CHEMICAL ENGINEERING TRANSACTIONS

VOL. 92, 2022

A publication of AIDIC

The Italian Association
of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Rubens Maciel Filho, Eliseo Ranzi, Leonardo Tognotti

ISBN 978-88-95608-90-7; **ISSN** 2283-9216

DOI: 10.3303/CET2292033

Production of Ecological Briquettes from Avocado Pit Waste as Biofuel

Diana C. Fanárraga Lukuy, Rosaura J. Jihuallanca Sánchez, Carlos A. Castañeda-Olivera*, Eusterio H. Acosta Suasnabar

Universidad César Vallejo, Campus Los Olivos, Lima, Perú
caralcaso@gmail.com

Most countries in the world depend on energy, and it is suggested that it be generated from renewable sources that do not have a negative impact on the environment. The avocado pit is a residue that originates from the consumption of avocado pulp and can be used as biomass due to its potential calorific value. Thus, this research developed ecological briquettes from avocado pit waste as biofuel. The briquettes were made from a mixture of avocado pit, sawdust and cassava binder in different proportions. The briquettes were cylindrical in shape, 7 cm long and 5 cm in diameter, and their calorific value, combustion time, humidity, ash content and amount of CO_2 emissions were evaluated. The results indicated that the best proportion for obtaining the ecological briquette was 70 g of avocado pit, 20 g of sawdust and 30 g of binder diluted in 120 ml of water. In addition, the briquettes showed reductions in CO_2 emissions and high calorific value. Finally, it is concluded that the ecological briquettes are a great alternative as biofuel and could be used as a source of energy for different domestic cooking activities in rural areas and recreational and leisure centers, benefiting the environment.

1. Introduction

Globally, fossil fuels are an authoritative source of energy because they have become a basic human need. Among the various countries of southern Africa, more than 50% of the charcoal produced in the world is consumed, and is used interchangeably in homes and industries (Cuvilas et al., 2010). In addition, the use of charcoal today has steadily increased, leading to an increase in carbon emissions in the form of CO_2 (Power, 2009). Therefore, there is an incentive to employ renewable energy sources such as the use of biomasses that absorb carbon dioxide (CO_2) during their growth and emit it in their combustion, so it is considered to have a zero greenhouse effect (Roni et al., 2017).

Biomass is a renewable energy source because its energy content comes from solar energy stored during the process of photosynthesis (EPEC, 2018). In addition, plant biomass has been used as a primary fuel, and due to the depletion of fossil fuels it constitutes a sustainable alternative (Callejon et al., 2009). Many researches used natural sources of energy, as is the case of bituminous coal to produce ecological briquettes, obtaining as a result of combustion, that the ash contains 1.3 % of unburned carbon with an efficiency of 81 % and 3 mg/m^3 of gas particles were emitted in smoke (Deniz ,2016). Barranco et al. (2016) produced eco-friendly briquettes from corn stover and cassava bioagglomerate, and their product recorded 50% less CO_2 emissions compared to that produced from firewood or wood chips. Similarly, Babajide et al. (2018) studied the physical and combustion characteristics of ecological briquettes made from agricultural waste and wood residues, being more environmentally attractive as it contributes to the reduction of CO_2 concentrations.

Researchers from the University of Cordoba together with engineers from the University of Almeria emphasize that avocado pits, almond shells and olive pits can be used as a source of biomass by virtue of their calorific value and thermal energy (Juarez et al., 2019). The avocado pit is the seed or residue generated when avocado is consumed, and is a potential source of fiber used for other vegetable by-products (Juarez et al., 2019).

In Peru, the use of charcoal plays an important role in the energy picture, mainly in domestic food preparation (Salo et al., 2011). Therefore, the present research aimed to elaborate ecological briquettes from avocado pits to reduce CO2 emissions.

Paper Received: 8 December 2021; Revised: 30 March 2022; Accepted: 17 April 2022
Please cite this article as: Fanarraga Lukuy D.C., Jihuallanca Sanchez R.J., Castaneda-Olivera C.A., Acosta Suasnabar E., 2022, Production of Ecological Briquettes from Avocado Pit Waste as Biofuel, Chemical Engineering Transactions, 92, 193-198 DOI:10.3303/CET2292033

2. Methodology

2.1 Raw material and components

The avocado pits were collected from the company Agroindustrias AIB S.A. located in the province of Chincha in Ica, Peru. This company is dedicated to the production and export of avocado pulp in a frozen state, generating large quantities of avocado pit waste.
To determine the percentage of the components, the total mass of the avocado, the mass of the avocado peel, the mass of the avocado pit and the avocado pulp were weighed (see Figure 1).

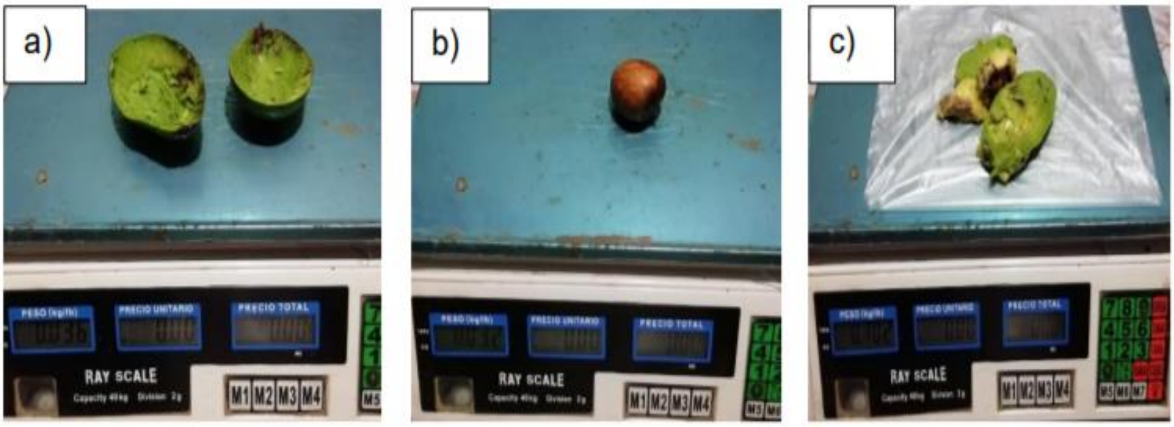

Figure 1: Weighing of avocado components: a) Mass of avocado peel, b) Mass of avocado pit and c) Mass of avocado pulp

2.2 Biomass preparation and characterization

The biomass used was the avocado pit. Vivero et al (2019) indicate that avocado pit is rich in potassium and antioxidants due to its high concentration of phenolic compounds.
To obtain the biomass, the avocado pits were previously washed before grinding. Subsequently, the biomass was air-dried (28 ºC) for 5 days, and then stored for later use.
The humidity and density of the biomass obtained from the avocado pit were analyzed. These parameters were evaluated to determine the water content of the biomass to be processed and to identify its variation in the production of ecological briquettes.

2.3 Elaboration and characterization of the ecological briquettes

The components that accompanied the avocado kernel biomass in the production of briquettes were sawdust and cassava binder as an additive. Sawdust (<1 mm) was obtained from different woods, mainly *Swietenia macrophylla* (mahogany) and *Aspidosperma polyneuron* (acerillo). Serret et al (2016) mention that sawdust is a component that has a calorific value of 17.86 MJ/kg. Regarding natural cassava starch of 87 % purity, this was obtained commercially from the supply markets located in the province of Chincha in Ica, Peru.
Briquettes were made in three different compositions: composition 1 (50 g avocado pit, 20 g sawdust, 20 g cassava starch and 60 ml water), composition 2 (60 g avocado pit, 20 g sawdust, 25 g cassava starch and 80 ml water) and composition 3 (70 g avocado pit, 20 g sawdust, 30 g cassava starch and 100 ml water). For this purpose, each composition was poured into a vessel and heated over low heat for 1 minute. Subsequently, the avocado pit and sawdust were added. Finally, the mixture was placed in PVC molds (7 cm long and 5 cm in diameter) and compacted using a manual briquette press (Figure 2-a). The briquette (Figure 2-b) obtained was air-dried for approximately 4 days.

Figure 2: Production of ecological briquettes: a) Manual briquetting press and b) Ecological briquettes

The ecological briquettes were evaluated for chemical parameters such as:

- Calorific value: It was performed by ASTM-D5865 Standard, using the calorimeter with an oxygen pump under specific conditions (Lyon, 2015).
- Burning time: It was determined using a digital timer.
- Moisture content: It was performed through gravimetric analysis according to ASTM- D7582 Standard.
- Ash content: The amount of ash was measured by gravimetric analysis according to ASTM- D7582 Standard.

On the other hand, to determine the amount of CO_2 emissions and the emission temperature, the ecological briquettes and traditional charcoal were subjected to incineration in a stove and the gases were measured using the Yowexa YEM-40L instrument (Arastirma, 2020).

3. Results

3.1 Avocado components

Table 1 shows the mass quantities of the components for a 170 g sample of avocado.

Table 1: Mass and percentage by mass of the components of a 170 g sample of avocado

N° samples	Total avocado mass	Avocado pulp mass	Avocado peel mass	Avocado pit mass
1	170 g (100%)	102 g (60%)	36 g (21%)	32 g (19%)

The avocado pulp and peel account for 60 % and 21 % of the total avocado mass, respectively. Meanwhile, the avocado pit occupies 19%, which is considered waste and was used in the production of ecological briquettes.

3.2 Biomass analysis

The biomass analysis performed at 23 ºC and 50 % relative humidity is shown in Table 2.

Table 2: Chemical analysis of biomass

Sample	Parameter	Method use	Results	Units
Avocado pit (100 g)	Humidity	Gravimetry	14.7	%
	Density	Internal	0.88	g/cm3

From Table 2 it is observed that the biomass used in the production of briquettes contains a low moisture content of 14.7%; therefore, the ignition of the biomass is slow. In addition, it contains a bulk density of 0.88 g/cc showing that it will have good adhesion with the other components.

3.3 Chemical characteristics of the ecological briquettes

Table 3 shows the results of the analysed parameters of the ecological briquettes.

Table 3: Chemical characteristics of the ecological briquettes

N° Composition	Humidity (%)	Calorific value (kJ/kg)	Combustion time (min)	Ash (%)
Composition 1	13.98	12,773.67	104	1.73
Composition 2	9.85	13,327.65	107	1.96
Composition 3	8.75	13,358.08	106	1.5

From Table 3 it could be observed that the briquettes obtained with composition 3 (70 g of avocado pit, 20 g of sawdust and 30 g of cassava starch as binder) presented the best characteristics such as moisture content, high calorific value, high combustion time and low percentage of ash.

The results of the analysis of CO2 emissions and T° of emission of the ecological briquettes and traditional charcoal are shown in Table 4.

Table 4: Chemical parameters of ecological briquettes

Fuel type	CO_2 (ppm x 0.285 kg of fuel)	T° emission (°C)
Avocado pit briquette	480	21.7
Traditional coal	1,432	22.7

From Table 4 it was possible to distinguish that the traditional coal had higher CO_2 emissions with 1432 ppm, unlike the avocado pit briquette of composition 3 (70 g avocado pit, 20 g sawdust and 30 g cassava starch) which emitted 480 ppm of CO_2 because the biomass releases the carbon dioxide it absorbs from the plants, generating a null effect. It was also observed that the traditional charcoal caused an increase in the ambient temperature (21°C) to a value of 22.7°C, while the briquette made from avocado pits reached a temperature of 21.7°C. Thus, it can be said that the ecological briquette generates a minimum temperature variation during combustion.

4. Discussion

This research used avocado residues for the production of ecological briquettes, obtaining as a result an environmentally friendly product, since these generate less CO2 emissions than traditional charcoal. These results are related to those reported by Afsal et al. (2020), who made ecological briquettes from vegetable waste and sawdust, indicating that the conversion of biomass into briquettes can be one of the best solutions to reuse a waste that helps reduce environmental pollution.

Concerning the evaluation of the chemical characteristics of ecological briquettes, Tábares et al. (2006) indicated that forest residue briquettes that are used efficiently and rationally should be characterized physically and chemically. Avocado pit biomass had a moisture content of 14.7 %, a value considered acceptable. Singh (2004) and Ujjnapa & Srrepathi (2018) who used cotton stalk and tamarind peel as biomass to make eco-friendly briquettes, obtained humidity values of 14.5 and 11.61 %, respectively. The authors indicated that the humidity content in biomasses should be less than 25 % to be of good quality.

In the research developed by Gendek et al. (2018), who made briquettes from 3 coniferous tree species achieved humidity values of 20 %, mainly due to the excess water used in the briquette making process. Also,

the calorific value of the ecological avocado pit briquettes was analyzed, obtaining a value of 13,358.08 kJ/kg. In contrast, in the research of Ajimotokan et al. (2019) and Chou et al. (2019) obtained a calorific value of 18,400 kJ/kg and 17,9 MJ/kg in briquettes made from rice straw with wheat bran and cassava husk, respectively.
The evaluation of the percentage of ash in the ecological briquettes followed the ASTM-D7582 Standard, obtaining a value of 1.5 %. These results agreed with Brunerova et al. (2020), who obtained values of 0.97% ash content in briquettes made from rice husks. Shiferaw et al. (2017) and Magnago et al. (2020) followed the procedure based on ASTM-D3174 to analyze the ash percentage in briquette made from wood waste, citrus peel and rice husk, obtaining values of 4.67 and 4.9%, due to the fact that the biomasses used contained a high humidity value.

5. Conclusions

The production of ecological briquettes from avocado pits was feasible because they emit less CO_2 during combustion, being an alternative to traditional charcoal. Likewise, composition 3 (70 g avocado pit, 20 g sawdust, 30 g starch and 100 ml of water) is the best composition for making ecological briquettes (7 cm long x 5 cm in diameter) from avocado pit because it contained less moisture, higher calorific value and generated a low percentage of ash compared to composition 1 (50 g avocado pit, 20 g sawdust, 20 g starch and 60 ml water) and composition 2 (60 g avocado pit, 20 g sawdust, 25 g starch and 80 ml water). On the other hand, the ecological briquettes made from avocado pits emitted 480 ppm of CO_2 as opposed to traditional charcoal, which emitted 1432 ppm of CO_2, demonstrating that these briquettes are environmentally friendly.

Acknowledgments

The authors would like to thank "Investiga UCV" of the Universidad César Vallejo for financial support for the publication of this research.

References

Afsal A.R., David B.V., Muhammed S.N., Parvathy U., Rakhi R., 2020, Experimental investigations on combustión characteristics of fuel briquettes made from vegetable market waste and saw dust, Materials today: Proceedings, 33 (7), 3826-3831.
Ajimotokan H., Ehindero A., Ajao K., Adeleke A., Ikubanni P., Shuaib- Babata Y., 2019, Combustion characteristics of Fuel Briquettes made from Charcoal Particles and Sawdust Agglomerates, Scientific African, 6.
Arastirma M., 2020, Environmental impact of bio- briquettes produced from agricultural residues concerning to CO2 emissions, Mustafa kemal university journal of agricultural sciences, 25(2), 217-224.
Babajide F.V., Oluwaseyi O. A., Rivi D. N., 2018, Performance evaluation of the physical and combustion properties of briquettes produced from Ago- wastes and wood residues, Recycling, 3 (3).
Barranco C., Mendoza J., 2016, Elaboración de biocombustibles sólidos densificados a partir de tusa de maíz, bio aglomerantes de yuca y carbón mineral del departamento de Córdoba, Ingeniería, 25 (4), 643-653.
Brunerova A, Roubik H, Brozck M, Van Dung D, Phung L, Hasanudin U, 2020, Briquetting of sugarcane bagasse as a proper waste management technology in Vietman. Waste Management & Research.
Callejon F.A., López J., 2009, Briquettes of plant remains from the greenhouses of Almería (Spain), 7, (3).
Chou C., Lin S., Lu W., 2009, Preparation and characterization of solid biomass fuel made from rice Straw and rice bran, 90.
Cuvilas C.A., Jirjis R., Lucas C., 2010, Energy situation in Mozambique: A review, 14 (7), 2139- 2146.
Deniz V. A., 2016, new binder in production of water- resistant briquettes from bituminous coals: Co- polymer binder, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 38(8), 1068-1074.
EPEC, 2018, Energía renovable: la biomasa, 4, (1).
Gendek A., Aniszewska M., Malaták J., Velebil J., 2018, Evaluation of selected physical and mechanical properties from cones of three coniferous tree species. Biomass and Bioenergy, 117(3), 173-179.
Juarez J., Guerrero J., Zamora J., Elizalde J., Bautista M., Bojórquez E., Ruíz E., 2021, Tissue-specific proteome characterization of avocado seed during postharvest helf life, Journal of Proteomics, 235,104-112.
Krizan P., Soos L., Vukelic D., 2009, A study of impact technological parametres on the briquetting process, 16, (3).
Lyon R., 2015, Thermal dynamics of bomb calorimeters, Review of scientific instruments, 8 (12), 125103.
Magnano F. R., Costa C. S., Ezirio M. J., Saciloto V., Parma G. O., Gasparotto E. S., Goncalves A. C., Tutida A. Y., Barcelos R. L.,2020, Briquettes of citrus peel and rice husk, Journal of Cleaner Production, 276, 123820.
Power P. G., 2009, El calentamiento global y las emisiones de carbono, Ingeniería Industrial, 4(27), 101- 122.

Roni M., Chowdhury S., Mamun S., Marufuzzaman M., Lein W., Johnson S., 2017, Biomass co-firing technology with policies, challenges, and opportunities: A global Review. Renewable and Sustainable energy reviews, 78, 1089-1101.

Salo M. H., Toivonen T., 2011, Allocating logging rights in Peruvian Amazonia- Does it Maller to be local, Plos One, 6 (5), E19704.

Serret G. N., Giralt O. G., Quintero R. M., 2016, Caracterización de aserrín de diferentes maderas, Tecnología química, 36 (3), 395-405.

Shiferaw Y, Tedla A, Melese C, Mengistu A, Debay B, Selamawi Y, Merene E, Awoi N, 2017, Preparation and evaluation of clean briquettes from disposed wood wastes, Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 39(20), 2015-2024.

Singh. E., 2004, Equilibrium moisture content of biomass briquettes. Biomass and Bioenergy, 26(3), 251-253.

Tabarés J., Ortiz L., Viar F., 2000 Feasibility study of energy use for densificated lignocellulosic material (briquettes), 79(10), 1229-1237.

Ujjnappa, S., Sreepathil, L., K., 2018, Production and quality testing of fuel briquettes made from pongamia and tamarind shell, Sadhana, 43(4).

Vivero A, Valenzuela R, Valenzuela, A, Morales G, 2019, Bioactive compounds and potential health benefits of avocado, 46(4), 491-498.