P. ISSN 2527-9629, E. ISSN 2548-8678
JOURNAL OF ENVIRONMENTAL ENGINEERING AND WASTE MANAGEMENT
In Collaboration With:
Managed by Environmental Engineering Undergraduate Program, School of Engineering, President University, Jl. Ki Hajar Dewantara, Kota Jababeka, Cikarang Baru, Bekasi 17550 – Indonesia

The Study of Making Biomass Briquettes from Spent Coffee Ground

Ramadhani FIthratullah[1,*]

[1]Environmental, Engineering, President University, Jababeka, 17530, Indonesia

Manuscript History

Received
31-05-2021
Revised
03-06-2021
Accepted
04-06-2022
Available online
30-04-2022

Keywords

Spent coffee;
Bio-briquets;
Carbonation;
Coffee

Abstract: Nowadays coffee becomes a culture in the community.this shifting from tea to the coffee is led by youngters that also can be seen in locally brand massive outlet grown, one of them is kopi Kenangan that broke MURI record. Rapid consumption means rapid waste, briquets is one of the tools to reducing the waste, but it need to be complied to the standard, the spent coffee ground is biomass that has the potencial as fuel if treated right. Then the result will find how close the potencial of the biomass from spent coffee ground to be use as fuel source. **Objectives:** The objective of this research is to know whether the Density, ash content and volatile of spent ground coffee briquets comply or not to the briquets Indonesia standard in Forestry Research and Development Agency 1994. **Method and results:** In this research spent coffee ground is used by fixed volume with the difference in coffee to tapioca to water ratio to find perfect balances. waste from local coffee shop taken to be treated into bio briquets then density, water content, and ash content is compared to briquets Indonesia standard in Forestry Research and Development Agency 1994 There are three treatments with variations on the amount of coffee where the volume of the briquets is kept the same. The volume is kept the same because the result is nearly mimicking one of the briquets design in Minister of Energy and Natural Resources Regulation No. 47 of 2006 the briquets from the spent coffee ground itself have passed the standard of density, ash content, and volatile matters Sample A has the best performance than others. **Conclusion:** Based on the results of the research using espresso spent coffee, it is very possible if it is processed in the right way, the most promising performance is in the composition of sample A but it does need to be improved.

* Corresponding author: author@domain.com

1 Introduction

Coffee is more than just a beverage nowadays, it becomes a culture in each region with many uniqueness in brewing and serving, but there are always common thing anywhere in the world, it is the spent coffee waste that already produced by the culture itself, from Ethiopian, Korean, Mexican, Turkish, Italian espresso, and other.[1]

In 2021 Indonesia itself was the fourth-largest coffee producer in the world after Colombia, Vietnam, and brazil at the top, coffee consumption in Indonesia was categorized low at 74.000 kg in the year 1998 but got increased to 288.360 kg in 2019 and increasing fast. This phenomenon is because of growing demand filled by a younger generation that switching from tea to coffee beverages and newfound locally produced coffee. The opportunity in coffee cultivation is very promising that Indonesia is the second largest that has a coffee plantation in the world at a total of 1.192.000 Hectare at the year 2018 that spread in 34 provinces in Indonesia at the year 2018 [2][3].

Peoples interest in coffee can also be marked by the emergence of modern coffee shops everywhere, starting in 2016 there were 1,083 outlet units and soared until 2019 to 2,937 outlet units [4]. Of the current coffee scene, “Kopi Kenangan” has 700 outlets which are recorded in the MURI record for "the fastest coffee shop growth in one year". The wave of transformation has made coffee customers become coffee lovers with the knowledge and ability to choose their specialty coffee. One of the most striking transformations is the use of an espresso machine. In addition, global coffee also flooded the Indonesian market such as Starbucks and coffee beans. In its final maturity, local coffee shops began to flood the market that had the knowledge to sell its single-origin with distinctive flavours in each shop. So the battle between coffee brewers increased dramatically [4].

However, the consumption rate is always having an impact on the waste generation of coffee include the coffee pulp, coffee silver skin, spent coffee ground, and coffee wastewater [5]. Spent coffee grounds are the waste product

from brewing coffee being accessible to customers as roasted beans, whole or ground, or indeed as instant/soluble coffee. Hence, beneath the “spent coffee grounds” term, one can incorporate those obtained from the soluble coffee industry as well as those created after brewing at cafeterias or at domestic. Approximately 0.91 g of the spent coffee grounds are created per 1 g of ground coffee, and almost two kilograms of wet spent coffee grounds are created for each kilogram of instant coffee made [5].

The chemical composition of coffee brews is dependent on the extractive effectiveness, which depends on different variables, including the coffee species, broiling degree, grinding grade, coffee/water proportion, water quality, temperature, pressure, and percolation time [5]. Subsequently, diverse extraction processes will lead to sensorial and chemically particular brews and, in this way, unmistakable spent coffee grounds [5]. In reality, industrial spent coffee constituents are much more successfully extracted [5].

In the research at PT Santos Jaya Abadi [6], only about 55% of the raw materials are turned into products, leaving about 45% of coffee grounds waste. They used the spent coffee waste as an additive to the conventional briquet process The mixture used is the tapioca is used 3% of the weight of coffee waste with a 1: 1 composition of adhesive and water [6].

The objective of this research is to know whether the Density, ash content and volatile of spent coffee ground briquets comply or not to the briquets Indonesia standard in Forestry Research and Development Agency 1994. about briquets fuels.

2 Method

2.1 Scope and Limitation

Scope:

1. The variables that were measured in this research are density, water content, ash content, volatile content, and fixed carbon.
2. The replication in this research is done by Duplo data.
3. Data analysis that uses is t-test; Two-sample assuming equals variances analysis.

Limitation:

1. Conducted in Bandung city from January 2021 until April 2021 that focuses on the recycling of spent coffee ground.
2. Fixed Dimension is used in terms of Briquets mold tools.
3. The experiment just uses only spent coffee ground, tapioca, and water as ingredients.
4. Spent coffee ground is taken from a local coffee shop.
5. The spent coffee ground comes from an espresso vending machine.
6. Spent coffee ground waste comes from arabica.

2.2 Research framework

The stage research had to be done in this experimental research below Figure 1.

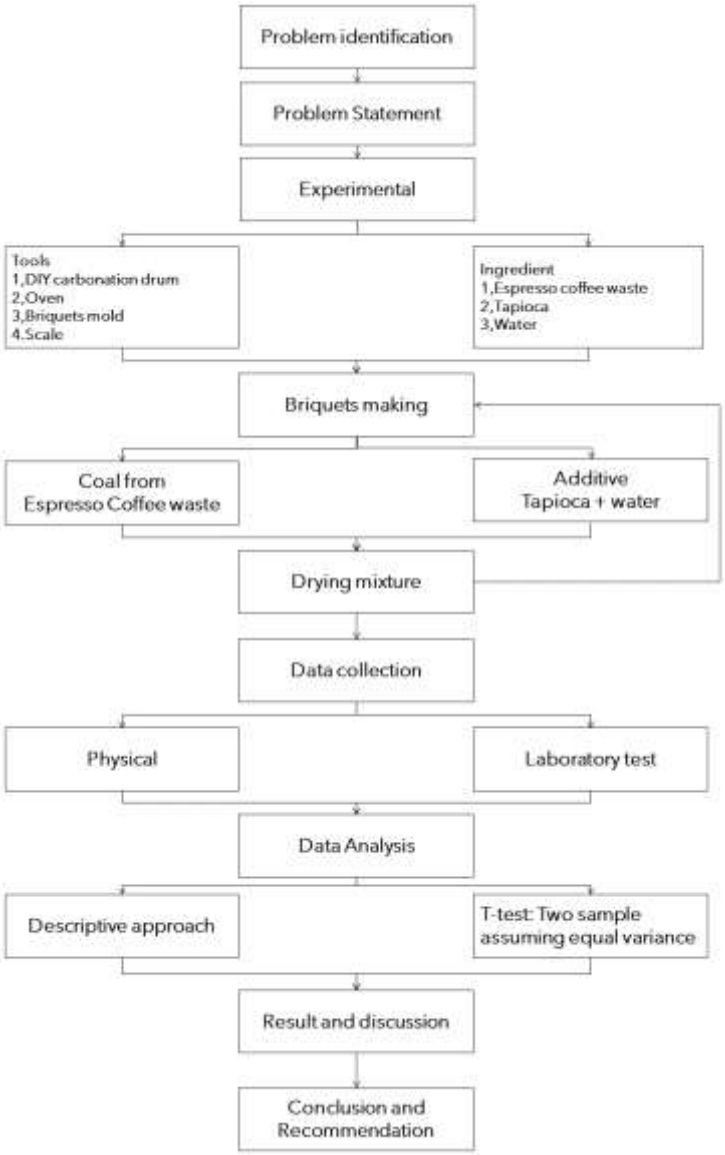

***Fig. 1**. Research framework*

2.3 Experimental method

The first step is to make a determination of the experimental method. There are three treatments with variations on the amount of coffee where the volume of the briquets is kept the same. The volume is kept the same because the result is

nearly mimicking one of the briquets design in Minister of Energy and Natural Resources Regulation No. 47 of 2006 briquets [7]. The amount of coffee is used because the estimated water content in coffee charcoal is around 7.62 % which is it has the potential to be used as a heat source if the treatment is right [6]. glue made tapioca by a minimum ratio of 3%-10% mass of the coffee waste that mixed with water than its mix with the carbonated spent coffee waste [6][8]. The experiment is uses 2 repetitive samples of each treatment.

Table 1. Composition of 3 different experimental treatment.

Sample	Desired Total Volume	Coffee (A)	Tapioca (B)	Water (C)	Total gram	Note
A	18 mm^3	9 g	4,5 g	4,5 g	18 g	Coffee to additive 1:1 and water to tapioca 1:1
B	18 mm^3	9 g	3 g	6 g	18 g	Coffee to additive 1:1 and water to tapioca 1:2
C	18 mm^3	6 g	4 g	8 g	18 g	Coffee to additive 1:2 and water to tapioca 1:2

The briquets are cast by using a compactor that has fixed volume, The design of the compactor itself will be correlating with the design of the briquets itself, in this case, briquets are designed to have 18 mm^3 or 38 mm x 26 mm x 1 mm [9]. So, the compactor will be designed as presented.

Fig. 2. Mould compactor

Collection of 1 kg Dry Coffee Waste is collected from a near coffee shop, then Tapioca also Water is prepared. Drying the coffee waste with temperature at 200-

^{o}C [10]. The carbonation Process is due by putting the coffee waste into the used paint cans that already holed to allow just a little oxygen to enter the cans, then cans put into Oven at 250^{o}C to be roasted while the can is rotated to ensure the spread of roasting process. The roasting process is stopped at 120 minutes [10]. The glue making process is start with scale the tapioca around 3%-10% of the coffee waste mass that mixed with water in 2:1 ratio with water then its stirred until has glue-like texture [8]. Then as considerate before the final composition of tested briquets is presented below.

Table 2.Compotition of briquets

Sample	Desired Total Volume	Coffee (A)	Tapioca (B)	Water (C)	Total gram
A	18 mm^3	9 g	4,5 g	4,5 g	18 g
B	18 mm^3	9 g	3 g	6 g	18 g
C	18 mm^3	6 g	4 g	8 g	18 g

Briquets then dried using indirect heat such as oven at 100^{o}C for around 1 Hour then dried again using direct sunlight and ambiance air until 1 x 24 hour.

2.3 Work procedure

2.3.1. Briquets Making

A. Preparation. Collection of 1 kg Dry Coffee Waste is collected from near coffee shop, then Tapioca also Water is prepared. Drying the coffee waste with Temperature at 100^{o}C because as we know water evaporate in this temperature range and because according to Setiawan at 30-200^{o}C the loss of mass in biomass is because the loss of water in it [10].

B. Carbonization Process. Carbonation Process is due by putting the coffee waste into the used paint cans that already holed to allow just little oxygen entering the cans, then cans put into Oven at 250^{o}C to be roasted while the can is rotated to ensure the spread of roasting process. The roasting process is stop at 120 minutes when all the coffee waste is already turn dark black, the temperature desired is around 200^{o}C until 400 ^{o}C where pyrolysis is occurred according to Setiawan [10].

C. Preparation of The Glue. The glue making process is start with scale the tapioca around 3%-10% of the coffee waste mass that mixed with water in 2:1 ratio with water then its stirred until has glue like texture [8].

D. Briquets molding. With desirable volume of briquets is 18 mm^3 and desired density is more or at least $^{1\ g}/_{mm^3}$ so the prepared charcoal will be A gram and B gram of tapioca that dilute with C grams of water that already mixed is poured into the simple compactor to be mold. [7]

Table 3. *Composition of Briquets*

Sample	Desired Total Volume	Coffee (A)	Tapioca (B)	Water (C)	Total gram
A	18 mm^3	9 g	4,5 g	4,5 g	18 g
B	18 mm^3	9 g	3 g	6 g	18 g
C	18 mm^3	6 g	4 g	8 g	18 g

E. Drying briquets brick. Briquets then dried using undirect heat such as oven at 100^{o}C around 1 Hours then dried again using direct sunlight and ambience air until 1 x 24 hour.

2.3.2. Briquets testing

Physic Test: ***A. Density.*** Jangka sorong, scale The measurement tool is prepared to measure the weight of the briquets, briquets volumes, and using equation (1) to find the density. [11].

$$\rho = {}^{m}/_{v} \quad (1)$$

Where: ρ = Density; m = mass; v = volume.

Chemical Test: ***A. Ash Content.*** Put the empty porcelain cup into the Oven at 105^{o} C within 30 minutes, then put to rest inside desiccator then measure the empty weight (A). put the sample around ±1 gram into the porcelain cup that already scaled before (B). put the porcelain cup that contain 1 gram of sample into the furnace at 600^{o} C around 4 hours, after that cup is take from the furnace to be cooled inside the desiccator about 2 hours then scaled until at least it has around 0.0005-gram deviation (C). then the result can be calculated using equation (3.4) [12][13].

$$Ash\ content(\%) = \frac{C-A}{B} x100\% \qquad (3.4)$$

B. Volatile Meter. Put the empty porcelain cup into the furnace at 105^{o} C within 1 hour, then put it to rest inside the desiccator for around 30 minutes then measure the empty weight (A gram). put the sample around ±1 gram into the porcelain cup that already scaled before (B gram). put the porcelain cup that contains 1 gram of sample into the furnace at 900^{o} C around 4 hours, after that cup is taken from the furnace to be cooled inside the desiccator for about 2 hours then scaled until at least it has around 0.0005-gram deviation (C). then the result can be calculated using equation (3.4) [14].

$$VM(\%) = \frac{B-C}{B-A} x100\% - Water\ content \qquad (3.5)$$

2.4 Data analysis Method

The result of Density, Ash content, and volatile matters will used descriptive research to explain the condition of Bio briquets. Processing primary data in the form of experimental with a laboratory measurement, then analyzed using statistics by using t-test analysis. The t-test determines the difference in the population mean value with the significant level is 0.05 (5% error rate and 95% confidence level) [15]. P One-tailed will be used on this study to determine the difference between groups in a specific direction [16]. The hypothesis to be tested in this research by using the t test is the minimum standard of Density, Ash

content, and Volatile matters for briquets Indonesia standard in Forestry Research and Development Agency 1994. It can be concluding the standard of density is 0.7 gr/cm^3, means the hypotheses are:

HO: μ density ≤ 0.7 gr/cm3, density does not comply to the standards significantly against briquets Indonesia standard in Forestry Research and Development Agency 1994.

Ha: μ density > 0.7 gr/cm3, density does comply with the standards significantly against briquets Indonesia standard in Forestry Research and Development Agency 1994.

Meanwhile, the minimum standard of Ash content on briquets Indonesia standard in Forestry Research and Development Agency 1994 is 8%, means the hypotheses are:

HO: μ x ≥ 8 %, Ash Content parameters do not comply with the standards significantly against the briquets Indonesia standard in Forestry Research and Development Agency 1994.

Ha: μ x < 8 %, Ash Content parameters do comply with the standards significantly against the briquets Indonesia standard in Forestry Research and Development Agency 1994.

Then, the minimum standard of Volatile matters on briquets Indonesia standard in Forestry Research and Development Agency 1994 is 30%, means the hypotheses are:

HO: μ x ≥ 30 %, Volatile Parameters does comply with the standards significantly against the briquets Indonesia standard in Forestry Research and Development Agency 1994.

Ha: μ x < 30 %, Volatile Parameters do not comply with the standards significantly against the briquets Indonesia standard in Forestry Research and Development Agency 1994.

Table 5*. Bio briquets standard in Forestry Research and Development Agency 1994*

No.	Properties	Briquets Quality Standard

1	Fixed carbon	> 60 %
2	Volatile meter	< 30 %
3	Ash content	< 8 %
4	Density	> 0.7 gr/cm^3
5	Water content	< 8 %

3 Results and Discussion

The briquette process is done to analyse the appropriateness of the uses of spent coffee waste to be a source of energy by comparing it to the briquets Indonesia standard in Forestry Research and Development Agency 1994, the quality test itself done by measuring the water content, ash content, Volatile matters, and fixed carbon as summarized in Table 6.

Table 6. Quality Test Summarized.

	Density		AC		VM	
	Sample	Average	Sample	Average (%)	Sample	Average (%)
A1	0,6625	0,6533	1,67%	1,68%	93,73%	93,99%
A2	0,6441		1,70%		94,25%	
B1	0,5819	0,5797	1,78%	1,78%	95,07%	95,01%
B2	0,5776		1,79%		94,95%	
C1	0,6105	0,6146	1,41%	1,35%	91,40%	91,76%
C2	0,6186		1,30%		92,13%	

The data showed that the average density is around 0.65 g in sample A, 0.58 g in sample B, and 0.61 g in sample C. the average water content is 4.9081% in sample A, 3.8544% in sample B, and 7.2711% in sample C. Ash content average in sample A is 1.6842%, B at 1.7842%, and C at 1.3542%. Volatile matters average in sample A is 93.9889%, B at 95.0114%, and C at 91.7645%. Then resulting in a Fixed carbon average at 0.5811% at A, 0.6500% at B, and C at 0.3898%. Then the test result then compared to the briquets Indonesia standard in Forestry Research and Development Agency 1994.

3.1 Discussion

A. Density. Briquets density is correlated with the capability to withstand its shape, that will also influence the energy inside the briquets, more dens it is more energy inside it, the longer burning and higher calorific value [17].

Density data can be seen that the A has the biggest density value than others, then sample C at second and sample B at third. If we look at Table 2. we can analyze the hypothesis of the phenomenon, as sample A has a composition of coffee waste to the additive ratio 1 to 1 with water to tapioca also 1 on 1, grams in detail coffee 9 g, tapioca 4.5 g, and water 4.5 gram. Then as we know the water is evaporated around 100-200^{o}C [10], then left the expected gram around tapioca and coffee waste. But in the making, sample A has the tendency to drop several charcoal powders, as the result of the additive is can't cover all the surface area of the charcoal powder that leads to losing the weight slowly and decreasing the quality.

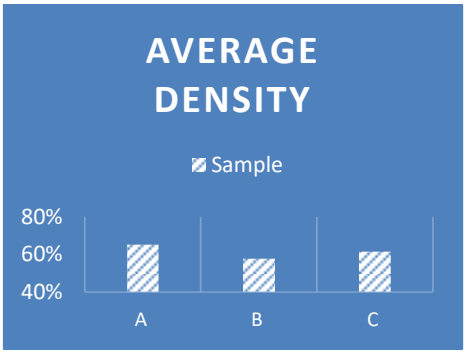

Fig. 3. Density averages.

Sample C is having charcoal to the additive ratio of 1 to 2 and tapioca to water is also 1 to 2, which resulting in good binding capability but has a lot of moisture that eventually will evaporate in the drying process. But as shown from data sample C gain a higher density than sample B because when cast the sample C is reshaping itself that reducing the high dimension over time until it stable or dried the sample c itself originally has a height of 20 mm but decreasing to 17 that leads to more dens value but in the actual practice it is very unstable.

Then Sample B when charcoal to additive is 1 to 1 but tapioca to water is 1 to 2 makes the briquets have the good binding capability that can be seen in the relatively little powder that drops over time and not too much moisture that resulting in good capability maintaining its shape.

Table 7. *Density T-test*

Density T test

t-Test: Two-Sample Assuming Equal Variances

Ho : miu ≥ 0,7

Ha : miu <0,7

	Sample A	*Sample B*	*Sample C*
Mean	0,653294074	0,579740772	0,579740772
Variance	0,000169329	8,93183E-06	8,93183E-06
Observations	2	2	2
Pooled Variance	8,46644E-05	4,46592E-06	4,46592E-06
Hypothesized Mean Difference	0	0	0
df	2	2	2
t Stat	-5,076	-56,90666667	-56,90666667
P(T<=t) one-tail	0,018344294	0,000154327	0,000154327
t Critical one-tail	2,91998558	2,91998558	2,91998558
P(T<=t) two-tail	0,036688587	0,000308654	0,000308654
t Critical two-tail	4,30265273	4,30265273	4,30265273

So, because p is less than alpha can be concluded Ho is rejected then Ha is accepted, which it can be said that the density result has complied with the bio-briquets standard of Indonesia in Forestry Research and Development Agency 1994. It also of good quality but the exact value does not pass the minimum value in standard.

B. Ash Content. Ash is left over from combustion bio briquets one of the constructing materials of ash is silica that will decrease the calorific value of the briquets [18]. The result of test showed in figure 4.

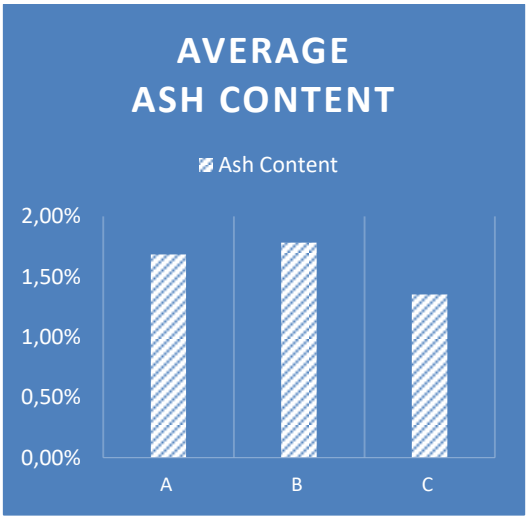

Fig. 4. Ash content averages.

B is the hugest value of ash content at 1,7842% then followed by sample A at 1,6842%, then C has the lowest ash content from all the samples at 1,3542%. Ash content is an inorganic residue in the form of minerals that do not disappear during the combustion process [19]. Coffee has high levels of organic matter which is easily bound during the combustion process and leaves ash as a residue. Ash has a negative effect on the calorific value, the smaller the ash value, the better the combustion. In addition to the elements contained in the coffee, the carbonation process and the length of coking affect the resulting ash content. [20].

Table 8*. Ash content T-Test.*

Ash content T test

t-Test: Two-Sample Assuming Equal Variances

Ho : miu ≥ 8%

Ha : miu < 8%

	Sample A	*Sample B*	*Sample C*
Mean	0,01684161	0,017841956	0,013541766
Variance	4,69967E-08	3,82561E-09	5,98338E-07
Observations	2	2	2
Pooled Variance	2,34983E-08	1,91281E-09	2,99169E-07
Hypothesized Mean Difference	0	0	0
df	2	2	2
t Stat	-412,0144795	-1421,221962	-121,5039728
P(T<=t) one-tail	2,94538E-06	2,4754E-07	3,38645E-05
t Critical one-tail	2,91998558	2,91998558	2,91998558

P(T<=t) two-tail	5,89076E-06	4,95081E-07	6,7729E-05
t Critical two-tail	4,30265273	4,30265273	4,30265273

Data analysis by using t-test: two sample assuming equal variances shown the P(T<=t) One-tail value is less than alpha (α = 0.05) in all samples So can be said that Ha is accepted that makes the samples does comply to the briquets standard of Indonesia in Forestry Research and Development Agency 1994. But the value itself has a good range which is less than 8 %.

C. Volatile matters. Volatile matters are formed from compounds that are decomposed from compounds other than water and are able to evaporate in briquets. Volatile matters affect the level of smoke produced during the combustion process which is caused by the content (CO) with alcohol derivatives.[21]. The content of volatile matters is influenced by the type of raw material used so that the selection of the type has a significant effect on the smoke produced by briquets. [22]. The test result from the sample is presented in figure 5.

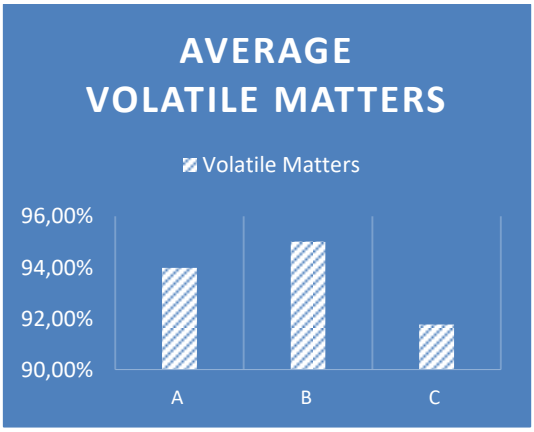

Fig. 5. Volatile matters averages.

The highest volatile matter was shown by sample C at 1.6298 then followed by B at 0.9772 and A at 0.7513. The level of volatile matters is influenced by the level of perfection in the carbonization process and the time in the charring

process.[21]. As explained in Chapter 3, where the sample and treatment carried out are the same, the amount of volatile presented is hypothesized because the coffee powder concentration varies because when mixed it is influenced by the composition of water and tapioca added.

***Table 9**. Volatile matters T-test.*

Volatile matters T test

t-Test: Two-Sample Assuming Equal Variances			Ho : miu ≥ 30% Ha : miu < 30%
	Sample A	*Sample B*	*Sample C*
Mean	0,939888965	0,95011406	0,917644705
Variance	1,36716E-05	7,80817E-07	2,62108E-05
Observations	2	2	2
Pooled Variance	6,83581E-06	3,90409E-07	1,31054E-05
Hypothesized Mean Difference	0	0	0
df	2	2	2
t Stat	244,7425499	1040,470616	170,6134467
P(T<=t) one-tail	8,34719E-06	4,61859E-07	1,7176E-05
t Critical one-tail	2,91998558	2,91998558	2,91998558
P(T<=t) two-tail	1,66944E-05	9,23719E-07	3,43519E-05
t Critical two-tail	4,30265273	4,30265273	4,30265273

So, because p is less than alpha can be concluded Ha is accepted, which it can be said that the result of the Volatile matter does comply with the bio-briquets standard of Indonesia in Forestry Research and Development Agency 1994. The exact value itself is more than the permittable percentage. But the exact number is over the maximum standard.

4 Conclusions

So, based on T-test results the briquets from the spent coffee ground itself have passed the standard of density, ash content, and volatile matters of Indonesia that stated in Forestry Research and Development Agency 1994. Sample A has the best performance than other with the result of passed all the standard variable with

best density result ,2nd place ash content result, and 2nd place volatile matters result. Based on the results of the research on raw materials using espresso spent coffee, it is very possible if it is processed in the right way, the most promising performance is in the composition of sample B but it does need to be improved. Based on practice of research and the result itself researcher suggest that the raw material preparation is done in longer period around 5 hours until 24 hours at 210 ^{o}C, then carbonation process is done at 350^{o}C until 400 ^{o}C to gain better result.

5 Acknowledgement

Thanks to the almighty God that led me to this phase of life and still guides me now and the next phase of life that will be more challenging. Thanks to my relative, Ambu, Abah, Kakang, dearest Elsa oktalia. Respected lectures especially my advisor mam Dr. Ir. Yunita Ismail M. Si, Galih bhara guseko and my beloved friend from elementary school until high College that encourages me in the hardest time. The researcher hopes the researcher will always find satisfaction in the learning process.

6 References

[1] "Coffee Culture Around the World: A Visual Guide," *Cruise1st Blog*, 2018. .

[2] BPS Indonesia, *Statistik Kopi Indonesia 2018*. Badan Pusat Statistik / BPS – Statistics Indonesia, 2005.

[3] "Indonesia: Coffee consumption TOTAL 2020," *Statistica*, 2021. [Online]. Available: https://www.statista.com/statistics/314982/indonesia-total-coffee-consumption/. [Accessed: 10-May-2021].

[4] Debora Laksmi Indraswari (Litbang Kompas), "Rajin Ngopi tapi Belum Rajin Genjot Produksi," *Tutur Visual*, 2021. [Online]. Available: https://interaktif.kompas.id/baca/rajin-ngopi/. [Accessed: 10-May-2021].

[5] L. Blinová, M. Sirotiak, A. Bartošová, and M. Soldán, "Faculty of Materials Science and Technology in Trnava Review : Utilization of Waste From Coffee Production,"

Res. Pap., vol. 25, no. 40, pp. 91–102, 2017.

[6] Dwi Khusna and J. Susanto, "Pemanfaata Limbah Padat Kopi Sebagai Bahan Bakar Alternatif Dalam Bentuk Briket Berbasis Biomass (Studi Kasus di PT. Santos Jaya Abadi Instan Coffee)," *Semin. Nas. Sains dan Teknol. Terap. III 2015, Inst. Teknol. Adhi Tama Surabaya*, pp. 247–260, 2015.

[7] L. Vinet and A. Zhedanov, "PEMBUATAN PELET DARI SERBUK LIMBAH KAYU MENGGUNAKAN ALAT PENGEMPA DAN CETAK SEDERHANA," *J. Phys. A Math. Theor.*, vol. 44, no. 8, p. 2019, 2011, doi: 10.1088/1751-8113/44/8/085201.

[8] E. U. A. Alpian, Raynold Panjaitan, Adi Jaya, Yanciluk, Wahyu upriyati, "document.pdf," *Agri Peat*, vol. 7, 2020.

[9] Menteri Energi Dan Sumber Daya Nineral, "Memtem energi dam sumber daya," INDONESIA, 047, 2006.

[10] B. Setiawan, D. A. Himawanto, E. P. Budiana, and P. Joko, "Analisa thermograbimetric pada Limbah pertanian," *J. Penelit. dan Pengabdi. Masy.*, vol. 4, pp. 49–56, 2016.

[11] nugrahani primary Putri and suprapto nadi, *Buku Panduam Praktikum Dasar 1*. 2019.

[12] Mirnawati, "PENGARUH KONSENTRASI PEREKAT GETAH PINUS TERHADAP NILAI KALOR PEMBAKARAN PADA BIOBRIKET SEKAM PADI DENGAN TEMPURUNG KELAPA," UIN Alauddin Makassar, 2012.

[13] Badan Standarisasi Nasional, "Metode Pengujian Kadar Air Agregat. SNI 03–1971–1990," *Badan Standarisasi Nas. Jakarta*, 1990.

[14] Fitria, "Penyusunan standar operasional prosedur (SOP) analisa kimia proksimat batubara," *J. Chem. Inf. Model.*, vol. 53, no. 9, pp. 1689–1699, 2013.

[15] "T Test (Student's T-Test): Definition and Examples," *Statistics How To*. [Online]. Available: https://www.statisticshowto.datasciencecentral.com/probability-and-statistics/t-test/. [Accessed: 25-May-2021].

[16] C. Rica and E. Salvador, "Consumo Mundial de Café," *Int. Coffe Organ.*, vol. febrary, p. 2019, 2021.

[17] E. SINURAT, "STUDI PEMANFAATAN BRIKET KULIT JAMBU METE DAN TONGKOL JAGUNG SEBAGAI BAHAN BAKAR ALTERNATIF," Universitas Hasanuddin, 2011.

[18] A. Masturin, "Sifat Fisik Dan Kimia Dari Campuran Arang Limbah Gergajian Kayu,"

Institute Pertanian Bogor, 2002.

[19] S. Artati, Wahyu Kusuma and R. D. Noriyanti, "Kajian eksperimental terhadap karakteristik pembakaran briket limbah ampas kopi instan dan kulit kopi," *J. Tek. POMITS*, pp. 1–6, 2012.

[20] Sudrajat, "Penelitian Pembuatan Briket Arang dari Batang dan Tempurung Kelapa," *Lokakarya Energi Nas.*, 1985.

[21] A. Triono, "Karakteristik Briket Arang Dari Campuran Serbuk gergajian Kayu Afrika Dan Sengon Dengan Penambahan Tempurung Kelapa," Institut Pertanian Bogor, 2006.

[22] Y. H. Lucky Budiawan, Bambang Susilo, "Pembuatan Dan Karakterisasi Briket Bioarang Dengan Variasi Komposisi Kulit Kopi," *PEMBUATAN DAN KARAKTERISASI Briket BIOARANG DENGAN VARIASI KOMPOSISI KULIT KOPI. J. Bioproses Komod. Trop. Vol. 2, No. 2. 2014. Hal 152-160.*, vol. 2, no. 2, pp. 152–160, 2014.