Introduction

Indonesia is one of the countries in the Asian region which is the world’s palm oil producer. Oil palm is a potential source of available biomass, and this is because oil palm is considered a multipurpose oil plant. After all, the oil palm tree is very productive and has a lot of uses in every different parts of the tree, from the fruit to the pulp of the palm, including the ability to produce biomass energy (Kaniapan et al., 2021). One of the palm oil wastes that can be utilized as biomass is waste of oil palm shells and empty fruit bunches. Oil palm shell is an organic waste containing sulfur, 55.82% carbon, and has a higher specific gravity than wood, reaching 1.4 g/ml. So that these characteristics allow the material to be suitable for making charcoal as an alternative fuel (Al-alang & Fadhillah, 2020). In addition, empty oil palm fruit bunches are organic waste derived from oil palm plants which can be used as an alternative fuel because they contain 46.62% cellulose, lignin and carbon, making them potential raw materials for briquettes because they contain high carbon (Amrullah et al., 2020). Palm oil waste can make briquettes as an environmentally friendly biomass energy.

Environmentally friendly energy is a renewable energy source and does not produce excessive pollutants so it does not damage the environment. Environmentally friendly...
energy can come from biomass. Biomass is organic material of plant or animal origin that can produce heat, fuel, or substitute for fossil-based products and materials such as coal, natural gas, and petroleum. Biomass can be found in plantations, forests and livestock manure. Biomass can also be a source of energy because it contains carbon elements which can produce heat. Biomass has the advantage of being renewable (Suganl & Hudaya, 2019). Biomass can be used as a substitute for fossil fuels whose existence is dwindling. In addition, it can also encourage the development and use of renewable resources (Yacob et al., 2021). Utilization of waste as biomass three benefits, including increasing overall energy efficiency because the energy content contained in waste is quite large. It will be wasted if not utilized, savings costs because waste disposing can often be more expensive than utilizing it and reducing the need for landfills because providing a place for storage will become more difficult and expensive, especially in urban areas (Parinduri & Parinduri, 2020). Biomass produced from plantations such as waste palm shells and empty palm oil bunches has great potential to be made into briquettes as an alternative energy source that is environmentally friendly (Azman & Pa, 2021). Therefore, innovation must maintain this energy so future generations can enjoy it. One of the efforts that can be made to preserve the existence of energy is to utilize plantation waste, namely palm oil waste, as an environmentally friendly energy source, namely briquettes.

Briquettes are charcoal that is processed in such a way that it can be used as an alternative energy source for everyday life (Aziz et al., 2019). Briquettes are solid fuels formed from mixing organic waste with other adhesive substances. The advantages of briquettes are that they have a longer heat resistance, do not smell, and have a longer shelf life (Suryajaya, 2020). In addition, briquettes are also known as an efficient organic matter compaction technique to produce better heat-containing biomass energy (Ranaraja et al., 2022). Briquettes derived from organic waste are called biobriquettes. Biobriquettes are an alternative energy source used for the combustion process. Usually, biobriquettes are made from a mixture of organic waste. Briquettes can also be used as an environmentally friendly energy source. These briquettes are expected to contribute to renewable energy as a substitute for coal, natural gas and petroleum. When compared with ordinary charcoal, briquettes have a higher economic value. In addition, briquettes can also maintain a longer flame (Katiandagho et al., 2023). This is because the smoke produced from the briquette burning process is less compared to other charcoal, so it can reduce the amount of carbon emissions that cause global warming.

Briquettes, an environmentally friendly energy source, can be used as teaching material in school science learning. The learning process is a learning activity carried out by students with the teacher's guidance. Students as subjects and teachers as facilitators to achieve educational goals in schools. One of the learning activities that can be carried out is to utilize the potential of the surrounding environment as a contextual learning resource so that the learning process becomes exciting and can provide meaningful learning experiences and knowledge to students. Engaging and contextual learning improves students' knowledge and skills (Irwandi & Fajeriadi, 2020). One of the learning materials that can be related to the use of briquettes is environmentally friendly technology material. The use of briquettes as teaching materials can be packaged in teaching materials. Thus, this research aims to design learning unit designs for environmentally friendly energy sources using palm oil waste briquettes as teaching materials.
Methods

This research begins with observing the potential of palm oil waste in the North Bengkulu region. Furthermore, the selected palm oil waste is shells and empty palm fruit bunches used as raw materials for briquettes. The waste was obtained from a palm oil processing factory in the North Bengkulu area. The waste of oil palm shells and empty fruit bunches is then processed into briquettes at the Lembaga Pengelolaan Hutan Desa (LPHD) in village Jajaran Baru, Megang Sakti, Musi Rawas Regency, South Sumatra Province. The tools used include writing machines, smoothing machines, mixing machines, printing machines, and trays.

In comparison, the materials used include palm shells, empty palm fruit bunches, and tapioca flour. The briquette-making procedures include coagulation, grinding, mixing, printing and drying. The resulting briquettes consist of three types of composition, namely briquettes A with a composition of 70% palm shells: 30% empty palm fruit bunches, briquettes B with a composition of 50% palm shells: 50% empty palm bunches, and briquettes C with a composition of 30% palm shells: 70% empty palm bunches with a ratio of 1:0.5. Furthermore, limited characteristic tests were carried out at Scofindo Bengkulu, which included tests of their physical properties to see the characteristics of the resulting briquettes, including texture, colour, used briquette test, briquette burning time test, calorific value and moisture content. The data obtained will then be analyzed descriptively. The data from the analysis will be developed into teaching materials packaged in designing learning units on environmentally friendly technology materials for junior high school students. Teaching materials are created using a needs analysis, including material analysis and interviews based on "KD. 3.10 analyzing environmentally friendly technological processes and products for the sustainability of life" in the 2013 curriculum. The sample for collecting needs analysis data was determined by purposive sampling, namely schools located in plantation areas and oil palm management, including SMP Negeri 47 North Bengkulu.

Results and Discussion

Based on the activities carried out, namely the manufacture of shell waste briquettes and empty palm oil bunches. Briquettes that have been developed can be seen in Figure 1.

![Figure 1. Three Types of Briquette Composition](image)

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The results of making briquettes were carried out at the LPHD in the village Jajaran Baru, Megang Sakti, Musi Rawas Regency, South Sumatra Province. The briquettes developed consist of three types of composition, as shown in Table 1. Palm oil waste can be used as an environmentally friendly energy source, namely briquettes.

CS-EFB Briquettes (oil palm shells and empty palm oil bunches) are blocks of block material used as alternative fuels with the raw materials of palm shells and empty palm fruit bunches. Oil palm shell is an organic waste that contains high sulfur carbon and has a higher specific gravity than wood which reaches 1.4 g/ml. So that these characteristics allow the material to be suitable for making charcoal as an alternative fuel (Al-alang & Fadhillah, 2020). Meanwhile, empty palm fruit bunches are organic waste with the most significant cellulose content, apart from hemicellulose and lignin, in smaller amounts. Therefore, briquettes are an alternative energy source that can be used as a substitute for some uses of kerosene (Pratama, et al., 2022). Shell briquettes and palm bunches are also environmentally friendly, have a low ash content, are smokeless and odourless, and are more durable and long-lasting (Suryaningsih & Pahleva, 2020). The factors that influence the quality of briquettes include the type of raw material, the casting process related to the temperature and set time, the particle size of the raw material, the type and concentration of adhesive, and the pressing and gluing techniques. Briquettes have good quality characteristics such as smooth texture, not easily broken, challenging, safe for humans and the environment and good ignition properties. These properties include easy ignition, long ignition time, no charcoal particles, little smoke that quickly disappears and a high calorific value. The burning duration will affect the quality and efficiency of combustion; the longer it burns with a constant flame, the better (Muliawan, et al., 2020).

Of the three types of briquettes produced, each briquette has a different composition. The differences in composition are presented in Table 1.

Table 1. Composition of Three Types of Briquettes

<table>
<thead>
<tr>
<th>No.</th>
<th>Briquette Type</th>
<th>Briquettes Composition</th>
<th>Texture</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Briquettes A</td>
<td>70% palm shells: 30%</td>
<td>Rough</td>
<td>Deep black</td>
</tr>
<tr>
<td></td>
<td></td>
<td>empty palm bunches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Briquettes B</td>
<td>50% palm shells: 50%</td>
<td>Bit rough</td>
<td>Deep black</td>
</tr>
<tr>
<td></td>
<td></td>
<td>empty palm bunches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Briquettes C</td>
<td>30% palm shells: 70%</td>
<td>Fine</td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td></td>
<td>empty palm bunches</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on Table 1, the resulting briquettes have different textures and colours. In briquette A, 15% adhesive was added, with a rough surface and dark black colour. In briquette B, 10% adhesive was added, with a coarse texture and dark black colour. Furthermore, 5% adhesive was added to briquette C which had a smooth texture and black colour. The difference in texture in each briquette is caused by the presence of macro and micro pores, which affect the ability to bind water. Coarse textured briquettes have low absorption because they have macro pores, so the ability to bind water is deficient. On the other hand, fine-textured briquettes have high water absorption because they have micropores, so the ability to hold water is very high (Muliawan, et al., 2020). Meanwhile, the carbon content in the palm shell affects the colour differences produced from the three types of composition. The darker the colour of the briquettes, the higher the carbon content in the briquettes. The adhesive was added 15%, 10% and 5% to each composition. Bond is one of the components in the briquette dough, which significantly affects the quality of the briquettes. This study uses tapioca flour as an adhesive. Tapioca flour was chosen as an adhesive because this adhesive produces relatively little smoke and
ash compared to other bonds. In addition, these adhesives are easy to find and relatively inexpensive. This adhesive binds the substance particles in the raw material during the briquette printing process, making the resulting briquettes compact (Saputra et al., 2021). The amount of adhesive added to the composition will affect the quality of the resulting briquettes. This aligns with the statement that the greater the amount of glue added, the lower the quality of the briquettes produced, and vice versa; the less adhesive added, the better the quality of the resulting briquettes (Bazenet et al., 2021).

The steps for making briquettes are as follows:

1. The process of making oil palm shells and empty fruit bunches of oil palm
2. Refining process of coconut shell charcoal and empty palm fruit bunches
3. The process of mixing the composition of the briquette dough
4. Briquette printing process
5. Briquette drying process

![Figure 2. Steps for Making Briquettes](image)

The steps for making briquettes begin with the process of writing the shells and empty fruit bunches of oil palm, the process of refining the charcoal from the shells and empty fruit bunches of oil palm, the process of mixing the dough for the composition of the briquettes, the process of printing the briquettes and the process of drying the briquettes. In the first stage, the authoring process is carried out, and the authoring process is a combustion process with certain air where changes occur from organic matter into carbon or charcoal. During the writing process, care must be taken so that the raw materials used do not turn into ashes but charcoal with energy content to be used as an alternative fuel. The time for the writing process depends on the raw materials and the size of the materials used, and the incoming oxygen (Dewi & Hudha, 2022). This process is carried out by

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inserting the empty palm shells and bunches into the writing machine separately using a temperature of 400-450°C for 7-8 hours. Burning time dramatically affects the quality of charcoal and its moisture content. The longer the burning time, the better the quality and efficiency of the combustion. And the lower the water content, the higher the heating value and combustion efficiency, and vice versa; the higher the water content, the lower the heating value and combustion efficiency (Alfernando et al., 2023). Besides writing time, temperature also affects the writing process. The higher the setting temperature, the lower the volatile matter content in the briquette so that the carbon content will increase (Sugiharto & Firdaus, 2021).

In the second stage, the grinding process is carried out; in this process, shell charcoal and empty palm oil bunches are put into the grinding machine for 30 minutes. This refinement aims to reduce the shell charcoal and empty palm oil bunches so they are easily mixed with the adhesive. In the third stage, the process of mixing the dough for the composition of the briquettes is carried out; in this process, shell charcoal powder and empty palm oil bunches and adhesive are put into the mixing machine for 30-60 minutes. Mixing the dough for this composition is carried out periodically according to the three types of composition described in Table 1. In the fourth stage, the briquette moulding process is carried out; the mixed briquette mixture is put into the printing machine and printed in a square shape. The briquette drying process is carried out in the fifth or final stage. In this process, the printed briquettes are placed in a square shape on a tray and then dried in the sun under direct sunlight for 2-3 days. The briquette drying process aims to reduce the water content contained in the briquettes so that the resulting briquettes have good quality in terms of calorific value and carbon content (Iskandar et al., 2019).

Furthermore, the resulting briquettes were tested for their physical properties to see the characteristics of the resulting briquettes, including texture, colour, used briquette test, briquette burning time test, calorific value and moisture content. Data on the results of the physical properties test are presented in Table 2.

### Table 2. Physical properties test results

<table>
<thead>
<tr>
<th>No.</th>
<th>Briquette Type</th>
<th>Briquettes used (g)</th>
<th>Burning time (minutes)</th>
<th>Calorific value (Kcal/kg)</th>
<th>Water content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Briquettes A</td>
<td>6</td>
<td>14</td>
<td>5971</td>
<td>5.70</td>
</tr>
<tr>
<td>2.</td>
<td>Briquettes B</td>
<td>7</td>
<td>16</td>
<td>5815</td>
<td>5.92</td>
</tr>
<tr>
<td>3.</td>
<td>Briquettes C</td>
<td>8</td>
<td>18</td>
<td>5556</td>
<td>5.94</td>
</tr>
</tbody>
</table>

Based on the results of the physical properties test in table 2. The briquettes that have good quality are briquettes A. This is because briquettes A have a high calorific value and low water content. This follows the statement that the higher the calorific value, the better the quality of the briquettes. The calorific value is used to determine the value of the heat of combustion that can be made by briquettes as fuel (Ristianingsih et al., 2015). The water content affects the calorific value of the briquettes. The water content in the briquettes should be as low as possible so that the resulting briquettes have a high calorific value so that they are easy to burn initially (Susanto & Yanto, 2013). In addition, the moisture content also affects the burning time of the briquettes. Therefore, the burning time also determines the quality of the briquettes because the higher the water content, the lower the calorific value which causes the slow burning process of the briquettes (Mahendra & Praswanto, 2022). The longer the burning time, the higher the ash content produced. Where the higher the ash content produced, the lower the quality of the briquettes produced (Biantoro & Widayat, 2021).
The developed briquettes have the potential to be developed into teaching materials for learning units on the topic of environmentally friendly technology. Based on the results of interviews with science teachers and an analysis of the needs of students at SMP Negeri 47 Bengkulu Utara, it was stated that 80% of the teaching materials used were still based on printed books from the Ministry of Education and Culture, 10% used books from other publishers, 8% used LKS, and 2% used other teaching materials, such as the use of PPT, games and so on. So that the teaching materials used are less varied and not yet contextual; this will affect the learning process, which causes students to find it challenging to understand the material presented. This aligns with the statement that contextual learning can provide opportunities for students to construct knowledge by discovering and experiencing it directly so that the learning process is more meaningful (Primayana, et al., 2019). This is supported by student statements presented in Figure 3.

Based on the analysis of the needs and potential of briquettes as well as the analysis of environmentally friendly technology materials, the results of this research analysis can be developed as teaching materials in the form of learning units on ecologically friendly technology materials referring to KD 3.10 Analyzing environmentally friendly technological processes and products for a sustainable life. Material selection is based on palm oil waste that has yet to be used optimally, and energy sources are starting to run low. This environmentally friendly technology material will explain ecologically friendly technology in the energy sector, discussing efforts to find alternative energy sources for the future. The learning unit book is part of the learning package book used by teachers and students in the learning process. Based on the integration of palm oil waste with environmentally friendly technology material presented in the initial framework of the learning unit, as shown in Figure 4.
The initial framework of the learning unit consists of three main parts: introduction, content, and closing. The introduction consists of 1) Instructions for use, which contain procedures for using environmentally friendly technology learning units. 2) Basic competencies that contain descriptions that students will learn, and 3) The learning objectives contain the objectives to be achieved in the learning process. The content section consists of 1). The concept of environmentally friendly technology contains material including understanding, benefits, and others. 2). Briquettes, as an environmentally friendly energy source, contain a general description of briquettes, and 3). Learning activities contain the objectives of implementing learning activities, tools, materials to be used, and activity steps that aim to facilitate students in carrying out learning activities sequentially. This learning activity aims to increase students' understanding and knowledge about environmentally friendly energy sources that can be made from plantation waste. The closing part consists of 1). Three feedbacks that contain discussion materials for students. 2). Reflection contains evaluation questions, and 3). The bibliography contains references used in environmentally friendly technology learning units. Teaching materials for this learning unit will contain the concept of environmentally friendly technology, general information about briquettes as an environmentally friendly energy source, and learning activities for students. They developed these learning units based on essential competencies and learning objectives using Canva software and professional pdf flip. Based on the initial framework of the learning unit, briquettes can be explained as an environmentally friendly energy source with the concept of technology in Figure 5.
Based on the learning unit design model shown in Figure 5, starting with an explanation of the concept of environmentally friendly technology, then explained briquettes, and then continued with student activities. This section is related to everyday life, which is closely associated with the surrounding environment so that when students read this learning unit, they do not have to translate examples of the application of the material to the real world. This is differs from textbooks that are made nationally, and sampling applications are more general, so students have to translate the terms in the application. This is what makes the advantages of learning units made by school teachers, and they will relate the material to the environment around them (Gunawan, et al., 2021) so that it is expected to increase students' knowledge and understanding of the utilization of palm oil plantation waste as an environmentally friendly energy source.
Conclusion

Palm oil waste can be used to make briquettes as environmentally friendly energy. Furthermore, these briquettes can be developed into teaching materials on ecologically friendly technology materials, packaged in learning units for Junior High School students related to everyday life and the surrounding environment.

Acknowledgement

Thank you to Lembaga Pengelolaan Hutan Desa (LPHD), in village Jajaran Baru, Megang Sakti, Musi Rawas Regency, South Sumatra Province for the permission granted in the observation and process of making briquettes. Ladies and gentlemen, science teachers at SMP Negeri 47 North Bengkulu have provided information related to teaching materials needed by junior high school students.

References


