



Development and Evaluation of Low Pressure Multi Briquetting Machine for Rural Areas

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAK designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors RJ, UHV, SMG, AKK and CR managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2019/v34i130113

Editor(s):

(1) Dr. Elena Lanchares Sancho, Professor, Department of Mechanical Engineering, University of Zaragoza, Zaragoza, Spain.

Reviewers:

(1) Dr. Oluwole, University of Ibadan, Nigeria.

(2) Dr. Klaus Doelle, USA.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/30814>

Original Research Article

Received 24 October 2016

Accepted 08 February 2017

Published 28 March 2019

ABSTRACT

A hand operated low pressure biomass multi briquetting machine was developed and evaluated which works using a screw press mechanism. The developed system mainly consists of multi square moulds, multi circular moulds, single circular mould pressing plates, base plate, supporting stand and steering wheel. Rice husk, tamarind kernels, groundnut shells, and sawdust were used as raw materials along with cow dung and tamarind powder as binding material for preparation of briquettes. The developed machine was tested with various combinations of agricultural residues and developed various combinations and proportions of raw material briquettes and studied the thermal and physical properties of developed briquettes. The developed machine is low cost and simple in operation and able to produce sixty briquettes per hour.

Keywords: *Screw mechanism; briquettes; Bio- waste; rural development.*

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1. INTRODUCTION

The need for alternative sources of energy has been a sensitive issue for the past years. In India, the harnessing and utilization of renewable energy has been a significant part of the government's strategy to supply the energy needs of the country. To minimize the dependence on imported fuel and to solve problems on energy shortage, considerable efforts have been made to utilize the country's available resources. The use of the several forms of renewable energy such as the geothermal, wind, and solar are studied and researched upon to maximize the benefits that can be harnessed for the country. Briquetting of biomass is a booming alternative energy source found in rural areas. Biomass fulfills 90% of the rural energy and 40% of urban energy needs. In India Agricultural & Horticultural activity generates annually about 500 – 600 million tons of agricultural waste. Major part of biomass produced in India is used for fodder, domestic fuel or construction material in rural housing, fuel for industrial boilers, etc. Crop residues are mostly used for direct burning with very low thermal efficiency [1]. The major residues are rice husk, coffee husk, coir pith, jute sticks, Bagasse, tree leaves, groundnut shells, saw dust, mustard stalks and cotton stalks etc. India's share of biomass energy usage is around 4.7% of the total energy demand of the world [2].

Sharma [3] reported that briquetting substantially increased density and calorific value of the biomass. In general, strength of briquette increases with briquetting pressure and binder content. The effect of added binder is simply to supplement or to substitute the forces of cohesion between particles under pressure [4]. Paper pulp has been reported to be a good binder for briquetting of biomass [5].

As discussed by Cheremisinoff et al. [6], biomass is essentially a plant material, ranging from algae to wood, in form. However, agricultural residues such as manures, straws, cornstalks, and other by-farming products, are considered to be one of the chief sources of biomass for energy production. The energy content of biomass is relatively uniform, on the order of 9000 Btu/lb (20,890.188 kJ/kg), which is roughly half to two-thirds of coal's heating value. Moreover, there are major advantages of biomass as fuel which are as follows: biomass contains negligible sulfur, generates little ash, and most importantly, is continually renewable. These advantages

make it more appropriate to use biomasses as fuel.

Akubuo OF and Okonkwo CO [7], stated that, the briquetting machine is of great importance to poor and developing countries as it addresses the issues surrounding the efficient utilization of abundant quantities of agricultural wastes and residues which provide an enormous untapped fuel resource. Amanor and Nartey I [8] suggested that, the manual biomass briquetting machine suitable for the production of biomass briquettes on a small scale with a production capacity of 488kg/h was designed and constructed and used in the production of biomass briquette using carbonized jatropha husk. Grover et al. [9], categorized the briquetting technologies on the basis of compaction into high pressure compaction, medium pressure compaction with a heating device and low pressure compaction with a binder. Ivan P. Ivanov et al. [10], suggested that the content of biological binder in the charge should be about 10 % in order to obtain the briquettes of satisfactory quality.

As the number of industries is growing day by day, the energy required is also increasing proportionately and the present power supply is unable to meet the energy demand. To combat this energy shortages developed as well as developing countries are keeping more efforts on R&D to tap alternative energy sources. As discussed by Maglaya et al. [11], briquetting increases the homogeneity of the mixture, allowing a more uniform and controlled combustion performance.

Biomass densification represents a set of technologies for the conversion of biomass into a fuel. The technology is also known as briquetting and it improves the handling characteristics of the materials for transportation, storage etc. This technology can help in expanding the use of biomass in energy production, since densification improves the volumetric calorific value of a fuel, reduces the cost of transport and can help in improving the fuel situation in rural areas.

Keeping in view, the advantages of the briquetted fuels in developing countries like India, where in many poor households, there is an acute shortage of fuel for domestic purposes and at the same time there is big demand for the conventional energy sources such as LPG for domestic consumption, many alternate sources of energy production are being explored. Briquetting technologies have always been on

large scale with high capacity machinery producing briquettes at high temperature and pressure. Though they are eco-friendly in nature, they could not cater to the needs of poor rural households and also could not generate employment opportunities for the rural poor.

There is need for low pressure manually operated technologies in briquetting that can help the rural households to meet their domestic energy needs without harming the environment. There is also need for generating employment opportunities for the rural people using these types of renewable energy technologies. The existing technologies have many technical and managerial problems. A low cost, small capacity, low pressure, manually operated briquetting machine is needed to sustain lives of the rural poor.

Variation of the parameters such as temperature and pressure, affects the performance of the briquettes produced. Along with that, the amount of the binding agent used in the production can also be a factor that affects the performance of the briquettes [12]. Most of the developed hand operated briquetting machines are able to produce a single briquette in pass; it may cause more drudgery of the operator and need more time. After going through many developments that took place in this direction and from the review of literature and research on the biomass briquetting, an attempt was made to develop a hand operated low pressure biomass briquetting machine

2. MATERIALS AND METHODS

A hand operated low pressure biomass briquetting machine was developed and evaluated at the College of Agricultural Engineering, Madakasira, which is based on screw press mechanism. The developed system mainly consists of multi square moulds, multi circular moulds, single circular mould pressing plates, base plate, supporting stand and steering wheel. A screw is a mechanism that converts rotational motion to linear motion, and a torque (rotational force) to a linear force. The screw passes through a hole in another object or medium, with threads on the inside of the hole that mesh with the screw's threads. When the shaft of the screw is rotated relative to the stationary threads, the screw moves along its axis relative to the medium surrounding it. The screw shaft can be driven by a handle or a wheel. It works by using a coarse screw to

convert the rotation of the handle or drive-wheel into a small downward movement of greater force. The screw rod carries a steering wheel at the upper end where as the lower end holds thick rectangular metal plate. The top of rectangular thick plate consists of a bearing in which the journal is fixed to the lower end of the screw shaft by nut and bolt and fixed body of the bearing was welded to the metal plate so that the rotary motion of steering wheel could be converted to linear motion of the thick plate. The bottom of rectangular thick plate consists of six number of iron rods welded to the plate at various places by matching the alignment of individual briquette mould to act as pistons. In this study two thick rectangular plates with iron rods were used. At the end of iron rods, various thick plates of uniform matching sizes to the specific mould of square and circular metal pieces were welded to press the biomass slurry inside the selected briquette mould as shown in Fig.1a and the CAD view of the developed system is shown in Fig. 1b. When the screw is rotated with the steering wheel, the linear motion of the rectangular thick metal plate with iron rods compresses the biomass in the mould into briquettes against a base plate and briquettes can be ejected by means of a simple rotation of steering wheel, hence the rectangular plate with pistons push the briquettes out. For briquettes ejections, the base plate must be pulled to one side.

2.1 Briquette Moulds

These are required to hold the biomass slurry and to act as cylinder during biomass pressing. The iron rods (pistons) which are welded to the rectangular iron thick metal plate at lower end of the screw shaft enters inside the cylinder and press the biomass against the base plate. In this study three types of moulds namely square (70×70×120 mm), circular cross sections (70mm \varnothing with depth of 120) and single circular cross section (105mm inner \varnothing , 110mm outer \varnothing with 120mm depth) mould were developed to produce six briquettes during each operation as shown in Fig. 2 a, b and c respectively.

2.2 Development of Pressing Plate with Pistons

These are made up of mild steel with six square plates welded to the rectangular thick metal plate pistons which were fitted to the lower end of screw shaft. The dimensions of the single square plate are 280 mm length, 180 mm width and 10 mm thickness which could be fitted to the end of

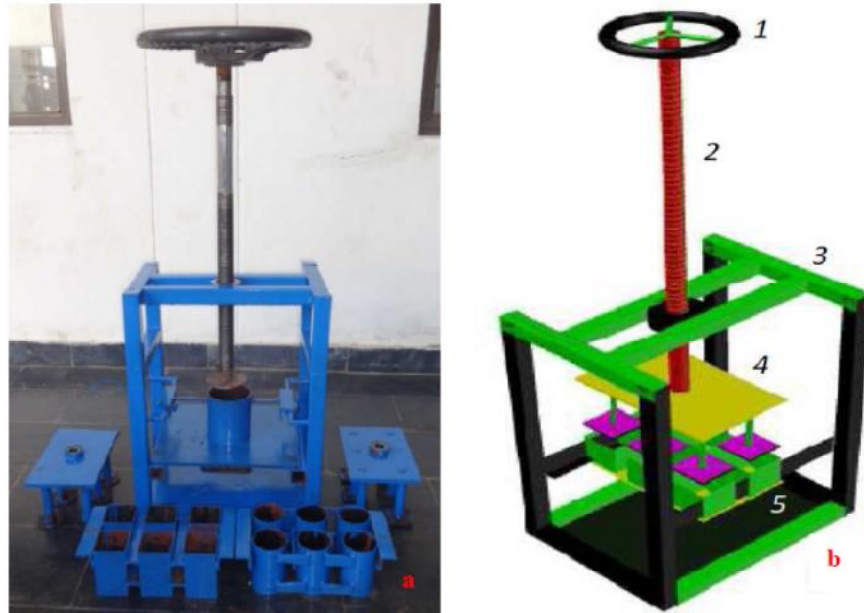


Fig. 1a. A view of developed hand operated briquetting machine, b. CAD view of briquetting machine

1. Steering wheel, 2. Screw rod, 3. Frame, 4. Pressing plates and 5. Moulds

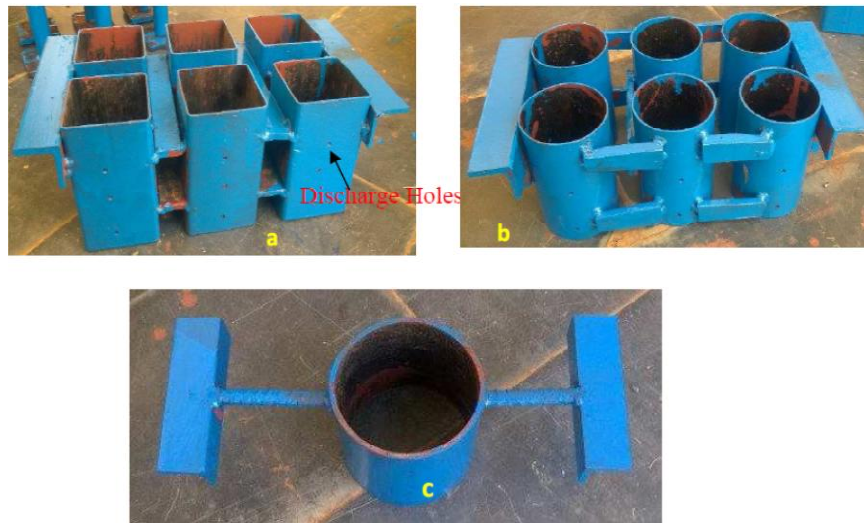


Fig. 2a. Developed square briquette moulds, b. circular briquette mould, c. Single briquette mould

the piston for square mould. Each of the square plate is having dimensions of 65×65×10 mm as shown in Fig. 3a and the dimensions of the circular single plate having the diameter of 5 cm with 10 mm thickness which could be welded to the extreme end of piston for circular mould is shown in Fig. 3b.

2.3 Biomass Briquettes Development

2.3.1 Raw materials used

The following raw materials were used in different proportions to develop the briquettes. The raw materials were mixed in different proportions and tested as three trials as follows:

2.3.1.1 Rice husk

Rice husk is the hard and protective shell covering over the rice kernel (*Oryza Sativa*) shown in Fig. 4a. For every tone of polished rice, 280 to 300 kg of rice husk is produced. It has medium calorific value and high ash content. The calorific value of the rice husk as a raw material is about 3000 Kcal/kg.

2.3.1.2 Saw dust

Saw dust is composed of fine particles of wood as shown in Fig. 4b. This material is produced from cutting with a saw, hence its name. The particle size ranges from 0.3-0.6mm. The calorific value of the saw dust as a raw material is about 3600 Kcal/kg.

2.3.1.3 Tamarind kernel

Tamarind kernel is the upper layer of the tamarind seed which is the by-product of tamarind seed (*Tamrindus indica* L.) shown in Fig. 4c. These are obtained at tamarind mills.

2.3.1.4 Ground Nut shell

Groundnut (*Arachis hypogaea*) shell shown in Fig. 4d is residue left after the removal of the kernel from the pod. It is commonly used as boiler fuel mostly in oil extraction mills. The bulk density is around 100 kg/m³. On an average one tonne of pods yield about 330kg of shell. Its ash content is low.



Fig. 3a. Developed square mould pressing plates, b. Developed circular mould pressing plate



Fig. 4. Various raw materials used for the development of briquettes

2.3.2 Proportions of raw materials used

The following raw material proportions were used to find the best combination of briquettes.

Trail-1:

- C-1: rice husks (100 gm) + saw dust (1kg) + tamarind kernel powder (200 gm) + dung (1 kg) + water (½ lit)
- C-2: tamarind kernel (1kg) + dung (300gm) + saw dust (300gm) + water (2 lit)
- C-3: Groundnut shell (250gm) + dung (1kg) + tamarind kernel powder (250gm) + Water (1lit)

Trail-2:

- C-1: rice husk (200 gm)+ tamarind kernel powder (500gm)+ dung (1.5 kg) + saw dust(1 kg)
- C-2: tamarind kernel (1½ kg)+ cow dung (500gm) + saw dust (300gm) +water(1½ lit)
- C-3: groundnut shell (400gm)+ tamarind kernel powder (500gm)+dung (1kg)+ water(2 lit)

Trail-3:

- C-1: rice husk(200 gm)+tamarind kernel powder (500gm)+ dung (2 kg) + saw dust (1 kg)
- C-2: tamarind kernel (1½ kg)+ cow dung (750gm) + saw dust (300gm) +water(1½ lit)
- C-3: groundnut shell(400gm)+ tamarind kernel powder (500gm)+dung (1½kg)+ water(2 lit)

2.4 Preparation of Raw Material for Briquettes

Before development of briquettes, the raw materials were soaked in water for 12h for easy binding and mixed the recommended proportions of biomass slurry. After mixing the raw material with different proportions the slurry was filled into the respective selected moulds as shown in Fig. 5.

2.5 Briquettes Development

After feeding the slurry into the selected moulds, the filled device were placed on the base plate of the machine and the loaded material was compacted with the help of pistons by rotating the steering wheel of screw shaft. Pistons are attached metal plates as discussed above. Plate is connected to screw shaft by nut and bolt arrangement. Pistons got linear motion by rotating the screw with the rotating wheel. When steering wheel rotates clockwise direction pistons press the respective briquettes as it got linear motion. The air and water inside the biomass slurry comes out from the holes made on the respective briquette holder. The briquettes under production are shown in Fig. 6.

2.5.1 Ejection stage of formed briquettes

After pressing, remove the base plate by rotating the steering wheel in anticlockwise direction and pulling out by a handle. Keep the collection tray just below the base plate position and again rotate the steering wheel in clockwise direction, so that the formed briquettes comes out from the individual briquette mould and dropped on collection tray as shown in Fig. 7a and b. The



Fig. 5. Loading of slurry in to the developed moulds
a. Slurry in circular mould, b. slurry in square mould



Fig. 6. Production of briquettes with developed machine along with square mould
a. Pressing of briquettes, b. A view of pistons inside the respective circular mould

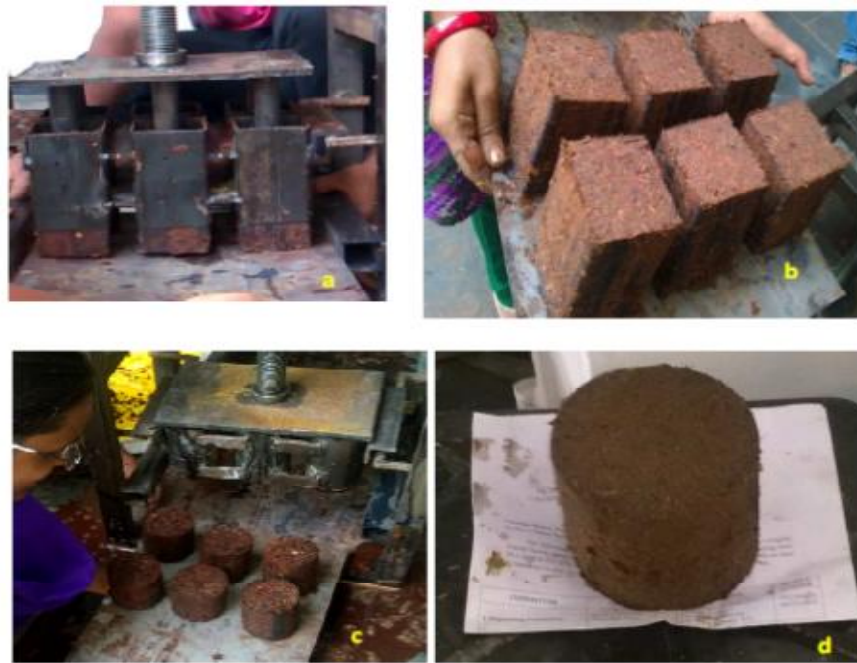


Fig. 7a. Ejection stage of formed square briquettes b. After ejection stage of formed briquettes,
c. Ejection stage of circular briquettes d. Single briquette after ejection

ejection stage of square briquettes from square mould and the circular mould and also the circular single briquettes are shown in Fig. 7c and d above. After collecting the formed briquettes from the machine, the briquettes were dried either by sun or oven drying to keep the more storage life and kill the fungus inside the biomass slurry.

2.6 Analysis of Physical and Thermal Properties of Briquettes

2.6.1 Determination of bulk density

For determining the bulk density of raw materials, a box of 70 x 70 x 120 mm dimensions was used. The density was determined by filling the

box with raw material and measured the weight. The bulk density of the briquettes was determined by dividing the mass of the briquettes to their volume.

$$\text{Bulk density} \left(\frac{\text{kg}}{\text{m}^3} \right) = \frac{\text{Mass of briquette}}{\text{voulume of briquette}}$$

2.6.2 Determination of resistance to water penetration

For measurement of the percentage of water absorbed by a briquette when immersed in water was determined to identify the storage life. Each briquette was immersed in 500ml of water at room temperature for 35 seconds. The percent gain of water was then calculated and recorded.

$$\text{Water gained by briquette}(\%) = \frac{w_1 - w_2}{w_1} \times 100$$

$$\text{Resistance to water penetration}(\%) = 100 - \text{water gain}$$

Where, W_1 = Initial weight of briquette, W_2 = final weight of briquette.

2.6.3 Determination of moisture content

The moisture content of the briquettes with different raw materials was determined by oven dry method. About two samples were selected from each composition of the raw material and measured the initial weight (W_1). Then the selected briquettes were kept in hot air oven for 24 h with temperature of $105 \pm 1^\circ$. After 24 hrs the briquettes are allowed to cool down for 5 min. The final weights were measured and noted. The moisture content (MC) on dry basis (d.b.) was calculated by using the following equation.

$$\text{MC}\% (d. b.) = \frac{(w_1) - (w_2)}{(w_2)} \times 100$$

Where, W_1 = weight of briquette before oven-drying, g, W_2 = weight of briquette after oven-drying, g

2.6.4 Determination of shatter resistance

After drying of the briquettes during transportation, the weight of briquettes may reduce, hence the shattering resistances of developed briquettes were measured. Each briquette was subjected to ten repeated drops

from a half meter distance on a concrete surface. Initial weight of selected briquettes were measured and noted as W_1 . After dropping from a specific distance, the final weight of briquette was measured, and then the percent loss was then calculated by using the following formula.

$$\text{Percent weight loss}(\%) = \frac{w_1 - w_2}{w_1} \times 100$$

$$\text{Shatter resistance}(\%) = 100 - \% \text{ weight loss}$$

Where, W_1 = weight of briquette before shattering, g, W_2 = weight of briquette after shattering, g

2.6.5 Determination of compression ratio

Compression ratio of briquettes of different combinations of raw material was determined as the ratio of density of briquette to the density of the raw material.

$$\text{Compression ratio} = \frac{\text{density of briquette}}{\text{density of raw material}}$$

2.6.6 Combustion studies of developed briquettes

The combustion studies were carried out under room temperature to know the quality of briquette. For combustion studies a chulha is constructed by arranging the bricks on three sides and fourth side as open to keep the fuel. A bowl having water up to 500 ml was taken and placed on the constructed chulha. Initially the temperature of water was measured by using infrared thermometer as shown in Fig. 8a and b. For testing the burning capacity of developed briquettes, three briquettes were considered from each of the combination and placed inside the chulha. For initial burning agent, an amount of 10 ml petrol was chosen and poured on the placed briquettes. For every five minutes, the raised temperature of briquettes (fire) and water was measured and noted down by infra-red thermometer as shown in Fig. 8a and b. Also the Time taken reach the boiling point temperature is measured by using infra-red thermometer, Measure the time taken to burn the fuel completely and finally the water evaporated after complete burning of the fuel was determined by deducting the water retained after complete combustion of fuel from the initial amount of water taken.



Fig. 8. boiling of water by burning developed briquettes
a. Burning of briquettes b. measuring temperature using infra-red thermometer

3. RESULTS AND DISCUSSION

The developed machine was tested with different raw materials (rice husk, groundnut shell, tamarind kernel and saw dust) and binding materials with different combinations. It was observed that, the tamarind proved to be the best raw material and its powder also good binding materials. Rice husk due to its roughness and abrasive nature, found difficulty in binding with other materials. The production capacity of the developed machine was determined and found to be 48 briquettes per hour. It requires two persons to operate the machine. The detailed performance results of briquettes are given below.

3.1 Bulk Densities of Briquettes in Various Combinations of Raw Material

After production of briquettes with different combinations of the raw materials, the bulk density was measured. The bulk density values of circular briquettes in first combination is 382.7 kg/m³, 401.5 kg/m³ and 391.7 kg/m³ in all the trails respectively, where as for square briquettes, the bulk density values are 398.7 kg/m³ 410.5 kg/m³ and 401.7 kg/m³ in all the trails respectively. The bulk density values of circular briquettes in second combination is 483.04 kg/m³, 492.7 kg/m³ and 474 kg/m³ in all the trails respectively, where as for square briquettes, the bulk density values are 475.5 kg/m³ 487.4 kg/m³ and 465.9 kg/m³ in all the trails respectively. The bulk density values of circular briquettes in third combination is 391.8 kg/m³, 397.8 kg/m³ and 407.4 kg/m³ in all the trails respectively, where as for square

briquettes, the bulk density values are 397.4 kg/m³ 402.5 kg/m³ and 419.7 kg/m³ in all the trails respectively.

The bulk density value for second combination (tamarind kernel (1kg) + dung (300gm) + saw dust (300gm)+water(2 lit) are found to be high compared to other combination. The comparison of bulk densities in all the combination in all the trails were presented in Fig.9a and b.

It was also observed that, the bulk density values are high in case of square briquettes as compared to circular briquettes in all the combination in all the trails due to more weight and volume copancy as compared to circular briquettes. It also indicates that substantial space could be saved in storage of briquettes and transport with this combination with square briquettes.

3.2 Moisture Content

The moisture content of developed briquettes after immediate development was measured as discussed above to know the burning capacity by initial and final weight (dried briquette weight). The moisture content of second combination in all the trails was found to be less. The moisture content values of circular briquettes in first combination is 35.7%, 38.25% and 37% in all the trails respectively, where as for square briquettes, the moisture content values are 60.4%, 53.2% and 68.8% in all the trails respectively. The moisture content values of circular briquettes in second combination is 30.5%, 32% and 28% in all the trails respectively, where as for square briquettes, the moisture

content values are 56.7%, 50.2% and 63% in all the trails respectively. The moisture content values of circular briquettes in third combination is 37.25%, 45.67% and 43.23% in all the trails respectively, where as for square briquettes, the moisture content values are 59.7%, 56% and 65.2% in all the trails respectively. It also observed that, for circular briquettes as compared to square briquettes shows that less moisture content and also absorb less moisture from the atmosphere during storage and transportation.

3.3 Shatter Resistance (%)

Tests were conducted for determining the hardness of the developed briquettes as discussed above. Randomly selected briquette of known weight and length was dropped from the height about half meter on concrete floor for ten times. The weight of disintegrated briquette and

its size was noted. The percent loss of material was calculated.

The shatter resistance values of circular briquettes in first combination is 66.3%, 67.38% and 68.2% in all the trails respectively, where as for square briquettes, the shatter resistance values are 40.4%, 42.4% and 41.7% in all the trails respectively. The shatter resistance values of circular briquettes in second combination is 83.1 %, 84.4% and 87.1% in all the trails respectively, where as for square briquettes, the shatter resistance values are 40.5%, 45.2% and 46.1% in all the trails respectively. The shatter resistance values of circular briquettes in third combination is 58.6 %, 59.5% and 56.4% in all the trails respectively, where as for square briquettes, the shatter resistance values are 41%, 42% and 48.1% in all the trails respectively.

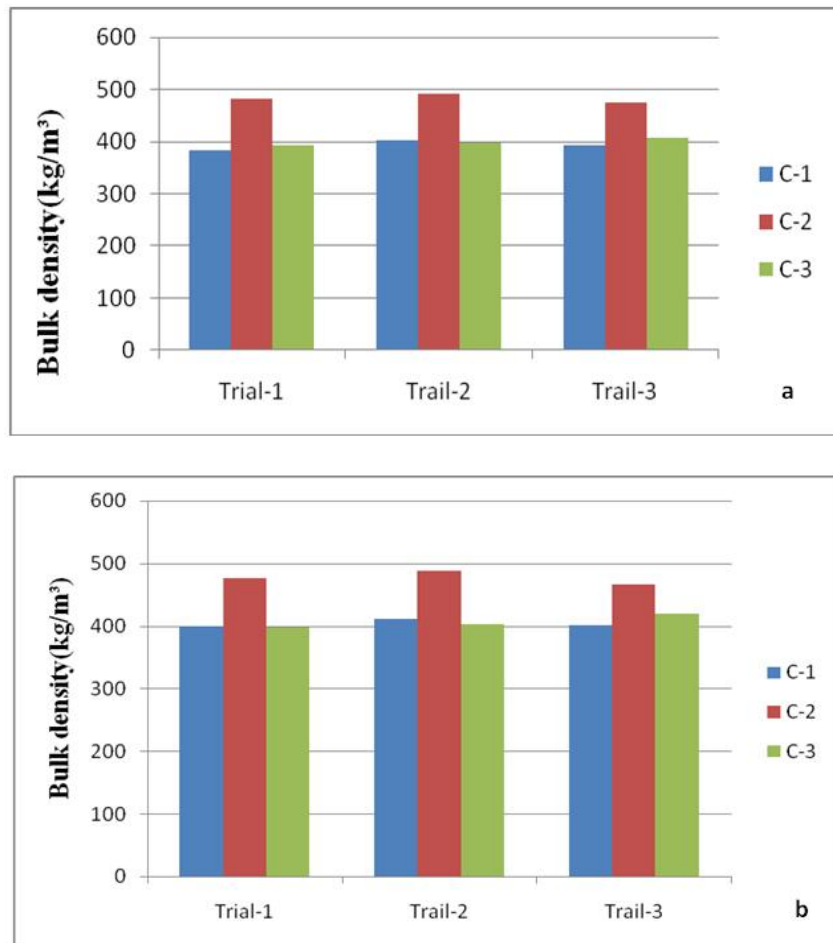


Fig. 9. Comparison of bulk density in three combinations of raw material in three trails
 a. Circular briquettes b. Square briquettes

The shatter resistance values for second combination (tamarind kernel (1kg) + dung (300 gm+ saw dust(300gm)+water(1lit)) was found to be high. It indicates that the tamarind has more hardness due to high shattering resistance enables the briquettes to stay in original shape even when handled roughly without care. The comparison of shatter resistance in all the combination in all the trails were presented in Figs. 10a and b.

3.4 Resistance to Water Penetration (%)

It is measure of percentage water absorbed by a briquette when immersed in water to estimate the resistance water absorbance from the atmosphere as discussed above. The water penetration values of circular briquettes in first

combination is 62.13%, 69.25% and 65.22% for circular briquettes in all the trails respectively, where as for square briquettes, the water penetration values are 58.2%, 60.4% and 58.4% in all the trails respectively. The water penetration values of circular briquettes in second combination is 75.15%, 78.1% and 76.9% for circular briquettes in all the trails respectively, where as for square briquettes, the water penetration values are 71.15%, 75.12% and 72.7% in all the trails respectively. The water penetration values of circular briquettes in third combination is 58.9%, 56.4% and 51.3% for circular briquettes in all the trails respectively, where as for square briquettes, the water penetration values are 56%, 51.7% and 52.3% in all the trails respectively.

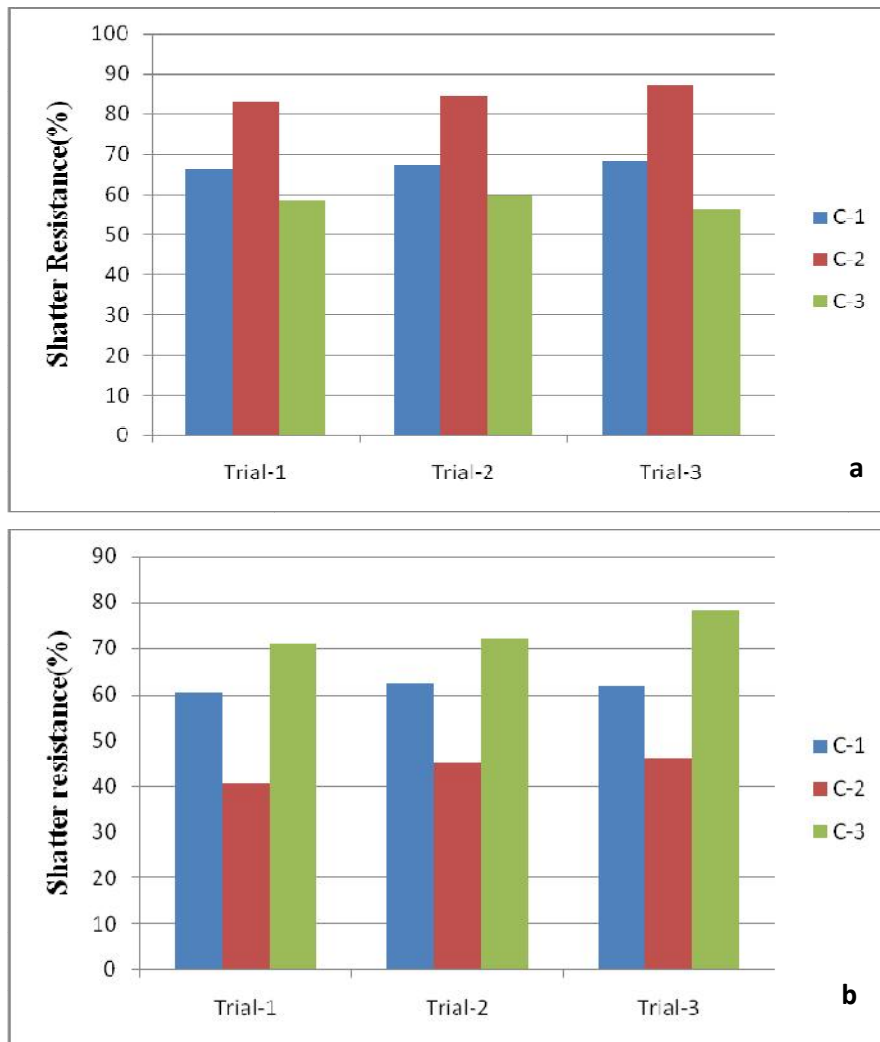


Fig. 10. Comparison of shatter resistance in three combinations of raw material in three trails
a. Circular briquettes b. Square briquettes

It was observed that combination-2(C-2) have high resistance to water penetration. The high resistance to water penetration makes the briquettes less prone to water absorption when stored in open places that retains the calorific values for long time. The comparison of moisture penetration in all the combination in all the trails were presented in Figs. 11a and b.

3.5 Compression Ratio (%)

Compression ratio was determined as the ratio of density of briquette to the density of the raw material to identify the compression and binding of the raw material. The compression ratio values of circular briquettes in first combination is

77.3%, 72.5% and 76.5% for circular briquettes in all the trails respectively, where as for square briquettes, the compression ratio values are 72.5%, 69% and 73.5% in all the trails respectively. The compression ratio values of circular briquettes in second combination is 97.5%, 92.7% and 93.5% for circular briquettes in all the trails respectively, where as for square briquettes, the compression ratio values are 93.5%, 89.5% and 91.7% in all the trails respectively. The compression ratio values of circular briquettes in third combination is 50.6%, 54.9% and 58.4% for circular briquettes in all the trails respectively, where as for square briquettes, the compression ratio values are 64.5%, 68.7% and 69.4% in all the trails

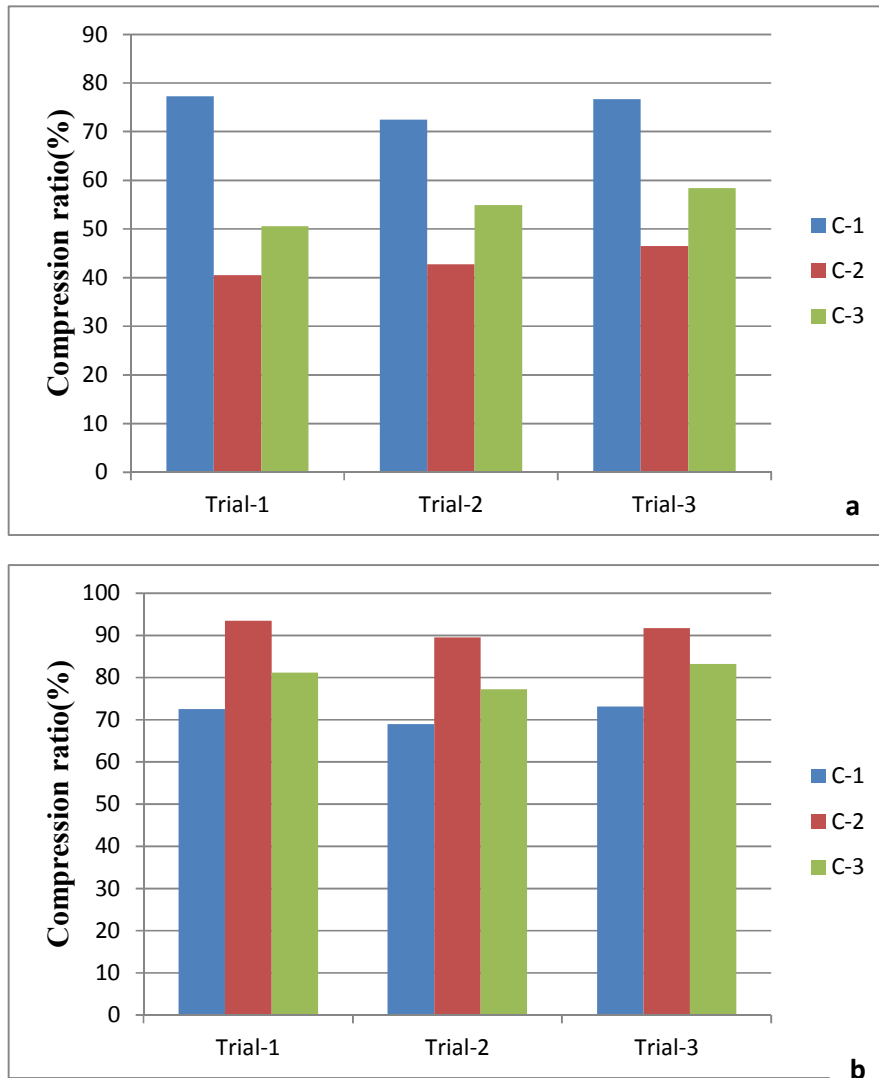


Fig. 11. Comparison of resistance to water penetration in three combinations in three trails
a. circular briquettes b. square briquettes

respectively. The comparison of compression ratio in all the combination in all the trails were presented in Fig.12 a and b. It was observed that the compression ratio values for combination-2 are high. It also observed that, for circular briquettes as compared to square briquettes more or less equal.

3.6 Combustion Studies

The combustion studies were carried out under room temperature to know the burning qualities of developed briquettes in all the combinations in all the trails. It was observed that, the temperature of fire as well as water has been increasing from starting to the test to the ending

of the test. It also observed that, the temperature of fire and water from starting to ending with the first combination circular briquettes was varied from initial to 157°C and 34 °C -82.5 °C where as for square briquettes initial to 152 °C and 34 °C - 84 °C. The comparison of burning characteristics of first combination are presented in Fig.13a and b.

The temperature of fire and water from starting to end with the second combination circular briquettes was varied from initial to 158°C and 34 °C -94.5 °C where as for square briquettes initial to 152 °C and 34°C -94°C where as the temperature of fire and water from starting to ending with the third combination circular

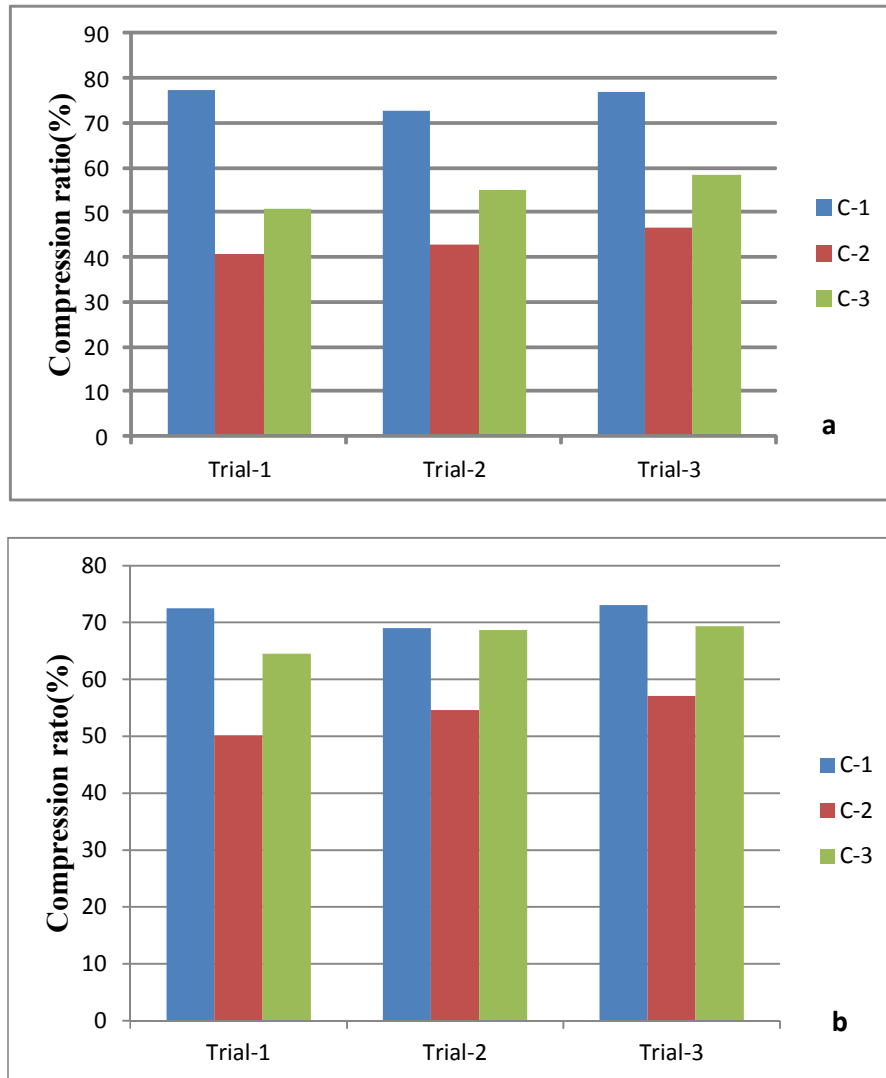


Fig. 12. Comparison of compression ratio in three combinations of raw material in three trails
 a. Circular briquettes b. Square briquettes

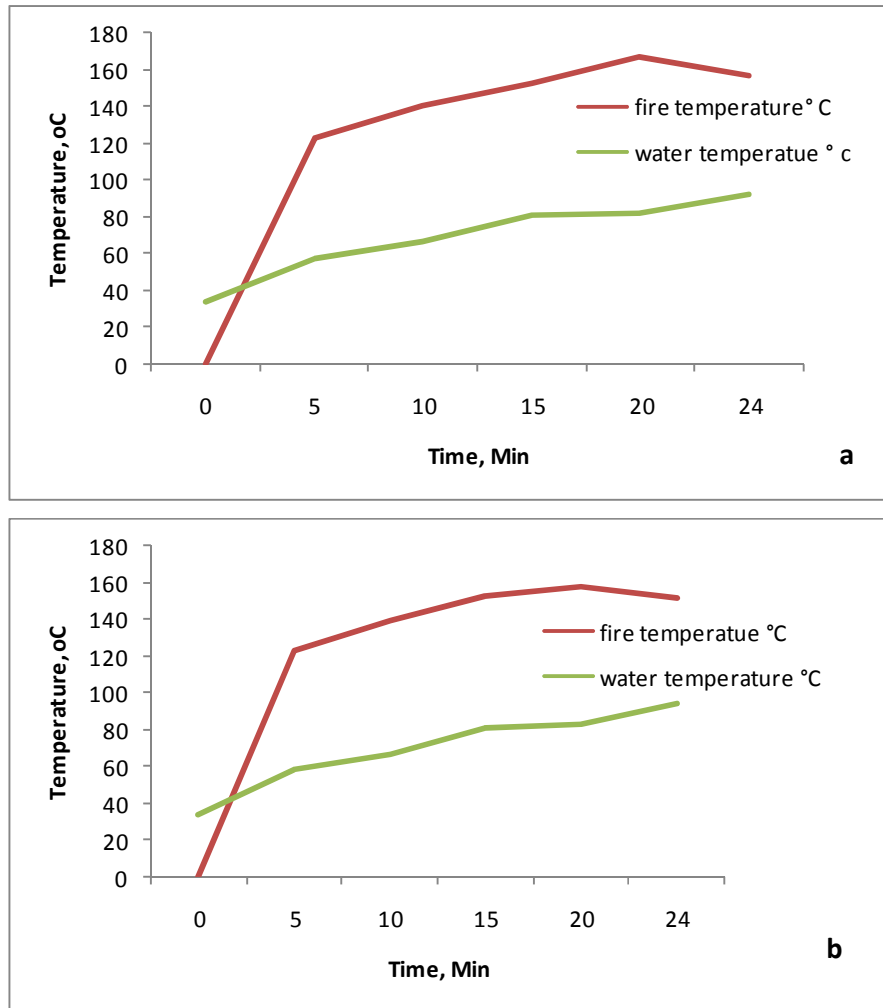


Fig. 13. Comparison between temperature and time for first combination
a. Circular shape briquettes b. Square shape briquettes

briquettes was varied from initial to 150 °C and 34 °C -89.5 °C where as for square briquettes initial to 152 °C and 34 °C -90 °C. Compared to the above all combinations the second combination (tamarind kernel (1kg) + dung (300 gm)) will gives the better burning efficiency with effectively but initially catching of fire is slow compared to all combinations.

4. CONCLUSIONS

A low pressure biomass briquetting machine which can produce multi briquettes at a time using locally available raw material was developed which could help the rural peoples. The developed machine was validated rigorously and Briquette with higher durability was produced using the constructed briquetting

machine. The machine had a capacity of 60 briquettes per hour and it required two persons to operate the machine. The developed machine was tested with various combinations of agricultural residues with different proportions of raw material and binder levels. It was observed good results during validation. It is hoped that this produced manually operated briquetting machine will be useful to small and medium scale briquette manufacturers. The briquettes had higher calorific value than the raw biomass. Use of the briquettes in local domestic stove with grate was found to be satisfactory.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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