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A RICE HUSK GASIFIER FOR PADDY DRYING

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Abstract

Due to energy crisis and constant increase in the price of fossil fuels, the world's trend changes to renewable sources of energy like solar, wind and biomass gasification. Substantial biomass potential is available in Pakistan in the form of agriculture or forest residue (rice straw, rice husk, cotton stalks, corn cobs, wood chips, wood saw, etc.). These can be best utilised for the production of producer gas or synthetic gas that can be used for drying of agricultural crops. The drying process is an important activity of post harvest processing for long-term storage. Rice husk is nowadays commonly used for biomass gasification and its heat content value is about 15MJ/kg. It constitutes about 30 percent of rice production. A rice husk gasifier was developed and evaluated on paddy drying at Japan International Cooperation Agency (JICA), Tsukuba International Center (TBIC), Japan. Rice husk gasifier has following major components; husk feeding system, ash chamber, burner, centrifugal fan, drying chamber, gasifier reactor, air duct and an electric motor of 0.37kW. The average drying plenum air temperature was recorded as 45°C during the drying process. The paddy 'IR 28' from initial moisture content of 24% was dried up to 14% moisture content for about 3.33h consuming 3kg/h of rice husk. The efficiency was found to be 58%. The rice husk gasifier can also be used for drying the fruits and vegetables, provided that heat exchanger should be attached with it. The overall performance of rice husk gasifier was satisfactory and will be beneficial for small scale farmers, food processors and millers as well.

Keywords: Biomass, Rice husk, Gasifier, Efficient energy system.

Introduction

Pakistan is a country facing energy crisis on many fronts. A viable strategy to solve the problem of energy deficiency in agriculture sector could be to take advantage of Pakistan's biomass potential. This is because Pakistan is producing millions of tonnes of biomass annually and hence there exists wider room for taking advantage of biomass energy for agriculture sector.

The annual average rice production for the last five years in Pakistan is 5.93 million tonnes (Table 1). Rice husk constitutes 30% of the rice production, which implies that annual average rice husk production in Pakistan is about 1.78 million tonnes. Therefore, this renewable source of energy can be exploited for drying of paddy by developing energy efficient technologies (Pathak and Singh, 1988).

Table 1. Availability of Rice husk in Pakistan (Anonymous, 2011)

Year	Production (1000 tonnes) paddy	Rice husk (1000 tonnes)
2006-07	5438.4	1631.52
2007-08	5563.4	1669.02
2008-09	6952.0	2085.6
2009-10	6882.7	2064.8
2010-11	4823.3	1446.99
5-year average	5931.96	1779.58

More than 1780 thousand tonnes of rice husk are produced every year in Pakistan (Anonymous, 2010-11). The rice-husk has heat content of

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15MJ/kg and it constitutes 30% of the rice production. There are two ways to get energy from rice husk: by direct burning or combustion and by indirect combustion with small amount of oxygen, called biomass gasification. Direct combustion increases green house gases and produced global warming effects whereas gasification by indirect combustion is the thermo-chemical process which changes biomass into useful and environmental friendly energy. By-products of gasification are carbon monoxide (CO), hydrogen (H_2) and methane (CH_4). The gas produced during gasification is known as producer gas or synthetic gas (Khan et al., 1998). Substantial quantity of rice husk is available at each rice mill. Rice husk energy cost is much lower, compared to the cost of energy obtained from coal and mineral oils (Table 2). Biomass has approximately 50 to 66% heat energy content compared with coal (Pathak and Singh, 1988). Biomass has a great potential for conversion into heat and mechanical power. As a result of rice husk gasification, some gases will be produced, which are listed in Table 3. These gases may be utilised as fuel in a boiler or in internal combustion engines. In future, biomass gasification technology will prove the cost-effective technology in the world (Pathak and Singh, 1988).

Table 2. Amount of energy produced by different fuels with their cost per tonne (Pathak and Singh (1988).

Material	Higher heating value MJ/kg	Cost/tonne
Rice husk (3.75Rs/kg)	15	3,750
Coal (10.26Rs/kg)	36	10,260
Diesel (94Rs/l)	46	94,000

Table 3. Composition of Rice husk producer gases (Anonymous, 1978)

Gases	Content
CO_2	4.2-7.7%
O_2	2.4-2.8%
H_2	4.8-7.8%
CH_4	4.5-7.2%
CO	22.7-25%
N_2	54.5-56.4%
Heat	1350-1586 Kcal/m^3

A study conducted by the Faculty of Agricultural engineering, University of Agriculture, Faisalabad, 2011, has shown that biomass could operate a 12kW single cylinder engine. Furthermore, gas produced by 18kg of corn cobs, charcoal, coal was 35, 41, and 39.7m^3, respectively (Ahmad et al., 2011).

Mahar (2011) assessed different technologies for converting agricultural biomass into energy and found biomass, biomass pellets and gasification technologies as most feasible, environmentally sound and economically viable.

In Pakistan, some paddy dryers are being run on paddy husk furnace, which creates environmental problems in the atmosphere:-

Objectives of the study

The objectives of the study were to:

- Develop a simple rice husk gasifier for small paddy growers.
- Evaluate the performance of rice husk gasifier for paddy drying.
- Perform the cost analysis of this technology.

Materials and methods

Development of prototype rice husk gasifier

The rice husk gasifier was developed in 2012, at the Agriculture Workshop Laboratory, JICA, Tsukuba International Center, Japan. The following design parameters were kept in mind, while developing the prototype of the gasifier:-

- It should be simple, portable and easy to operate.
- It should be light in weight, less than 40kg.
- It can be manufactured by local material using local manufacturing technology.

The rice husk gasifier consists of husk feeding system, husk chamber, burner, centrifugal fan, drying chamber, gasifier reactor, air duct and electric motor. Table 4 presents the list of material needed for gasifier. The inner view is shown in Fig. 1. The following design calculations were made to predict the rice husk required to dry 250kg paddy from 24% moisture content to 14%:

- Total water in 250kg paddy = 250 x 0.24 = 60kg
- Dry matter at 0.0% M.C = 250-60 = 190kg

- Final weight of produce at 14% moisture content = 190 x 100/100-14 = 221kg
- Water to be removed = 250 – 221 = 29kg
- Total energy required: 3000 kg/kg of H_2O×25kg = 87MJ
- Energy content of rice husk = 15MJ/kg
- Required rice husk = 87MJ/15MJ = 5.8kg
- Paddy layer recommended = 20 to 60cm
- Heated air temperature = 40 to 45°C
- Air quantity ratio = 0.5 to 1m^3/sec per tonne of paddy.

Table 4. Bill of material cost (MS Steel Price@Rs.120/kg)

S.No.	Item/description (mm)	Unit	weight	Quantity	Estimated price (Rs.)
1	Ash Chamber (510×510×110)	kg	8.38	01	1,005.60
2	Agitator (Diameter 460)	kg	5	01	600.00
3	Shell (Diameter 470)	kg	9.40	01	1,128.00
4	Burner (Diameter 70)	kg	6.02	01	722.40
5	Duct with shell cover (120×120×1400)	kg	8.0	01	960.00
6	Fan with 0.5 hp motor	No	----	01	4,500.00
7	Insulation material	$Meter^2$	----	01	1,000.00
8	Nut and Bolts (M6×15)	No	----	06	30.00
9	Nut and Bolts (M8×20)	No	----	06	30.00
10	Nut and Bolts (M6×15)	No	----	04	24.00
11	Drying Chamber (250 kg capacity)				25,000.00
12	Manufacturing cost				15,000.00
	Total Price				50,000.00

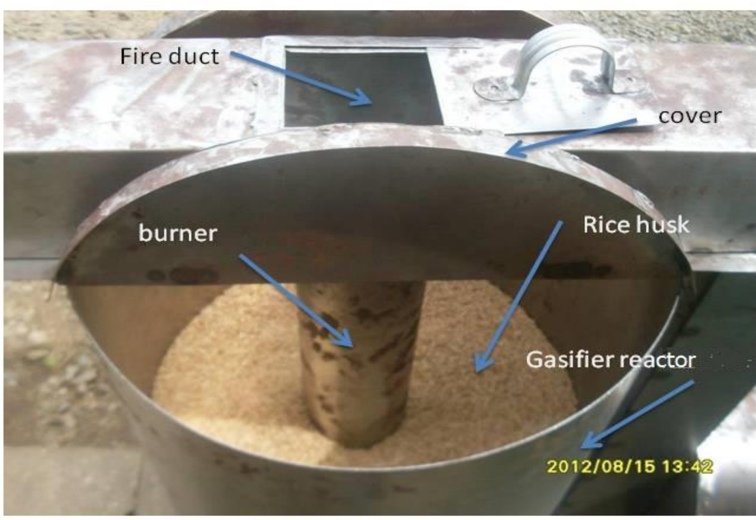

Fig. 1. Inside view of the rice-husk gasifier

Evaluation of a rice husk gasifier for paddy drying

The rice husk gasifier was field evaluated at Japan International Cooperation Agency (JICA) Agriculture Workshop, Tsukuba International Centre, Japan, on September 5, 2012. The key parameters measured were relative humidity of ambient air, plenum air of exiting air from the paddy grain; ambient temperature, plenum air temperature and temperature of paddy grain leaving the gasifier; drying time required for a batch of paddy drying; air flow rate entering the plenum; and the weight of the paddy grain loaded in the drying chamber. A picture of a rice husk gasifier is shown in Fig. 2.

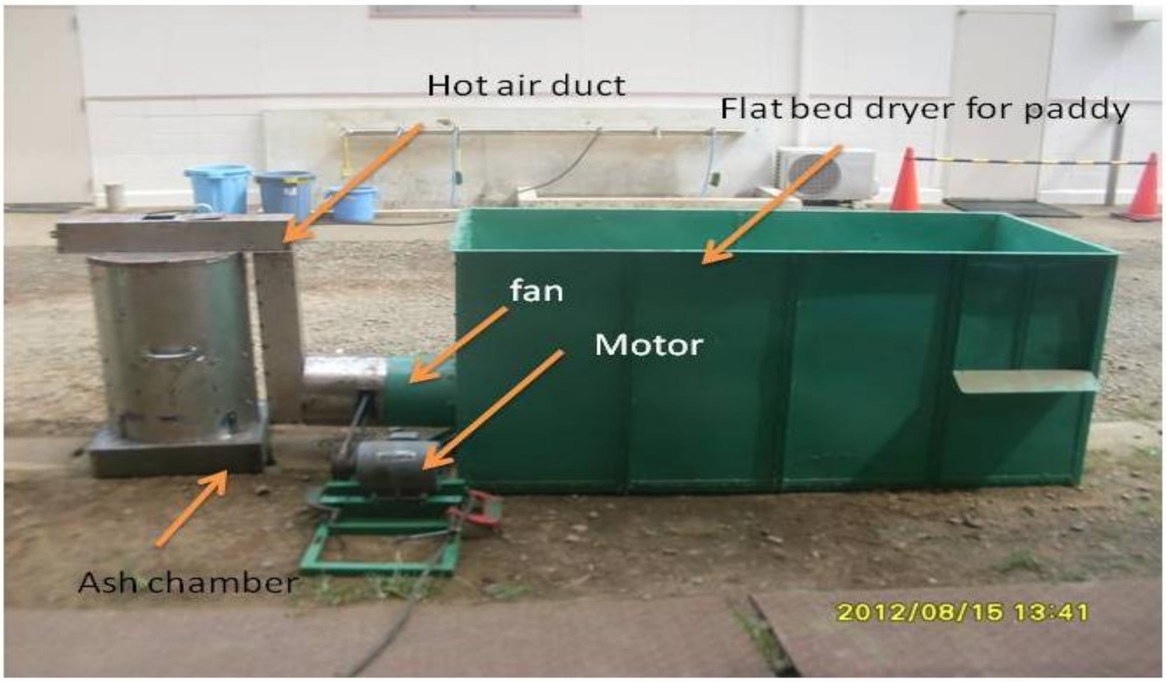

Fig. 2. A view of a rice husk gasifier

Instrumentation and Methodology

The temperature and relative humidity of ambient air, plenum air and exiting air from paddy grain were measured with digital thermohygrometer. The air flow rate was measured with velometer. Moisture content of paddy was measured with digital moisture meter. Three samples were collected from top, center and bottom for measuring the moisture content. The data was recorded at the start of drying operation and later, measurements were made after every 30 minutes. The drying time and the quantity of paddy grain loaded during the test. The loading and unloading time for the drying chamber was also measured in order to calculate the labour needed for loading and unloading of the paddy in the drying chamber.

Results and Discussion

Initial and final moisture content of paddy grain, air flow rate, quantity of grain loaded and the drying time during test conducted are presented in Table 5. Initially, the total mass of paddy before drying was 250kg with initial moisture content 24% and after drying was 221kg at 14% moisture content was recorded. Therefore, 29kg of water removed within 3.33h of operation process at an average drying air temperature 45°C. The air flow rate during the test was recorded to be 0.3m^3/s. The drying operation consumed 10kg of rice husk per batch of 250kg. The overall efficiency was calculated as 58% and no smoke was seen during the operation. The samples located at bottom layer were found quickly dried as compared to top layer. Hence, it is suggested that after every 30 minutes, the paddy should be stirred manually from bottom to top layers for uniform drying process.

Table 5. Performance test results of rice husk gasifier for paddy drying

S.No	Item/ Description	Specifications
1	Commodity	Paddy
2	Variety	IR 28
3	Loading capacity of gasifier	10kg
4	Loading capacity of dryer	250kg
5	Total drying time per Batch	3.33h
6	Initial moisture content	24%
7	Final moisture content	14%
8	Air drying plenum temperature	45^0C
9	Rice husk consumption	3kg/h
10	Average moisture removal/hr	3%/h
11	Drying cost of paddy Rs/kg	1.11
12	Average ambient temperature	31^0C
13	Ambient relative humidity	50%
14	Average exit temperature	33.5^0C
15	Gasifier efficiency	58%
16	Air flow rate	$0.3m^3/s$
17	Initial weight of paddy before drying	250kg
18	Final weight of paddy after drying	221kg

Efficiency of rice husk gasifier = required rice husk/rice husk consumed

= 5.8/10 x 100 = 58%

The economic analysis is the most important for farmers as well as the end users to find out the cost of drying. Table 6 reveals the cost analysis of rice husk gasifier. The methodology used to anticipate the fixed and variable cost was that presented by Kepner et al. (1978). The purchase price of the new rice husk gasifier for paddy drying was estimated to be Rs. 50,000/- and the useful life of rice husk gasifier for paddy drying is assumed to be 15 years. The annual fixed cost of rice husk gasifier for paddy drying was calculated to be Rs. 6850/- Annual drying capacity of rice husk gasifier for paddy drying is assumed to be 30 tonnes/year. Therefore, the fixed cost of drying paddy is predicted to be Rs.1112/tonne. For paddy drying operation, about 13.3 man-hours per tonne are needed. The rice husk consumption is about 40kg/tonne of paddy drying and repair and maintenance cost is estimated to be Rs. 33.3/tonne. Hence, the total variable cost is predicted to be Rs. 883/tonne. This makes the total cost (fixed + variable cost) about Rs. 1112/tonne. Therefore, the cost of drying per kilogram of paddy was Rs. 1.11. The gasifier is economical and environment friendly, compared to diesel dryers. This gasifier is 8 to 9 times more efficient than the conventional methods, using diesel or LPG dryers by the rice mills. Due to lack of drying facilities at farm level, farmer cannot store its crop for a prolonged period; hence, he disposes off its product soon after harvesting to vendors or rice mills at nominal cost. By adopting this gasifier, he can store and sell crop at his own will.

Table 6. Cost analysis of Rice Husk Gasifier for paddy drying

Item	**Rice Husk Gasifier (900×470Ø)**
Purchasing cost of gasifier with drying chamber (Rs.)	50,000
Useful life (years)	15
Salvage value (10%)	5,000
Fixed cost (Rs./year)	
Depreciation	3000
Interest (14%) on average investment	3850
Total fixed cost (Rs./year)	**6850**
Variable cost (Rs./Year)	
Electricity/30 tonnes/year	6000
Repair and maintenance cost (Rs./year) 2% of purchase price	1000
Husk cost@Rs.150/40kg/tonne of paddy drying	4500/30 tonne
Labour cost (Rs 500/tonne of paddy drying)	15000/30 tonne
Total cost (Rs./year)	**33350**
Dried paddy output capacity (kg)	30000
Drying cost of paddy (Rs./kg)	**1.11**

Conclusions and Recommendations

Following conclusions were drawn from this study:

- Biomass gasification is an efficient and attractive energy system for agriculture purposes, like, grain, fruit and vegetable drying, green house, room and water heating system.
- Gasification is the best way to minimize the environmental impacts.
- The construction of gasifier is simple and can be built by local manufacturers.
- Gasifier is a very cheap technology for poor farmers, progressive farmers, millers, food processers and small industries.
- For the skin type grains (paddy, sunflower, canola, groundnut, buck wheat, etc.), there is no need of heat exchanger in drying but in case of fruit and vegetables drying, heat exchanger should be attached for the best quality.

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