The Effects of Moderate Die Pressure on Maize Cob Briquettes : A Case Study in Phitsanulok, Thailand

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Abstract

Concerning with energy shortage and environmental issues, renewable energy seems to be one of the promising energy resource for alleviating the problems. One of the most important energy resources, particularly for developing countries, is biomass. With regard to the biomass, agricultural residues account for the largest amount available worldwide. The residues are available as a free, indigenous and environmentally friendly energy resource. For the case of Phitsanulok, one of the most important crops in this area is maize. The productivity according to the previous data of the province was over 142 kton per year for this kind of crop. Hence, approximately 39 kton of maize cob was available in this area. In this study, the maize cob briquetting process was investigated. Raw materials used were maize cob and molasses, which performs as the briquette binder. The die pressure range was limited to a modest one, less than 15 MPa. Several factors, which are the percentage of relaxation in length, the percentage of increased volume, the impact resistant index, the percentage of weight loss, and the water resistance, had been examined. It was found that the final percentages of relaxation in length and increased volume after 96 hours exposure to the laboratory atmosphere were in the range of 15%-18% and 20%-28%, respectively. All briquettes produced showed the great results on the impact resistant test. Nonetheless, for the case of water resistant investigation, the dispersion times for all briquettes were less than one minute.

Keywords: briquette, Maize cob, agricultural residue, sustainable energy

Intended category: sustainable energy

1. Introduction

With regard to energy shortage and environmental issues, it is widely accepted that renewable energy will play a major role in the foreseeing year. One of the most important energy resources, particularly for developing countries, is biomass. In general, this kind of energy resource can be divided into three main groups viz. biomass plantation, forest residues, and agricultural residues. It has been reported that over 33 percent of energy consumption for developing countries can be supplied from this kind of energy resource [1-2]. Moreover, the carbon dioxide generated during biomass energy conversion will be compensated by its photosynthesis process. Thus, nearly zero net gain carbon dioxide can be obtained from this process, particularly for biomass plantation.

Out of three categories of biomass, agricultural residues account for the largest amount available worldwide. Hence, for developing and agricultural-based countries, the utilization of the residues from agricultural sectors as primary or secondary sources of energy is considerably attractive. The residues are available as a free, indigenous and environmentally friendly energy resource.

It is observed that several kinds of agricultural residues are available and ready to be utilized as fuels. Examples of this category are coconut shells, corncobs, and bagasse. Nonetheless, it is widely accepted that the majority of the residues are not appropriate to be used as fuels directly. As compared to other kinds of fuels, agricultural residues have lower density, higher moisture content, and lower energy density. Besides, the low bulk density and dusty characteristics of the biomass also cause problems in transportation, handling, storage, entrained particulate emission control, and direct combustion [3-6].

One of the promising technologies is briquetting process, which has been investigated by several researchers [3-13]. The technology may be simply defined as the densification process for improving the biomass fuel-characteristics. The important properties of briquettes affected the fuel-quality are their physical and chemical attributes. Examples of the characteristics are density, size of briquettes, compressive strength, and moisture content. Heating value and energy per unit volume are also included in the cluster.

It appears that one of the most extensively technologies for briquetting is piston-and-die press. With regard to this compact process, the pressure is developed against the end of the die to form die-shape briquettes. Besides, preheating of materials is unnecessary since the process can be done at room temperature. Generally, biomass resources contain certain components that perform like binder material during the process. Thus, for some kinds of biomass the briquetting process may be done without binder material.

In this study, a moderate pressure piston-and-die briquetting process was investigated . The pressure range was limited to 15 MPa. According to the biomass waste available in the area, maize cobs were chosen as the raw material. The effects of moderate die pressure on their relaxation and water resistance of maize-cob briquettes were investigated.

2. Maize Cob in Phisanulok

Nine districts (or Amphur) altogether constitute 10,896-km^2 territory of Phitsanulok, a province in Northern Thailand. The northern and eastern regions of Phitsanulok are mainly mountainous and hilly. Arable plains are available in parts of the central, western and southern locations. This area has a generally hot and humid climate. Vast areas of this province are devoted for agricultural sectors. Rice, maize, groundnut, cassava, and banana are examples of crops available in the province.

Maize is one of the most important agricultural products for this province. As can be seen from Fig. 1, during the crop year period 2000/2001, approximately 103,116 acres/year had been devoted for maize plantation. Therefore, the productivity obtained in that crop year was exceeded 142,130 tons [14]. Moreover, it can be seen from the graph, Bang Rakam district accounted for the highest productivity. Also, the quantities of maize produced in Neon Maprang and Nakon Thai districts were considerably high as compared to the rest.

Generally, for maize industries in Phitsanulok, maize cobs will be left and disposed after milling processes. It seems that this kind of waste contains a considerable amount of energy. Hence, there is a possibility to utilize maize cobs as raw material for fuel production, in other words, maize-cob briquette manufacture.

In order to calculate the amount of maize cob available in the area, the residue-to-product ratio, 0.273, was utilized for computing. From Fig. 1, it can be concluded that the quantities of the maize cobs available were over 38,301 tons. As shown in the graph, more than 70% of maize cob available in Phitsanulok was at Bang Rakam, Noen Maprang, and Nakon Thai districts.

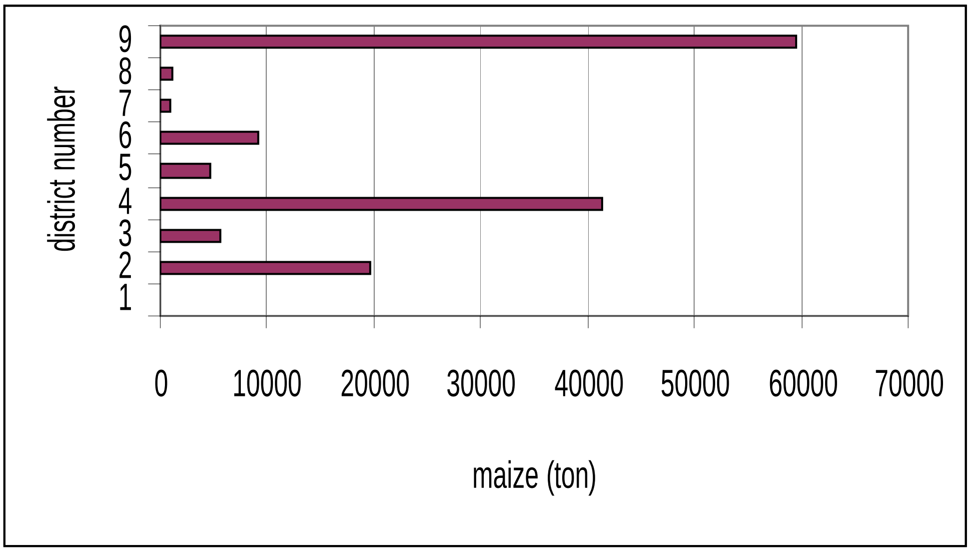

Fig. 1. The quantity of maize produced in Phitsanulok in 2001.

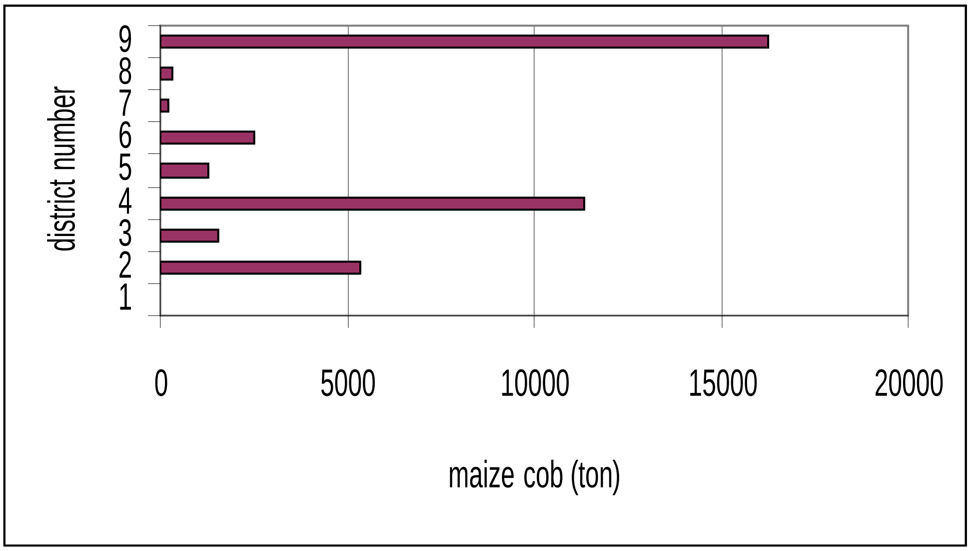

Fig. 2. The quantity of maize cob available in Phitsanulok in 2001.

List of the districts in Phitsanulok

1. Bang Krathum	2. Noen Maprang	3. Wang Thong
4. Nakon Thai	5. Chat Trakan	6. Wat Bot
7. Phrom Piram	8. Muang	9. Bang Rakam

3. Experiment

3.1 Preparation of raw materials

Maize cobs utilized in the experiment were obtained from a mill at Nakornthai, a district in Phitsanulok. Nonetheless, it is apparent that this kind of biomass needs some processes in order to decrease its size before briquetting. The maize residue, therefore, was chopped into small pieces. Next, they were sieved to 0-5 mm particles, with the purpose of eliminating large particles that may cause failures of the process. The maize cobs as raw material were then mixed with molasses, which is a by-product from sugar cane manufacture. Molasses performs as the binder for briquetting process. By utilizing a mixer, both maize cobs and molasses were blended until mould-condition was achieved. Also, in order to examine the effect of die pressure only, the specified percentage of the binder in this study was fixed at 23% of the weight of the briquette.

The moisture content of the material was also investigated by adapting the ASAE S358.2 DEC99 moisture measurement method [15]. 30 gram of pre-screened maize cob was selected as a representative sample. The weight of the sample and container was evaluated by using a laboratory analytical balance. Next, the sample was dried in a laboratory oven cabinet at 103^{o}C for 24 h. After the removal, the material and its container were placed in a desiccator to cool down to room temperature. The sample was then re-weighed in order to calculate its moisture content.

3.2 Briquetting process and characteristics of briquettes

A 38-mm ID × 100-mm height cylindrical die was utilized to produce briquettes from maize cobs. The upper piston compressed raw material against the other end of the die to form briquettes by using a semi-automatic laboratory hydraulic press machine. The machine used was also fabricated with a pressure switch component to facilitate the pressure control.

In order to produce a briquette, 100 g of the material, 73% maize cob and 23% molasses, was prepared by utilizing an analytical balance. The pre-weighed material was then compacted by using the press machine. As mentioned above, the upper limit for this study was set to 15 MPa. Thus, three ultimate-pressures viz. 7, 10, and 13 MPa were applied to the specimens. Concerning with the dwell time, it was set to 15 seconds for all cases. In other words, the holding time was 15 seconds after the determined pressure was achieved.

All briquetting experiments were conducted at laboratory condition, 50-60% humidity and 27^{o}C. Five test samples of each condition were prepared for the experiments. Furthermore, for eliminating the effects of other factors, the experimental design used was RCB (randomized complete block design).

3.3 Physical properties of briquettes investigation

The relaxation in length, the relaxation in volume, the impact resistance, and water resistance of the briquettes were investigated by adapting some standard tests as the following:

In order to investigate the stabilities of the briquettes, the relaxation in length and the relaxation in volume of them were suddenly measured after removal from the die. Then measurements of the length and diameter of the briquettes were conducted again at 15 min, 30 min, 1 h, 2 h, 3 h, 6 h, 9 h, 12 h, 18 h, 24 h, 48 h, 72 h, and 96 h after the compact process. All dimensional measurements were accomplished by utilizing a digital vernier caliper.

By adapting the ASTM method D440-86 of drop shatter for coal, the impact resistance tests were studied. After leaving the briquettes for 96 hours, the briquettes were dropped from the height of 2 m onto a concrete floor. The number of pieces that the briquette breaks into was recorded. In order to assess the impact resistance, an impact resistance index (IRI) was chosen as the criterion. Ten drops were set as a standard for the experiments. After the first drop, the pieces of briquettes that weighed less than 5% of the initial weight was not included in the IRI calculation [13].

For the briquette density investigation, the ASAE S269.4 DEC96 standard was adapted [15]. Each briquette was weighed in air by using the analytical balance and placed into a plastic bag. Then, they were immersed into a scaled container filled two-third with water. After immersion, the sample was elevated to approximately 50 mm under the water surface and the volume of the water was then recorded for computing its density.

The investigation of the water resistance of the briquettes was conducted at 96 h after the compact process. The briquettes were arbitrarily investigated by immersing the briquettes into a container filled with room-temperature water. The times required for the onset, 50%, and 100% dispersion in water were recorded.

4. Results

4.1 Effect of die pressure on briquette relaxation in length

The percentage of elongation, or relaxation in length, is expressed as

$$\%Elongation = \frac{\left[\sum_{i=1}^{k} L_t - \sum_{i=1}^{k} L_0\right]}{\sum_{i=1}^{k} L_0} \tag{1}$$

where L_0 is the length of the briquettes immediately measured after removal from the die, L_t is the length of the briquettes measured at the time “t” after the briquetting process, and k is the number of test samples. The calculated results from the experiment, which are the effects of the briquetting pressure on the relaxation in length of briquettes, are shown in Fig. 3, Fig. 4, and Fig. 5.

According to the graphs, the curves for all cases have the same pattern. There is a very rapid increase in the length of briquettes followed by a slight rise curve. Also, it was found that the maximum elongation took place within 15 minutes after the removal. It appears that the percentage of relaxation for the case of 7 MPa briquettes was account for the highest value, about 45% higher as compared with the rest. Hence, the higher the compaction pressure was, the lower was the percentage of elongation in length for the first fifteen minute. The percentage then gradually decreased for the next 24 hours. After one day, it was found that the increase in the length of briquettes is considerably low, i.e., the length is almost stable for all cases.

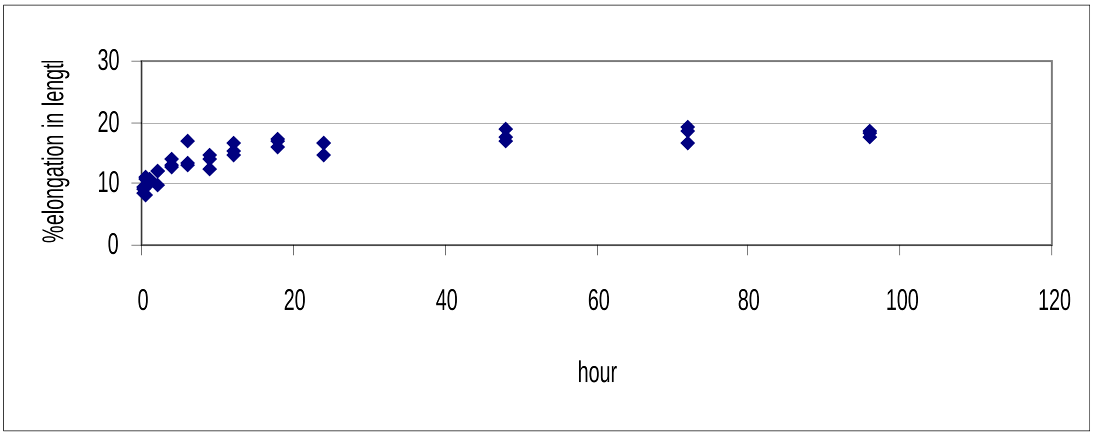

Fig. 3. The percentage elongation in length for the case of 7 MPa briquettes.

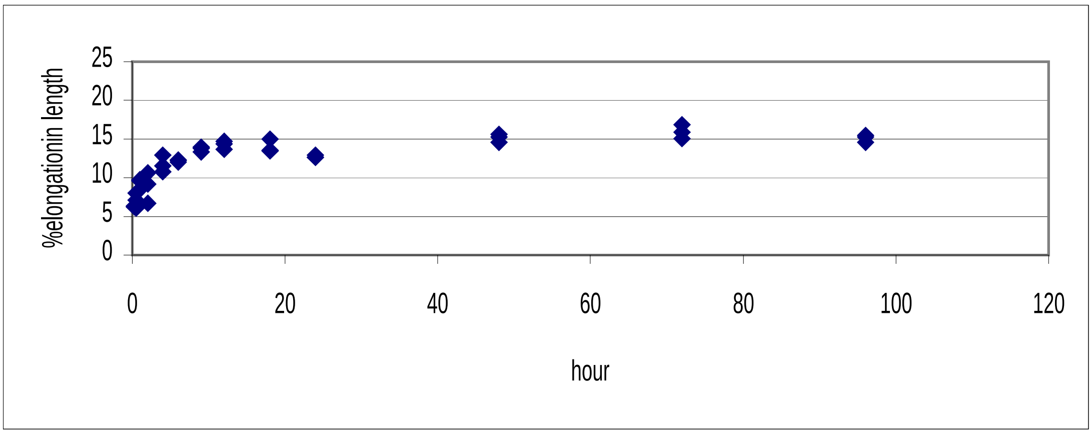

Fig. 4. The percentage elongation in length for the case of 10 MPa briquettes.

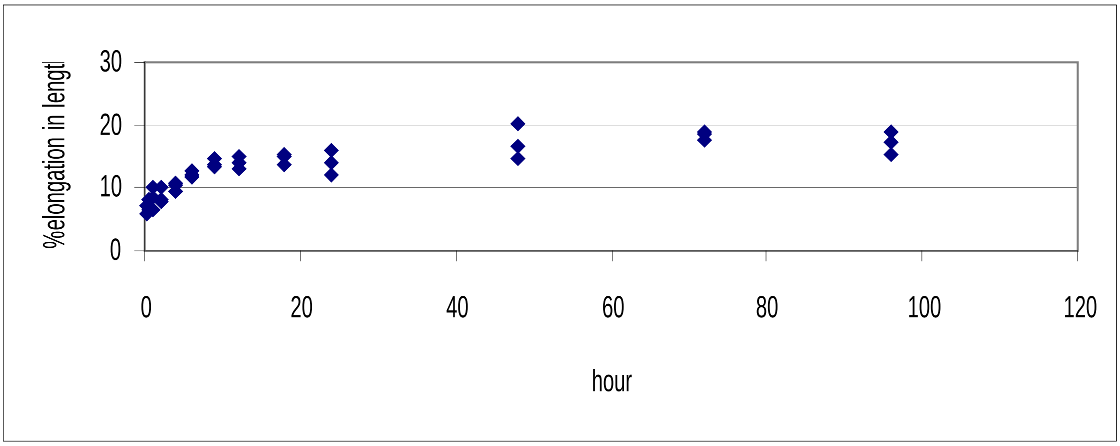

Fig. 5. The percentage elongation in length for the case of 13 MPa briquettes.

4.2 Effect of die pressure on briquette increase in volume

The percentage relaxation in volume, or increase in volume, is expressed as

$$\%Increased \quad Volume = \frac{\left[\sum_{i=1}^{k} V_t - \sum_{i=1}^{k} V_0\right]}{\sum_{i=1}^{k} V_0} \qquad (2)$$

where V_0 is the volume of the briquettes suddenly measured after removal from the die, V_t is the volume of the briquettes measured at the time "t" after the briquetting process, and k is the number of test samples. The computed results, products of their diameters and lengths, are shown in Fig. 6, Fig. 7, and Fig. 8.

As can be seen from the graphs, the shape of all curves is similar to those of Fig. 3-5. After the first three hour, the percentage of increased volume was slightly decreased until almost stable within 24 hour. The highest value of percentage relaxation in volume after 96 hour was accounted for the 7 MPa briquettes.

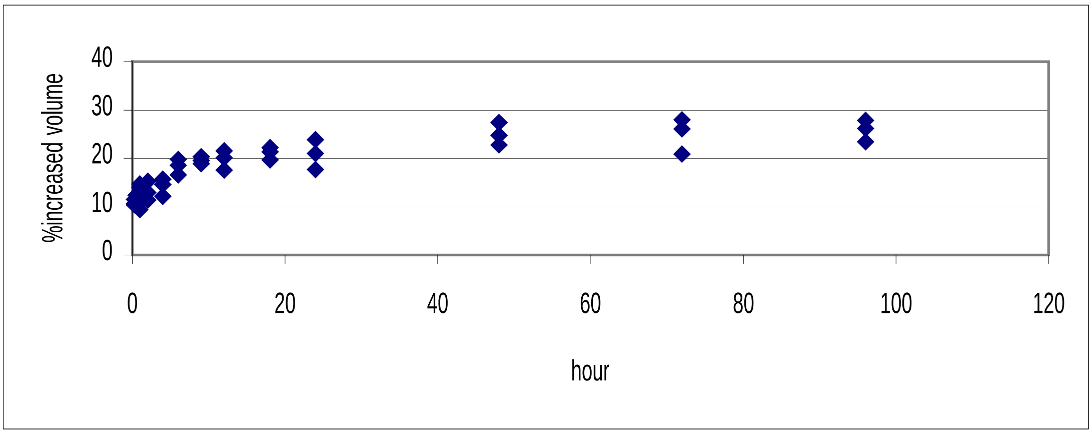

Fig. 6. The percentage of increased volume for the case of 7 MPa briquettes.

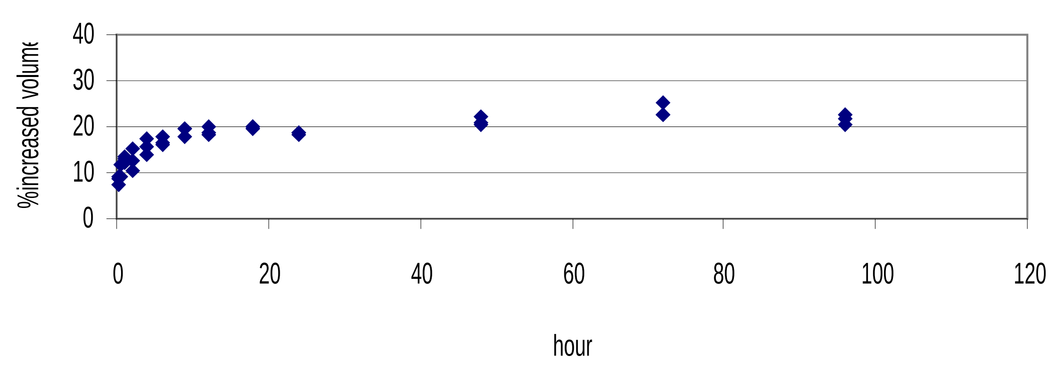

Fig. 7. The percentage of increased volume for the case of 10 MPa briquettes.

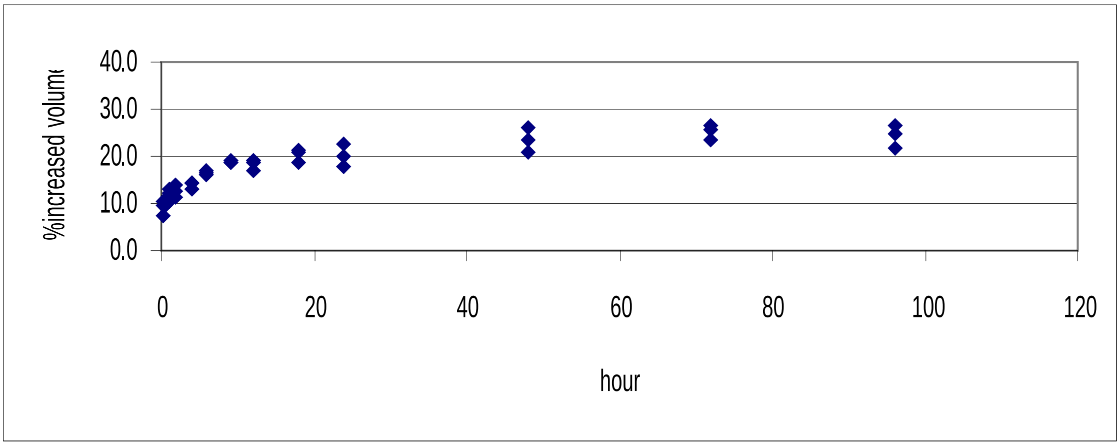

Fig. 8. The percentage of increased volume for the case of 13 MPa briquettes.

4.3 Effect of die pressure on briquette durability

The strength of briquettes were investigated from the impact resistant test. After repeatedly dropped the briquettes from 2-m height to the laboratory concrete floor, the number of pieces that briquettes broken into were recorded. The impact resistance index, IRI, can be expressed as

$$\mathrm{IRI} = \frac{100\mathrm{x}N}{n} \tag{3}$$

where N is the number of drops, and n is the total number of pieces that weigh more than 5% of the initial weight after N drops [13]. However after the 30 drops, all the briquettes studied did not shatter into pieces i.e., the IRI was 3000. Since the impact resistant index of 1000 was set as the lowest acceptable value, all the briquettes investigated passed the test. In order to study about the weight loss, the number of drops was increased to 30. The percentages of weight loss after 10 drops, 20 drops, and 30 drops were calculated and shown in Table 1. Furthermore, the dispersion time of briquettes in cold water was also studied. The onset dispersion times of the briquettes occurred within the first 10 seconds after the immersion. Moreover, for all cases, the 100%-dispersion times were less than one minute.

Table 1. The percentage of weight loss after 2-m drop

Die pressure (MPa)	The percentage of weight loss		
	10 drops	20 drops	30 drops
7	0.27	0.52	0.64
10	0.26	0.36	0.50
13	0.30	0.43	0.65

Table 2. Dispersion time of briquettes in cold water

Die pressure (MPa)	Dispersion time of briquettes in cold water (second)		
	The onset point	50%	100%
7	9.0	30.0	45.3
10	8.7	30.5	47.1
13	8.8	27.6	51.0

4.4 The properties of material and briquettes

Table 3 shows the moisture content of maize cob and the densities of briquettes. Also, some pictures of the briquettes produced are shown in Fig. 9.

Table 3. The properties of maize cob and briquettes

Moisture content of maize cob (%)	7.5
Longest dimension of maize cob particles (cm)	0.5
Density of 7 MPa briquette (g/cm^3)	0.709
Density of 10 MPa briquette (g/cm^3)	0.808
Density of 13 MPa briquette (g/cm^3)	0.842

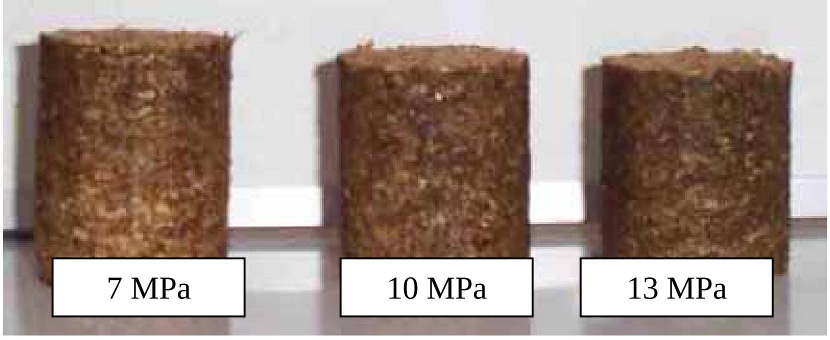

Fig. 9. Some of briquettes produced at die pressure of 7 MPa, 10 MPa, and 13 MPa, respectively

5. Conclusion

With regard to the experimental results, it was found that the maximum relaxation in length and the increased volume for all cases took place within the first 15 minutes after the ejection from the die. Also, after 96 hours exposure to the laboratory atmosphere, it appears that the values of relaxation in length and increased volume were less than 18% and 28%, respectively. According to the impact resistant test, all briquettes showed great durability results and did not shatter into pieces after 30 drops. The dispersion times in room temperature water, however, were less than one minute for all cases.

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