IAEEE - GP
Global Publisher
International Association of Energy, Environment and Economy

Study of Behavior of Spent Coffee Grounds Briquettes to Preserve Their Integrity under Conditions of Transport and Storage

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ABSTRACT

Currently, one of the main problems that affect forest areas and the health of rural inhabitants in poor and developing countries, is the use of firewood as the only energy source, due to deforestation and chronic lung disease in people who are exposed to its smoke for long periods. Different alternative fuels based on biomass obtained from crop wastes such as sugar cane bagasse, coffee pulp, rice husk, leaves and sawdust of branches, and peels of fruits, have been studied in order to obtain a sustainable solid and less harmful fuel. For compressive test, briquettes samples were tested in universal testing machine. The abrasive resistance was measured by using a mill adapted for the proposed size of briquette. Finally, the shatter resistance was evaluated taking as a guide the job done by Birwaktar and Asamoah, where the samples were left in free-fall from a height of 1 m several times until they got broken. As a general conclusion, these briquettes composition have good mechanical properties in order to keep the shape, size and density in current process of transport and storage in boxes one on the top of the other

Keywords: briquettes, spent coffee ground, solid biomass

1. INTRODUCTION`

Computer models suggest that rising temperature will lead to a cascade of consequences that affect the hydrologic cycle, sea level, human health, the survival and distribution of organisms, and the use of natural resources by people. In addition, poorer nations are generally more vulnerable to consequences of global warming [1]

In less-developed countries, wood has been the major source of fuel for centuries. As a fact, wood is the primary source of energy for nearly half of wold´s population, meanly for cooking.

According to Johnson, three billion people in the world use wood biomass in the form of firewood or charcoal as the only energy alternative, causing deforestation problems, together with lung diseases as emphysema and chronic pulmonary obstructive disease [2]. It is estimated that throughout the world there are 1,3 billion people who cannot obtain enough wood or must harvest wood at a rate that exceeds it growth. Also, burning wood is a source of air pollution because it is burned in open fires or in inefficient stoves. This results in high amounts of smoke, particulate matter and other incomplete combustion products. Respiratory illness is common in women and children who spend more time in the home. [1] [3]

Therefore, new sources of biomass have been studied and developed. They are made from organic waste mainly of agricultural products. In this context, waste from coffee crops and productions appear as an alternative source of energy to mitigate problems related to use of wood. The spent coffee grounds are the main by-product of the coffee brewing process and are obtained by both domestic brew preparation (at coffee shops, restaurants, homes) or during the industrial preparation of instant coffee. [4]. This solid wasted has been used as fuel in form of pellets or briquettes to cook and heat in rural regions. It is used as a fertilizer, cosmetic formulation, wastewater treatment, and bleach agent as well. [5] [6]

During the manufacture of briquettes, application of an appropriate technology or process is essential to guarantee their shape and integrity in transport, delivery and storage operations, so that the biomass residues are used effectively as the energy source. The aim of this paper therefore, is to analyse the mechanical behaviour of briquettes made with spent coffee grounds (SCG) mixed with recycled newspaper (RNP) as binder substance to determine which composition presents the suitable mechanical properties.

2. EXPERIMENTAL METHODOLOGY

2.1. Manufacture of briquettes

2.1.1. Mixture preparation

Initially magazine, bond and newspaper, were tested as a binder for SCG. After several tests, it determined the magazine is difficult to cut and shred, besides, to be less soluble in water. Between bond paper and newspaper, the second got chosen since the briquettes made with this binder turned out to be more compact. Therefore, it was left as the only binder to make the different SCG-RNP compositions.

To evaluate the mechanical properties, SCG-RNP compositions of 50-50, 70-30 and 80-20 by weight were elaborated. The preparation of mixture got made by dissolving 1 kg of newspaper cut into fine pieces in 4 litres of water, which was left to soak for 24 hours (Figure 1). The following day, the soaked paper got weighed for manual mixing with the coffee grounds in the SCG-RNP compositions as follows.

- Composition 50-50: 1 kg of SCG, 0.80 kg of RNP
- Composition 70-30: 0.70 kg of SCG, 0.30 kg of RNP
- Composition 80-20: 0.80 kg of SCG, 0.20 kg of RNP

Figure 1. Preparation of mixture

Once the mixtures were made, they were compacted in the Peterson-type briquetting press.

2.1.2. Compaction of mixture

Briquettes use experiences in countries such as Spain, Ukraine, Russia, and the United Kingdom, were analysed. In rural areas, the lack of conventional heating is supplied with chimneys and biomass-based boilers. These systems use biofuels from different biomass such as sawdust, shavings, branches, stems, shells, grains, among others, to produce briquettes or pellets.

In the case of briquettes, Peterson presses are used. These machines are composed of a metallic and wood frame, a hydraulic jack, a drainage system, and a press-molding device as shown in figure 2.

Figure 2. Peterson briquetting press

The manually operated hydraulic jack puts the mixture under pressure of 6.796 MPa. The average dimensions obtained for the selected compositions are shown in figures 3 and 4, together with table 1.

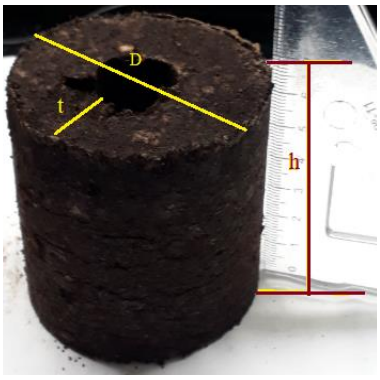

Figure 3. SCG-RNP briquettes dimensions

Figure 4. Batch of briquetes made to be tested

Table 1. Average dimensions for the different SCG-RNP compositions

Composition	***Height h (mm)***	***Thickness t (mm)***	***Diameter D (mm)***
50-50	48,7	22,48	64,08
70-30	49,75	22,05	64,55
80-30	50,23	22,33	64,65

2.1.3. Drying process

Briquettes made in the Peterson press are exposed directly to sunlight to ensure suitable moisture removal and to give them compaction properties.
This drying process takes an average of four days. The best indicator for the drying process is the formation of the Penicillium fungus on the surface.

2.2. Study of mechanical behaviour of briquettes

2.2.1. Compression strength test

The compression test for briquettes was applied on the SHIMATZU E-50 Universal Testing Machine for eight samples of each composition. As shown in figure 5.

Figure 5. Compression strength test in universal testing machine

2.2.2. Shatter resistance test

According to Birwatkar´s work, the briquettes shatter resistance was evaluated, dropping them in free fall from a height of 1 m as shown in figure 6 [7]. Asamoah also recommend this test [8]. Repetitions were made until the briquette got completely broken in pieces. The initial weight of the entire briquette and the weight of the largest piece were measured and compared to obtain this index with the equation.

$$\%\, shatter\ resistance = \left(1 - \frac{w_1 - w_2}{w_1}\right) \times 100$$

Where w_1 corresponds to the weight of the complete briquette before impact and w_2 is the weight of the piece plus after impact.

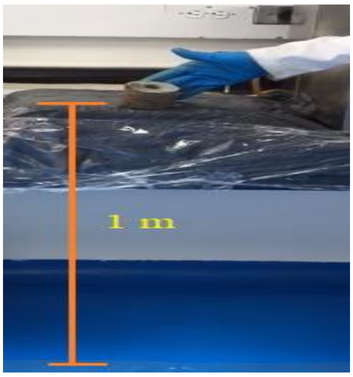

Figure 6. Shatter resistance test

2.2.3. Abrasive resistance

According to the stipulations of the EN 15210-2 standard, six samples of briquettes of each composition were subjected to a rotating drum of 20 cm in diameter, 30 cm in length, for 5 minutes by rotating it at 25 rpm [9]. The Armfield CEN-MKII-11 didactic ball mill was selected and adapted to the size of the manufactured briquettes as shown in figure 7.

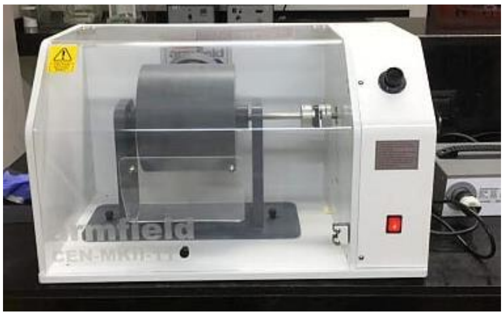

Figure 7. Armfield CEN-MKII-11 didactic ball mill

Instead of placing a flat dividing plate on the drum, a sheet of sandpaper 100 was placed on the inner walls to provide the abrasive medium.
The weight of each briquette was measured before and after the test with a precision electronic balance. The abrasion resistance was determined using the final mass in percent after rotation as an indicator, employing the equation.

$$\%\, abrasive\ resistance = \left(1 - \frac{w_1 - w_2}{w_1}\right) \times 100$$

Where w_1 and w_2, correspond to the weight of the briquette before and after rotation in the drum respectively.

3. RESULTS AND DISCUSSION

The values obtained from the mechanical tests were compared and analysed, with stipulated parameters in the Colombian Technical Standard NTC 2060 and other standards, together with the experiences of different authors who carried out similar tests [10].

3.1. Compression strength tests

Figure 8 shows the deformation tendency of the briquettes after failure in the compression test.


Figure 8. Final appearance of briquette after compression test

For all the compositions, there was a characteristic deformation in the radial direction. But, as the percentage of RNP binder in the mix decreased, a greater detachment of material took place. Table 2 and figure 9 show the results of this test for the tested briquettes.

Table 2. Compression strength in (N) for briquettes SCG-RNP

Briquette	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Average load**
50-50	251,04	235,27	225,672	239,16	182,132	200,795	219,653	204,5312	219,78165
70-30	144,467	117,178	89,4981	97,4717	67,549	96,2683	78,6523	90,387	97,683925
80-20	102,37	80,657	76,5223	79,3676	64,3987	86,8943	76,5219	75,4213	80,269138

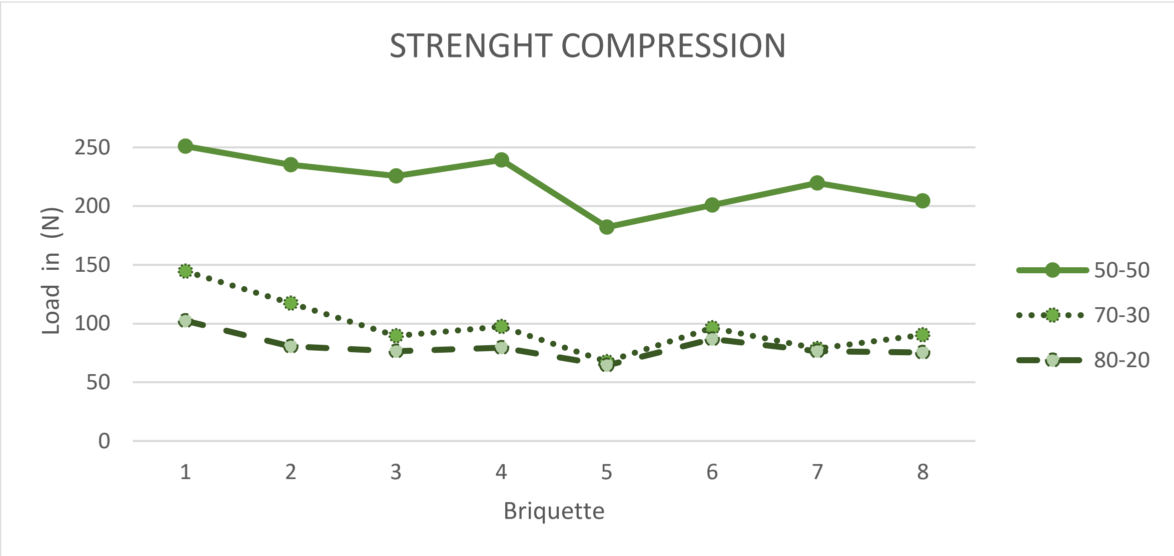

Figure 9. Graphic behaviour of compression strength of briquettes SCH-RNP

According to the NTC 2060 standard, the compression strength for biomass briquettes weighing more than 40 g should not be less than 588.23 N or 60 kgf. In the present project, the samples had weights between 48 and 61 g. The 50:50 composition samples showed better crush resistance when loaded on the universal testing machine. On average, they supported a load of 219.78 N, alike the values of 96.26 and 86.89 (N) registered by those of 70:30 and 80:20 respectively. The values obtained do not fulfill this requirement, but in similar studies carried out on batches of briquettes with different binders, it is evident that they do not reach this value either. Cubero-Abarca´s study obtained average fault load values 538.93 N [11] . The study carried out in Ecuador by Balseca registered an average failure load of 237.74 N [12]. Lisowskis´ test calculated the resistance to crushing stress for SCG pellets at 1.75 MPa, compared to the 68.148 kPa obtained in the present project for the 50-50 composition [13]. However, the value of this last reference would be below that established by this standard. According to the graph in figure 8, a marked difference is evident in terms of compressive strength based on the amount of RNP contained. Therefore, it proves that this binder has a notable impact on the increase in resistance to this load condition.

Although the minimum compression or crushing load was under standard requirement, these briquettes would support many briquettes established in table 3 based on their weight and the load held.

Table 3. Number of briquettes held on top

Composition	Maximum load on top (N)	Briquettes stacked on top
50-50	219,78	443
70-30	97,683	153
80-20	80,27	137

3.2. Shatter resistance tests

Table 4 and figure 10 show the results of this test for the tested briquettes.

Table 4. Shatter resistance in (%) for SCG-RNP briquettes

Briquette	1	2	3	4	5	Average (%)	Number of launches in free fall
50-50	98,763	97,830	95,556	95,117	99,469	97,347	20
70-30	52,937	47,812	66,071	49,937	52,789	53,909	7
80-20	47,903	47,942	54,854	48,575	56,071	51,069	4

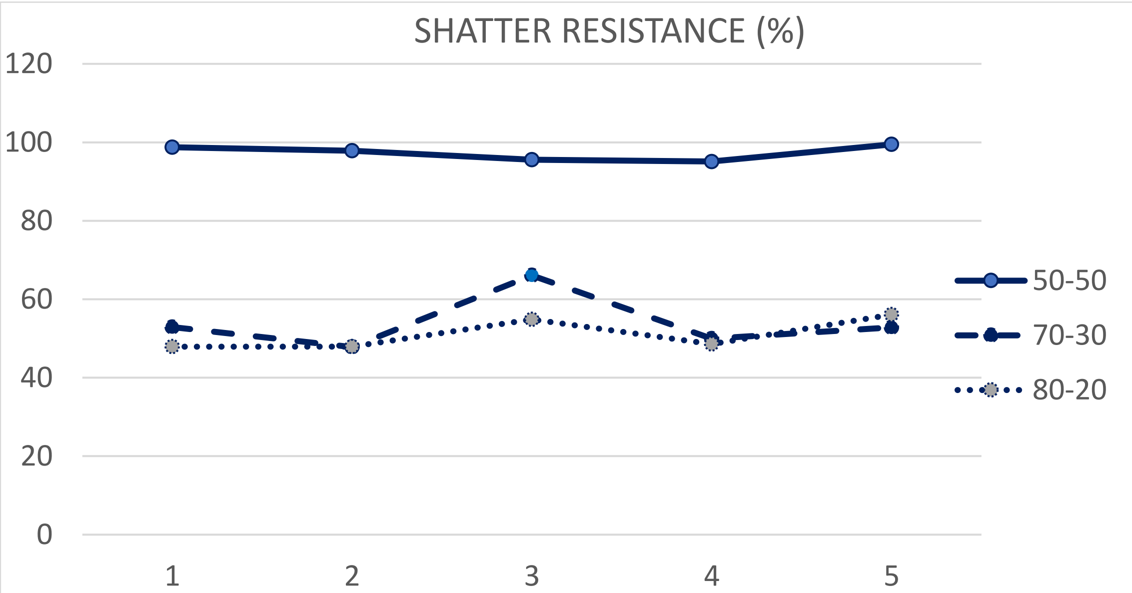

Figure 10. Graphic behaviour of shatter resistance of briquettes SCG-RNP

The newspaper as a binder improves the compaction of the mixture and prevents the briquettes from collapsing when thrown in free fall. In the experiment, at a large amount of paper, more launches are needed to fragment the briquette. By decreasing its proportion, the briquette becomes more brittle. Bargazan, suggest as suitable values for this indicator those greater than 56% [14]. Law´s test found that coffee grounds develop high impact resistance when agglomerated with rice husk. Approximately 96% was this indicator, while when mixed in different proportions with sugar cane bagasse, this was of almost 100%. Brunerova´s study, found that this indicator improves in SCG briquettes agglomerated with wood shavings or sawdust, but does not give a suitable response to compression [15].

Regarding this indicator, the 50-50 composition would guarantee the physical integrity of the briquettes if they were to suffer an unforeseen fall.

3.3. Abrasive resistance tests

Table 5 and figure 11 show the results obtained in the abrasion test. According to requirements of NTC 2060, this test must be applied to a batch of 100 briquettes in a rotating drum with a diameter of 1.0 m. The reference for this test was the Standard EN 15210-2. A smaller number of samples are allowed to be subjected to rotation and to evaluate the detachment of material. A sheet of sandpaper 100 was placed on the walls of the drum, rather than a flat barrier inside the drum.

Table 5. Abrasive resistance in (%) for SCG-RNP briquettes

Briquette	**1**	**2**	**3**	**4**	**5**	**6**
50-50	98,9613	99,5602	98,6468	99,0222	99,0295	99,0421
70-30	95,4466	96,9214	94,6786	93,1858	97,6184	94,5522
80-20	93,0301	90,0676	86,5218	94,8882	96,3218	96,1330

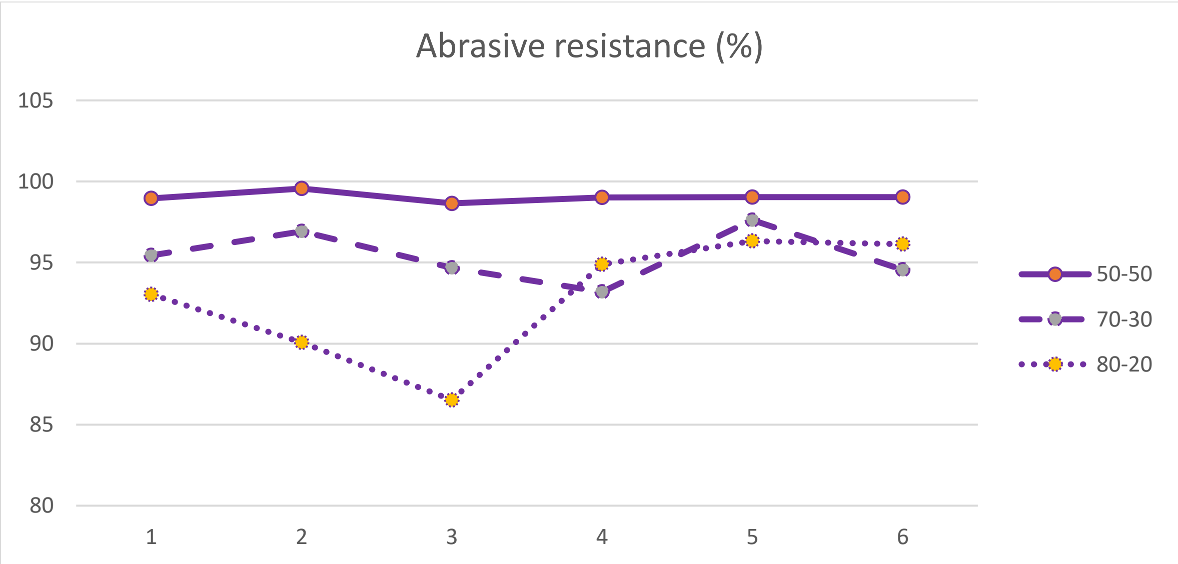

Figure 11. Graphic behaviour of abrasive resistance of briquettes SCG-RNP

The test showed the newspaper maintains the physical integrity of the briquettes, detaching less than 2% of material after undergoing the rotation of the drum, the impact between them and the contact with the sandpaper wall. Law carried out the abrasion test or also called durability, for the briquettes of rice husk and mud, obtaining values between 96% and 100%. This resistance increased as the amount of SCG was added. The combination of cane bagasse and SCG remained very close to 100% regardless of composition [16]. Brunerova in her study obtained that the abrasion resistance is high in briquettes whose composition consists of 100% sawdust or sawdust - erased in 50-50 or 75-25. On the other hand, this study verified that the resistance of wood chip briquettes had a low resistance to abrasion (below 50%) [15]. The results of this test obtained in the present study suggest that the combination of SCG with RNP makes the briquette highly resistant to abrasion. In practical applications these briquettes would not present significant material detachment, when colliding with each other as would happen in transportation. Their integrity, presentation and performance in the combustion process would not be affected.

CONCLUSIONS

Despite not having reached the compressive strength limit, the briquettes showed high axial load support values. In practice these briquettes can support a considerable quantity of briquettes stacked on top of each other. This result ensures that they will not be disintegrate when arranged in boxes.

The briquettes, whose composition was 50-50, showed a high resistance to impact. They required several launches to show material detachment which was less than two percent. This composition would guarantee that in the event of accidental falls such as those that can occur in loading and transport processes, its integrity or shape will not be affected. As the binder content gets reduced, they become more brittle.

The 50-50 composition showed good abrasion resistance when rotated against sandpaper covered walls. Detached material was less than two percent, unlike compositions with less binder. In practice, this behaviour showed the fact that the contact between briquettes or the friction between them would not produce material losses when packed in boxes. It is not necessary to put cardboard or separation divisions inside, which would save costs for this concept.

These mechanical tests showed that RNP, contributes significantly to improve mechanical properties of briquettes based on coffee grounds. In addition to being a readily available material.

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