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Energy utilization pattern of local rice mills in Mungeli district of Chhattisgarh state

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Abstract
The present study has been conducted in two modern rice mills which have capacity of 4 t/h and 2 t/h for parboiled rice and raw rice respectively. Both the rice mills are located in Mungeli district of Chhattisgarh state. The entire research work has been carried out by the way of self-investigation with helping hands. Energy consumption data has been measured for each machineries of rice mills. After the entire study, it was noticed that the total electrical energy consumed in production of one tonne parboiled rice milling is 50.10 kWh/t, thermal energy is 826.50 kWh/t and also the maximum manual energy consumed is 4.19 kWh/t. Further, it was estimated that, the total electrical energy consumed in production of one tonne raw rice milling is 30.97 kWh/t and manual energy consumed is 1.82 kWh/t. In case of parboiled rice mill consumed net electrical energy is 21.98 kWh which is about 56% higher than that of raw rice mill. These data generated from this study could be used for detection of power losses used in different processes of rice milling. It could help in efficient utilization and selection of process as well as machineries for milling of both raw and parboiled rice.

Keywords: Rice mill, energy consumption, electric energy, Chhattisgarh.

Introduction
Energy is the prime mover of any economy and engine of growth around which all sectors of economy revolve. Improvement on energy generation, estimation and conservation are important for development of industries (Sardianou, 2007) [5]. Hence, there is need to have little precise idea of the energy consumption of different production areas, energy efficiencies of different operations and machineries used in different operations. This study helps to understand more about the ways energy and fuels are used in a rice milling industry starting from cleaning to bagging operations and also help in identifying the areas where waste of energy can occur and where scope for improvement exists (Goyal *et al*., 2014) [6].
Rice contributes around 45 per cent of India's cereals production and is the main staple food for almost 65% of the population in India (Bisne *et al*., 2009) [1]. India is the 2nd largest producer and consumer of rice in the world (Ray *et al*., 2016). Rice cultivated in about 44 Mha with a total production of 104 MT in 2015-16 accounting for 22.81% of global production. In Chhattisgarh, a newly born state known as "rice bowl", rice is sown in 3.7 Mha out of the total geographical area of 4.78 Mha, rice (Pandey *et al*., 2012) [3]. The average productivity of rice in Chhattisgarh is 1.2 to
1.6 t/ha. Paddy itself cannot be consumed in its raw form and it needs to be suitably processed into rice to enable it for human consumption. Hence, milling is required to convert paddy into rice. Milling of Paddy is one of the oldest and largest agro processing industry in Chhattisgarh State with more than 1500 registered rice mills, out of which Mungeli district contributes about 3% of total rice mills in the state (Ekka *et al*., 2016) [4].

Materials and Methods
Plant Description of Rice Mills
Harvested paddy undergoes some sequential operation (soaking, steaming, drying, milling and finally weighing and bagging) which convert it to the final primary product known as milled rice. All these processes have been carried out in rice mill. The present study was conducted at two different rice mills (M/s Vardhaman Rice Mills Pvt. Ltd.) in Mungeli district of Chhattisgarh state which was equipped with modern rice milling machineries. The capacity of raw rice milling plant was 2 t/h and parboiled rice milling plant was 4 t/h. The data required for accomplishing the objectives of the study were collected both from primary and secondary sources. The primary data collected from the mill owners by interviewing and different questionnaires. In case of secondary data, various secondary sources like records maintained by the mill owners, official publications, references, and official data from government offices

etc. were used. It was also necessary to supplement the interviews with secondary research, including review of related literature and gathering of published secondary data. Thementire methodology of rice milling process is shown in Fig. 1.

Raw rice mill

The milling section consists of oscillating type paddy cleaner, destoner, a rubber roll sheller, an indented tray type paddy separator, a cone polisher, a grader and bucket elevators. All the machines were in series and interconnected by chutes that were fed by bucket elevators. The operation of weighing and bagging were done manually.

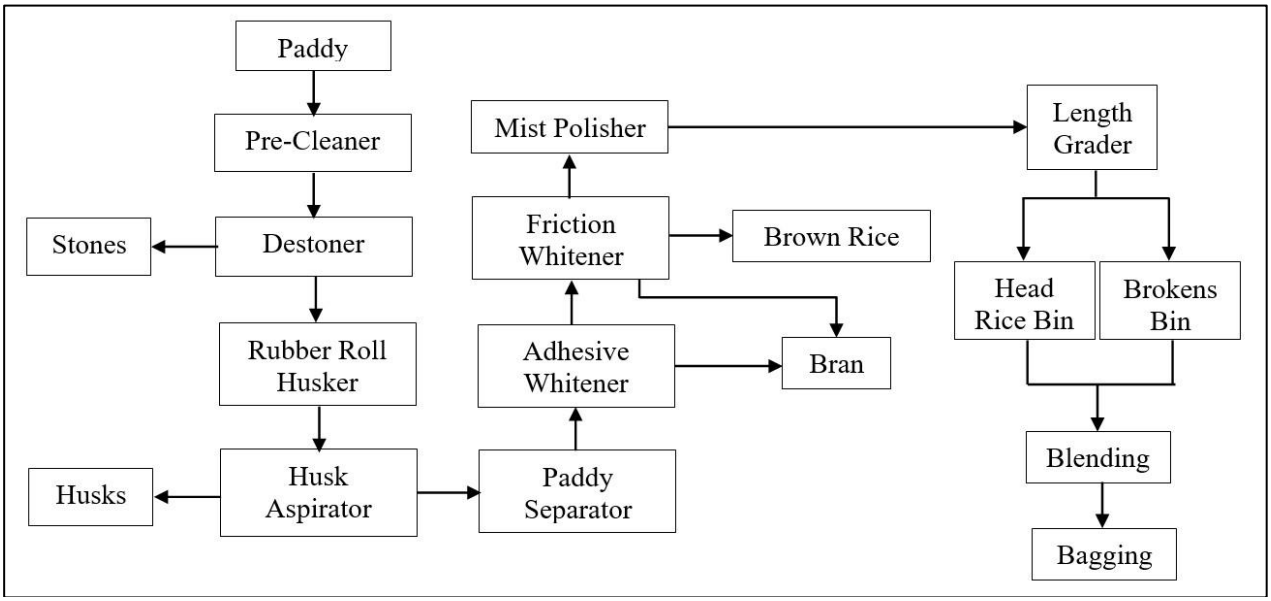


Fig 1: Schematic diagram of different processes adopted in raw rice milling

Parboiled rice mill

Milling section of parboiled rice mill consisted of a paddy cleaner, a rubber roll sheller, a husk aspirator, a compartment type paddy separator, three cone polishers, an indented cylinder type rice grader and bucket elevators. The operation of weighing and bagging were done manually. In parboiled rice mill, polishing of paddy requires higher attrition due to increase in hardness during the parboiling treatment.

Methods of Measurement

Different methods were adopted and formula were used to measure the various parameters required for calculating the total energy consumption in the rice milling process.

Measurement of electrical energy in paddy processing

An electrical energy meter (kilowatt-hour) was used to measure the electrical energy consumption. The energy meter was connected in the electric circuit of individual machine. The machines were operated without load for 30 minutes and thereafter with load for 30 minutes and observations of electrical energy consumption were taken with or without load simultaneously.

Determination of husk content

To determine husk content of paddy, 100 grams of paddy were taken. Their weight was noted down. From these data, the percentage of husk was determined using the following formula.

$$\text{Husk Percentage} = \frac{\text{Weight of husk}}{\text{Weight of paddy}} \times 100$$

Human energy estimation

Following constants were used to convert them in term of MJ (Mittal *et al*. 1985).

1 man-hour = 1.96 MJ = 0.544 kWh
1 woman-hour = 1.57 MJ = 0.436 kWh

Water requirement for soaking operation

The quantity of water required to fill the pore space of paddy was calculated by using following expression:

$$W_p = \frac{W_u \times P_v}{B_d} \times 100$$

where, Wp = weight of water required to fill the pore space of paddy, kg

Wd = weight of paddy to be soaked, kg Pb = porosity of paddy, per cent Bd = bulk density of paddy, kg/m3

Thermal energy estimation

The temperature of the water from initial temperature to the soaking water temperature was calculated by following formula:

$$E_1 = W \times C_w \times \Delta t_1$$

where, E1 = heat required for soaking, kJ W = total weight of water, kg CW = specific heat of water, kJ/kg 0C
$\Delta t1$ = temperature difference of initial water and heated water for soaking purpose, 0C.

Eenergy consumption in drying operation

To determine the energy consumption in drying operation, the following formula was used:

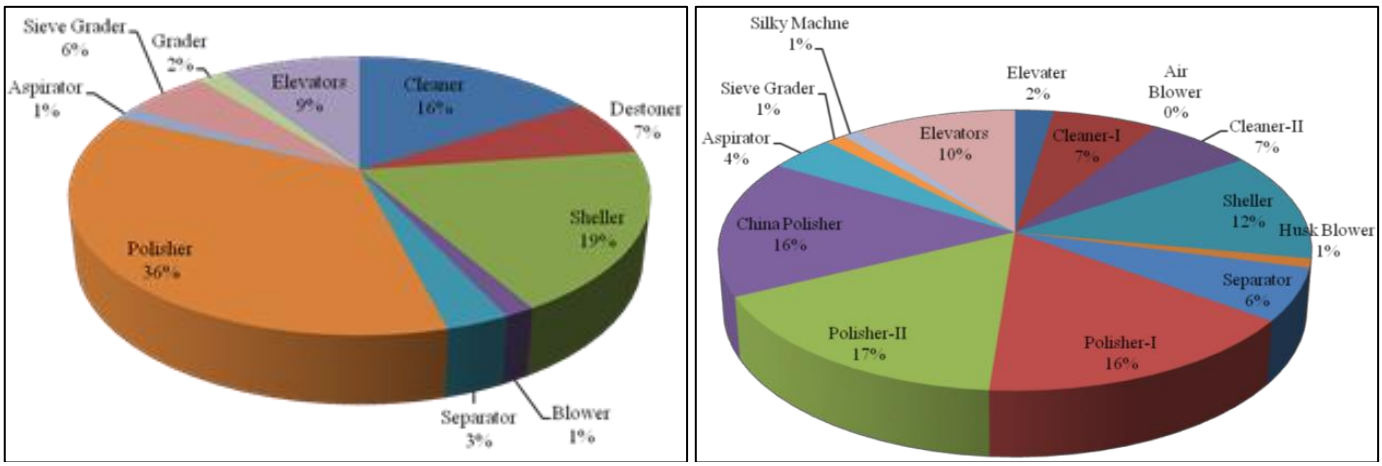
$$E_{dr} = \frac{(W_{dr} \times C_f) + E_{el} \times T) + M_h}{Q_{dr}} \times 100$$

where, Edr = energy consumed, kWh/t of paddy Wdr = quantity of fuel used for drying, kg Cf = calorific value of fuel used, kWh/kg Eel = electrical energy consumed, kWh/h T = drying time, h
Mh = human energy, kWh
Qdr = quantity of paddy dried, t

Results and Discussion

The milling machinery needs higher electrical load for its several operation viz. pre-cleaning, shelling, separation, grading, polishing, etc. The total energy consumed was found to be 922.81 kWh/t of paddy processed by a 4 tonne per hour capacity modern parboiled rice mill out of which the total electrical energy consumption, thermal energy consumption and manual energy consumption was measured to be 55.96 kWh/t, 862.50 kWh/t and 4.35 kWh/t, respectively. Similarly, in case of raw rice milling, the total energy consumed was found to be 32.96 kWh/t of paddy processed by a 2 tons per hour capacity modern raw rice mill out of which the total electrical energy consumption and manual energy consumption was measured to be 29.73 kWh/t and 2.96 kWh/t, respectively.

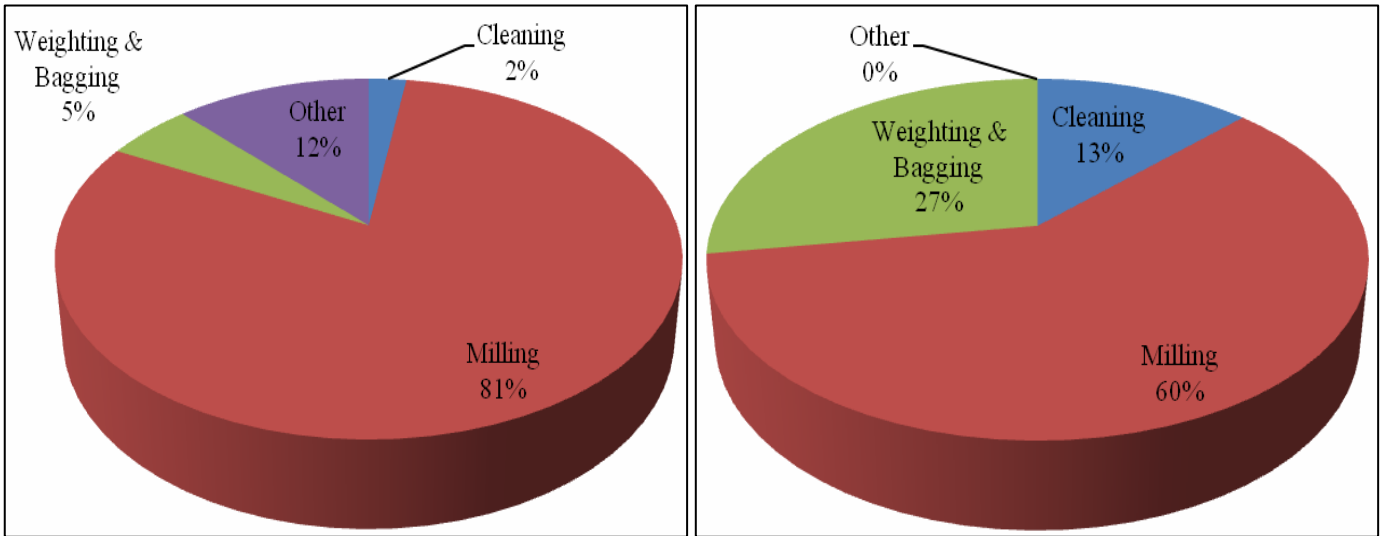
The results of equipment-wise net electrical energy consumption obtained from the raw rice milling and parboiled rice milling for 30 minutes duration were graphically presented in Figure 2(a) and Figure 2(b).



(a) Raw Rice Milling (b) Parboiled Rice Milling

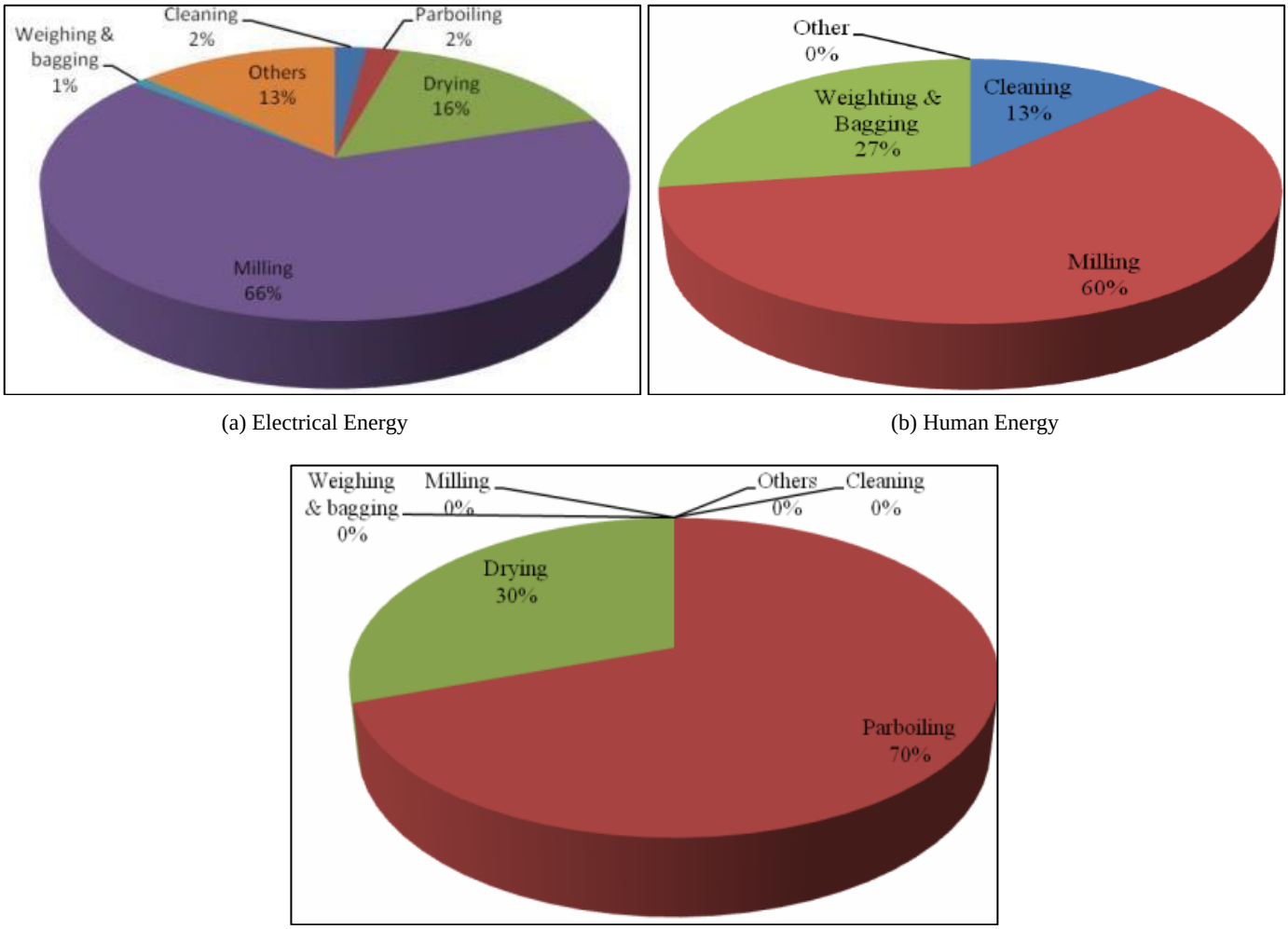
Fig 2: Net Electrical Energy Consumption (N.E.E.C)

In raw rice milling process, it is obvious form the Fig. 3a that, maximum net electrical energy was consumed for polisher (5.07 kWh/t) followed by sheller (2.65 kWh/t), cleaner (2.28 kWh/t), elevator (1.32 kWh/t), destoner (0.94 kWh/t), sieve grader (0.8 kWh/t), separator (0.42 kWh/t), grader (0.25 kWh/t), aspirator (0.2 kWh/t) and blower (0.2 kWh/t). In case of parboiled rice milling as evident from Fig. 3b, the highest net electrical energy was required by the different polishers (10.62 kWh/t) followed by sheller (2.74 kWh/t), different cleaners (2.89 kWh/t), separator (1.34 kWh/t), aspirator (0.9 kWh/t), sieve grader (0.27 kWh/t) and husk blower (0.24 kWh/t). The operation-wise energy consumption in both raw and parboiled rice milling was presented in Figure 3 and Figure 4, respectively.



(a) Electrical Energy (b) Human Energy

Fig 3: Operation-wise Contribution of Energy Consumption in Raw Rice Milling



(a) Electrical Energy

(b) Human Energy

(c) Thermal Energy

Fig 4: Operation-wise Contribution of Energy Consumption in Parboiled Rice Milling

From the Figure 3, it was evident that electrical energy consumption in raw rice milling is maximum for milling operation followed by other operations (lighting, bucket elevators, etc.), weighing & bagging and cleaning. In case of parboiled rice milling maximum electrical energy was consumed milling operation followed by drying, other operations, cleaning, parboiling and weighing & bagging as evident from Figure 4. In case of thermal energy consumption in parboiled rice milling, maximum energy was consumed in parboiling operation followed by drying, cleaning, weighing & bagging, etc.

Both the rice mill selected in the study was modern rice mill, hence less manual energy was consumed in the milling process. The total manual energy used was 2.96 kWh/t and 4.35 kWh/t in raw rice milling and parboiled rice milling, respectively. Higher manual energy has been used in parboiled rice milling due to the involvement of more processes like soaking, steaming and drying in parboiling the rice.

Conclusions

These data generated from this study could be used for detection of power losses used in different processes of rice milling which helps in efficient utilization and selection of process and machineries for milling of both raw and parboiled rice.

The following specific conclusions were drawn from the study:

- Total electrical energy consumed in production of one tonne parboiled rice milling is
- 50.10 kWh/t, thermal energy is 826.50 kWh/t and also the maximum manual energy consumed is 4.19 kWh/t.
- Total electrical energy consumed in production of one tonne raw rice milling is 30.97 kWh/t and manual energy consumed is 1.82 kWh/t.
- The parboiled rice mill consumed net electrical energy is 21.98 kWh which is about 56% higher than that of raw rice mill.
- Parboiled rice mill consumed 96.44% more energy for production of one tonne milled rice as compare to the raw rice mill.

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