Briquettes Optimization of Palm Shell Waste and LDPE Plastic based on Particle Size and Compressive Strength as Alternative Fuels

by Yusraida Khairani Dalimunthe FTKE

Briquettes Optimization of Palm Shell Waste and LDPE Plastic based on Particle Size and Compressive Strength as Alternative Fuels

Y K Dalimunthe[1,2], **Widayani**[3] **and I D Aditya**[4]

[1]Physics Department, Institut Teknologi Bandung, Bandung, Indonesia
[2]Petroleum Engineering Department, Universitas Trisakti, Jakarta, Indonesia
[3]Physics Department, Institut Teknologi Bandung, Bandung, Indonesia
[4]Physics Department, Institut Teknologi Bandung, Bandung, Indonesia

E-mail: yusraida@trisakti.ac.id

Abstract. The purpose of this study was to find the optimal parameters of the briquette making process (particle size and pressure), where optimization was carried out based on the values of physical properties, namely density, elastic modulus and ultimate tensile strength. The method used in this study was to vary the particle size of palm shell charcoal waste with particle sizes of 40, 60, 80 and 100 mesh mixed with chopped LDPE plastic with a size of 0,5 x 0,5 cm, starch adhesive and water with a predetermined composition, then the briquettes are given varying pressures of $30N/m^2$, $40N/m^2$, $50N/m^2$, $60N/m^2$, $70N/m^2$ and $80N/m^2$. The results of this study found that the highest density value was 808,71 kg/m^3, the highest elastic modulus value was 50 MPa, and the highest ultimate strength is 4,81 Mpa. Based on the values of density, elastic modulus and ultimate tensile strength, it can be concluded that the most optimal briquettes are produced from a particle size of 80 mesh and a pressure of $70N/m^2$ with a density value of 796,08 kg/m^3, an elastic modulus of 40 MPa and an ultimate strength of 4,81 MPa.

Keywords: Alternative energy, briquettes, palm shells, LDPE, biomass

1. Introduction

Although oil is a non-renewable energy source, fuel oil is still the first choice for daily life, leading to the depletion of the earth's oil reserves. Natural gas and other alternative energies are not maximized for self-consumption, which creates a fuel crisis, especially for fossil fuels. The increasing population causes the need for fuel to increase so other alternative sources are needed. One of the energy that needs attention to be developed is biomass. Biomass itself is also known as biofuel. This energy comes from organic materials such as crops, plantations, or industrial and household waste [1].

Oil palm shell is one of the wastes derived from biomass which accounts for 60% of the production of PKO (Palm Kernel Oil). A palm oil mill with a capacity of 100.000 tons of fresh fruit bunches per year will produce around 6.000 tons of palm shells, 12.000 tons of fiber and 23.000 tons of empty palm fruit bunches. Palm shell waste is the hardest part of the palm oil component, so far its utilization has not been maximized, among others, as fuel for boilers and filling potholes in oil palm plantations. The oil palm shell has the characteristics of a gray-black color, irregular shape and quite high hardness. The advantages of palm shells compared to coal when used for fuel include that they do not contain sulfur. The results of chemical analysis of palm shell waste taken from the palm oil industry in South Kalimantan are 6,19–6,45% moisture content; ash content 6,59–8,73%; negative sulfur content; carbon content 13,23-14,96% and calorific value 4548,5– 4587,96 cal/gr. Palm oil shells and other solid wastes from CPO (crude palm oil) industrial waste can be used for various needs, including as raw materials for charcoal and are expected to replace wood raw materials [2]. There is no need to doubt the supply of palm shells, considering that the area of oil palm plantations in Indonesia is still very large [3].

LDPE (Low-Density Polyethylene) has a low density of around 0,742 gr/ml and a viscosity of 0,78 gr/ml. The melting point of LDPE is 115^{0}C, it has very high chemical resistance, but it is easily soluble in benzene and tetrachlorocarbon (CCl4). LDPE plastic is of them used for plastic bags, plastic lids, frozen meat wrapping plastic, and various other thin plastics [4]. So it is expected that the addition of low-density polyethylene plastic in the manufacture of jellies with palm shells can provide better briquette characteristics.

Research that utilizes biomass waste and plastic waste has been carried out a lot. Several recent studies have used plastic and biomass waste. In particular, studies using radiata pine sawdust, linear low-density polyethylene (LLDPE), and polypropylene (PP) plastics suggest a significant increase in plastic usage as a result of drop tests. Increased plastic content. Briquettes manufactured at 300kN pressure with 10% addition of PP plastic show excellent weather ability with 100% survival against [5]. Furthermore, the waste mixture ratio of 50% coal dust, 40% plastic, and 10% sawdust produce briquettes with the best combination of handling and energy properties. High-energy briquettes have a calorific value of 26,5–33,8 MJ/kg, which is significantly comparable to the maximum value reported for high-energy coal of 27 MJ/kg, while the compressive strength is 0,7 MPa [6]. Research conducted [7] by utilizing plastic bottle caps from home industrial health drink lids (infused water) and tapioca flour shows that at 40 mesh particle size, best properties i.e. moisture content 0,5 ± 0,05%, ash content 2 ± 0,25%, volatile content 15 ± 0,51%, combined carbon content 82,5 ± 0,32%, and 9.982,779 ± 240,017 calorific value in cal/gr. Based on the results of instant analysis, it can be concluded that the particle size of 40 mesh can improve the briquette quality compared with 100 mesh. The calorific value produced from briquettes of plastic waste and paper pulp to boil water as much as 200 gr and 300 gr produces a heat of 78-102^{0}C [8]. In 2018, the best composition of mixing bark, plastic, and oil was studied for its effect on the physical and chemical properties of the resulting briquettes. The results showed that the addition of 70% waste oil and 30% used plastic as additives affected the performance of formation briquettes with the highest calorific value of 33,56 MJ/kg [9].

Furthermore, research on briquettes related to the size of the charcoal particles making up the briquettes has also been carried out a lot. Research on coal briquettes mixed with peanut shell waste and starch as an adhesive by looking at the effect of mesh size to analyze the density, moisture content, ash content, toughness and calorific value using descriptive methods, it was found that the quality of coal briquettes mixed with peanut shell waste with the highest density of 0,99 gr/cm^3, the lowest moisture content of 2,20%, the lowest ash content of 3,05%, the highest toughness of 1,52% and the highest calorific value of 5298,2 cal/gr [10]. The effect of the ratio of coconut shells and water hyacinth and variations in particle size to the characteristics of briquettes gave the result that the best composition of briquettes was obtained from a mixture of water hyacinth and coconut shells at a ratio of 1:4 with a particle size of 60 mesh, with the highest calorific value of 6.851,33 cal/gr, the lowest ash content was 8,19%, the lowest moisture content was 1,05%, the volatile matter content was 13,79%, the density value was 0,98 gr/cm^3, the combustion rate was 2,9x10^{-3} gr/sec and the compressive strength was 11,32 kg/cm^2. These results comply with SNI, Japanese standard, England, and America, while the compressive strength of briquettes only met British standards [11]. Effect of particle size on PET bottle briquette properties based on immediate analysis: ash content, moisture content, bound carbon content, volatile content and calorific value. The study design used was a combustion temperature of 4500°C, a combustion time of 60 minutes, and particle sizes of 40, 60, and 100 mesh. The results show that the 40 mesh particle size provides the best properties: moisture content of 0,5 ± 0,05%, ash content of 2 ± 0,25%, volatiles of 15 ± 0,51%, the combined carbon content of 82,5 ± 0,32%, and calorific value have shown that. Based on the close-up analysis result of 9.982,779 ± 240,017 cal/gr. From this, it can be concluded that the particle size of 40 mesh can improve the briquette quality compared to 100 mesh [12]. The next research is to determine the emission of carbon monoxide (CO) and the combustion rate of briquettes mixed with rice husk and teak sawdust and their effect on the grain size of the briquettes. The research methodologies include material drying, material carbonization, 40 mesh (420 µm), 60 mesh (250 µm), and 100 mesh (149 μm) material grinding and sieving, briquette printing and pressing, and briquetting included drying. Additionally, carbon monoxide emissions and briquette burning rates were tested. Carbon monoxide (CO) emissions decrease with coarser briquettes. A variation of mixing rice husk and teak sawdust in a ratio of 50:50 out of 40 mesh grids produced the lowest carbon (CO) emissions at 509 ppm/s. The coarser the briquettes, the faster the burning rate and the faster the briquettes burn out, but the resulting calorific value is still low, ranging from 3,420 to 4,889 cal/gr. The highest burning rates were found for briquette samples using rice husk and teak sawdust at a ratio of 50:50, 40 mesh briquette particle size 0,0138 gr/s [13]. Effect of particle size on mechanical properties and combustion rate in briquettes mixed with rice husk and coffee husk where the methodology in this study included carbonization of the material, grinding and screening of the material with variations in particle size of 40 mesh, 60 mesh and 100 mesh. Then printing and pressing briquettes with a constant loading pressure of 75 kg. The results of the mechanical quality test show that particle size affects the density, durability and compressive strength of the briquettes. The particle size of 100 mesh gives the best density value at a loading pressure of 75 kg of 598 gr/cm^3. The best value of 98% durability and the best compressive strength value of 1,937 kg/cm^2 were obtained using a particle size of 40 mesh. The effect of particle size on the characteristics of the rate and duration of combustion indicates that the larger the particle size, the slower the combustion rate, thus requiring a longer burning time. Good results on the rate and duration of combustion were found in samples with a particle size of 40 mesh which had a combustion rate of 0,867 gr/minute and a burning time of 60 minutes [14]. Research using water hyacinth and coconut shell raw materials to obtain briquettes with the highest calorific value and good quality briquettes, here the ratio of water hyacinth to coconut shell is 1:1, 1:2, 1:3, and 1:4 with grain size variations of 10, 42 and 60 mesh, using tapioca glue at 10% of raw material weight. Measurements show that the optimal composition of briquettes is 1:1 mixture of water hyacinth and coconut shell. 4 Particle size 60 mesh, maximum calorific value 6.851,3311 cal/gr, minimum ash content 8,1918%, minimum moisture content 1,0140%, 13,7890% volatiles, density value 0,98 gr/cm^3, burning rate 2,9x10-3 gr/s, compressive strength 11,3234 kg/cm^2 [15]. Therefore, research was conducted on optimizing palm shell waste briquettes and LDPE plastic based on particle size and compressive strength as an alternative fuel.

2. Methode

This research begins with preparing tools and materials to be used as research objects. In this research, what will be carried out is to find the optimal parameters of the briquette-making process (particle size and pressure), where optimization is carried out based on the values of physical properties, namely density, elastic modulus and ultimate tensile strength of the main ingredients of palm shell waste and LDPE plastic. The variables in this study are:

Independent variable:
The independent variable of this study was the particle size of palm shell waste charcoal, namely 40 mesh, 60 mesh, 80 mesh and 100 mesh each of 20 gr, then mixed with chopped LDPE plastic waste with a size of 0,5 x 0,5 cm, 0,8 gr as well as 2 gr starch and 15 ml water. Each mass of this composition is fixed and carried out the same for each briquette sample based on the mesh size. The use of no more than 10% plastic is the limit for combining plastic waste in the manufacture of briquettes with good and safer ignition and combustion characteristics. Furthermore, in the printing process each briquette based on a predetermined mesh size is pressed with a piston with pressure variations of 30N/m^2, 40N/m^2, 50N/m^2, 60N/m^2, 70N/m^2 and 80N/m^2.

2. Dependent variable:
   1. ρ = Density (kg/cm^3)
   2. E = Elastic modulus (N/m^2)
   3. σ_u = Ultimate tensile strength (Pascal)

3. Research Steps

The steps in this study can be seen in the research flowchart in Figure 2 below.

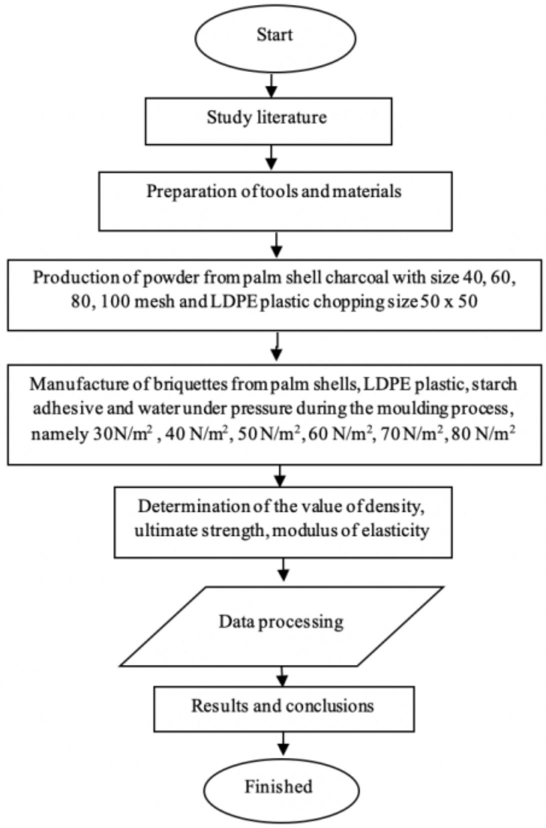

Figure 1. Research flow chart

4. Testing of Mechanical Characteristics

Mechanical characteristic testing is carried out at the Advanced Physics laboratory, ITB which includes:

1. Density
   Density testing was carried out using the direct measurement method with a calliper. The test procedure is:
   a. Measure the specimen (diameter and length) of the dried briquettes by using a vernier calliper to calculate the volume.
   b. Weigh the specimen and record the mass of the briquette.
   c. Calculate density by dividing the mass of the specimen by its volume.
2. Ultimate strength and modulus of elasticity
   The Testing Procedure:
   a. Placing the late-made briquettes on the test bed of the Universal Testing Machine tool.
   b. Turn on the Universal Testing Machine test tool.
   c. Pressing the reset button on the force and strain measurement display
   d. Provide vertical loading at a speed set by the operator until the briquettes crack under pressure.
   e. Record the compressive force value shown on the force size display on the Universal Testing Machine test equipment.

3. Perform data processing to create graphs:
   a. Studying the effect of particle size (U) and pressure (P) on density (ρ)
   b. Studying the effect of particle size (U) and pressure (P) on the elastic modulus (E)
   c. Studying the effect of particle size (U) and pressure (P) on ultimate tensile strength (σ_u)

3. Result and Discussion

Following are the results and discussion of the physical properties of briquettes made from palm shell waste and LDPE plastic. Figure 2 shows briquettes that have been made by varying the mesh size of palm shell charcoal, namely 40 mesh, 60 mesh, 80 mesh and 100 mesh mixed with chopped LDPE plastic with a size of 0,5 x 0,5 cm, starch adhesive and water with a predetermined composition then pressed with various pressures of 30N/m^2, 40N/m^2, 50N/m^2, 60N/m^2, 70N/m^2 and 80N/m^2 which were then tested in the laboratory.

Figure 2. Briquettes that have been made

1. Effect of particle size (U) and pressure (P) on density (ρ)

Table 1 and figure 3 show the density values resulting from briquettes made by varying the particle size (U) of palm shell charcoal and the different pressure (P) in each briquette.

Table 1. effect of particle size (U) and pressure (P) on density (ρ)

Mesh	Density (kg/m^3)					
	30N/m^2	40N/m^2	50N/m^2	60N/m^2	70N/m^2	80N/m^2
40	699,04	668,4	687,9	706,52	662,28	711,48
60	771,53	797,38	808,71	787,12	764,32	763,87
80	685,65	787,49	767,13	803,57	796,08	777,4
100	703,38	749,51	753,81	752,44	790,16	730,32

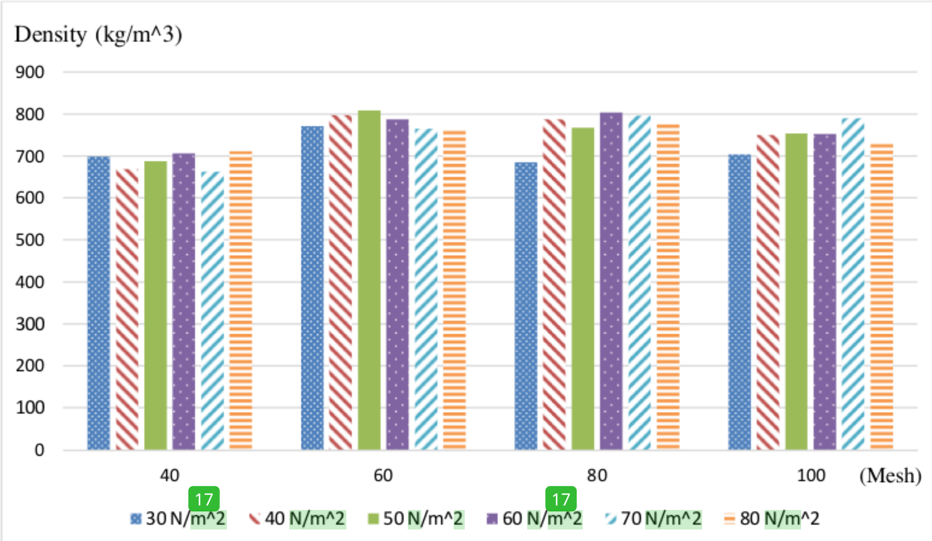

Figure 3. Effect of mesh size on density

At each particle size based on pressure variations, it can be clearly observed that the change in density values with increasing pressure is applied during the briquetting process. In sizes 60, 80, and 100 mesh, it can be seen that there is an increase in density values when the pressure value is increased, but the density values decrease again when given a higher pressure, namely at a pressure of 80N/m^2. This shows that the optimal value for density is not at the highest pressure of 80N/m^2, but rather at a pressure that is in the middle area, namely in the range of 40N/m^2, 50N/m^2, 60N/m^2 and 70N/m^2. This explains that the smaller the particle size when given pressure past its optimum point, the more uncompact the briquettes will be and it is possible that when given even higher pressure past the maximum limit the briquettes will crumble so that maximum density is not obtained. However, it is different from the case with briquettes with a size of 40 mesh where the particles are the largest, the highest density value is obtained at the highest pressure, namely 80N/m^2. From the previous briquette pattern, namely 60, 80 and 100 mesh where when given a pressure of 80N/m^2 the density value decreases, so there is a possibility for briquettes with a particle size of 40 mesh when given pressure above 80N/m^2 it will produce an even higher density or it could be maximum or even decrease again. This means that in general the particles when pressed will have a certain maximum pressure to produce the maximum density. Based on the results, the lowest density was obtained from briquettes made at a particle size of 40 mesh and a compressive strength of 70N/m^2, namely 662,28 kg/m^3, while the highest density was produced from briquettes made at a particle size of 60 mesh and a compressive strength of 50N/m^2, namely 808,71 kg/m^3.

2. Effect of particle size (U) and pressure (P) on the elastic modulus (E)

Table 2 and figure 4 show the modulus of elasticity (E) values resulting from briquettes made by varying the particle size (U) of palm shell charcoal and the different pressure (P) in each briquette based on its density value.

Tabel 2. Effect of particle size (U) and pressure (P) on the elastic modulus (E)

Mesh	Elastic Modulus (MPa)					
40	30N/m^2 ρ (699,04)	40N/m^2 ρ (668,4)	50N/m^2 ρ (687,9)	60N/m^2 ρ (706,52)	70N/m^2 ρ (662,28)	80N/m^2 ρ (711,48)

	30	**8**	**20**	**20**	**20**	**30**
60	ρ (771,53)	ρ (797,38)	ρ (808,71)	ρ (787,12)	ρ (764,32)	ρ (763,87)
	30	**40**	**30**	**20**	**40**	**30**
80	ρ (685,65)	ρ (787,49)	ρ (767,13)	ρ (803,57)	ρ (796,08)	ρ (777,4)
	30	**40**	**20**	**50**	**40**	**50**
100	ρ (703,38)	ρ (749,51)	ρ (753,81)	ρ (752,44)	ρ (790,16)	ρ (730,32)
	30	**40**	**20**	**40**	**50**	**30**

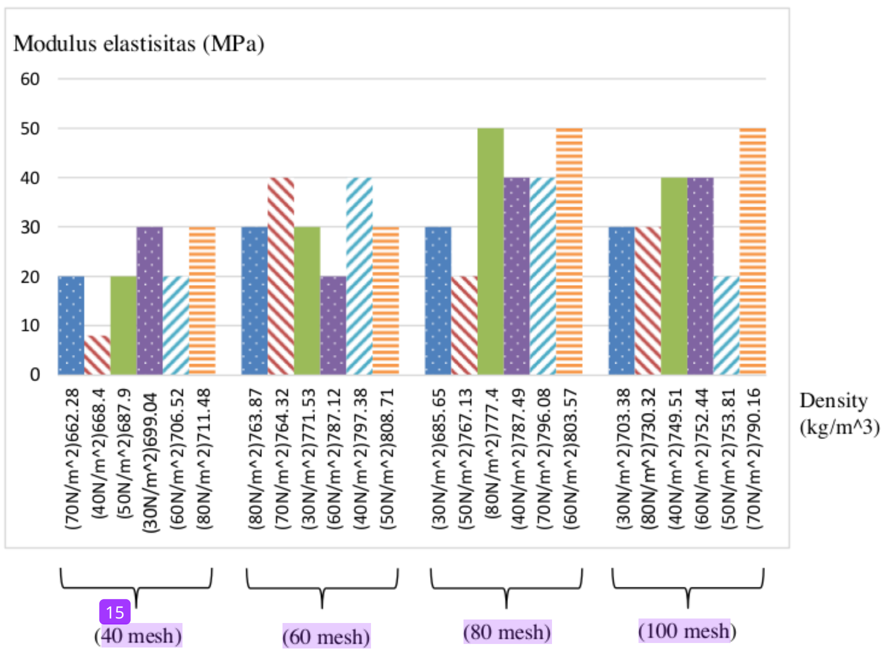

Figure 4. Effect of particle size (U) and pressure (P) on the elastic modulus (E)

In Figure 4 the density values of the briquettes have been sorted from lowest to highest density values for each mesh size based on table 3. From the figure it is generally seen that the value of the elastic modulus increases with increasing mesh size (smaller particle size), this is consistent with the theory that density determines the compactness of the briquettes so that the value of the modulus of elasticity also increases. However, as can be seen from Figure 4, where the highest density value is produced from particles with a size of 60 mesh and pressure of 50N/m^2 does not seem to produce the highest elastic modulus, as well as the other highest density values at different particle sizes, it does not mean that a higher density will produce a higher elastic modulus than briquettes with lower density, this could be due to the addition of LDPE plastic to the briquette which affects the bonding between the particles and can also be caused by the non-uniform distribution of plastic in each briquette so that it will affect its density and cohesiveness which will ultimately affect the elastic modulus value of the briquette itself. However, in general, it can be seen that the average value of the modulus of elasticity continues to increase as the mesh size increases. Based on the graph, it can be seen that the lowest elastic modulus value is produced by briquettes with a density of 668,4 kg/m^3 which is produced from briquettes with a particle size of 40 mesh and pressure of 40N/m^2 where the modulus of elasticity is 8 MPa while the highest modulus of elasticity is produced by briquettes with a density of 803,57 kg/m^3, 777,4 kg/m^3 and 790,16 kg/m^3 produced from briquettes with a particle size of 80 mesh at a pressure of 60N/m^2, a particle size of 80 mesh at a pressure of 80N/m^2 and a particle size of 100 mesh at a pressure of 70N/m^2 with a value of 50 MPa each.

3. Effect of particle size (U) and pressure (P) on ultimate tensile strength (σ_u)

Table 3 and figure 5 show the ultimate strength (σ_u) values produced from briquettes made by varying the particle size (U) of palm shell charcoal and the different pressure (P) in each briquette based on its density value.

Table 3. Effect of particle size (U) and pressure (P) on ultimate tensile strength (σ_u)

Mesh	Ultimate Strength (MPa)					
40	30N/m^2 ρ (699,04)	40N/m^2 ρ (668,4)	50N/m^2 ρ (687,9)	60N/m^2 ρ (706,52)	70N/m^2 ρ (662,28)	80N/m^2 ρ (711,48)
	2,39	**1,33**	**1,82**	**2,09**	**2,17**	**2,3**
60	ρ (771,53)	ρ (797,38)	ρ (808,71)	ρ (787,12)	ρ (764,32)	ρ (763,87)
	2,95	**3,40**	**3,34**	**3,22**	**2,96**	**2,81**
80	ρ (685,65)	ρ (787,49)	ρ (767,13)	ρ (803,57)	ρ (796,08)	ρ (777,4)
	2,42	**2,83**	**3,01**	**4,01**	**4,81**	**3,96**
100	ρ (703,38)	ρ (749,51)	ρ (753,81)	ρ (752,44)	ρ (790,16)	ρ (730,32)
	2,95	**3,47**	**4,09**	**4,26**	**4,45**	**3,25**

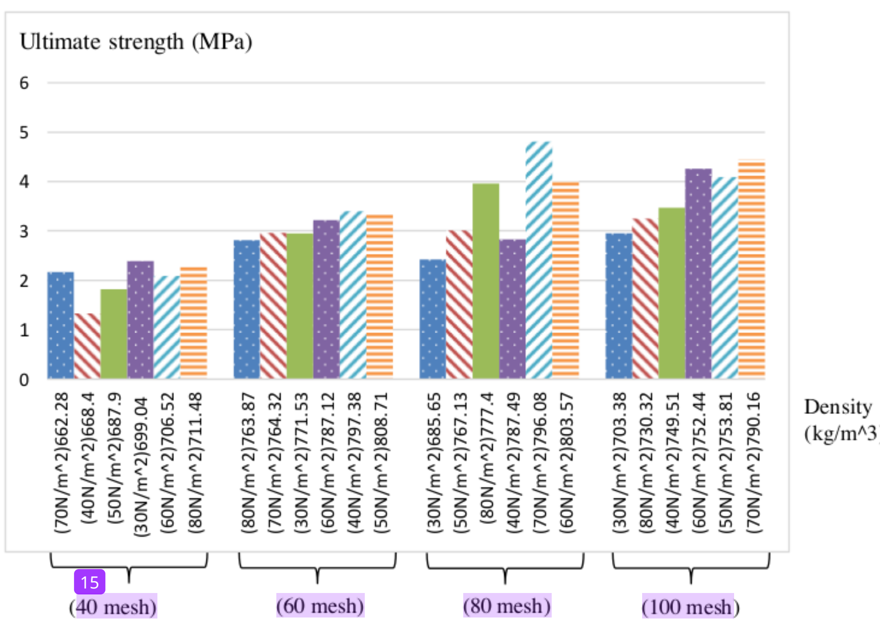

Figure 5. Effect of particle size (U) and pressure (P) on ultimate tensile strength (σ_u)

In figure 5 the density values of the briquettes have been sorted from lowest to highest density values for each particle size based on table 4. From the figure it is generally seen that the ultimate strength value increases with increasing mesh size (smaller particle size), this is consistent with the theory that density determines the cohesiveness of the briquettes so that the ultimate strength value also increases. The mechanical properties of the briquettes themselves can be investigated using the compressive strength test (ultimate tensile strength). In theory, a denser product will produce a harder sample so that it will produce good mechanical properties for product transportation and storage [16]. However, as can be seen from figure 5, where the highest density value is produced from a particle size of 60 mesh and pressure of 50N/m^2 does not seem to produce the highest ultimate strength, as well as the other highest density values at different particle sizes, it does not mean that a higher density will produce higher ultimate strength than briquettes with lower density, this could be due to the addition of LDPE plastic to the briquette which affects the bonding between the particles and can also be caused by the non-uniform distribution of plastic in each briquette so that it will affect its density and compactness which will ultimately affect the value ultimate strength briquette itself. However, in general, it can be seen that the average ultimate strength value continues to increase with increasing mesh size. Based on the results, it can be seen that the lowest ultimate strength value is produced by briquettes with a density of 668,4 kg/m^3 which is produced from briquettes with 40 mesh particles and a pressure of 40N/m^2 where the ultimate strength value is 1,33 MPa. These results also confirm the value of the elastic modulus in figure 4 previously, where the lowest elastic modulus was also produced by particles of 40 mesh size with a pressure of 40N/m^2, while the highest value of ultimate strength was produced by briquettes with a density of 796,08 kg/m^3 which were produced from briquettes with a particle size of 80 mesh and pressure is 70N/m^2 where the ultimate strength value is 4,81 MPa.

So from a series of tests both through density, modulus of elasticity and ultimate tensile strength tests, it can be concluded that the most optimal briquettes are produced from briquettes that have the highest ultimate tensile strength value of 4,81 MPa which is produced from briquettes made from the size of head shell charcoal particles palm 80 mesh with a given briquetting pressure of 70N/m^2, where the density value is 796,07 kg/m^3 and the modulus of elasticity is 40 MPa.

4. Conclusion

From the results of the study, we can conclude that:

1. The lowest density value is owned by briquettes made from palm shell charcoal particle size of 40 mesh and compressive strength of 70N/m^2 which is 662,28 kg/m^3 while the highest density is produced from briquettes made from palm shell charcoal with particle size of 60 mesh and compressive strength of 50N/m^2 which is 808,71 kg/m^3.
2. The lowest elastic modulus value was produced by briquettes with a density of 668,4 kg/m^3 which was made from a particle size of palm shell charcoal of 40 mesh and a pressure of 40N/m^2 where the modulus of elasticity was 8 MPa while the highest modulus of elasticity was produced by briquettes with densities of 803,57 kg/m^3, 777,4 kg/m^3 and 790,16 kg/m^3 which were made from the particle size of palm shell charcoal 80 mesh pressure 60N/m^2, 80 mesh particles pressure 80N/m^2 and 100 mesh particles pressure 70N/m^2 with a modulus of elasticity of 50 MPa each.
3. The lowest ultimate strength value was produced by briquettes with a density of 668,4 kg/m^3 which was made from a particle size of palm shell charcoal of 40 mesh and a pressure of 40N/m^2 where the ultimate strength value was 1,33 MPa while the highest ultimate strength value was produced by briquettes with a density of 796,08 kg/m^3 which is made from a particle size of palm shell charcoal of 80 mesh and a pressure of 70N/m^2 where the ultimate strength value is 4,81 MPa.
4. The most optimal briquettes are produced from briquettes that have the highest ultimate strength value of 4,81 MPa which is produced from briquettes made from a particle size of palm shell charcoal of 80 mesh with a given briquette pressure of 70N/m^2, where the density value is 796,07 kg/m^3 and a modulus of elasticity of 40 MPa.

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6. Acknowledgments

This article was written by Yusraida Khairani Dalimunthe, Widayani and Irfan Dwi Aditya based on the results of a study entitled " Briquettes Optimization of Palm Shell Waste and LDPE Plastic based on Particle Size and Compressive Strength as Alternative Fuels" which was funded by the Faculty of Mathematics and Natural Sciences, ITB through Student Activity Assistance Program 2023. The contents are fully the responsibility of the author.

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