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Adoption of Integrated Solar System with Thermic fluid working medium for Parboiling Rice Mills in Tamilnadu

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Abstract

Tamilnadu is having more than 3000 rice processing or manufacturing units popularly known as Rice Mills. The typical Rice Mills are energy intensive and huge quantity of waste generation sector especially in sorting contaminants, parboiling process and husk removal. The two major process in the boiled rice manufacturing industry are Parboiling and Drying of paddy, in which steam is used as the thermal energy source through rice husk/ firewood boilers having $SEC_{(t)}$ of 195- 280 kg /ton of paddy. Therefore Parboiled rice processing is considered to be water and energy intensive and therefore affects the environment significantly. The thermal energy consumption for par-boiled rice process is 2800- 3800MJ/ton paddy, of which 20-30% is for Parboiling process and steaming process and 60 -70% for paddy drying process. Several attempts were made already to adopt solar system as an alternative source of thermal energy which has been trailed for hot water and hot air generation separately. These approaches had resulted in increase in high investment with very low rate of return and resulted as a non attractive in economic terms. Hence, this study has been focused on study of thermal energy requirement of the above processes of rice mill and to check the viability of adoption of an integrated solar thermal system with thermic fluid as working medium. The expected outcomes of this study will be reduction of $SEC_{(t)}$ to be less than 100 kg /ton of paddy to null value and also to make carbon neutral.

Keywords: Parboiling Ricemill; Integrated Solar system with Thermic fluid ; Specific Energy Consumption $SEC_{(t)}$

1. Introduction

Rice is the main food staple for most of the countries particularly Asia- Pacific regions, that has been cultivated by farmers in a micro level to industries of large scale. Due to the richness in nutrients and pack of various minerals, Rice is the highly consumed food in all parts of the world and considered as central to the food security of over half of the world population. Among the world's total rice production 95 percent has been contributed by developing countries. [7] However, the emission and pollutants from a rice processing units has to be considered which is accounting for 5 to 10 percent of global methane gas emissions and consuming 3,000 to 5,000 liters of water per kilogram of paddy processed. [8] The Asian countries like India will contemplate rice mills as a traditional sector and the largest food industry. Every year India makes an average turnover of Rs. 40 thousand crores and more. In India around 80-90 million tonnes of rice has been manufactured every year and this grain has been consumed as main food staple. The Rice processing segment in India has been contributed by more than 50 % of the overall rice production is processed by modern mills, despite of high cost, mills based on conventional process contributes 40%, and the hand pounding type of processing contributes rest. (Shweta et al. 2011).

2. Methodology

In this article, Process flow, energy consumption profile, SEC and fuel usage pattern for Rice Manufacturing Industries were investigated. For this purpose, several Rice mills (modern rice mills) plants with different capacity from 2 tpd to 10 tpd located in the India - Tamilnadu regions were reviewed. The study focused on Parboiled rice manufacturing type of rice mills. The electrical energy consumed as well as thermal energy consumed in the par boiling process of paddy only considered and energy consumed in milling / hulling section were therefore eliminated from the scope of study. Out of the 15 mills considered initially, twelve mills were found to have near to similar energy consumption pattern in the parboiling process of paddy section.

2.1. Production process:

The raw material paddy has been subjected to several processes, before it arrives stock yard for bagging. The complete paddy processing to produce parboiled rice could be grouped into following major steps:

a. Paddy preparation:

The contaminants like rice straw, dust, stone, sand, present in raw paddy obtained from field are removed using air blower and screened through a vibrating screen with different perforation size. This approximate process time for this raw paddy preparation is about 2-3 hours for every batch of production. Post preparation, the cleaned paddy is stacked in vertical silos for temporary storage before undergoing other processing steps like soaking, parboiling etc.

b. Soaking:

Cleaned paddy from storage silos is transferred to mild steel soaking pit through conveyors. For soaking every tonne of paddy, around 1,200 kg of hot water is required approximately. In this process of soaking the paddy in hot water of temperature around 85 °c, the quantity of heat required is estimated as 72,000 kCal, which is needed to raise the temperature of water from its normal standard temperature i.e 25°c [4]. Most of the large scale units have effluent treatment plants (ETP), but in general the waste water from this soaking pit is directly drained into sewage line without any treatment. The process of draining the waste water takes approximately 60min for one complete batch of soaked paddy. The soaked paddy is left as it is in soaking bin for about eight hours after draining of water.

c. Steaming:

The soaked paddy is cooked by using steam generated from in-house boiler in parboil rice manufacturing process. In case of raw rice, this steaming operation is not required. During this stage, two steaming vessels are used with one in operation at each batch for steaming 600–700 kg of soaked paddy with a process time of 10 minutes per batch where, the steam expels out from the vessel indicating it has reached the top surface of the steaming bowl and steaming process is completed. Soaked paddy from earlier step is transferred to steaming vessel by gravity or by manually and the entire batch takes around four hours for complete steaming by using two bins.

d. Drying:

Steamed paddy is dried either on open concrete floor of the yard in sun light or by indirect heat transfer in hot air dryer system. In case of hot air dryer, hot air is either generated in a steam-based heat exchanger or direct hot air generator with automatic temperature controller to maintain hot air temperature as per process requirement. Steamed paddy with around 32% of moisture is first transferred to port dryer where moisture is reduced to 22% then further transferred to second dryer for final moisture reduction to the level of 13–14%. The entire drying process takes about 1-30 hours based on the mode of operation. Dried paddy is stored in silos as an intermediate storage before milling section.

e. Milling:

Rice is milled from paddy with husk and bran as by-products. Rice husk is the main secondary product in rice milling, and these husk mostly consumed internally as a fuel to the boiler. Another, high premium by-product is bran which contains 60% of nutrients in rice kernel is sold out for production of value added edible items. In general, Rice bran accounts for about 8% of total weight of paddy being processed. In the milling section, dried paddy is subjected to various subsequent processes like screening, de-husking, separation, cone polishing, separation and grading, silky polishing, etc., depending upon the existing facilities in the rice milling plant. After completion of the above entire process final polished rice is transferred to rice yard for manual or automatic bagging.

2.2 Energy Consumption and Energy Intensive Parboiling Process:

Energy consumption in the rice milling cluster is mainly of two forms i.e. Electrical and Thermal Energy. The electrical energy has been consumed by the motors in milling section, conveyors, dryer blower and auxiliaries of boiler section. The thermal energy requirement and consumption is available only in parboiled rice manufacturing mills, where paddy is processed through Soaking, Steaming and drying process. These thermal energy intensive processes are not available in raw rice manufacturing mills. The thermal energy requirement is in the form of steam which has been generated through steam boiler is used for soaking and drying the steamed paddy. These steam boilers use rice husk or any agro residue as a fuel. The steam is used for heating the water. In some units, the separate hot air generators are used. Therefore the Parboiling process becomes the significant as well as energy intensive process in Rice mill industry. In a parboiled unit, paddy steaming and dryer sections account for major thermal energy consumption. The average 'specific energy consumption' (SEC) of parboiled units in studied group of units is 0.061–0.064 per tones, the SEC of a hulling unit is estimated to be 40 kWh per tonne of rice processing production (equivalent to 0.003 toe per tonne).

The schematic diagram (Figure 1) of a typical energy intensive Parboiling Rice manufacturing process is shown as below.

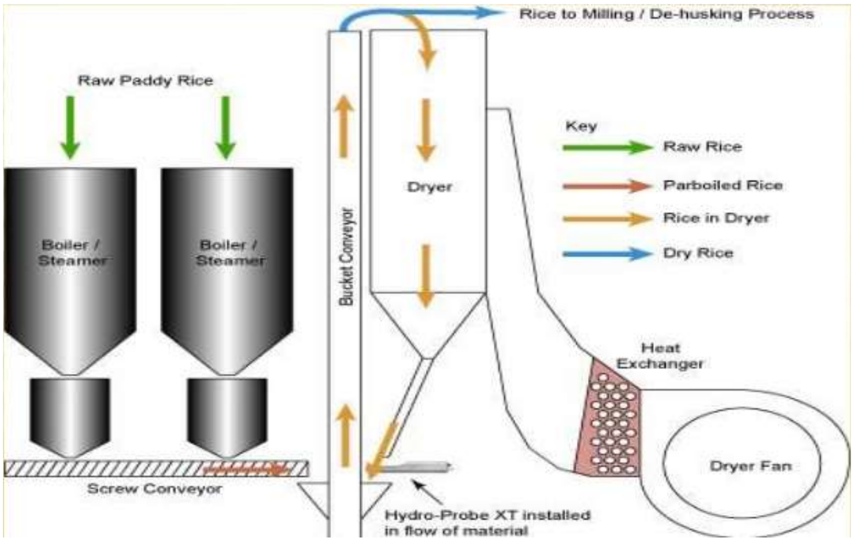

Figure 1 Parboiling Rice Manufacturing Process

2.3 Energy scenario:

The rice mills mainly use husk produced during processing of paddy for meeting the internal thermal loads. Very few units use fire wood or briquette along with rice husk. Electricity is sourced from grid for meeting the demand of electrical loads in the mill. Grid electricity is supplied by local DISCOM. The details of major energy sources and tariff s are shown in the table below. Rice husk is a secondary output product of rice processing which has a good utilization value considering as a biomass fuel. Almost 85% of rice husk is used in-house to produce steam through husk boilers and the balance 15% is sold out. Generally, steam at 8-10 kg/cm^2 pressure is used in parboiling section. The average capacity of boilers used in rice mills is about 2.5 tph. Steam is used mainly for following purposes in a rice mill:

- Soaking using steam by direct injection in steaming bowls
- Steam cooking
- Dryers for generation of hot air in heat exchangers for drying of wet paddy after completion of steaming process.

Typical energy consumption range of typical Parboiled rice mills:

- Husk/wood (tpy) : 101-1200
- Electricity (kWh/year) : 1.10 -5.51 Million units
- Total energy (toe/year) : 110 - 384
- Specific Energy Consumption : 195- 280 kg of fuel / ton of paddy
- Specific Power Consumption : 25 – 34 kWh / ton of paddy

2.4 Energy Conservation Measures in Parboiling Process:

Pillaiyar (1998) has narrated that soaking process with a bath time of 60 min at 70 °C followed by draining the water and tempering for 4 h restricted the grain moisture and on steaming the moisture content increases to 28 %. The paddy parboiled by short soaking tempering (SST) which dries at a higher rate and reduces drying time by 25 %. Alternate method is sand parboiling technique, in which the soaked paddy is mixed with hot sand maintained at a temperature of 150–180 °C. In a traverse time of 40–60 s through the commercial mechanical sand roster, the soaked paddy is gelatinized and dried to a moisture level of 16–18 % through a co-current process. In the last decade, an innovative parboiling system using thermic fluid medium was developed by Paddy Processing Research Center (PPRC), in which, the soaked paddy is subjected to a gelatinization unit and then dried at faster rate and it reduces drying process time by 40% [5].

2.4. a Solar water heater

Both small and medium rice mills in the cluster provide significant scope for adoption of solar water heaters that can be used for generation of hot water at about 60–70°C. Hot water is required in soaking of paddy in steam bowls. Apart from soaking process, the hot water can also be used as boiler feed water that would help in fuel saving. The estimated energy saving potential is 700 tonnes per year of husk (equivalent to 220 toe). The equivalent monetary saving is `1.5 million.

2.5 Energy Conservation Measures in Drying Process:

An improved emission free technology in adopting solar energy for drying process is the use of solar dryers where heating of air through a solar collector is used for the process. The two application modes of solar dryer used are: natural convection dryers where the air flow is induced by thermal gradients; and forced convection dryers forced air through a fan is heated in a a solar collector then passed through dryer. (Brenndorfer et al. 1985)[2].

Several work has been undertaken for development of cost effective and energy efficient solar collectors for agro drying applications (Brenndorfer et al. 1985; Davidson 1980)[2]. The elementary type of collector is the bare plate that has an air duct and the uppermost surface of which acts as the absorber plate. The covered plate collector in its various forms utilises a translucent cover above the absorber plate. Compared to bare plate collectors, the covered plate collectors are more heat effective but the limitations are due to complex design and high cost.

3. Conclusions

Energy conservation through efficient utilization of energy as well as switching to Green energy (solar) is a difficult approach to the food processor / researchers. Parboiled Rice mills are one of the most energy intensive food processing industries. The quantity of rice husk used as fuel is reduced then it would enable the rice industry to market unused rice husk as a cash product. A significant reduction in energy losses is possible in areas such as steam distribution including insulation and steam traps, steaming bowl, and paddy dryer. Further, it may be noted that the level of reuse of water from different processes in rice mills is very low, which has a potential for improvement in water scarce countries like India. Hence the study is required to integrate the above energy conservation techniques in parboiling process will lead to emission free cost effective method. The study will focus on thermic fluid system using renewable energy that can be used for all the thermal energy requirements in the rice mill industry to tap maximum heat from the system as well as to reduce fuel requirements. Therefore it has been inferred from the above study is that adoption of Solar System with Thermic fluid working medium for Parboiling Rice Mills in Tamilnadu is techno economically viable.

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