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Evaluation of some Properties of Briquettes Produced from Rumen Residues as a Biofuel

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ABSTRACT

Most of the energy used in the world coms from such fossil fuels sources such as (coal, natural gas, and uranium). Due to the world's growing population and uncontrolled urbanization, it became necessary to search for alternative and renewable sources of fuel. Rumen waste is produced in large quantities in slaughterhouses. It causes a problem in getting rid of it because it is a source of insect contamination and leaving it also makes it a source of groundwater pollution. The rumen waste is straw and hay, and therefore the conversion of this waste into biofuel briquettes doubles the benefit of it, as it is used as a source of fuel and disposed of as a source of pollution. This research was done to study some properties of the briquettes produced from rumen waste to evaluate its performance as a biofuel. The results revealed that the average value of the loose materials density was 0.16 gm/ cm^3 whereas the average briquette density increased more than 4 times and reached 0.663 g/ cm^3. The average vertical compressive strength of the briquettes produced was 1.31 MPa. On the other hand, the generated briquettes' average longitudinal compressive strength was 0.8 MPa. The shatter index which reflects the briquettes was around 73%.

Keywords: Rumen residue, biofuel, briquettes

INTRODUCTION

The goals of the Kyoto Protocol held in Japan١٩٩٧ was to reduce greenhouse gas emissions and oil prices in the world which become high. The EU has collectively developed a strong drive to reduce the use of fossil fuels and switch to renewable energy. (Deutmeyer *et al.,* 2012; Hasan, and Ammenberg, (2019). The growth of the world's population and the consequent increase in energy demand, as well as the growing global awareness of the shortcomings of the earth's natural resources, have made energy a valuable commodity. Renewable energy plays a unique role in solving global energy shortages. These produced from natural and renewable resources and do not contribute to environmental problems such as climate change, acid rain, radioactive waste, and air pollution (Al Mamun *et al.*, 2018; Ichu. *et al.*, 2019).

The use of non-renewable energy sources such as fossil fuels and natural gas can be reduced in the near future. its remaining reserves are only sufficient for the next 40 years. Because of that many industries replaced fossil by biomass because of its feature as neutral CO_2 emissions. So many European countries are now using wood briquettes or pellets for local energy the supplies (Mustelier *et al.,* 2012; Deac *et al*, 2016 Khlifi *et al.,* 2020).

Biomass briquettes have been used to make the usage of biomass sustainable. Briquettes have a variety of uses in developing countries, such as for home cooking, as a home heating alternative, and in ovens and boilers. Briquettes can be made from residues, with or without a binder. If heated during the process, only biomass containing lignin can produce briquettes without the use of binders. The heat softens the lignin and turns it into an adhesive. (EsauMwinuka 2015).

Ragasri and Sabumon (2023) mentioned that meat consumption globally increased about 40% in the last decade. This consumption reached about 253 million ton in 2020. This increase in meat consumption is because of the increase in world population. As a result of that solid and liquid wastes of the slaughterhouses _wastes increased. Although the variety of the technologies for slaughterhouse waste management but this management is not effective in developing countries. Mozhiarasi and Natarajan (2022) said that one of the industries with the quickest rate of growth is the slaughterhouse industry, which may be attributed to the rising demand for food due to global population growth. There are enormous amounts of garbage coming from the slaughterhouse. It is a center for infections that can infect both people and animals. This highlights the growing requirement for a secure and efficient disposal technique to stop the spread of illnesses after the slaughter of animals. However, because it may be utilized as a replacement energy source to reduce reliance on fossil fuels, it may be a viable resource for the recovery of value-added goods. Inadequate handling of these wastes leads to many health problems as well, such as respiratory ailments and waterborne infections from open burning of wastes. The intricacy involved in the segregation, collection, transportation, treatment, and disposal of these solid wastes has a significant impact on environmental sustainability, making it another global issue. Kabeyi and Olanrewaju, (2021); Elfaki and Abdelatti (2015). said that in order to comply with environmental regulations and prevent health and environmental disasters, slaughterhouses generate enormous volumes of various solid wastes and wastewater that need to be processed and disposed of. Environmental standards in the European Union and other nations mandate the thorough handling and elimination of waste from slaughterhouses; yet abattoirs generate enormous amounts of waste that need to be handled using a variety of authorized methods. Whittle and Insam (2013) stated that, animals and people can become infected with bacterial, viral, and parasite diseases found in slaughterhouse wastes. It is critical to identify efficient, secure, and timely ways to dispose of these

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wastes in order to lower the risk of illness. In this context, burning, hydrolysis, and anaerobic digestion are the available methods.

Sandoval *et al.,* (2020); Gebrehawariat *et al*., (2016) and Inci *et al*., (2013) mentioned that rumen contents are profusely waste produced in slaughterhouse as by-product and which mainly considered as environmental pollutant. This waste can pollute the atmosphere and cause a bad odor if it gets away directly into the near circumference. Added to it prevalent disease because it is a good habitat for the insects and disease vectors. The most dangerous effect is that it contaminates the groundwater because of leaching. Pancapalaga *et al*., (2021) stated that waste produced from slaughterhouses causes several environmental problems. The rumen's contents are one of the slaughterhouse wastes. It includes grass that the cattle haven't completely eaten and fermented. Sankar *et al.*, (2021) stated that the contents of the rumen make up around sixteen percent of the animal's live weight in inedible wastes. The methods for getting rid of rumen digesta, including drying, come with a lot of processing, and running costs. Sugito and Ratnawati (2020) mentioned that content of rumen is the most prevalent solid residues from slaughterhouses (SHHs) that is produced during operations and is often dumped in landfills. SSW contains high levels of nutrients (N and P) and organic matter. Because of the unstable organic debris, fresh SSW should not be applied to the soil. It also contains seeds from weeds and diseases.

Akande and Olorunnisola(۲۰۱۸) said that One potential answer to the solid waste issues in developing nations is the conversion of biomass into high density briquettes. Because green energy offers so many advantages for the environment and the economy, there has been a huge interest worldwide in the development of technologies that utilize these renewable energy sources. These wastes have low bulk density, high moisture content and heating efficiency so that it is difficult to handle, store and transport it. Conversion of these wastes to briquettes is a solution to these problems.

The aim of this work is to study some properties of the briquettes produced from rumen residues and evaluate their performance as a biofuel to conversion it into a valuable and economic product.

MATERIALS AND METHODS

The experimental work was done in the laboratories of Agricultural and Biosystem Engineering Department and soil science Department, Faculty of Agriculture, Menoufia University, and Laboratory of concrete properties, Menoufia University's Department of Civil Engineering, Faculty of Engineering.

The pressed material mixing.

In this work, two types of residues were used to be pressed as briquettes, rice straw and rumen residue. Rice straw which lags the rice harvesting process. It is collected in bales and stored to be used later. Rumen waste is a residual result from slaughtering animals in slaughterhouses. The main component of rumen residue is undigested straw. After slaughter, the animal produces about 25 kg of this residue (fresh weight). The moisture content of fresh rumen wastes the rumen residuals were open air dried for about two weeks depending on the weather to reduce the moisture content to 10% the used moisture content to press the residues (Shams El din and El Rawy 2012). The drying process also makes the residual odor free.

The raw materials mill process

The residuals were milled in a hammer mill (Pardevo) Fig (1). Twelve cutting knives were placed in a methodical manner around the rotor. It provided also with a sieve of 50 mm holes diameter and the average particle lengths were measured. The smaller particle size range in length between less than 10 mm to 50 mm was used to produce the briquettes Akpenpuun *et al.* (2020).

Fig. 1. Hammer mill (Pardevo)

The raw materials moisture content.

The moisture content level of 10 (w.b) % was taken to press the milled residuals to produce the briquettes. In the range of 10% moisture content denser, stable and durable briquettes are produced (Oladeji and Enweremadu 2012) The milled materials moisture content was also measured by instant digital apparatus for measuring the woody materials moisture content (Feuchite Messer -DURO). The moisture content was also confirmed. Samples of 100 g milled materials were dried at 70 C for 48 hours. The samples were weighed after drying and the moisture content was calculated (Ryan *et al.* 2013).

The raw materials mixing.

After drying the processed residues (Ruman residue and rice straw) and the moisture content reach 10%, they were mixed by the ration 1:1 of rice straw and rumen residue. That means the same weight of the rumen residue and straw were mixed. They were well mixed in a cylindrical drum to be homogeneous, then stored in a container until pressed.

Press Process.

Screw press machine (Shimada) Fig (2) was used to press the milled materials. The cylindrical die of the machine is surrounded by two heaters to produce solid briquettes and make the briquetting process smooth and continuous. They heated the die to about 180 $^{\circ}$C as shown. Because of the reduction in the spaces between the particles, strong bonds are created in the briquette during compression as reported by Yank *et al.,* (2016).

Fig. 2. Briquettes Press Machine.

A frictional effect is caused between the die wall and the produced briquettes while the briquettes are getting out from the press die. In addition, there a combined friction due to the internal friction in the pressed materials itself and due to press materials and the press screw, this causes an additional increase in temperature of pressed material. Then it is forced through the die, where the briquette is formed (Abdel Aal *et al.*,2023). The briquettes were pressed at 70 MPa as recommended by the press machine manufacturers.

The material density

Loose bulk material density

The standard method ISO17828:2015 for to measure the loose materials density. A measured container was cleaned, dried, and weighed. It was computed what the container's volume was. After adding loose material to the container, shaking it to fill it, and weighing it, the bulk density of the loose material was computed.

To ensure accuracy, this job was done five times, and the average figure was used as the outcome.

Briquette bulk density

The produced briquettes were cylindrical in shape with a cylindrical hole in the center, as presented in Figure (3), so the briquettes density was measured using the displacement method, as presented by Bhagwanrao and Sinfaravelu (2014) and Raiber *et al.,* (2006).

Fig. 3. The cylindrical shape briquettes

The briquette was weighted and coated with wax and then it was immersed in a filled to a specific level with water. The measuring cup has also specific volume. The displaced volume was measured, and briquette density was calculated.

Test of Briquette Compressive Strength.

In the Laboratory of Properties and Testing of Materials, Civil Engineering Department, Faculty of Engineering, Menoufia University, Egypt, a briquette compressive strength test was carried out. A universal testing of (ELE International), was used to determine the treated briquettes' longitudinal and vertical compressive strengths (MPa) as presented in Figure (4).

3 briquettes of diameter 47 mm with a hole of diameter 16.15 mm and height of 5 cm were tested.

Fig. 4. Briquette Compressive Strength test machine

Durability test

Shatter index test following ASTM standard D440 was used to test the produced briquettes durability. This test simulates the forces encountered during discharging the briquettes from the trucks onto the ground.

After being dropped from a height of two meters, the briquettes were let to fall freely onto the concrete floor until they broke. Five briquettes were randomly selected to investigate the treatment. Following the dropping, a 0.35 cm mesh screen was put over the briquettes and fractions, and they were sieved. The weight of the material maintained on the screen divided by the weight of the briquettes prior to the dropping was used to indicate the durability rating for each kind of briquette as presented by Lavanya *et al.,* (2018).

Equation (1) calculated the durability of the briquettes was as follow:

$$\textbf{Shatter index} = \frac{Bz}{nB} \times 100$$

Where:

Bz = Briquette weight that was kept on the screen after dropping (g).
B = Briquette weight before dropping (g).

RESULTS AND DISCUSSION

Materials density

Briquette density is a crucial physical characteristic for handling and logistical system design. Briquette size, shape, Moisture content, particle density are important factors affecting its density. Density has a direct impact on cost of shipping and storage costs Bhagwanrao, and Singaravelu, (2014). In addition to its uniform shapes and sizes of the densified briquette, that make them easy to handle using standard handling and storage equipment also. That allows to be transported it over longer distances also Ibrahim (2019).

Loose Materials Density

The results indicated that the average value of the loose materials density was 0.16 gm/ cm^3 (0.16 mg /m^3). This value for barley and oat straws is within the recommended range. as reported by Adapa *et al.,* (2010). They also mentioned that the screen sizes utilized for grinding might be the cause of this density figure. According to several studies, feedstock and densification circumstances affect the density value of densification. Particle size and distribution are two crucial variables that impact the physical characteristics of unprocessed materials. The distribution and size of the particles affect density. Particle distribution size as seen in the available space as well. Therefore, density is a significant factor in briquette durability as well.

Briquette density

The density of briquettes has a significant impact on its properties. The denser the briquettes, the more intense of fire when they are burned. The duration of a briquette's combustion and the intensity of its heat are correlated with the size of the briquette. Generally, the larger the briquette, the more extended duration of combustion and the higher the heat output. Briquette density is significantly influenced by raw material properties, particularly by moisture content and particle size as mentioned by Abdul Rahman *et al.,* (2015) and Olaoye and Kudabo, (2017).

The results presented in Fig (5) indicated that the average briquette density was 0.663 g/cm^3. Briquette density can also be presented as 0.663 Mg/m^3. When the density of the loose materials is compared to the density of the briquettes, the density of the briquettes is four times greater. That means, the briquettes will only take up about a quarter of the space needed to store the loose materials. On the other hand, the costs of transporting the briquettes will also be reduced to a quarter compared to the process of transporting the loose materials.

Figure (5) illiterates the density of the loose materials and the density of the produced briquettes.

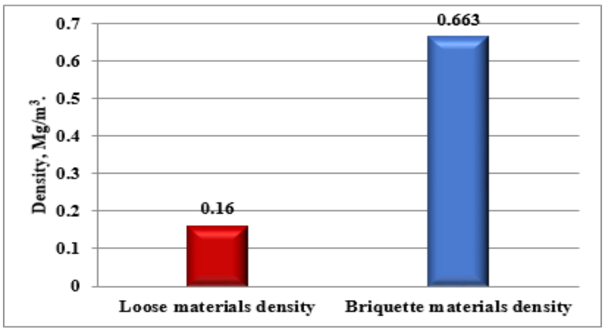

Figure 5. The density of the loose materials and the density of the produced briquettes

Briquette Compressive Strength.

For handling, transporting, and storing, briquettes with a high density and mechanical strength are preferred. High density briquettes are desired to reduce transport and storage costs. To avoid breakages, briquettes having a high compressive strength that is, > 2.56 MPa—are preferable. Briquettes used as a solid biofuel may be made from straw by a method comprising crushing and compression, where a piston or extruder is used for compression (Okot *et al.,* 2018). Controlling factors which have a great impact on the compressive strength of the produced briquettes are particle size distribution, the milling process, pressing temperature and die pressure. Die Pressure hits have a significant impact on physical properties such as briquette elongation and void formation of the formed briquettes and combustion characteristics, as confirmed by the former studies.

Based on the work conducted, the average vertical compressive strength of the briquettes produced was 1.31 MPa. On the other hand, the generated briquettes' average longitudinal compressive strength was 0.8 MPa.

In contrast to the briquettes' compressive strength value mentioned above by (Okot *et al.,* 2018), it was clear that produced briquette vertical compressive strength value is about 50% of the former value. That means the produced briquettes seem to be weak. This will be declared by the durability test. This also leads us to think if the briquetting process should be made by adding binding material to produce stable briquettes. Another reason that the press temperature (180 ^{0}C) may be insufficient to produce more stable briquettes.

Durability Test

The work's findings show that the manufactured briquettes' shatter index was around 73%, which represents how stable but not hard the briquettes are. This led us to improve the quality of the produced briquettes.

In this concern, there are many solutions proposed. The first suggestion is to rise the die heat whiten pressing process to 200 ^{0}C or more and hopefully that may produce more stable and rigid briquettes. The second suggestion is to add bend material. The suggested material in this case is urea formaldehyde or starch. Another choice to modify the mixing ratio, may be the other materials which are found in the rumen reduce the stability and the rigidity of the briquettes.

CONCLUSION

The results indicate that the average value of the loose materials density was 0.16 gm/ cm^3 and after briquetting process the average value of briquettes density reached about 0.663 g/cm3 that mean that briquette density increased about more than 400% of the loose materials. In terms of compressive strength, the findings show that the generated briquettes' average vertical compressive strength was 1.31 MPa. On the other hand, the generated briquettes' average longitudinal compressive strength was 0.8 MPa. Similarly, the results show that the manufactured briquettes' shatter index was around 73%, which illustrates how the briquettes are stable but not overly hard. As presented the quality of the produced briquette must be improved.

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تقييم بعض خصائص القوالب المنتجة من مخلفات الكرش كوقود حيوى

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قسم الهندسة الزراعية والنظم الحيوية – كلية الزراعة بجامعة المنوفية – شبين الكوم - مصر

الملخص

تعتبر الطاقة من العناصر الأساسية لأنشطة التنمية الحضارية الإنسانية. تتم تلبية معظم احتياجات العالم من الطاقة من خلال الموارد غير المتجددة مثل الوقود الأحفوري (الفحم والغاز واليورانيوم). ومع ذلك، سيشهد العالم نقصا في هذه الطاقة على مدى العقود القليلة المقبلة بسبب التوسع السكاني في العالم والتوسع الحضري الجامح. وأصبح من الضروري البحث عن مصادر بديلة ومتجددة للوقود. ومن الرائع أن هذا المصدر عبارة عن نفايات يمكن التخلص منها عن طريق تحويلها إلى منتج اقتصادي وقيم مثل الوقود الحيوي. يتم إنتاج نفايات الكرش بكميات كبيرة في المسالخ. مما يسبب مشكلة في التخلص منه لأنه مصدر للتلوث الحشري كما أن تركه يجعله مصدراً لتلوث المياه الجوفية. مخلفات الكرش هي عباره عن القش ، وبالتالي فإن تحويل هذه المخلفات إلى قوالب وقود حيوي يضاعف الفائدة منها، حيث يتم استخدامها كمصدر للوقود ويتم التخلص منها كمصدر للتلوث. أوضحت النتائج المتحصل عليها أن متوسط قيمة كثافة المواد السائبة بلغ ٠,١٦ جم/سم٣ بينما زاد متوسط كثافة المادة السائبة أكثر من ٤ مرات ووصل إلى ٠,٦٦٣ جم/سم٣. وكان متوسط قوة الضغط الرأسي للقوالب المنتجة ١,٣١ ميجا باسكال. من ناحية أخرى، كان متوسط قوة الضغط الطولي للقوالب المنتجة ٠,٨ ميجا باسكال. وكان مؤشر التحطيم الذي يعكس القوالب حوالي ٧٣٪. القوالب المنتجه تحتاج الى تحسين فى عمليه انتاجها ودراسه المزيد من خصائصها فى أعمال قادمة.