Analysing The Effect of Rice Hush and Saw Dust in Preparation of Briquettes Using Hand Operated Briquetting Machine

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Abstract. Air pollution is caused by the millions of tonnes of agricultural waste that are produced year and either incinerated or burned inefficiently in loose form. Briquettes made of biomass can be used as a substitute for wood charcoal. One of the renewable energy sources developed to aid in the fight against global warming is briquetting technology. Solid fuels are still visible in usage in Rural areas and the excess availability of waste materials in the form of Biomass is used in areas near forest zones where wood and charcoal are used as fuel for general purposes. Deforestation results from rural residents' use of wood fuel and charcoal, even though agricultural waste is generated in large quantities there. Thus, the use of biomass as fuel is a substitute for conventional fuels to limit their usage. The traditional fuels can be partially replaced by biomass in the form of briquettes. Different biomass ratios were compared to manufacture charcoal blocks. The blocks are prepared using manual compressing equipment where three different samples were prepared with different combinations of utilizing a proportion of husk of rice, straws of rice, saw dust and Cow dung and the prepared samples were named S1, S2 and S3. The samples were tested to understand their moisture content considering the variables attained using the ANOVA technique and further understand the sample's cost efficiency. The results obtained from the comparative analysis of the proximate analysis revealed that S3 briquettes have the lowest moisture content while S2 briquettes (rice husk, rice straw and cow dung (10: Among the three samples, the S2 briquettes (10:05:40) displayed the highest moisture content. The comparative strength results stated that the highest compression density measured in S3 briquettes was 0.91 g/cm^3. S2 briquettes consisting of rice husk, rice straw, and cow dung (10:05:40) had the highest moisture content (63.11%), whereas S3 briquettes had the lowest (23.64%).

1. Introduction

The modern era demands a thirst for energy which is usually fulfilled using fossil fuels. The increasing dependency on fossil fuels has led to its depletion, leading to a rise in its prices and cost of handling. Conventional

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fuel prices have skyrocketed, and fuels also contribute to air pollution by releasing more unburned carbon along with SO_2. India generates vast amounts of crop residue each year which when burned in open fields creates seasonal air pollution spikes. Crop-residue fires during peak burning seasons discharge massive amounts of particulate matter, gases and smoke into the atmosphere resulting in a sharp increase in ambient $PM_{2.5}$ levels. These conditions lead to decreased visibility while creating smog episodes which bring about health risks. The practice of converting excess biomass into densified solid fuels like briquettes provides a sustainable approach to decrease open burning while tapping into agricultural waste as renewable energy. Such toxic waste proves to be hazardous to human health leading to ailments such as diarrhoea, and cancer in human body parts such as the lungs, kidney and even affecting human skin. The hazardous smog is even toxic to the environment. To get over these issues, alternative fuel is required. One effective solution to these issues is the use of renewable energy sources. One of the most affordable and accessible renewable energy sources is biomass, which is created when natural waste decomposes. Biomass is an energy source derived from organic waste. Both electrical and other types of energy, such as thermal energy, can be produced from this sustainable and renewable energy source. Agricultural waste residues, manure, scrap timber, forest debris, and some crops are examples of materials that can be turned into biomass fuels. The creation of green energy can continue eternally with a steady supply of garbage from municipal solid waste and the construction and demolition of structures that are not employed in the production of paper. Furthermore, biomass provides readily available fuel and a pollution-free atmosphere [1]. Heat and power may be produced from biomass. Agricultural waste materials, such as rice husk, coir pith, sawdust, and various plant leaves, are readily accessible. The low bulk density and high moisture content of agricultural wastes make them unsuitable for use as fuel. Compressing biomass makes it easy to turn it into solid fuel referred to as briquetting. Briquettes are the term for compressed biomass. These briquettes have the following key benefits: complete fuel combustion, ease of handling, minimal transportation costs, and ease of storage. The briquettes won't sustain any sort of damage when being handled, stored, or transported [2].

Water and other volatile components are removed from both plant and animal materials to create charcoal, a lightweight black carbon residue. The most common method for producing charcoal is slow pyrolysis. Charcoal can be heated without oxygen through a process called slow pyrolysis. Charcoal may burn at a greater temperature as a result of the removal of water and other ingredients, which is an advantage over simple firewood. Charcoal burns closer to full combustion, which results in primarily carbon dioxide and very little smoke as byproducts [3]. The structure of charcoal is determined by its composition, which also includes different amounts of oxygen and hydrogen. It is occasionally empirically stated that gunpowder-making carbon was C_7H_4O. The source material must be free of non-volatile chemicals to produce very pure charcoal. The process known as "briquetting" is commonly used to condense or densify scattered burnable components into a solid composite of different sizes and shapes using compression and the proper adhesives. Charcoal and biomass briquetting is essential to the characteristics and combustion of solid fuels. The various granular hydrocarbons' heating characteristics and combustion capabilities have been investigated [4]. To reduce debris and carbonise the end result, two processes were proposed: carbonization-briquetting (CB) and briquetting-carbonization (BC). To create charcoal briquettes, the BC methods first densified the parent material, and then they carbonised the densified output. The CB method first carbonised the raw material, then crushed it if necessary to create powdered charcoal, which is then briquette [1]. Several materials and procedures were used to create the briquettes, and their thermal characteristics were examined to determine whether they would work well as solid fuel [3-6]. The literature reveals extensive research on individual biomass briquetting through motorized systems but presents limited exploration of hand-operated briquetting machines for mixed agricultural residues like rice husk and sawdust with comparative assessments of their moisture content, density and combustion properties. This paper fills a research gap by examining different rice husk–sawdust ratios created through a hand-operated briquetting machine to determine ideal compositions for rural use.

1.1 Biomass

Densifying loose agricultural compacted in blocks under pressure is known as biomass briquetting. Briquettes are primarily used to replace charcoal for energy utilization for household applications [8]. Biomass, particularly plant material, is considered a potential energy source since it can be transformed into fuel. Biomass comes in many forms, including industrial, agricultural, and plant wastes, as well as animal and plant residues [9].
Charcoling is a method for densifying agricultural wastes and residues that increases overall concentration, lowers the water molecule, and produces charcoal with uniform shapes and sizes for interacting with, transport, and storing. One definition of charcoal blocking is a product made by mechanically converting loose, small-particle materials, either with or without a binder, into a variety of shapes and sizes. Using hard coal, charcoal, and waste

wood, Russian inventor F.P. Veshinakov created a process for making briquettes [7]. When compared to agricultural leftovers that are lost, briquettes have high specific densities (between 1100 and 1200 kg) and bulk densities (between 80 and 120 kg) (Srivastra, 2009). This suggests a ten-fold reduction in material volume through briquetting [10]. The technology for briquetting biomass has historically evolved in two different ways. Japan has separately created the screw press technology, whereas the United States and Europe have worked to perfect the reciprocating ram/piston press [11].

Regarding storability and combustibility, it is generally acknowledged that screw-pressed briquettes are significantly superior to ram-pressed solid briquettes, even though both technologies have advantages and disadvantages. No information regarding the production of European machines in Japan has been recorded, while Japanese machines are now being built in Europe under a licensing deal [12]. Modern briquetting technology is crucial to using agricultural wastes for maximum energy and calorific value. The purpose of the briquetting procedure in this study is to look into the creation of an alternative environmentally friendly fuel. Rajasthan has made significant contributions to the nation's yellow revolution. After harvesting, Rajasthan produces a lot of waste despite having a huge capacity for mustard production. Biomass has a high calorific value and is mostly utilised as home cooking fuel or burned on farms because it spoils easily and is difficult to dispose of throughout the year. In addition to increasing the net calorific value per unit volume, using mustard stalk waste to make briquettes reduces deforestation by offering an alternative to both conventional fuel and fuel wood. The technique of densifying biomass to enhance its fuel properties is known as briquetting technology [13]. To create biomass briquettes that may be utilised as environmentally benign fuel for cooking in Chula and for gasification to generate power, effective briquetting equipment has to be developed. Additionally, it may be sold directly to consumers for domestic usage. Noteworthy, such process of compress blocks of Biomass is still in its infancy and has a lot of room for design advancements that would boost dependability and lower energy usage when briquetting agricultural waste [14].

The traditional method of burning loose agricultural waste residues, such as rice husks, groundnut shells, and palm kernel shells, is also linked to poor thermal efficiency, fuel loss, and extensive air pollution. By increasing their net calorific value per unit, compressed briquettes alleviate these issues, lower transportation and storage costs, and increase energy production (Grover et al., 1996). This project focuses on the first briquette manufacture process using cow dung and biomass. Based on the waste and building materials that are readily available, these briquetting techniques are the most appropriate for rural communities. The briquettes are held together primarily by a binder, and the manufacture should be carried out in hand-operated presses that are made locally. By offering a substitute for burning wood for cooking and warmth, briquette production helps to preserve forests and avoid issues like soil erosion and desertification. Husks, hulls, maize stocks, grass, leaves and other agricultural waste can be briqueted to create a useful resource. Briquetting creates numerous microbusiness options, such as manufacturing the presses from locally accessible materials, supplying resources, and producing, selling, and delivering the briquettes. Rural women and children spend much of their time gathering firewood rather than going to school or doing other activities that generate cash. The availability of briquettes as an alternative fuel to replace firewood can also enhance their living conditions [15-17].

The requirements and components of the briquetting system were described, and several methods for boosting the processes and removing bottlenecks were suggested to increase the biomass briquetting system's production [17]. The drying behaviour of infrared radiation was tested on four common biomass briquettes, including spent coffee grounds, cotton stalks, eucalyptus bark, and populus tomentosa leaves. This is because the spent coffee grounds have a lower surface temperature than the other three samples [8]. The impact of binders on various charcoal and biomass briquettes was investigated and contrasted [9]. Research has been done on the behaviour of several solid fuel briquetting systems based on their burning efficiency [11–12]. A range of briquetting techniques, raw materials, and applications were examined [13–16]. To confirm the effects of various solid fuels and briquetting methods on their characteristics and combustion performance, more research is necessary. Briquettes with an 80% by weight molasses content and varying ratios of 40:60, 30:70, and 20:80 for the charcoal to molasses were made while taking into account several factors, including specific mass, microstructure, and flammability [18]. To determine the heating value of biomass briquettes generated from cow dung waste as a solid energy source, this article examines the impact of binder type. Using cow dung as the binder, the study examines the impact of binder type and composition to produce biomass briquettes with a better heating value. To make biofuel, many samples are made using various combinations of sawdust and rice husk that are bound with cow manure. The test evaluates the samples' density and determines their cost

2. Methods and Materials

This section presents the materials used in the investigation to define the properties of materials used and further presents the methodology adopted for briquetting of biomass. The samples in different proportions will be defined to identify the appropriate proportion for the different samples which are considered in this analysis. The hand press machines are used to compress the agro waste to create small-size pellet briquetting in rural regions near villages which includes a storage facility where they can be prepared and bought to use to develop energy. As per considering geographical location, results were primarily extracted from Udainagar near Indore Madhya Pradesh. The climate in Udainagar is more varied than most. With temperatures as high as 45 degrees Celsius, the summer months are unusually hot and dry. Approximately 700 mm of rain falls on Udainagar during the monsoon season, while the winter months are pleasant. Briquettes with a diameter of 79 mm, a thickness of 32 mm, and a diameter of 25 mm that pass through the middle of the briquette length are what it is intended to generate. The design's objective is to create an effective briquetting machine that can compress biomass using pressure. The device is operated manually as it is portable and easy to handle.

Table 1 Features of the Briquetting Machine

Part	PCS	Description
A	1	Vertical Support Height-1090mm, Width-100mm, Diameter-5mm
B	1	Top Spacer Lenth-200mm, Width-100X 50mm
C	1	Pusher Lever Lenth-1080mm, Diameter-30mm
D	1	Base plate Lenth-200mm, Width-175mm
E	1	Mold box, Lenth-200mm, Diameter-110mm, holes on 3mm centre
F	1	Mold box Cover, Lenth-450mm, Height-150mm
G	1	Piston, Lenth-310mm, Diameter-105mm, hole 32 mm Deep.
H	1	Center pipe Height-700mm, Diameter-30mm.

The specification of briquetting machine is tabulated in Table 1 which has vertical support with dimensions 1090x100x5mm, dimension of the Top spaces is 200x100x50mm,the Pusher Lever- 1080x30mm, Base Plate, Mold Box- 200x175mm, Mold Box Cover-450x150mm, Piston size lands with lenght as 310mm and diameter 105mm hole depth was found to be 32mm and the center pipe height is 700mm with diameter 30mm as shown in Fig 1.

Fig 1 hand-operated briquetting machine with a piston press

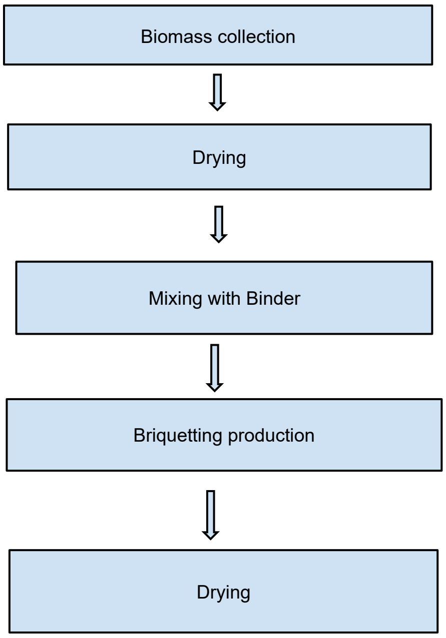

Fig 2 Flow chart for briquette process [4]

As per the flow chart in Fig 2, rural regions are generally filled with biomass generated via agricultural waste, nature in form of dry leafs and twigs and animal waste in form of Cow dungs. The collected waste is later spread on surfae and sun dried in form of mixture. The collected waste is mixed and binded in batches for setting it for the next step. Manual machines are used for compressing the batches in briquett in small peinces whihc can be easily used for domestic and industrial purpose. The final pieces are left for drying and further packages for easy handling and transportation.

2.1 Materials

In India and around the world, rice straw is one of the most prevalent lignocellulose agricultural wastes as shown in Fig 3. Due to the high cost of fuel and the pressing need to reduce greenhouse gas emissions and air pollution, rice straw is a significant field leftover and an energy input. However, it is rarely utilised as a renewable energy source.

Fig 3 Rice Straw [6]

a) Rice Husk

Rice kernels are covered in a hard, protective shell called the rice husk shown in Fig 4. Between 280 and 300 kilogrammes of rice husk are produced for every tonne of polished rice.It contains a lot of ash and has a middling calorific value. High percentages of residual carbon in the ash produced in standard furnaces, such as step grate furnaces, are prevented from burning uniformly and completely by the silica-crowned tubular structural structure of the husk. The outer layer of rice grains, known as rice husk, is a great resource for biomass preparation because of its high calorific value, abundance, and environmental advantages. It can generate biomass in a variety of ways for fuel, energy generation, and other uses. Direct use of rice husk as fuel for cooking, heating, or power generation is possible. In industrial boilers, furnaces, and kilns, rice husk can be used as fuel to heat or produce steam. Due to its relatively high calorific value (about 15–18 MJ/kg), it is frequently used to provide steam for processing in rice mills. Both raw and processed forms, such as pellets, can be used to heat spaces or prepare food in rural areas by burning rice husks in stoves. The vast quantity of rice husk, which is frequently a by-product of milling rice, makes it an inexpensive fuel alternative. Using rice husk as fuel encourages sustainability and lessens agricultural waste by making use of a resource that would otherwise be thrown away. A reasonable quantity of heat is released by the rice husk, which has good burning qualities. The high ash concentration of rice husk makes it difficult to use since it can cause residue accumulation, fouling, or slagging in boilers and stoves, requiring frequent cleaning and maintenance. For easier handling, transportation, and burning, rice husk must be compressed into pellets or briquettes because of its low density.

Fig 4 Rice Husk [8]

b) Saw Dust

The fine wood particles created when wood is chopped with a saw make up sawdust. Approximately 3600 kcal/kg is the calorific value of sawdust, and its particle size ranges from 0.3 to 0.6 mm. In specific boilers, furnaces, or stoves made to handle fine, light materials, sawdust can be burned directly as fuel. This material is used in small-scale industrial heating activities as well as household heating systems.

Sawdust must be dry for efficient burning and must be burned under controlled conditions to avoid incomplete burning and excessive smoke. Sawdust is dried until its moisture content falls below 9%. Using a briquette press or pellet mill, the dried sawdust is compacted into tiny pellets or briquettes. Higher energy density and ease of handling and transportation are among its benefits.

When it comes to pelletising, gasification, or combustion, drying is essential. Sawdust can be blended with other biomass to enhance its energy content and combustion properties. Keep sawdust dry to avoid deterioration and lower the chance of fire. Sawdust may be turned into biofuel, which helps manage wood waste sustainably and offers a renewable energy source.

2.2 Binder Material

When sun-dried, cow dung makes a good fuel in and of itself. It can also be utilised as a binding material in addition to raw materials. Due to its sticky nature, it is advised to utilise it as a binder in amounts between 50 and 85 percent of the raw material. In addition to organic stuff and water, cow dung also contains inorganic components such as phosphorus, potassium, and nitrogen. The lignin content and fibrous character of this substance add to its binding capabilities. Using cow dung can raise the calorific value of fuel because it has a higher calorific value than other fuels. Additionally, when cow dung is dried in the sun, it can be used as fuel. It can be utilised with the raw materials as a binding material. Due to its sticky nature, it is advised to utilise it as a binder in amounts between 50 and 85 percent of the raw material. Cow dung shown in Fig 5 can be used to boost the calorific value of fuel because it has a higher calorific value. The density and longevity of the biomass briquettes were enhanced by the inclusion of cow manure. Briquettes with cow dung binder showed calorific values ranging from 13 to 20.5 MJ/kg, contingent on the kind of biomass and the amount of binder. There was a consistent rate of combustion and less smoke produced than with loose biomass. For energy applications, cow dung-bound briquettes were appropriate because of their somewhat increased but still controllable ash content.

By lowering methane emissions from open decomposition, using cow dung as a binder helps with waste management. Further reducing deforestation is the use of biomass briquettes in place of wood-based fuels.

Fig 5 Cow Dung [5]

2.3 Mixing with binder

The charcoal briquettes are strengthened by the binding material. Cow dung, which is employed as a binding material, is combined with rice straw. Different combinations of measure elements were explored to produce briquettes of the appropriate grade. Where sample one was prepared using ten parts of rice straw and forty parts of cow dung, sample two was prepared using ten parts of rice husk five parts of rice straw forty parts cow dung and the last sample was prepared with twenty parts of sawdust five parts of rice straw and forty part of cow dung. As a general rule, the material should be hand-pressed to form a binding after the water was added, so the measured quality of water was added to the mixture.

2.4 Briquetting production

When using cattle excrement as an adhesive component for burning, the main ingredients were rice straw, rice husk, and sawdust. Briquettes were made using a hand-operated machine that was powered by electricity. The piston's geometry pushed the material forward.

2.5 Cost Analysis

The cost of producing briquetting from cow manure, rice husk, and rice straw using piston press technology was examined. In order to assess the manufacturing costs of various briquettes, economic research also took into account the cost of operating a power-operated system. The table below provides a full cost analysis of the economics of briquette production. The cost of the briquettes made for this study was analysed using the following economic parameters. The analysis of variance through one-way ANOVA determined if briquette composition affected the measured properties in a statistically significant manner. In the study, the briquette sample type including S1, S2 and S3 served as independent factor while moisture content, density and selected fuel properties functioned as dependent variables. The null hypothesis for each response claimed that the mean values of the briquette compositions were identical and the alternative hypothesis declared that at least one mean was significantly different. The ANOVA test was executed with a significance level of 5% ($\alpha = 0.05$) through MS Excel. A test was completed to check for normality and homogeneity of variance before performing ANOVA analysis. Each response variable underwent F-statistic and p-value computation to determine statistical significance of briquette composition effects when $p < 0.05$ followed by analysis of physical and combustion behaviour differences between S1, S2 and S3.

3. Results and Discussion

The physical, combustion, and proximate and final analyses of the biomass briquettes that were generated are discussed and the results are presented in this part. Machine performance and cost analysis are further presented using ultimate and proximity analysis. The proportions of basic materials vary, as is evident. Briquettes with slightly varying dimensions were produced using ten parts of rice straw and forty parts of cow dung, sample two was prepared using ten parts of rice husk five parts of rice straw forty parts cow dung and the last sample was prepared with twenty parts of sawdust five parts of rice straw and forty part of cow dung.). In comparison to the other two ratios, the S3—sawdust, rice straw, and cow dung—produced heavier briquettes than the other two. Although the briquettes' diameters were same in each instance, there was a slight variation in length. Using the S3 ratio of sawdust, rice straw, and cow dung (20:05:40), the longest briquettes (6.19 em) are made, followed by the first and second ratios. Table 2 discusses the composition of various Briquettes samples (S1, S2, and S3). The three mixtures were selected to represent practical relevant combinations of locally available residues. The biomass ratios extend from mixtures that mainly consist of rice straw to those mainly composed of sawdust while all formulations maintain a substantial amount of cow dung because of its binding capabilities. S1 (rice straw + cow dung) is the simplest and most basic mixture expected to be widely available in the countryside; S2 adds rice husk to take into account the influence of a higher-ash, more silica-rich residue on briquette quality; and S3 includes a larger proportion of sawdust, since this is known to enhance densification and burning duration. The study tested three contrasting but realistic biomass ratios to find an optimal composition achieving balanced ignition behaviour along with density strength and production ease under the specified hand-operated briquetting conditions.

Table 2 Composition of briquette samples S1, S2 and S3

Sample ID	**Rice husk (parts)**	**Rice straw (parts)**	**Sawdust (parts)**	**Cow dung (parts)**	**Total parts**	**Rice husk (% by mass)**	**Rice straw (% by mass)**	**Sawdust (% by mass)**	**Cow dung (% by mass)**
S1	0	10	0	40	50	0	20	0	80
S2	10	5	0	40	55	18.18	9.09	0	72.73
S3	0	5	20	40	65	0	7.69	30.77	61.54

3.1 Density of briquettes

Briquettes' relative compactness and portability were assessed to establish their density, which enhances their burning quality and is also utilised to raise It is evident that briquettes made of rice straw are denser than other biomass. Different biomass types were discovered to have varying average briquette weights. The briquette had the lowest value and S3 had the highest. Because the briquette's diameter shrinks depending on the biomass's moisture content. As a result, the maximum density of S3 briquettes was determined to be 0.91g/cm^3, indicating that it differs from other biomass briquettes in terms of durability, strength for transportation, and burning time. Table 3 discusses the properties of various Briquettes.

Table 3 Physical Properties of Briquettes: Weight, Volume, and Density

Briquettes	**Briquette's average weight, in grams**	**Average Volume of briquettes, (cm^3)**	**Average Density of briquette, (kg/m^3)**
S1	500	29.12	1.8
S2	450	23.47	2.1
S3	400	29.12	1.5

*B-Briquettes, AWB-Average Weight of briquette, AVB-Average Volume of briquettes, ADB-Average Density of briquette.

3.2 Examination of Proximates

Importance of such examinations enhances its ability to provide an approximate understanding of the energy values and extent of emissions of pollutants during burning. The ratio represents the approximate value of the various contents. Relative to other biomass, the S1 briquette had the highest moisture content (9.87%) while the S3 briquette had the lowest (7.67%). After burning, the S1 briquette left the highest amount of ash residue (25.54%), whereas the S3 briquette had the lowest amount of ash residue (16.01%). Briquette S1 had the highest volatile matter (65.54%), while S3 had the lowest (63.29%). Briquettes with S3 content had a fixed carbon percentage of 10.01 percent at the minimum and 18.97 percent at the maximum. S1 had the lowest calorific value at 2410.68 kcal/kg, while S3 had the highest at 3231.54 kcal/kg, which is higher than other briquettes and emits more energy. Proximate Analysis of Produce briquettes is being discusses in Table 4. Briquette performance as solid fuel depends heavily on moisture content and density measurements. When briquettes contain low moisture content they need less energy for water evaporation during combustion which aids easy ignition and increases heat output but they produce less smoke compared to briquettes with high moisture content that require longer ignition times and display diminished thermal efficiency. Density of the briquette defines the mass (energy) per unit of volume: Denser briquettes deliver higher mechanical strength resulting in lower damage rates during transport and extended burning durations along with stable heat release. The results indicate that S3's low moisture content and S2's high density will enable better ignition quality and burning duration and greater fuel efficiency compared with S1.

Table 4 Proximate Analysis of Produce briquettes

Briquettes	**Parameters**				
	Moisture Content%	**Ash%**	**Volatile Matter%**	**Field Capacity%**	**Calorific Value(kcal/kg)**
S1	9.87	25.54	65.54	1.45	2410.68
S2	13	21	64	6	3288.1
S3	7.67	16.01	63.24	17.13	3231.54

*VM- Volatile Matter, FC- Field Capacity, MC- Moisture Content

3.3 Ultimate Analysis

Carbon, hydrogen, oxygen, and sulphur are among the different elemental chemical ingredients that are revealed by the final analysis as shown in Table 5. The amount of air needed for the rate of combustion, as well as the volume and combustion gases, can be determined with its help. S1 and S2 briquettes were found to have 44.62% C, 5.3% H, 33.27% O, 3.14% N, and 0.54% S, respectively, according to the composition analysis of the briquettes as received.

Table 5 Ultimate analysis of briquettes

Content	Briquettes		
	S1	S2	S3
C	44.62	47.24	51.15
H	5.3	5.8	5.85
O	33.27	31.13	34.61
N	3.14	2.28	1.45
S	0.54	0.65	0.54

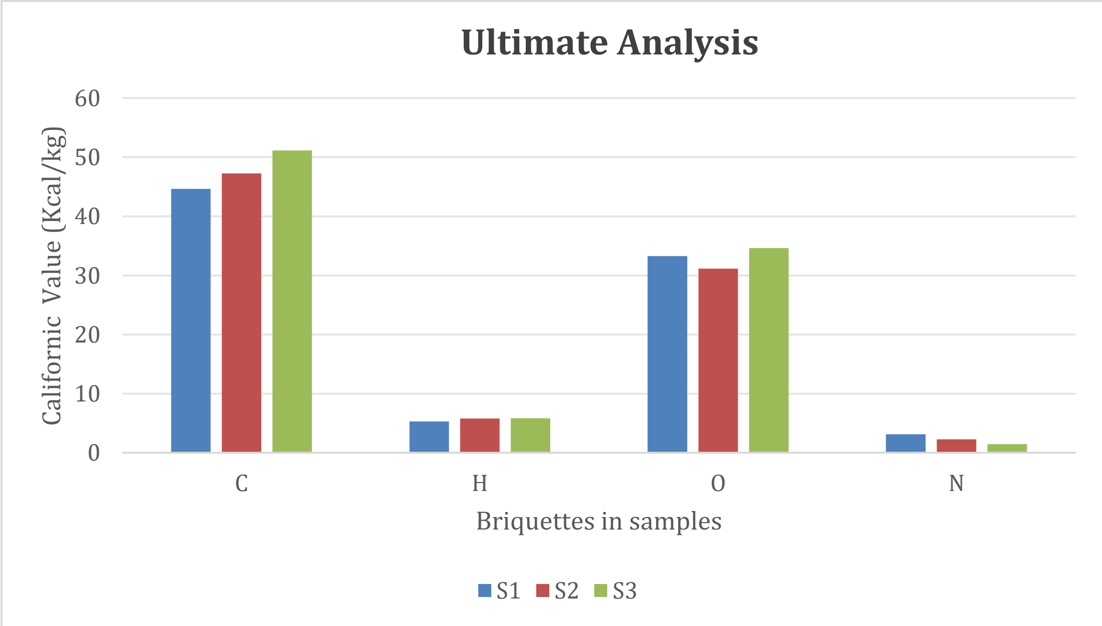

Fig 6 Calorific Value of briquette

As shown in Fig 6 the S3 briquette had 34.61% oxygen, 1.45% nitrogen, 5.85% hydrogen, 51.15% carbon, and 0.54% sulphur. Carbon, which makes up from thirty to sixty percent of solid composition while O lands in between thirty to forty percent, identified as primary ingredient of biomass analysed using the gas analysis approach, according to the results. Typically, N along with S make up less than 1% of dry biomass, while hydrogen, the third major component, makes up between 5% and 6%.

4 Cost Analysis

Information about the cost of producing briquettes using various biomass types is presented in Table 6. The cost of production obviously varies depending on the type of biomass used to make briquettes.

Table 6 Cost analysis of briquette production

Briquettes	Cost of production. Rs. (Machine unit+ briquetting)	Gross income (Rs/h)	Net income (Rs/h)	Cost of production (Rs/kg)
S1	124.36	165	41.73	0.99
S2	129.36	185	56.73	1.3
S3	139.36	189	51.73	1.07

Across all biomass briquette production kinds, the operating machine's cost stayed at Rs. 24.74 per hour. On the other hand, the cost of producing briquettes varied depending on the biomass's purchase rate. Power-operated machines were found to have the highest production costs for S3 briquettes (Rs. 139.36 per hour) and the lowest for S1 briquettes (Rs. 124.36 per hour). The net revenue (Rs/h) from selling briquettes at 4 Rs/kg was found to be Rs. 165.00 for S1 briquettes and Rs. 189 per hour for S3 briquettes. Net income was found to be Rs. 56.73 per hour for S2 briquettes and Rs. 51.73 per hour for S3 briquettes. In comparison to other biomass briquettes, the manufacturing of briquettes from S2 utilising power-operated equipment was therefore determined to be more profitable.

5. Conclusions

India produces around 500 million metric tonnes of agro-residues every year. The high volume of this resource is either burned openly or used inefficiently which results in both pollution and unnecessary waste. The briquetting process stands as a straightforward solution to convert agricultural residues into solid fuels which can be easily handled and stored while allowing simplified transport. This study produced hand-operated briquettes from rice straw, rice husk, sawdust and cow dung mixtures and analyzed their physical, proximate and ultimate properties to determine proper fuel formulations for rural use.

- Three briquette samples labeled S1, S2, and S3 were constructed from rice straw, rice husk, sawdust and cow dung components with cow dung used predominantly as the binder. All briquette samples had identical diameters but S3 produced the longest briquettes measuring up to 6.19 cm. Table 2 reveals S2 as the briquette mixture with the highest density compared to the lowest density found in S3.
- Typically materials with elevated densities demonstrate stronger compaction properties while also supporting enhanced mechanical robustness and extended combustion durations.
- The study produced three hand-made briquette formulations (S1, S2 and S3) using different combinations of rice straw, rice husk sawdust and cow dung. The high cow dung content in all briquettes resulted from its use as binder material. All three briquettes had the same diameter, but S3 generated the longest briquettes (maximum length of 6.19 cm). The physical property tests showed that sample S2 achieved the highest density value while sample S3 had the lowest. The results indicate that S2 demonstrates improved compaction characteristics which may lead to extended burning time.
- The proximate analysis outcomes confirmed that all samples maintained moisture content within acceptable levels. The moisture content of S3 recorded the smallest percentage at 7.67% while S2 showed the greatest percentage at 13.00%. The ash content dropped from S1 (25.54%) to S2 (21.00%) reaching the minimum value in S3 (16.01%) and S1 showed the highest volatile matter (65.54%) which then decreased to 64.00% in S2 and to 63.24% in S3. The energy output ranked S2 as the best fuel followed by S3 and then S1 showing values of 3288.10 and 3231.54 kcal/kg for S2 and S3 respectively against 2410.68 kcal/kg for S1.
- The ultimate study revealed carbon content rose from S1 (44.62%) to S2 (47.24%) and S3 (51.15%) while hydrogen content increased from S1 (5.30%) to S2 (5.80%) and S3 (5.85%). S2 recorded the least oxygen percentage at 31.13% when compared to S1's 33.27% and S3's 34.61% which resulted in S2 reaching the highest calorific value alongside uniformly low nitrogen and sulphur levels in all samples reducing NOx and SOx emission possibilities. Both S2 and S3 briquettes demonstrated superior energetic performance with S2 achieving the peak calorific value and S3 offering the highest carbon content and lowest ash levels.
- The production cost per hour for S1, S2 and S3 briquettes showed minimal variation because raw material proportions and operating conditions differed slightly but remained economically viable for rural or small-scale applications. The briquettes function as an affordable decentralized renewable energy source because they derive energy from local agro-residues and cow dung despite their lower calorific value compared to commercial coal. The correct ratios between biomass and binder generate enough heat energy to support domestic cooking and small-scale industrial tasks which helps cut down on open-field biomass burning and deforestation.

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