Characterization of the process of compaction of residual biomass from the palm oil industry

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Abstract. To produce fuel briquettes from the waste of the biological processing process, this biomass is pre-dried and pressed into briquettes. Subsequently, prepared fuel briquettes are used for heating residential premises and factory workshops. The aim of the study was to develop a technology for producing briquettes from biomass with specified characteristics. Basic technical specifications for oil palm biomass compression are determined, based on certain variables to be monitored in the manufacture of briquettes from this material. Briquettes were manufactured under certain conditions. The briquettes were tested. According to the test result, a correlation has been established between the initial data (fiber length, relative humidity of raw materials and compression time) and the results obtained (compression strength, durability and volumetric density). Biomass with a relative humidity of not more than 8% has been determined to be used in the production process. The ideal values for quantitative variables have been established: relative humidity of the air 8%, fiber length 85 mm and compression time 20 s.

1 Introduction

The use of wastes that are abundant and cheap, especially from clean resources, has become more urgent than ever. A large amount of agricultural biomass is a source for sustainable biofuel production and offsetting greenhouse gas emissions [1-6]. Crop straw and agricultural residues in the waste streams of commercial processing plants have low own costs and have traditionally been a recycling problem. In fact, new tools need to be developed to process biomass to make it suitable for biofuel production [5-9]. The process of biomass torrefaction is important to transform it into a biofuel with improved calorific and physical strength. However, the production of torrefeerable biomass is loose, powdery and heterogeneous.

The quality of fuel pellets is usually assessed by their density and durability. A high density of granules represents a higher energy per unit volume of material, while durability

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is the stability of granules to various shear and impact forces applied during processing and transportation. High density increases the storage and transportation capacity of pellets. Since the use of boilers and gasifiers is usually volume-dependent, changes in apparent density should be avoided. An apparent density of 650 kg/m³ is indicated as a concept for wood pellet manufacturers [6, 10-12]. Our desire to increase the durability of pellets leads to problems with the operation of the pellet supply systems, futile emission of dust from the bowels, increased fire and explosion risk during pellets processing. It was found that the type of agricultural biomass does not significantly affect the density of pellets, while pre-treatment with steam explosion, the applied pressure and the size of the sieve have a significant impact. In addition, a correlation was found between the density of granules with the applied pressure and the size of the hammer mill screen with the highest values of R². It was found that the density of Stover corn briquette granule or switchgrass granules significantly depends on the pressure, particle size, humidity, and preheating temperature. Pellets made of shredded biomass pre-treated by a microwave have significantly higher density [13-19] and tensile strength than raw samples or pre-treated with microwave distilled water. This is especially important that the type of agricultural biomass, pretreatment by steam explosion, applied pressure, and size of the screen all have a significant impact on the granule durability. No statistically significant correlation (value R²) of the change in durability with applied pressure and size of the hammer crusher was found. In general, the durability of pellets increases with increasing applied pressure and grinding sizes, as well as with the use of pretreatment. The strength of maize or wheat briquettes depends heavily on the pressure, humidity and temperature of heating, while the size of the particles has no significant effect. An analysis of the results of measurements well known that the average strength of wild giant rye and compound feed pellets increased from 63.08% to 89.26% and 61.47% to 89.21%, respectively, when the size of the hammer mill sieve increased from 0.8 to 3.2 mm, which may be mainly due to mechanical blocking of relatively long fibers at higher grinding sizes [8, 20-25]. They also showed that at any specific compressive load, the strength of crushed biomass pellets with a humidity of 12% was significantly higher than that of samples with a humidity of 9 and 15%, and showed that a humidity of more or less 12% would reduce the quality of the pellets.

One way to modernize this material and to improve its technological and burning properties is to seal it into briquettes with a higher density than the original bulk density of the material.

2 Methods

Samples were made taking into account the following factors: fiber length (50 mm, 85 mm and 120 mm), relative humidity (8%, 12% and 16%) and compression time (0 s, 20 s and 40 s) to measure the apparent density of briquettes, the following elements are required, parameters: support (0.5 mm) and balance (0.1 g).

The research procedure was based on 1. Weighing of briquette. The briquette shall be weighted using weights that are as accurate as possible, always seeking a minimum of one-tenth of a gram in the measurements. 2. By measuring the length of the briquette using a caliper, the length of the briquette is measured a total of 6 times to find the average measurement taking into account the geometric irregularities that appear in the briquettes. 3. The briquette diameter was measured in the same way as the length measurement, six diameter measurements were made along the briquette to establish the average value, which is an accurate measurement. 4. Analysis of the obtained data and obtaining the apparent density after estimation calculations [25-30].

The compression strength measurement was performed on a Shimadzu AGX PLUS de 300 kN machine (Fig. 1) present in the IEI laboratory. The briquette is held vertically by
heads that move at a certain speed to the point where the briquette fails due to the compression exerted on it Fig. 1.

Fig. 1. Shimadzu AGX PLUS de 300 kN machine.

Measuring the speed of rotation is also a necessary element for determination of the mechanical strength of briquettes. For this purpose, the briquettes are placed in the drum, the lid is placed on and in the frequency converter determines the speed at which the drum should rotate.

3 Results and Discussion

Based on the tests performed, the relationships between the initial data (fiber length, relative humidity of raw materials and pressing time) and the results (compressive strength, durability and apparent density) were established. At 50 rpm, the drum should run for a total of 5 minutes, but it is necessary to check the speed of the drum during each test. Finally, the briquettes are removed from the drum and weighed, providing the data necessary to determine the mechanical strength index of each briquette. Data analysis and determination of the durability index based on the fact that the MD is equal to the ratio of (final mass) to (initial mass).

Excel organizes the data and determines the durability indicators for each briquette. The statistical software processes the data obtained in tabular form; the graph shows each of the classification factors compared to treatment factors. The results below are primarily the results of mechanical properties according to their relevance to the study. Then the results are analyzed. First, the characteristics of the compaction process of the residual biomass, the results on the bulk density, and then the indicators of durability and compressive strength are given [15, 18].

For bulk density, the results have a correlation coefficient of 84.53% and an average absolute error of 0.048 g/cm³; taking into account three independent experimental variables.
The effect of each of these variables can be seen in Fig. 2 and Fig. 3.

![Graph of the main effects for bulk density.](image)

**Fig. 2.** Graph of the main effects for bulk density.

![Response surface for bulk density.](image)

**Fig. 3.** Response surface for bulk density.

The statistical processing of these dependency graphs has shown that the parameter that has the greatest influence on the apparent briquette density is the relative humidity, the ratio of which is inversely proportional to the parameters being analyzed, while there is a greater apparent density of elements with relative humidity of 8%. The specified parameter is linearly reduced to the minimum values for elements with a relative humidity of 16%. At the same time, it was found that the fiber length is the second parameter in order of influence on the apparent density, that is, as relative humidity is inversely proportional to the apparent density, but the variation is smaller, and finally it can be seen that the compression time is a variable with the least influence on the parameter.
Fig. 4 Relation between parameters and mechanical durability index

Based on the data from the statistical program, we can see how relative humidity is positioned as the dominant variable that largely determines the stability of the briquette, because the content of water in the briquette has a negative impact on its structure and stability. In contrast to other tests, in this case, a longer fibre can improve the strength characteristics of the briquette. This can be explained by the connections of Fig. 4: more numerous interfibre compounds which develop in longer fibre. In addition, there is evidence that the compression time does not significantly affect tests results. From the relevant graphs, we can conclude that relative humidity is positioned as the parameter that most affects the behaviour of briquettes under pressure loads in terms of mechanical strength and density. This represents the inverse proportionality of the measured characteristic, since the relative humidity values of 8 % represent higher values of compressive strength compared to briquettes, whose humidity was 16 % of the cases in which the lowest values were obtained.

The length of the fibre takes second place depending on the compressive strength, and these changes more smoothly compared to relative humidity [29]. Time, in turn, is the least influential variable, as before.

4 Conclusions

This study examined the relationship between parameters and drew a number of important conclusions. Relative air humidity of more than 8% should be used in biomass production. We recommend the use of medium-length fibres, as the length of the fiber affects the test results. The ideal values for quantitative variables are 8% relative air humidity, 85 mm fiber length, and 20 seconds compression time.

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