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EVALUATION OF THE MECHANICAL AND THERMAL CHARACTERISTICS OF MAIZE HUSK BRIQUETTE AS AN ALTERNATIVE ENERGY SOURCE

Dilibe I. Ntunde[*1], Mathew I. Ibe[2], Johnson E. Igwe[3]

[1,2,3]Department of Mechanical Engineering
Michael Okpara University of Agriculture, Umudike, Nigeria

Abstract. This paper presents the mechanical and thermal characteristics evaluation of maize husk briquette as an alternative energy source to enhance sustainability and efficiency. The experimental test conducted for a 0.6kg weight of briquette showed the volatility and moisture content to have a mean value of 62.52 and 0.27%; while the compressive strength was revealed to be 3.06k N/m^2. The thermal evaluation showed that the mean burn temperature of the maize husk briquette rose from 70.70°C to 83.34°C in 8 minutes, 98.72°C in 10 minutes and finally 100°C in 12 minutes; when compared to fire wood which burns slowly from 46°C in 5 minutes, to 53°C in 9 minutes, 68°C in 10 minutes, 82°C in 12 minutes, 94°C in 18 minutes and finally to 100°C in 21 minutes. Further, the comparative analysis result revealed that the maize husk briquette has more oxygen and nitrogen at 44.64 and 4.22%, compared to charcoal. It also has more ash content of 11.47% due to its volatility to burn effectively. On the other hand, the maize husk briquette has a low carbon and sulfur contents after burning at 43.55 and 0.051%. These findings will help address the disposal challenges of accumulated maize husk at and crop residues as an alternative sustainable source to meet green environmental and technological demands.

Key words: *Briquette, energy source, husk, thermal conductivity.*

INTRODUCTION

The use of wood is on the increase, and on a daily basis especially in the less technologically developed countries of the world.

[*]Corresponding Author. E-mail: ntunde.dilibe@mouau.edu.ng; dilibedilis@gmail.com

With deforestation becoming a major problem in many parts of the developing world, the increased scarcity of fuelwood for household cooking, leaving kerosene and gas as the major cooking fuels. An estimated 3 billion people in our current estimated 7.63 billion people in the world rely on wood, kerosene, biomass, and coal for cooking in general, which has led to rapid deforestation and loss of more than 3% of the world's forests on a yearly basis, [24]. The use of fuel wood in the large scale by especially the rural communities without same force of replenishing the depletion, poses serious environmental consequences in many countries and the world in general. Biomass fuels are long term potential sources of renewable energy, because of its abundant availability and CO_2 neutral. Depending on the technology selection, biomass can be used as fuel in various forms; liquid, gas and solid. Also, biomass is an indispensable renewable resource, and having it in the form of wood and agricultural wastes constitute one of the third largest alternative source of primary energy in the world aside from coal and oil [3]. The common practice is to burn these residues as waste by recycling to ameliorate the accumulation of greenhouse gases.

Consequently, there is an increasing need to source for alternative as it pertains to fuels, especially as it concerns cooking so as to reduce deforestation leading to the cutting of trees for the purpose of fuel wood. One of such energy sources is the use of biomass for briquette production through carbonized or un-carbonized densification and manufacture processes. The process of compressing this waste into a product of higher density than the original raw material state is known as densification, [17] Using agricultural residues as energy is an attractive option. Briquetting is a compacting or densification process to increase the low bulk density of biomass to high density, from 150–200 kg/m^3 to 900–1300 kg/m^3 [2]. Biomasses, especially from wood and energy crops, are important energy carriers that contribute to the energy demand.

For these waste residues to become a more attractive alternative fuel, they have to be upgraded to improve their burning performance. However, there is need to subject them to conversion processes in order to mitigate these problems. One of the promising solutions to these problems was the application of briquetting technology.

It is a kind of technology to obtain clean energy from the use of bio-waste to create usable and effective briquettes to replace traditional firewood and charcoal in various domestic activities.

These products with uniform shape and sizes can be more easily handled using existing handling and storage equipment and thereby reduce cost associated with transportation, handling, and storage [8].

Burning briquettes as a fuel completes a natural cycle; on combustion they only release as much carbon dioxide back in the atmosphere as was originally absorbed by the growing tree during photosynthesis. Briquettes can be used for power generation or for thermal application but mostly they are used for thermal application in industries replacing conventional fuel. [1] investigated the impact of particles on mechanical durability of wheat straw briquettes, and observed that the increase of the rotational speed of the working chamber caused a slight decrease in the value of the mechanical durability of briquettes for all investigated fractions. [21] focused on briquettes produced from wheat, oat, canola, as well barley straw, and proved best particle size between 25–32 mm. [15] investigated the optimal feedstock particle size and its influence on final briquette quality, and conclusion, results values did not support prevailing opinion that smaller particle sizes are more suitable for briquette production.

Subsequently, [27] investigated The Effects of Some Processing Parameters on Physical and Densification Characteristics of Corncob Briquettes, and concluded that the processing parameters such as particle size, % binder ratio and compaction pressure significantly affected the physical and densification characteristics of briquettes produced from corn-cob. Good quality and highly storable briquettes can be produced from the blend of corncob and cassava starch gel [12]. This was because the briquettes produced have sufficient density and relaxed density. Furthermore, the shelf-life of the stored briquettes showed reasonable stability even after six months of storage. Also, the bulk density of the relaxed briquettes, which is 315 kg /m^3, was higher than the residue materials was 50.32 kg/m^3. This translated into 626% volume reduction. It also provides technological benefits and a desirable situation for material storage, packaging and transportation, and lastly; hence, the finer the particle size, the more positive attributes of good quality briquette such particle has. In the similar manner, the lower the binder ratio, the better the briquettes, while higher compaction pressure will result in more quality briquettes [26].

Further, [19] investigated the production of charcoal briquettes from biomass for community use, stating that the three biomass types were tested for their suitability for making charcoal briquettes, sugarcane bagasse (SB), cassava rhizomes (CR), and water hyacinth (WH). As fresh biomass samples were sun dried and then burnt in a 200 liter incinerator with a controlled amount of air. The resulting char particles were mechanically pressed into a hollow-cylindrical shape. It was found that the CR charcoal briquettes had the best properties in terms of heating value, compressive strength, and extinguishing time. Additionally, [29] looked into the various production methods, procedures and processes that are deployed to process loose biomass into biomass briquettes, they established the cactus binders is insensitive to working pressure on compaction due to binder's composition, concluded that the optimum briquetting parameters are pressure of 19MPa and loose biomass to binder ratio of 35:36.

Other studies such as [25] explored and compared the effects of three different binders, including starch, enhanced treated bio-solids and microalgae, on density, durability, energy content and combustion characteristics of fuel briquettes produced from blends of maize husks, corn cobs and bagasse, in a multilevel factorial design experiment. [10] Investigated Characterization of Briquettes from Maize Bran and Palm Kernel Shell, concluding that Fuel characterization of briquette produced from maize bran and palm kernel shell was done and the ultimate analysis for the briquette resulted into 45.67%, 5.80%, 0.05%, 1.78% and 46.70% for Carbon, Hydrogen, Sulphur, Nitrogen and Oxygen respectively. Proximate analysis gave 18.97%, 64.54%, 14.16%, and 21.30% for moisture content, volatile matter, ash content and fixed carbon respectively. The values of volatile matter and ash content are good and acceptable compared to the results from the previous work. The briquette performance was evaluated compared to firewood through water boiling test which showed that 1 kg of the briquette took 15 minutes to boil 2litres of water where as it took 1.2 kg of firewood 21 minutes to boil the same quantity of water.

Maize Factories could be done on the cottage, small, medium and large-scale, depending on availability of capital and the raw materials [26]. The husks are used for the production of potassium Hydroxide solution or as fuel for milling plants. It can be seen that virtually all parts of maize are useful. The disposal challenges of accumulated maize mills and crop residues on the field will be resolved through briquetting and its attendant energy utilization.

Hence, harnessing maize bran for energy will promote maize cultivation and guarantee national food security and heat will be generated for domestic an industrial cottage applications, since lots of potential energy abounds in these residues, therefore reducing the current pressure on forest products for rural energy supply. However, there is the need to subject the strength and durability of this biomass product to tests; hence, this paper presents the mechanical and thermal evaluation of maize husk briquettes to perform a comparative analysis, as an alternative energy source to wood charcoal.

MATERIALS AND METHODS

The material used for the experimental analysis was Maize husk, with the unwanted materials were removed and sorted to ensure a fine pure particles of the husks.

Afterwards the husks were molded into briquettes using a molder and extruder that transform it into a briquette without the use of any binder. The briquettes were further developed by using a compressing machine operating with an efficiency of 94% to produce two variable samples A and B.

The physical properties of the developed briquette samples were determined by conducting some experimental tests.

First, the size and weight were measured for each sample then the density was determined afterwards using the ratio of the mass to the volume. The mass was obtained by using a digital weighing scale, while the volume was calculated by taking the linear dimensions (length, breadth and thickness) of the briquette by means of a vernier caliper.

Subsequently, the percentage volatile of the briquette was established when a 2g of pulverized sample in a crucible was placed in the oven that was set to burn at a temperature of 550ºC for 12mins until a constant weight was obtained. Then, the briquette was removed and weighed after cooling; where the values of these parameters were used to determine the percentage volatile matter using eq. (1); where P_{VM}, Rh_{Bb} and Rh_{Ba} are the Percentage of Volatile Matter of the Maize husk briquette, Weight of oven dried sample of maize husk briquette; and Weight of sample of maize husk briquette after burning for 12mins in the furnace at 550ºC.

$$P_{VM} = \frac{Rh_{Bb} - Rh_{Ba}}{Rh_{Bb}} \times 100 \qquad \text{……………………………. (1)}$$

The moisture content of the maize husk material before and after briquetting was determined using experiment standard for Moisture Content [30], where the initial weight (W_1) of the sample was first recorded before being placed in an oven set at 103ºC for 24 hours. The samples were then removed and cooled in a desiccator, and reweighed for the final weight (W_2); where; *MC*, W_1, and W_2 are the Moisture Content, the weight of briquette before going into Oven, and the weight of briquette after oven experiment as expressed in eq. (2),

$$MC = \frac{W_1 - W_2}{W_2} \times 100 \qquad \text{……………...……………………... (2)}$$

Further, the compressive strength was determined by using a universal strength-testing machine of 100 kN capacity with standard method [30]. The test was carried out 21 days after briquetting when the briquettes had attained their maximum strength. The peak stress displayed at the end of each test was recorded.

The percentage ash content and percentage fixed carbon were determined using eq. (3) and (4) respectively, according to [31] by placing it in a crucible; where the weight of the crucible plus specimen was determined. This content was then burnt in a furnace at 550°C until all the carbon was eliminated. It was heated slowly at the start to avoid flaming and the crucible was protected from strong drafts at all times to avoid mechanical loss of test specimen. The weight of the samples after burning were recorded as the weight of the oven-dry test specimen given in eq. (3); where P_A, W_A and Rh_{Bb} are the ash Percentage, weight of ash and weight of oven dried sample of maize husk briquette.

$$P_A = \frac{W_A}{Rh_{Bb}} \times 100 \qquad (3)$$

Further, the fixed carbon percentage (P_{FC}) was calculated by subtracting the sum of percentage volatile matter (P_{VM}) and percentage ash content (P_A) from 100 in eq. (4); while, the Gallen Kamp Ballistic Bomb Calorimeter apparatus was used, to determine the heating value of the biomass briquettes.

$$P_{FC} = 100 - (P_{VM} + P_A) \qquad (4)$$

Additionally, a comparative analysis of the physical and thermal characteristics for the maize husk briquette and charcoal were done to determine the material that emits the least greenhouse gases to produce the required heat as source energy to the society.

RESULTS AND DISCUSSION

The results of the experimental test conducted for the physical Characteristics of the developed maize husk briquette showed the size, weight, and compressive strength of the material. The value for the mean density and volatility for the variable briquette samples A and B were 524kg/m^3 and 62.52%, for an average weight measured of 0.6kg. Subsequently, the compressive strength and moisture content were evaluated at 3.06 kN/m^2 and 0.27%.

Table 1. Physical and Fuel Characteristics of Briquette from Maize

Parameters	Unit	Maize Husk Briquette Samples		Mean Value
		A	B	
Length of the Briquette	mm	60	62	61
External diameter of the Briquette	mm	39	39	39
Weight of the Briquette	kg	0.06	0.06	0.06
Volatility	%	62.51	62.53	62.52
Moisture Content, MC	%	0.27	0.27	0.27
Compressive Strength	kN/m^2	3.05	3.07	3.06

The proximate analysis gave the percentage volatile matter, percentage ash and percentage fixed carbon of the briquette; while the ultimate analysis was performed on finely ground and oven dried samples to find the amount of Carbon, Hydrogen, Nitrogen and Sulphur (C, H, N, and S) by using the CHNS Elemental Analyzer. The experiments were performed two times and the mean readings were taken for all the characterization. The briquette from the mixture has an ash content and fixed carbon of 11.47%, and 21.00%. Further, results of the heating value of the briquette was 24.21 for all samples, with a composition values of 43.55%, 4.20%, 0.05 %, 1.35% and 44.64% for carbon, hydrogen, sulfur, nitrogen and oxygen respectively. Consequently, the mean value for the chemical composition of the briquette in Fig.1., showed that the maize briquette contains carbon and oxygen at 43 and 44%; and sulfur and hydrogen as the lowest values a t 0.5 and 4.2% were the highest and lowest elements respectively.

Table 2. Thermal Characteristics of Briquette from Maize

Parameters	Unit	Maize Husk Briquette Samples		Mean Value
		A	B	
Heating Value	MJ/kg	24.21	24.21	24.21
Carbon Content	%	43.57	43.54	43.55
Hydrogen Content	%	4.20	4.21	4.20
Sulfur Content	%	0.05	0.06	0.05
Nitrogen Content	%	1.36	1.34	1.35
Oxygen Content	%	44.65	44.63	44.64
Ash Content	%	11.48	11.46	11.47
Fixed Car Moisture	%	21.00	21.01	21.00

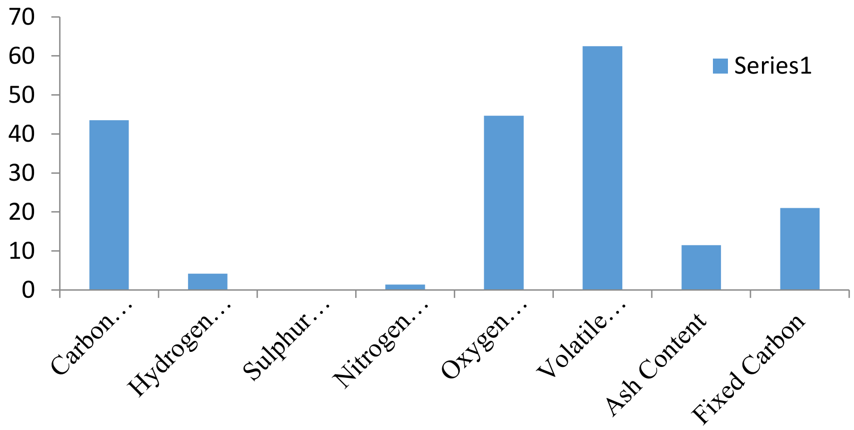

Fig. 1. Percentage composition of Maize Husk Briquette

The results of the physical and thermal characteristics of Maize husk briquette and two sources of charcoal according to [31] were presented in Table 3.

The comparative analysis results revealed that the carbon and sulfur contents of 43.55% and 0.051% for the maize husk is less than that of the charcoal from oak and pine at 87.01% and 0.150% and 86.10% 0.250% respectively.

However, the needed hydrogen and oxygen content for the maize husk at 4.220 and 44.64% are higher than the charcoal. Also, the ash content after burning was evaluated to be 11.47, with a high nitrogen content value of 1.350 as compared to charcoal at 0.5% and 0.2%.

Table 3. Combustion Characteristics of Maize Husk Briquette and Charcoal

Parameters	Unit	Maize Husk Briquette 550ºC	Charcoal (Made from oak) 550ºC	Charcoal (Made frompine) 550ºC
Length of the sample	mm	61.01	58.71	59.05
External diameter of the sample	mm	39.10	42.32	38.26
Weight of the sample	kg	0.06	0.08	0.08
Carbon Content	%	43.55	87.01	86.10
Hydrogen Content	%	4.20	2.40	2.50
Sulphur Content	%	0.051	0.150	0.250
Nitrogen Content	%	1.350	0.50	0.20
Oxygen Content	%	44.64	6.90	9.60
Volatile Matter	%	62.52	14.70	18.10
Ash Content	%	11.47	3.10	1.70
Fixed Carbon	%	21.10	82.20	80.20

CONCLUSION

The mean burn temperature of the maize husk briquette rose from 70.70 ºC to 83.34 ºC in 8 minutes, 98.72 ºC in 10minutes and finally 100 ºC in 12minutes. Compared to fire wood which burns slowly from 46ºC in 5mins, to 53ºC in 9minutes, 68ºC in 10minutes, 82ºC in 12minutes, 94ºC in 18minutes and finally to 100ºC in 21minutes. The rapid combustion observed could be due to porous nature of the maize bran briquettes compared to the relatively dense firewood. The porosity in the maize husk briquettes to leave more readily and be consumed rapidly in the flame. The comparative analysis result revealed that the maize husk briquette has more oxygen and nitrogen compared to charcoal. It also has more ash content and volatility to burn effectively. On the other hand, the carbon, nitrogen and sulfur contents of the maize husk briquette after burning was low when compared to charcoal. These findings will help address the disposal challenges of accumulated maize husk at mills and crop residues on the field will be resolved through briquette making and its attendant energy utilization as an alternative sustainable source.

REFERENCES

[1] Arkadiusz D., Łukasz S., Mateusz K., Krzysztof M., and Krzysztof K. 2020. The Impact of Particles Comminution on Mechanical Durability of Wheat Straw Briquettes. Energies p.13.

[2] Branca G., Cacchiarelli L., Cardona C. A., Felix E., Gianvenuti A., Kojakovic A., Maltsoglou I., Martchamadol J., Rincon L., Rossi A., Seghetti A., Steierer F., Thofern H., Thulstrup A., Tolli M., Valencia M., and Valle S. 2014. Bioenergy and food security rapid appraisal (BEFS RA) briquettes user manual", Food Agriculture organization of the United Nations (FAO), Italy, pp. 1– 44.

[3] Chen L., Xing L., Han L. 2009. Renewable energy from agro-residues in China: Solid biofuels and biomass briquetting technology. Renew. Sustain. Energy Rev., 13, pp. 2689–2695.

[4] Frank O. O., and Akhihiero T. E. 2011. Fuel briquettes from water hyacinth-cow dung mixture as alternative energy for domestic and agro-industrial applications. J. Energy Technol. Policy 2011, 3, pp. 56–61.

[5] Grover P. O., Mishia S. K. 1996. Biomass Briquetting: Food and Agricultural Organization, of the United Nation Journal.

[6] Havrland B., Ivanova T., Łapczyńska-Kordon B., Kolarikova M. 2013. Comparative analysis of bio-raw materials and biofuels. In Proceedings of the 12th International Scientific Conference on Engineering for Rural Development, Jelgava, Latvia, pp. 23–24

[7] Ismaila A., Zakari I.Y., Nasiru R., Tijjani B.I., Abdullahi I., Garba N. N. 2013. Investigation on biomass briquettes as energy source in relation to their calorific values and measurement of their total carbon and elemental contents for efficient biofuel utilization. Adv. Appl. Sci. Res. 4, pp. 303–309.

[8] Kambo H. S., and Dutta A. 2015. A comparative review of biochar and hydrochar in terms of production, physicalchemical properties and applications. Renew. Sustain. Energy Rev. pp. 45, pp.359–378.

[9] Karunanithy C., Wang Y., Muthukumarappan K., Pugalendhi S., 2012. Physiochemical Characterization of Briquettes Made from Different Feedstocks. Biotechnology Research International, Volume 2012, Article ID 165202, p. 12

[10] Lim J., Abdul Manan Z., Wan Alwi S. R., Hashim H., 2018. A review on utilization of biomass from maize industry as a source of renewable energy, Renew Sustain. Energy Rev. 16 (5) pp. 3084-3094.

[11] Long H., Li X., Wang H., Jia J. 2013. Biomass resources and their bioenergy potential estimation: a review, Renew. Sust. Energy Rev. 26., pp. 344-352.

[12] Mallika T., Thanchanok P., Kasidet P., Pisit M., Prasong W. 2015. Effect of Applied Pressure and Binder Proportion on the Fuel Properties of Holey Bio-Briquettes. International Conference on Alternative Energy in Developing Countries and Emerging Economies, Energy Procedia 79, pp. 890 – 895.

[13] Mansaray K. G., and Ghaly A. E. 1997. Physical and thermochemical properties of maize husk. Energy Sour. 19 (9). pp. 989–1004.

[14] Mckendry P. 2002. Energy production from biomass (Part 1): Overview of biomass. Bioresource technology, 83., pp. 37–46.

[15] Moral M. N. A., Shakya G. R., and Toan P. K. 2005. "Technology Packages: Screw-press briquetting machines and briquette fired stoves", S. C. Bhattacharya and S. Kumar (eds.), Thailand Regional Energy Resources Information Center (RERIC), pp. 1–76.

[16] Osvalda S. 2011. Characterization of Biomass as Non-Conventional Fuels by Thermal Techniques, Progress in biomass and bioenergy production, S Shahid Shaukat, Croatia, InTech, pp. 299–324.

[17] Suttibak S., and Loengbudnark W. 2017. Production of charcoal briquettes from biomass for community use". International Conf. on Mech. Eng. (TSME-ICoME 2017). IOP Conf. Series: Materials Science and Engineering 297.

[18] Tamilvanan A. 2013. Preparation of Biomass Briquettes using Various Agro-Residues and Waste Papers. Journal of Biofuels (IndianJournals.com). Vol. 4 Issue 2., pp. 47-55.

[19] Tumuluru J. S., Tabil L. G., Song Y., Iroba K. L., Meda V. 2015. Impact of process conditions on the density and durability of wheat, oat, canola, and barley straw briquettes. Bio-Energy Research, 8, pp. 388–401.

[20] Werther J., Saenger M., Hartge E. U., Ogada T., Siagi Z., 2000. Combustion of agricultural residues. Progress in energy and combustion science. 26 (1), pp.1-27.

[21] World Health Organization. Household Air Pollution and Health, Fact Sheet 2018.
[22] Worldometers. Current World Population 2005.
[23] Zribi W., Aragüés R., Medina E., Faci J. M. 2015. Efficiency of inorganic and organic mulching materials for soil evaporation control. Soil and Tillage Research, 148, pp. 40–45.
[24] Oladeji1 J. T. and Enweremadu C. C. 2012. The Effects of Some Processing Parameters on Physical and Densification Characteristics of Corncob Briquettes. International Journal of Energy Engineering 2012, 2(1): pp. 22-27.
[25] Uba G., 2020."Investing in maize production and maize processing". Jan. 19, 2020. https://guardian.ng/business-services/investing-in-maize-production-and-maize-processing
[26] Reuben S., and Daniel M. M. 2017. Production of loose biomass briquettes from agricultural and forestry residues. International conference on sustainable material processing and manufacturing, kruger national park, SMPM 2017. Procedia Manufacturing 7., pp. 98-105.
[27] Muazu R. I., Stegemann J. A. 2017. Biosolids and microalgae as alternative binders for biomass fuel. Vol. 194: pp. 339–347.
[28] Tasnim M., and Temitope O. 2015. "Characterization of Briquettes from Maize Bran and Palm Kernel Shell". International Journal of Material Science Innovations (IJMSI). Vol. 3(2). pp. 60-67.
[29] Kaliyan N. and Morey R. V. 2009. Factor Affecting Strength and Durability of Densified Biomass Products, Biomass and Bio Energy 33, pp. 337–359.
[30] ASTM E871 – 82. 2013. Standard Test Method for Moisture Analysis of Particulate Wood Fuels. ASTM International: West Conshohocken, PA, USA.
[31] Cordero T., Marquez F., Rodriguez-Mirasol J., Rodriguez J. J. 2001. Predicting heating values of lingo cellulosics and carbonaceous materials from proximate analysis. Fuel 80(11). pp. 1567-1571.

PROCENA MEHANIČKIH I TERMIČKIH KARAKTERISTIKA BRIKETA OD KUKURUZNE LJUSKE KAO ALTERNATIVNOG IZVORA ENERGIJE

Dilibe I. Ntunde, Mathew I. Ibe, Johnson E. Igwe

Department of Mechanical Engineering
Michael Okpara University of Agriculture Umudike, Nigeria

Sadržaj. Ovaj rad predstavlja procenu mehaničkih i termičkih karakteristika briketa od kukuruzne ljuske kao alternativnog izvora energije za poboljšanje održivosti i efikasnosti.

Eksperimentalni test sproveden za briket težine 0,6 kg pokazao je da isparljivost i sadržaj vlage imaju srednju vrednost od 62,52 i 0,27%; dok je utvrđena čvrstoća na pritisak 3,06kN/m^2. Termička procena je pokazala da je srednja temperatura sagorevanja briketa od kukuruzne ljuske porasla sa 70,70^{o}C na 83,34^{o}C za 8 minuta, 98,72^{o}C za 10 minuta i konačno 100^{o}C za 12 minuta; u poređenju sa ogrevnim drvetom koje gori sporo od 46^{o}C za 5 minuta, do 53^{o}C za 9 minuta, 68^{o}C za 10 minuta, 82^{o}C za 12 minuta, 94^{o}C za 18 minuta i konačno do 100^{o}C za 21 minut.

Rezultati uporedne analize pokazuju da briket od kukuruzne ljuske ima više kiseonika za 44,64 i azota za 4,22% u poređenju sa drvenim ugljem.

Takođe ima više pepela za 11,47%, zbog svoje isparljivosti, zbog osobine da efikasno sagoreva.

Istovremeno, briket od kukuruzne ljuske, ima nizak sadržaj ugljenika i sumpora nakon sagorevanja od 43,55 i 0,051%.

Ovi rezultati će pomoći u rešavanju izazova odlaganja i sačuvane kukuruzne ljuske i ostataka useva kao alternativnog održivog izvora energije, zbog ispunjavanja ekoloških i tehnoloških zahteva i normi.

Ključne reči: *Briket, izvor energije, ljuska, toplotna provodljivost.*

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