IJASD

Development and Testing of Compressed Organic Fuel Logs: A Sustainable Cooking Alternative

Sheeraz Aleem Brohi[1*], Muhammad Hussain[1], Mehmood Laghari[1], Sher Ali Shaikh[1], Farooque Ahmed[1]

[1]Faculty of Agricultural Engineering and Technology, Sindh Agriculture University, Tandojam

*** Correspondence:** Sheeraz Aleem Brohi sabrohi@sau.edu.pk

Citation | Brohi. S. A, Hussain. M, Laghari. M, Shaikh. S. A, Ahmed. F, "Development and Testing of Compressed Organic Fuel Logs: A Sustainable Cooking Alternative", IJIST, Vol. 07 Issue. 01 pp 113-126, March 2025

Received | Feb 13, 2025 **Revised |** March 18, 2025 **Accepted |** March 19, 2025 **Published |** March 20, 2025.

Organic waste materials such as bovine excrement and agricultural residues are increasingly being recognized as sustainable fuel sources. However, conventional combustion methods contribute significantly to air pollution. This study explores the potential of log-making machinery to compress organic materials into dense logs, which combust more efficiently and produce lower emissions. The logs were produced from a mixture of animal excrement and agricultural waste using a specialized log-making apparatus, and their physical properties and performance were evaluated across 11 different log compositions (LOG-1–LOG-11). The key parameters assessed included shrinkage diameter, weight reduction, length reduction, moisture content, and bulk density. Performance metrics such as ignition time, burning rate, and ash content were also measured. The results indicated that the diameter shrinkage during drying ranged from 10% to 35%, whereas the mass loss varied between 21% and 38%. The moisture content ranged from 30% to 52%, with bulk density values between 1230 and 1540 kg/m³. The ignition time was recorded at 46 to 52 seconds, and the burning rate varied from 0.07 to 0.012 kg/min, with Log-4 exhibiting the highest burning rate. Notably, Log-8 demonstrated a lower ash content than Log-9, suggesting a greater fuel efficiency. These findings highlight the versatility of balanced compositions such as LOG-8 for various applications, contributing to more efficient agricultural practices and environmental sustainability.

Keywords: Organic Waste, Biomass Fuel, Log-Making Machinery, Environmental Sustainability, Cow Dung.

Introduction:

Energy is a fundamental necessity for citizens, playing a crucial role in sustaining their modern way of life. Daily, the manufacturing sector and population growth fuel increasing energy demand, consistently surpassing the available supply. To meet these requirements, energy must be produced from a range of eco-friendly sources. Pakistan is significantly dependent on nontraditional energy sources. These alternate energy sources include solar, wind, tidal, biomass, and geothermal energy sources. Biomass is among the most important and widely available sources of sustainable energy on Earth [1]. In countries like Pakistan, where 70% of the population is engaged in agriculture, biomass or agricultural waste with high energy content can serve as a valuable energy source. All organic materials derived from plants, including crops, trees, and algae, are referred to as biomasses. All vegetation, whether on land or in water, as well as all organic waste, is considered biomass, because they are created when green plants use photosynthesis to transform sunlight into plant material [2]. Biomass resources are considered organic matter because their chemical bonds store solar energy. The chemical energy of the carbon, hydrogen, and oxygen molecules is released during digestion, combustion, and decomposition when the bonds between the molecules are broken. As it has historically been a significant source of energy for humans, biomass is currently thought to account for approximately 10–14% of global energy production [3]. According to a previous study [4], biomass is a plant material produced when sunlight, water, and atmospheric CO2 combine to form carbohydrates, which are the building blocks of biomass. Less than 1% of available sunlight is typically converted into storage by photosynthesis. Most of the currently used biomass is domestic energy. Logs, chips, bark, and sawdust made of wood make up approximately 46% of biomass energy. Renewable energy can be obtained from agricultural wastes, including dried sugarcane leaves, rice straw, rice bran, tree bark, wheat straw, mustard waste, rice husk, pigeon-pea stalk, groundnut shell, coffee husk, cotton stalk, sunflower waste, sugarcane bagasse, maize stalk, bajra cobs, cocopeat (coir dust), and corn stalk [5-6]. Forest debris exists in the form of wood chips, twinges, sawdust, bamboo, wild grasses, bushes, leaves, and rubbish. This waste is frequently burned, which leads to smoke and fly ash. Burning agricultural waste in an open environment leads to air pollution and substantial energy loss, exceeding 100 million tons. Hence, an alternative system is needed to efficiently convert biomass into energy [6]. There has been a recent trend of resuming the use of biomass to burn fossil fuels. The global pollution level would decrease if biomass waste were used instead of conventional energy. Therefore, it is essential to develop a strategy for converting biomass into a sustainable source of electricity. Logs can be utilized as coal and wood alternatives by converting forestry and agricultural refuse into valuable biomass. Farmers can use logs produced using log-making equipment as an energy source instead of cakes formed from cattle dung. Farmers can prepare logs from cattle manure using log-making equipment instead of using the conventional method. Long cattle dung logs are made from waste biomass, such as sawdust, rice husk, rice straw, coco peat, and cattle dung. Direct combustion may offer a direct, short-term energy solution by employing various agricultural leftover energies created by adopting multiple techniques such as thermochemical, biological, or chemical [7]. Burning agricultural waste in open areas results in significant energy loss and air pollution, amounting to over 100 million tons. Farmers still make cattle dung cakes using age-old techniques [8]. Cow dung cakes have traditionally been used as fuel. In some cases, dung is mixed with agricultural residues to reduce moisture content for improved combustion. Burning logs of cattle manure provide heat and flame for boiling, roasting, and other applications. Insects, especially mosquitoes, have been seen to be repelled by the smoke produced when cattle dung logs are burned. As a result, certain regions intentionally use cow dung as a natural insect repellent [9]. Cattle dung logs are particularly advantageous as they are environmentally friendly. The use of cow dung log-making equipment has increased the production rate of cattle dung logs. By using log-making machinery, farmers can prepare more logs in a shorter amount of time. Log-making machinery made from cow dung will aid in the government's goals. The performance assessment of log manufacturing involves the utilization of a combination of other agricultural wastes and excavated cows as the base material to prepare logs. This has increased the demand for cow dung sticks; however, supply remains an issue because it is difficult to create long logs [10]. Cow dung logs are used as fuel for many purposes such as cooking, heating boilers, and chambers. Different methods have been used to generate energy sources. The main aim was to automate the cow-dung log-making process. Therefore, this study aimed to produce logs from cow dung and other agricultural waste sources.

Literature Review:

Biomass Energy and Its Significance:

Biomass is a widely available renewable energy source derived from agricultural residues, forestry waste, and animal manure. It stores solar energy in chemical bonds and releases it through thermochemical or biological processes, contributing to 10–14% of global energy production [11]. Common feedstocks include rice husk, wheat straw, sugarcane bagasse, and cow dung. Biomass conversion into fuel reduces reliance on fossil fuels and mitigates environmental pollution.

Development of Log-Making Machines:

Log-making machines have enhanced biomass utilization by efficiently converting agricultural residues into fuel logs. Verma et al. [6] developed an automatic machine that processed cattle dung and rice straw into fuel logs within 1–5 minutes. Kannaki et al. [12] introduced a semi-automated machine, reducing labor dependency. Musthak et al. [13] emphasized the need for standardized production to address size and shape irregularities.

Techniques for Biomass Energy Utilization:

Briquetting and Pelletization:

Briquetting improves biomass energy density and handling properties. Studies indicate cow dung enhances mechanical strength and calorific value in biomass briquettes [11, 14]. Geta et al. [15] found that molasses and cow dung mixtures increased fixed carbon content (52.77%) while lowering ash content (6.03%). Pelletization further enhances biomass fuel efficiency. Akbar et al. [16] optimized bagasse-based pellets with a calorific value of 16.43 MJ/kg, while Sohail et al. [17] reported superior energy density in bamboo leaf pellets bound with cow dung.

Combustion and Alternative Biomass Applications:

Wzorek et al. [18] observed improved ignition and burnout temperatures in animal dung blended with agro-industrial biomass. Szymajda et al. [19] found cow dung pellets to have 98.7% kinetic durability and a density of 470 kg/m³. Krizan et al. [20] highlighted maize straw's competitiveness as an alternative fuel source.

Objectives:

This study aims to;

1. To prepare and determine the physicochemical properties of logs made from different ratios of organic materials
2. To evaluate the combustion performance of logs made from various ratios of organic materials

The novelty of the Research:

This study introduces an innovative approach to utilizing biomass residues for clean energy by developing high-density compressed organic fuel logs as a sustainable alternative to firewood and charcoal. Unlike conventional biomass fuels, these fuel logs offer improved combustion efficiency, reduced emissions, and enhanced durability, making them more practical for household and commercial cooking. The research also explores optimized compression techniques to enhance fuel properties, contributing to renewable energy solutions, waste valorization, and environmental sustainability.

Material and Methods:

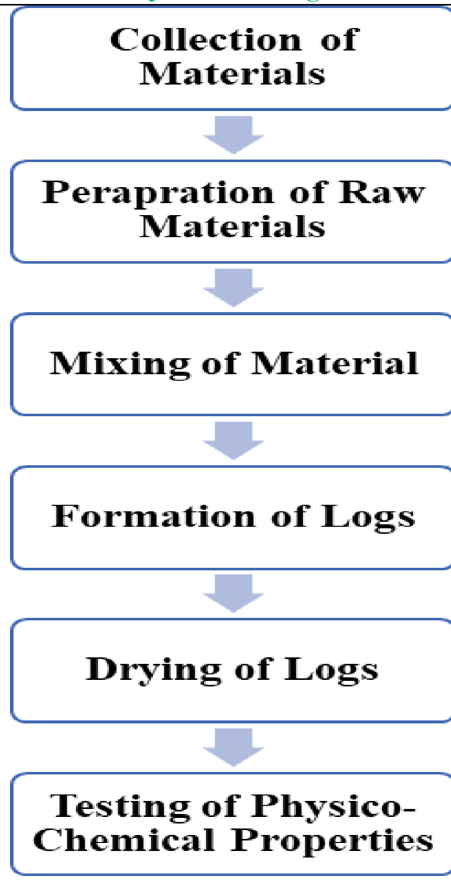

Figure 1. Flow diagram of a methodology

Collection of materials

Experiments were conducted in the laboratory of the Department of Energy and Environment, Faculty of Agricultural Engineering, SAU, Tandojam. Biomass feedstock, including crop residues from sugarcane and bananas, was collected from fields near Tandojam. Sawdust was acquired from woodworking shops, whereas cow dung was collected from a dairy farm at the Sindh Agriculture University. Sun-dried sugarcane trash and banana leaves were precision-cut and ground separately using an electric chopper to optimize their dimensions for log formation.

Preparation of Logs:

Cow dung, aged for three days to reduce moisture, was mixed with binders and different proportions of agricultural waste by weight to further decrease moisture content. The mixture was prepared in a ratio of 70% cow dung to 30% agricultural waste. The machine used in this study was acquired to produce logs from cow dung and agricultural waste. It consists of a die, screw conveyor, outer drum, and storage hopper. The raw material was fed into a storage hopper made of iron sheets (Figure 2). The screw conveyor, powered by a 2 HP motor, is located within the outer drum of the primary feedstock container. The extruded logs were shaped by a die at the end of the drum, determining their final cylindrical shape with a length of 45 cm and diameter of 3 in. The logs were then dried and tested. The specifications of the log-making machine are listed in Table 1.

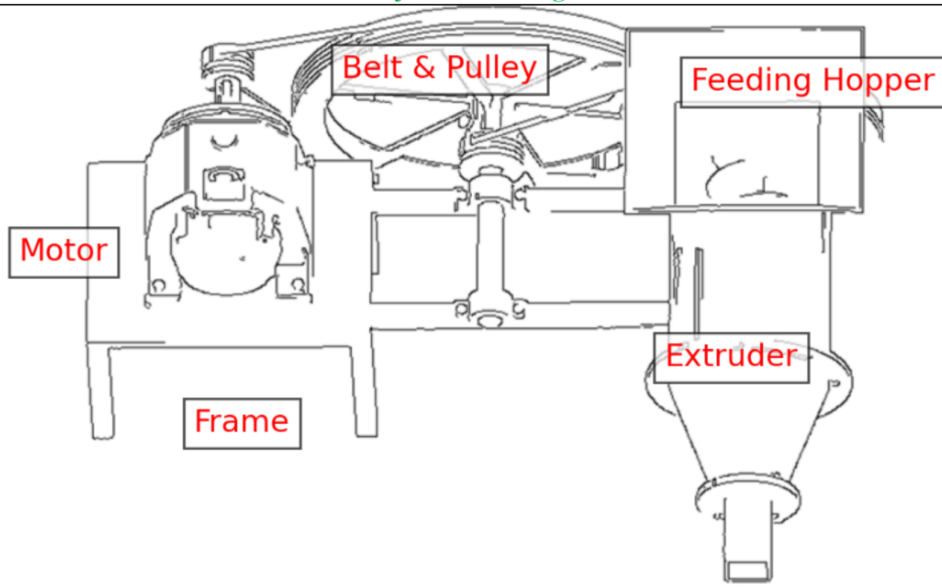

Figure 2. Sketch of logs making machine

Table 1. Specifications of log-making machine

S. No.	Component	Specification
1	Overall dimension LxWxh (mm)	945 x 550 x 940
2	Power source	2hp/ 1.5 electric motor
3	Hopper (L x W x h) mm	325 x 325 x 250
4	Conical auger length (mm)	190
5	Dimension of tray (L x W x h) mm	366 x 115 x 400
6	Number of the exit hole	1
7	Driven pully (mm)	230 x 50
8	Weight of machine (kg)	144
9	Cost of the machine (PKR)	80,000
10	Labor requirements	2

Composition of Logs:

Table 2 shows the details of the log composition, indicating the proportions of organic waste components, including cow dung, sugarcane trash, banana leaf waste, and sawdust.

Table 2. Composition of organic waste by weight percentage in various logs

Log	Cow Dung	Sugarcane Trash	Banana Leaves Waste	Sawdust
Log-1	100 %	-	-	-
Log-2	70 %	30%	-	-
Log-3	70 %	-	30 %	-
Log-4	70 %	-	-	30 %
Log-5	70 %	15 %	15 %	-
Log-6	70 %	15 %	-	15 %
Log-7	70 %	-	15 %	15 %
Log-8	70 %	10 %	10 %	10 %
Log-9	70 %	20 %	10 %	-
Log-10	70 %	-	20	10 %
Log-11	70 %	10 %	-	20 %

Physico-Chemical Parameters of Log:

Shrinkage:

Shrinkage in log diameter was determined to assess the reduction in size due to drying. The diameter of each log was measured before and after sun-drying using a vernier caliper. The shrinkage percentage was calculated using the following equation:

$$\text{Shrinkage} = \frac{D - d}{D} X\,100$$

where D is the Diameter of the log (cm) before, and d is after sun-drying.

Weight Reduction:

The weight reduction was determined by recording the initial weight of the logs before drying and their final weight after oven-drying for 24 hours at a set temperature. A digital weight balance with an accuracy of 0.01 g was used for precise measurements. The weight reduction was calculated using the following equation:

$$\text{Weight reduction } (\%) = \frac{W - w}{W} X100$$

Where W is the initial weight of log (g) and w is the weight of dried log (g)

Length Reduction:

For all log compositions, the initial log length of 45 cm was consistent. The final log length after drying was altered using moisture extraction. Three samples were selected for each log composition to ensure a precise outcome. The formula employed to quantify the extent of length reduction is as follows:

$$\text{Length reduction } (\%) = \frac{L - l}{L} X100$$

Where L is the initial length of the log (cm) and l is the length of the dried log (cm)

Moisture Content:

The moisture content of the logs was determined by weighing the sample before and after oven drying. A digital weight balance was used for accuracy. The formula used for calculation was:

$$\text{Moisture content } = \frac{Wi - Wf}{Wf} X100$$

Where Wi is the initial weight of the sample (g) and Wf is the final weight of the sample (g)

Bulk Density:

The following formula was used to calculate the bulk density of the logs.

$$\text{Bulk density} = \frac{W}{V}$$

Where W is the weight of raw material (kg) and V is the volume of core cutter (m)

Ash Content:

For ash content, one-gram oven-dried log samples were placed in a crucible and heated in a muffle furnace at 750°C until no further weight loss was recorded. Ash content was calculated by dividing the weight of the ash by that of the oven-dried sample.

$$\text{Ash content } (\%) = \frac{\text{Weight of ash (g)}}{\text{Weight of sample}}\ x\ 100$$

Ignition Time:

The ignition time was measured by applying a direct flame from a standard lighter to each log sample and recording the time taken for the log to catch fire using a stopwatch. To ensure accuracy, multiple replications were performed, and the average time was calculated.

Burning Rate:

The burning rate was determined by measuring the rate at which the log combusted completely in the presence of air. A pre-weighed log was ignited in a controlled setup, and the time required for complete combustion was recorded. The burning rate was calculated using the equation:

$$\text{Burning rate (kg/min)} = \frac{\text{Mass of fuel consumed (kg)}}{\text{Total time taken (sec)}}\ x\ 100$$

Result:

Shrinkage Diameter of Logs:

Figure 3 displays significant variations in the shrinkage of the diameter in different logs (Log-1 to Log-11) subjected to various compositions of organic waste, with shrinkage percentages ranging from 10% to 35%. These findings emphasize the impact of various material compositions on the log shrinkage behavior. Log-1, with 100% cow dung, exhibited the highest shrinkage percentage at 35%, representing the maximum diameter reduction, whereas Log-3, with 70% cow dung and 30% banana leaf waste, showed the lowest shrinkage percentage at 10%, signifying the minimum decrease in diameter.

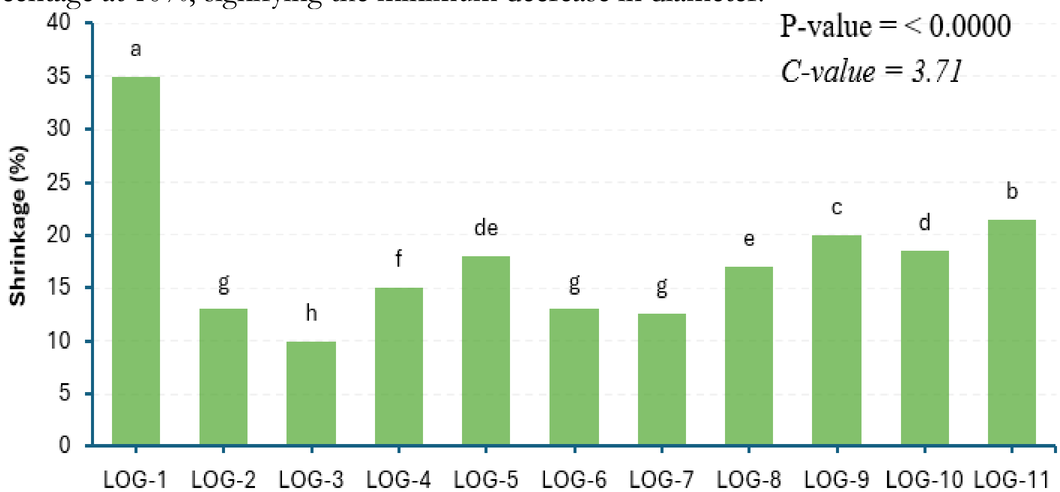

Figure 3. Shrinkage diameters of different logs. Different letters (a, b, c, and d) among the mean values indicate significant differences at P<0.05.

Weight Reduction of Logs:

Figure 4 shows the weight reduction percentages for various logs exposed to different combinations of organic waste, indicating significant variations in weight loss among the logs, ranging from 21% to 38%. Log-1, with 100% cow dung used as farmyard manure, experienced the most significant weight reduction, with a 38% decrease in mass, indicating an extensive weight reduction of organic materials. In contrast, Log-4, with 70% cow dung and 30% sawdust, showed the lowest weight reduction percentage at 21%, demonstrating the least change in mass due to its composition.

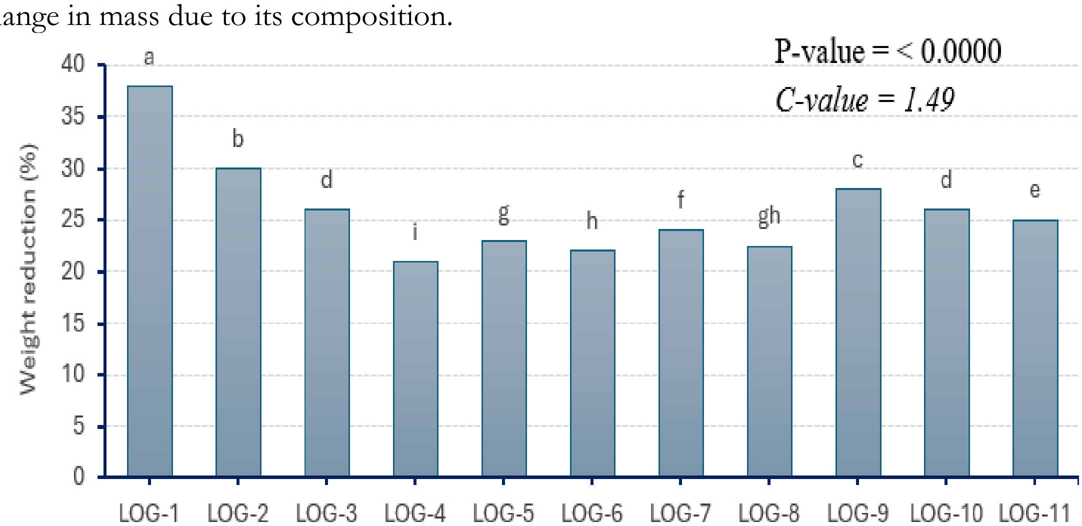

Figure 4. Weight reduction for different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Length Reduction of Logs:

Figure 5 illustrates the length reduction of logs under different compositions (LOG-1 to LOG-11) and their changes owing to the decomposition and shrinkage of organic waste materials. The results revealed significant variations in the length reduction, ranging from 2.2% to 11%. LOG-1 experienced the greatest reduction in length at 11%, which was attributed to the composition of 100% cow dung, indicating substantial shrinkage or shortening of organic materials. In contrast, LOG-3 showed the lowest reduction of 2.2%, reflecting minimal changes due to the different decomposition rates of its composition, which included 70% cow dung and 30% banana leaf waste.

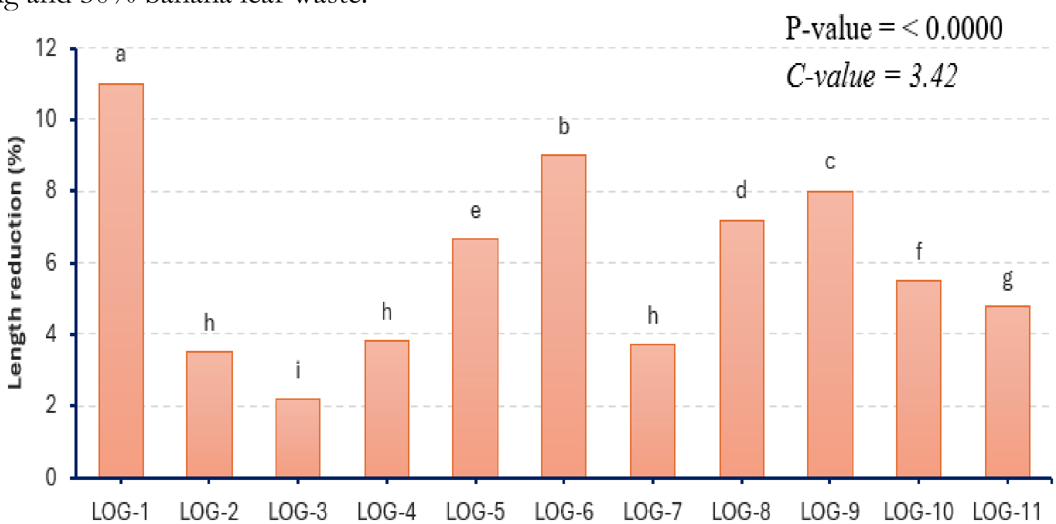

Figure 5. Length reduction of different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Moisture Content of Logs:

The moisture content of different logs (LOG-1 to LOG-11) is expressed as a percentage, and the results are shown in Figure 6 Moisture content significantly influences decomposition, microbial activity, and overall organic material behavior. LOG-1 exhibited the highest moisture content (52 %), likely because of the 100% composition of the cow dung. In contrast, LOG-7 had the lowest moisture content (30 %), reflecting the dry composition of 70% cow dung, 15% banana leaf waste, and 15% sawdust. These findings underscore the importance of monitoring moisture levels for effective waste management and agricultural practices, emphasizing the need to understand the specific composition of each log.

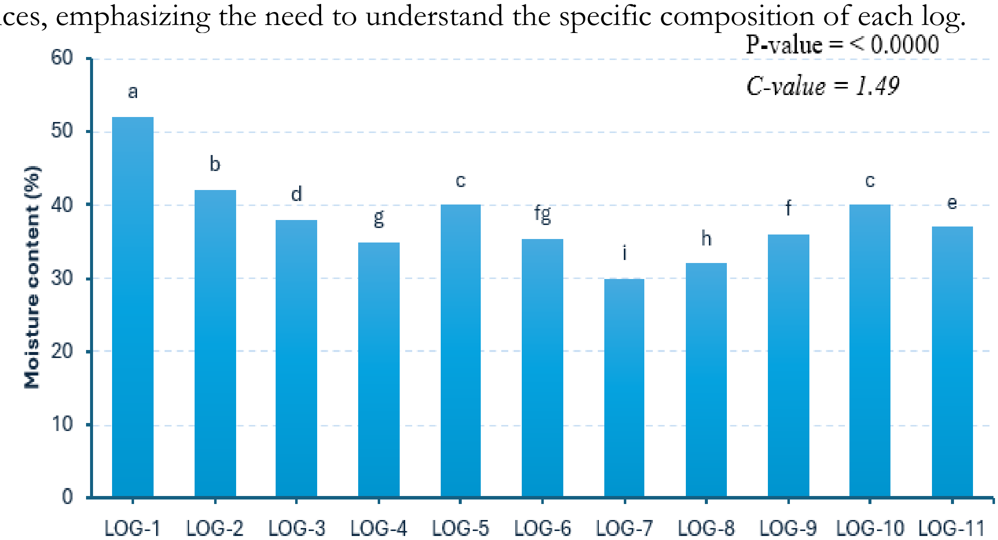

Figure 6. Moisture content of different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Bulk Density of Logs:

Figure 7 illustrates the bulk density of 11 logs (LOG-1 to LOG-11) and their corresponding physical properties, which are crucial parameters for understanding the material characteristics. LOG-1 exhibited the highest bulk density of 1540 kg/m³, indicating that tightly packed material was affected using 100% cow dung. In contrast, LOG-4 demonstrated the lowest bulk density of 1230 kg/m³, possibly influenced by the combination of 70% cow dung and 30% sawdust, indicating less densely packed logs. These findings highlight the significant variations in bulk density due to different compositions of organic materials, emphasizing the importance of understanding material characteristics for effective waste management and agricultural practices.

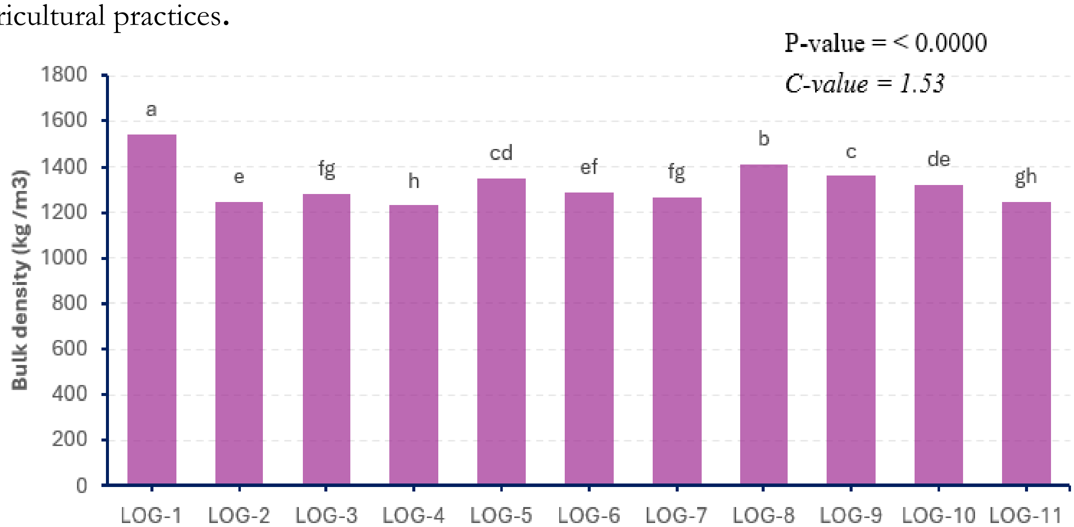

Figure 7. Bulk densities of different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Ignition Time of Logs:

Figure 8 illustrates the ignition time of the logs (LOG-1 to LOG-11) to evaluate their combustion characteristics, representing the duration for the material to catch fire when exposed to a heat source. LOG-4 exhibited the longest ignition time of 56 s, indicating a significant resistance to catching fire owing to its composition of 70% cow dung and 30% sawdust. In contrast, LOG-9 had the shortest ignition time of 46 s, likely owing to its composition of 70% cow dung, 20% sugarcane trash, and 10% banana leaf waste, indicating quicker ignition.

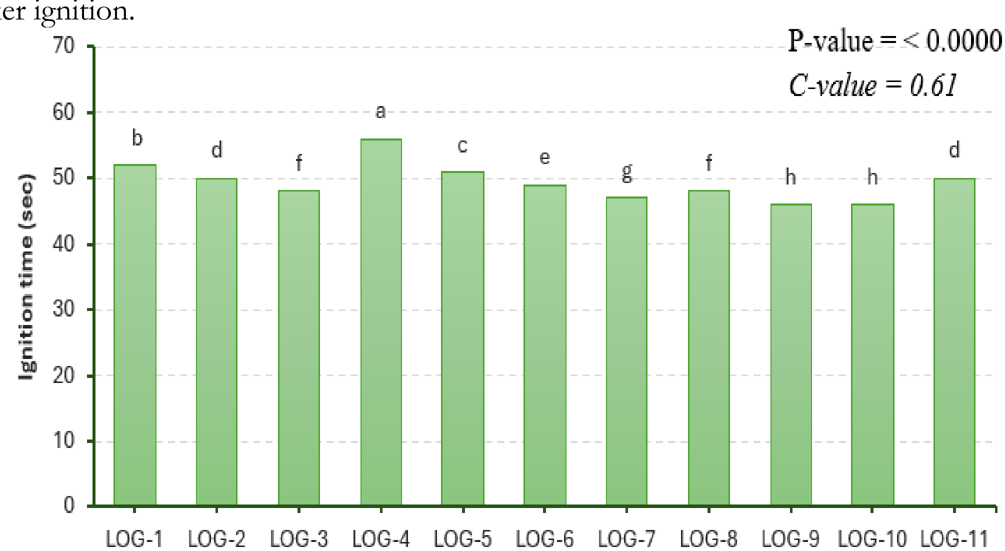

Figure 8. Ignition times for different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Burning Rate of Logs:

Figure 9 illustrates the burning rates of different logs (LOG-1 to LOG-11) when exposed to a heat source. The burning rate ranged from 0.07 to 0.12 (Kg/min) for various logs (LOG-1 to LOG-11). The results indicated significant variations in the burning rates owing to the different compositions of organic materials. LOG-1 had the lowest burning rate, which was likely attributable to its composition of 100% cow dung used as farmyard manure. In contrast, LOG-8 exhibited the highest burning rate, probably due to its balanced composition of cow dung, sugarcane trash, banana leaf waste, and sawdust.

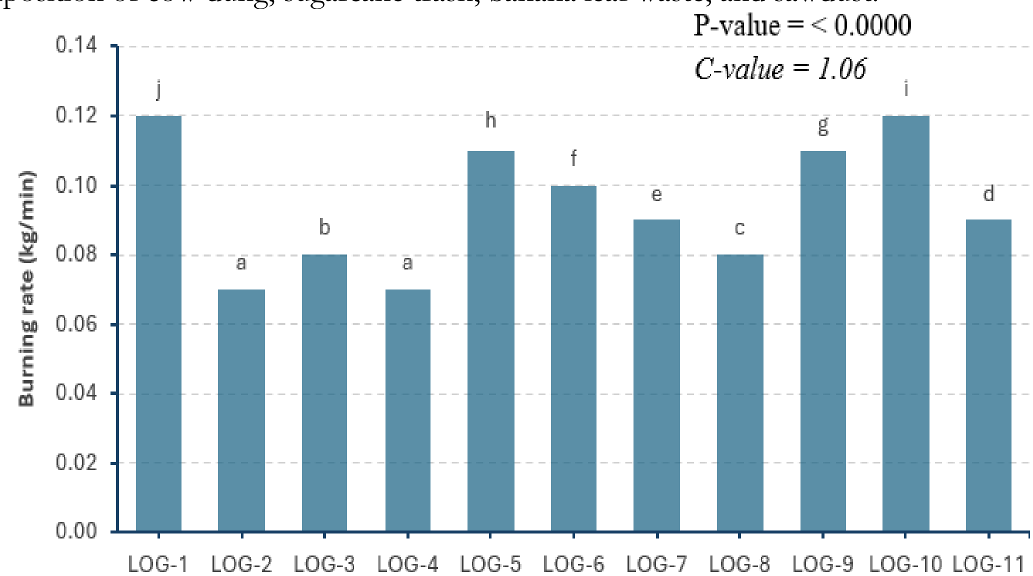

Figure 9. Burning rates of different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Ash Content of Logs:

Figure 10 offers insights into the mineral content or inorganic residue present in different logs (LOG-1 to LOG-11) by showing their ash content expressed as a percentage. The ash content is a crucial parameter that influences the nutritional value and combustion properties of organic materials. LOG-1 displayed the highest ash content of 14%, which was likely attributed to its 100% cow dung composition. In contrast, LOG-9 exhibited the lowest ash content (9 %), likely because of its composition of 70% cow dung, 20% sugarcane trash, and 10% banana leaf waste.

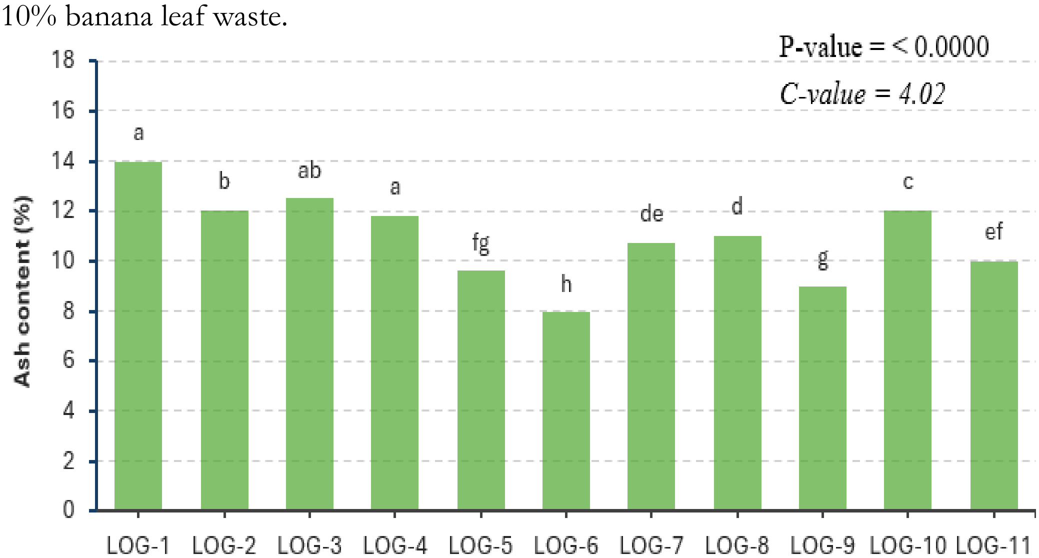

Figure 10. Ash content of different logs. Different alphabets (a,b,c,d) among the mean values show significant differences at P<0.05

Discussion:

Effect of Different Agricultural Wastes on Physiochemical Properties of Logs:

Shrinkage in diameter is a crucial physical property influencing the combustion behavior and efficiency of biomass fuels, including logs. This study observed significant variations in shrinkage percentages (10% to 35%) among different logs (Log-1 to Log-11) subjected to various organic waste compositions. Log-1, composed of 100% cow dung, exhibited the highest shrinkage of 35%, indicating substantial decomposition and structural changes. Logs with materials with higher moisture retention tended to show more significant shrinkage. These findings align with [6], who reported shrinkage in the diameter of logs made from cattle dung and agricultural residues, attributing it to moisture loss and log compression during drying. The biomass feedstock and heating conditions are crucial for efficient combustion systems. Weight reduction in logs is influenced by moisture content, processing methods, and material type. Notable differences in weight loss percentages (21% to 38%) were observed among the logs. The organic material composition affected the weight reduction due to varying decomposition rates. Research by [6] on logs made from cow dung reported weight losses of approximately 26% and 30% during drying, respectively. Moisture content, density, temperature, humidity, and material properties affect length reduction during log drying. Logs exhibited significant variation in length reduction (2.2% to 11%). Shrinkage in length reported in [6] for logs made from cow dung and wheat straw ranged from 10% to 15%. Moisture content significantly influences combustion efficiency.

Moisture content significantly affects combustion efficiency, influencing heat output and smoke production. In this study, log moisture content ranged from 52% to 30%, with higher moisture leading to inefficient burning and increased smoke, while lower moisture improved combustion efficiency. Limited studies exist on log moisture content and its combustion performance. However, research on biomass briquettes provides relevant insights. Kpalo et al. [22] reported that briquettes with 5–10% moisture content performed well in terms of stability and combustion efficiency. Our findings suggest that logs, with their broader moisture range, exhibit different combustion behaviors, likely due to variations in structure and drying conditions. Logs with lower moisture showed higher efficiency, aligning with previous reports that link reduced moisture to higher calorific value [26]. Our findings indicate that cow dung-based logs retain more moisture than briquettes, affecting combustion performance. Proper drying is essential to enhance efficiency. Future research should optimize drying techniques and material composition for improved log-based biofuel performance. Bulk density affects combustion efficiency, with higher-density logs burning longer and producing more heat. The bulk densities of the different logs ranged from 1230 to 1540 kg/m³. Researchers [6] have observed varied bulk densities based on the raw material types used in log production. Bulk density significantly influences combustion efficiency, with higher-density logs burning longer and producing more heat. In this study, log bulk density ranged from 1230 to 1540 kg/m³, with denser logs exhibiting better combustion performance.

Although studies on log density are limited, biomass briquettes offer useful comparisons. Previous research [27] reported briquette densities of 851 kg/m³ for coconut shells, 793 kg/m³ for rattan waste, 678 kg/m³ for banana peels, and 470 kg/m³ for sugarcane bagasse. Agricultural waste-based charcoal typically falls within 760–1800 kg/m³ [28], aligning with our findings for rattan and coconut shell logs. Lower-density materials, like banana peels and sugarcane bagasse, tend to have higher porosity, reducing combustion efficiency.

Effect of Different Agricultural Wastes on the Performance of Logs:

Ignition time is a crucial parameter that determines the ease of ignition logs and the speed at which heat can be provided. It can vary depending on the raw material and production process. The study found ignition times for logs (LOG-1 to LOG-11) ranged from 46 to 52 (Sec). Ignition time is the time taken for a material to catch fire when exposed to a heat source.

These findings align with [23], who evaluated briquettes made from sawdust and rice husks, finding an average ignition time of 2.56 minutes. Ignition time is influenced by moisture content, bulk density, total solid content, raw material type, log size and shape, and additives or binders. Denser, more homogeneous logs tend to have shorter ignition times than those made from heterogeneous materials. Ignition times vary significantly based on specific materials and production processes.

The burning rate of logs is influenced by material type, moisture content, size, density, and burning conditions. Hardwood logs burn more slowly, producing long-lasting fires, while softwood logs ignite quickly but burn faster. Additionally, denser materials tend to burn more slowly and last longer, whereas less-dense materials combust more rapidly. Production methods and material properties also play a significant role in combustion performance. Due to the limited studies on log combustion, the results were compared with biomass briquettes. The study found that burning rates for different logs (LOG-1 to LOG-11) ranged from 0.07 to 0.12 kg/min. In comparison, previous research by [29] reported burning rates of 0.07 kg/min for logs made from cow dung and rice husk and 0.06 kg/min for those composed of cow dung and sawdust. Similarly, biomass briquettes showed burning rates of 0.00166 kg/min for animal manure briquettes and 0.00108 kg/min for sawdust briquettes, indicating that briquettes made from animal manure burn faster than those from sawdust.

Ash content in logs affects combustion efficiency and ash production. Logs with lower ash content produce less ash and have higher combustion efficiency. The study found ash content ranged from 9 to 14% for different logs (LOG-1 to LOG-11), providing insights into mineral content or inorganic residue. These findings are similar to [25], who found that the ash content of briquettes made from cow dung and various biochar sources varied depending on the biochar type used. Specifically, cow dung briquettes had 15.67% ash content, while those with rice husk had 20.13% ash content, and those with coconut shells had 16.83% ash content.

Conclusion:

This study effectively demonstrated the viability of producing compressed organic logs from bovine excrement and agricultural waste utilizing log-making machinery. The assessment of physical properties revealed substantial variations in shrinkage diameter, weight reduction, moisture content, and bulk density among the diverse log compositions. The performance metrics indicated that specific logs, particularly Log-4 and Log-8, exhibited superior combustion rates and reduced ash content, rendering them more efficient fuel alternatives. The findings underscore the potential of utilizing organic waste as a sustainable energy source that not only diminishes reliance on conventional fuels but also mitigates atmospheric pollution associated with open-burning practices. Through optimization of these logs' composition, their applicability to various energy requirements can be enhanced, while promoting environmental sustainability. Subsequent research should focus on scaling up production processes and exploring additional applications of these logs in energy generation to further support sustainable agricultural practices in Pakistan and other comparable contexts.

Acknowledgment: The corresponding author is very thankful to the Department of Energy and Environment at the Faculty of Agricultural Engineering and Technology for the support of the lab and instruments.

Author's Contribution: All the authors contributed equally

Conflict of interest: The authors declare there is no conflict of interest in publishing this research in IJASD.

References:

[1] Mohtasham, J. (2015). *Renewable energies.* Energy Procedia, 74, 1289-1297.

[2] Naqvi, S. R., Jamshaid, S., Naqvi, M., Farooq, W., Niazi, M. B. K., Aman, Z., & Afzal, W. (2018). Potential of biomass for bioenergy in Pakistan based on present case and future perspectives. *Renewable and Sustainable Energy Reviews*, 81, 1247-1258.

[3] Yalley, P. P. K., & Manu, D. (2013). Strength and durability properties of cow dung stabilised earth brick. *Civil and Environmental Research*, 3(13), 117-125.

[4] Eloka-Eboka, A. C., & Inambao, F. L. (2017). Effects of CO_2 sequestration on lipid and biomass productivity in microalgal biomass production. *Applied Energy*, 195, 1100-1111.

[5] Hassan, L. G., Sani, N. A., Sokoto, A. M., & Tukur, U. G. (2017). Comparative studies of burning rates and water boiling time of wood charcoal and briquettes produced from carbonized martynia annua woody shells. *Nigerian Journal of Basic and Applied Sciences,* 25(2), 21-27.

[6] Verma, N., Victor, V. M., & Dewangan, D. (2022). Performance evaluation of log making machine for production of log by using cattle dung and other agricultural residue.

[7] Adapa, P. K., Karunakaran, C., Tabil, L. G., & Schoenau, G. J. (2009). Potential applications of infrared and Raman spectromicroscopy for agricultural biomass. *Agricultural Engineering International: CIGR Journal.*

[8] Patil, R. A., & Deshannavar, U. B. (2017). Dry sugarcane leaves: Renewable biomass resources for making briquettes. *International Journal of Engineering Research and Technology*, 10(1), 232-235.

[9] Tamire, M., Addissie, A., Skovbjerg, S., Andersson, R., & Lärstad, M. (2018). Socio-cultural reasons and community perceptions regarding indoor cooking using biomass fuel and traditional stoves in rural Ethiopia: a qualitative study. *International Journal of Environmental Research and Public Health*, 15(9), 2035.

[10] Ali, M., Saleem, M., Khan, Z., & Watson, I. A. (2019). The use of crop residues for biofuel production. *In Biomass, Biopolymer-Based Materials, and Bioenergy*, 369-395.

[11] Obi, O. F., Pecenka, R., & Clifford, M. J. (2022). A review of biomass briquette binders and quality parameters. *Energies*, 15(7), 2426.

[12] Kannaki, S., Nithyapriya, S., Abinesh, M., Gayatri, N., Harish, V., Manikandan, R., & Kailash, M.S. (2020). Design and modeling of automatic cow dung log making machine, *International Journal of Recent Technology and Engineering* (IJRTE),8, 2999-3002.

[13] Musthak, I. A., Mohammadsahul, S. B., Purvesh, J. P., Durgesh, B. P., Vaishal, J. B., Mitul, R. M. (2020). Design and development of cow dung stick manufacturing machine. *International Journal for Research in Engineering Application and Management,6,* 1-3.

[14] Patil, R. A., Deshannavar, U. B., Ramasamy, M., Emani, S., Issakhov, A., & Khalilpoor, N. (2021). Briquetting of dry sugarcane leaves by using press mud, cow dung, and buffalo dung as binders. *International Journal of Chemical Engineering*, *13*(2), 127-132.

[15] Geta, T. T., Tsegaye, M., Yadeta, G., Alemu, T., Sugebo, B., & Genene, D. (2022). Production and characterization of pellets from carbonized pinus patula sawdust. *Renewable Energy Research and Applications*, *3*(2), 175-181.

[16] Akbar, A., Aslam, U., Asghar, A., & Aslam, Z. (2021). Effect of binding materials on physical and fuel characteristics of bagasse-based pellets. *Biomass and Bioenergy*, *150*, 106118.

[17] Sohail, H., Hassan, M., Anwar, M., Masuad, S. F. B., & Ahmad, W. (2021, March). Biomass pelletizing: Characterization of cow dung assisted solid recovered bio-fuel from agricultural waste. In *2021 4th International Conference on Energy Conservation and Efficiency*, 1-6.

[18] Wzorek, M., Junga, R., Yilmaz, E., & Niemiec, P. (2021). Combustion behavior and mechanical properties of pellets derived from blends of animal manure and lignocellulosic biomass. *Journal of Environmental Management*, *290*, 112487.
[19] Szymajda, A., Łaska, G., & Joka, M. (2021). Assessment of cow dung pellets as a renewable solid fuel in direct combustion technologies. *Energies*, *14*(4), 1192.
[20] Križan, M., Krištof, K., Angelovič, M., Jobbágy, J., & Urbanovičová, O. (2018). Energy potential of densified biomass from maize straw in form of pellets and briquettes. *Journal of Renewable Energy, 17*(4), 25-33.
[21] Singh, V., Singh, R., & Kumar, A. (2019). Development of an eco-friendly briquetting machine for production of rural waste-based biomass briquettes. *Journal of Cleaner Production*, 222, 721-729.
[22] Kpalo, S. Y., Zainuddin, M. F., Manaf, L. A., & Roslan, A. M. (2020). Production and characterization of hybrid briquettes from corncobs and oil palm trunk bark under a low pressure densification technique. *Sustainability*, *12*(6), 2468.
[23] Mulyani, S., Imran, A., Yani, M., & Rahman, M. A. (2020). The effect of sawdust and molasses adhesive content on the physical and combustion properties of briquette fuel from coconut shell waste. *Energy and Fuels*, 34(2), 1358-1366.
[24] Bhoi, P., Patel, J., Patel, S., & Patel, R. (2021). Review on biomass briquetting and its performance characteristics. *International Journal of Emerging Technology and Advanced Engineering*, 11(6), 447-453.
[25] Majumder, S. D., Ghosh, A., & De, S. (2021). Experimental Investigation of briquettes formed from various sources of biochar mixed with cow dung as alternate source of energy–A West Bengal study. *Materials Today: Proceedings*, 46, 7996-8001.
[26] Akowuah, J. O., Kemausuor, F., & Mitchual, S. J. (2012). Physico-chemical characteristics and market potential of sawdust charcoal briquette. *International Journal of Energy and Environmental Engineering*, *3*, 1-6.
[27] Bot, B. V., Sosso, O. T., Tamba, J. G., Lekane, E., Bikai, J., & Ndame, M. K. (2021). Preparation and characterization of biomass briquettes made from banana peels, sugarcane bagasse, coconut shells and rattan waste. *Biomass Conversion and Biorefinery*, 1-10.
[28] Zandersons, J., Kokorevics, A., & Gravitis, J. (1999). Studies of bagasse charcoal briquetting, reduction of the ash content in charcoal, and preliminary material and energy estimations for the design of a pilot plant of bagasse charcoal. *UNU/IAS Working Paper*, (58), 1-33.
[29] Jain, V., Chippa, R. C., Chaurasia, P. B. L., Gupta, H., & Singh, S. K. (2014). A comparative experimental investigation of physical and chemical properties of sawdust and cattle manure briquette. *International Journal of Science, Engineering and Technology*, *2*(7), 1514-1521.