, 1996). However, majority of these uses are not practiced in Sri Lanka.

Paddy husk has been used as a fuel in several industries, especially in rice processing mills. The calorific value of the Paddy husk is about 13 to 15 MJ/kg (Anshu *et al.,* 2004), which is little less than that of fuel wood. The heating value of three kilograms of husk is equivalent to that of one kg of oil. Analysis on the paddy husk has shown that the carbon comprises over 30% (Assureira, 2002). Therefore, paddy husk can be considered as a good source of biomass energy.

Paddy husk has been identified as a major pollutant in many areas where paddy processing is practiced. Due to difficulties in handling and absence of proper uses, a considerable amount of husk is disposed improperly resulting environmental consequences. Pollution of water bodies and the atmosphere are common problems. When husk is burnt in open air, emission of CH_4, CO, SO_2, particulate matter (soot) and fly ash is observed. The low density of husk makes it difficult to store and increases the cost of transportation.

Literature indicates that in many Asian countries, especially Bangladesh, Thailand and India, efforts have been made to develop stoves to use paddy husk. Most of those stoves were developed based on the designs of traditional cooking stoves in these countries. These stoves lack the control on combustion process and result in variable energy flow throughout the period of operation.

Densification and briquetting are common physical conversions of rice husks, which could address these problems. Densification may involve the process of increasing the material density. Pressing it to form cubes of high-density husk is briquetting. Baling, cubing, pellet and tablet formation and roll compaction are also possible transformations. It minimizes the problems from raw dust, storage and handling while improving burning characteristics. Since it forms a specific shape and a size, it is easy to maintain constant amount of material burnt with respect to time.

The objective of the study was to develop a fuel block using paddy husk and a natural binding agent to minimise problems from raw dust storage and handling, while improving combustion characteristics and facilitating a uniform burning rate.

MATERIALS AND METHODS

The experiment consisted of two main steps as preparation of paddy husk blocks and evaluation of them for combustion characteristics.

Preparation of the fuel block

Paddy husk was collected from small-scale mills, which are equipped with steel hullers and rubber roll shellers. Moisture content of husk and binding agent were measured using the oven dry method by heating them to 105^0C for 72 hours.

Moulding as blocks

With application of pressure using a mechanical device (Dynamometer), the block got more compacted, hardened and stuck to the inner surface of the mould. As a result, it was difficult to remove the block manually without damage. The blocking with hand pressure is an economical and simple approach and therefore, the rest of the procedure was conducted only by this method.

Size of 10 cm x 10 cm x 20 cm wooden mould was used in preparing husk blocks. The dimensions can be changed but it may need less thickness to facilitate faster drying and to prevent from disturbance on the combustion process by the resulting ash that is high in the case of paddy husk.

Selection of a binding agent

Three different plant extracts were tested initially as binding agents;

1. Leaf extracts of the *Neolitsea* species.
2. Extract from Cocoa fruit peel.
3. Tamarind seed powder.

Tests on leaf extract of *Neolitsea cassia* ("Dawul Kurudu") and *Neolitsea fuscata* ("Kudu Dawula") indicated strong bonding which is enough for handling the block. Rind of Cocoa fruit was boiled for about 10 minutes to soften it and squeezed to extract the mucilage. Then it was mixed with paddy husk and tested for bonding strength. Tamarind seed were dried and ground to obtain powder. The powder was mixed with water and boiled until it reached the glutinous stage. Then it was mixed with paddy husk and used to build blocks. Out of three different options assessed above, the leaf extract from *Neolitsea* extract was used for further development of the paddy husk block due to convenience in extraction, availability in abundance and under utilization in other applications.

Selected quantities of leaves were blended with water to make extract and then it was thoroughly mixed with paddy husk in varying amounts. The mould was filled with the mixture and pressurized with support of a lid. When the pressure was released after compression, there was some expansion in the block. Observations were made on the resulting final heights. Initially, 500 g of husk was used to make a block, but the thickness of the block was about 7 cm and it took about two weeks to dry under direct sunlight. Therefore, 300 g was used thereafter with different leaf amounts of 50 g, 60 g, 70 g and 100 g. The height of the block was 4.5 cm.

Evaluation of the fuel block

The selected block was tested for compressive strength and bulk density. The compressive strength was measured using a Dynamometer. The combustion characteristics of the blocks were tested by burning them in a simple stove shown in Plate 1.

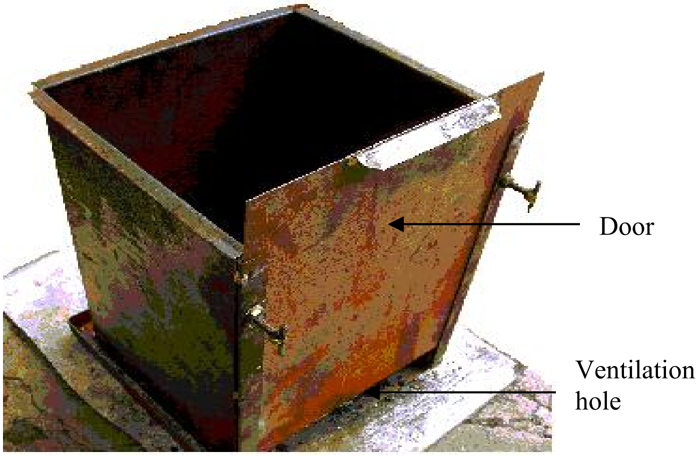

Plate 1. Stove used in combusting the fuel blocks.

As a mean to achieve a uniform burning rate, a side of the block having surface area of 4.5 cm x 10 cm was ignited and airflow was facilitated by adjusting the door. Temperature of the exhaust air during the burning process using a thermometer and the time taken were measured to determine burning rate. Velocity of the exhaust air and the area of the exhaust vent were measured to find the volume flow rate. Dry weight of the block and residual material after combustion were weighed. Ash contents of the two raw materials were found using muffle furnace by giving 550^0C temperature for 4 hours. The calculation of the combustion efficiency of material was based on the following Equations 1 and 2.

$$Combustion\,Efficiency\,of\,material = \frac{M_i - M_f}{M_{cb}} \quad (1)$$

$$M_{cb} = [\; M_{husk}(1 - \%ash) \;] + [M_{leaves}(1 - \%ash)] \quad (2)$$

(Assureira, 2002)

Where, M_{cb} = Total combustibles except ash
M_i = initial weight of the dried block
M_f = Weight of the residual matter.
M_{husk} = Weight of the paddy husk used.
M_{leaves} = Weight of the leaves used as a binding agent.

Paddy husk fuel block in domestic cooking

Fuel block was cut into pieces of about 5 cm x 5 cm x 5 cm and the cubes were fed into a commercially available domestic stove consisting two pot holes, made of clay which is known as "*Anagi Lipa*". Eight pieces (about 300 g) were fed at a time. A piece of wire mesh was used to arrange the husk cubes with adequate ventilation at the fireplace. Water boiling was done to evaluate the cooker efficiency, which is defined as the ratio of energy transferred to the water to the energy liberated by burning fuel.

RESULTS AND DISCUSSION

Preparation of paddy husk fuel block

The fuel block made out of husk generated from a Rubber Roll Sheller was not successful due to large particle size. Grinding of husk to reduce particle size is required if blocks are to be made from the husk out of the Rubber Roll Sheller. Out of the three binding materials tested, powder of tamarind seeds and the *Neolitsea* leaf extract were satisfactory in making blocks which are strong enough for handling. To form blocks out of powder of tamarind seeds, further testing is needed with different ratios of paddy husk. High amount of mucilage from cocoa peel has to be used with husk to obtain strong bonding. With different amounts of *Neolitsea* leaf extract added, the dimensions of the fuel block made from 300g of husk were about 20 cm x 10 cm x 4.5 cm after compression. After sun drying the blocks for about one week, weight reached about 300 g/block. A picture of a finished fuel block is given in Plate 2.

Plate 2. Paddy husk fuel block.

Evaluation of the fuel block

Combustion characteristics

A fuel block made of paddy husk, water and leaf extract of 300 g : 500 ml :100 g burnt for about six hours and fifteen minutes while the block of 300 g : 500 ml : 50 g burnt for about four hours and twenty minutes. Fuel block with higher leaf extract resulted lower burning rate and thus, it gave lower temperature in the exhaust air. Further, the fuel blocks with high leaf extract content showed partial combustion in outer crust than the fuel blocks with low leaf extract content as illustrated sequentially in Plates 3 and 4, respectively.

The combustion efficiency values obtained from burning of one block made with different leaf extract contents are given in Table 1. The combustion efficiency of material decreases with increasing amount of leaf extract for tested ratios as evident in Plates 3 and 4. The estimated average volumetric flow rate of exhaust air was 0.001 m^3/s.

Plate 3. Appearance of fuel block with 100 g of leaf extract after combustion.

Plate 4. Appearance of fuel block with 50 g of leaf extract after combustion.

Table 1. Block properties and combustion characteristics

Composition of a block (before drying)	Block dry weight (g)	Temperature of exhaust air (^0C)	Combustion duration (hr:min)	Combustion efficiency of material (%)
300 g : 500 ml : 50 g	292	48	3.40	91.77
300 g : 500 ml : 60 g	303	48	4.00	89.09
300 g : 500 ml : 70 g	270	46	4.30	85.58
300 g : 500 ml :100 g	302	45	6.15	*

Note: *: data are not available

It was observed that during the first half an hour of these tests, the temperature of the exhaust air was low due to thermal inertia and then it reached a higher value and remained approximately a constant. The blocks should be arranged tightly inside the furnace. If there is a gap between two blocks, a passage is provided for airflow that facilitates spreading of fire to hind surfaces, resulting in increased temperature of exhaust air due to greater burning area as illustrated in Plate 5. This condition has to be prevented to have a uniform burning rate. When two blocks were burnt instead of one block, combustion was faster. Therefore, when more blocks are burned, higher temperature can be obtained. The fuel blocks made, have improved the residential time and by burning them in a more efficient furnace which has good control over the air supply can achieve very high combustion efficiency of the material.

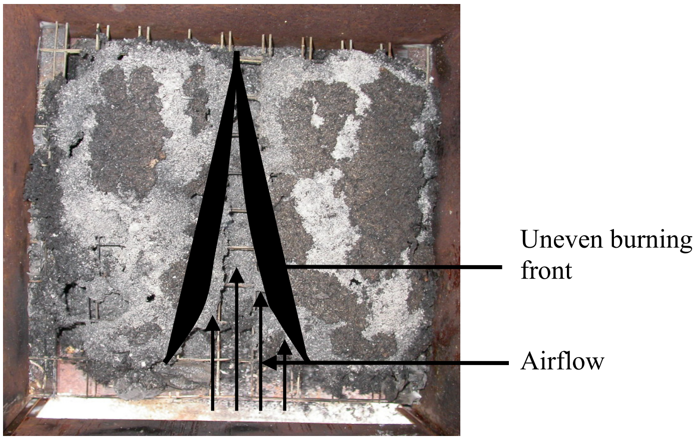

Plate 5. Changing burning surface of two blocks.

Generation of smoke did not seem to have an observable difference with time. More control of primary and secondary air followed by the CO and CO_2 gas analysis can be used to improve the combustion efficiency of the system. Therefore, further research is needed to develop an efficient furnace suitable for this task.

However, the block of 300 g with 50 g of binding agent burnt in a simple furnace gave promising results on approximately constant temperature of exhaust air over the burning process except the start-up phase. The ability to increase the temperature of the exhaust air with increasing number of blocks burnt is given in the Table 2.

Table 2. Temperature of exhaust air in the furnace

Time (hours:min)	Temperature of exhaust air (^{0}C)	
	One block	Two blocks
0.00	30	33
1.00	45	80
2.00	47	75
2.20	*	68
2.30	*	65
3.00	47	32
3.20	50	
3.45	44	

Note: *^{2} data are not available

Environmental concern

The major polluting agent of paddy husk combustion is CO, and particulate matter such as soot and fly ash. Fuel block improves the combustion characteristics because it increases the fire retention time. Levels of unfavourable gas emissions may be less but it should be supported with the results of an exhaust gas analysis.

Handling and storage

Compressive strength of the fuel block is 0.3 MPa while clay bricks used for construction have 0.5 to 2 MPa strength. Therefore, these fuel blocks are strong enough for handling and transportation. After drying of the block to a sufficient level of strength, its bulk density was about 310 kg/m^3 and can be stored under ambient condition without mould attacks. However, the blocks, which are not dried enough, can reabsorb moisture making them susceptible for mould growth and cockroach attacks.

Paddy husk fuel block in domestic cooking

Cubes of husk were burnt for about 15 minutes with a flame and then for about 10 minutes it appeared in red colour. Within 10 minutes from the start, it could boil one litre of water. In this process, pyrolysis is prominent at the initial stage. The efficiency of the cooker was about 14%. However, this result does not include the energy dissipated through the second stove that takes energy from the same source. For efficient use of blocks, it is recommended to use a designed stove especially for this purpose.

Cost effectiveness of paddy husk fuel block

For making 160 blocks in one session (6 hours) only with the support of available grinders and manpower, the estimated cost is Rs. 650.00. Increasing the number of blocks produced at a time can reduce the unit cost.

In briquetting, paddy husk should grind to a fine powder in a hammer mill and mix with Clay Bentoate or Yucca starch as a binder and water to form a paste and should put in a screw press machine to make pellets (Singh and Kashyap, 1985). However, it can be done without a binder and grinding of husk by giving special conditions such as high pressure. The high investment on the heated screwdriver machines required for this method may prohibit small-scale industries from production of briquettes. In comparison with briquetting method, fuel block preparation is very simple, less expensive and more feasible in introducing technology to small-scale millers. This will help to improve the productivity of the paddy sector and also the socio-economic status of the farming community.

CONCLUSIONS

The following conclusions can be drawn on the basis of results obtained in the experiments. The leaf extract of *Neolitzea* tree can be used to make paddy husk block with sufficient strength. The compression of the mixture of raw material with hand pressure was adequate. Burning rate can be changed with the percentage leaf extract added. The combustion efficiency of the selected block was about 91% and it has achieved approximately a uniform burning rate. Both these conditions can be improved with a suitable furnace which has good control over the air flow. As an alternative to firewood, smaller size cubes made of husk can be used in domestic stove.

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