The Chemical Properties and the Combustion Duration of Fuel Briquettes from Corn Kernel Residues, Thailand

Arunpak Pitakpong[a]

[a] School of Public Health, University of Phayao
Email:[a]aompitakpong@gmail.com

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

Abstract: This research was studied the feasibility of using corn kernel residues from the plants to manufacture the frozen sweet corn to make the fuel briquettes. The initial stage of the research was the analysis of the chemical properties of corn kernel residues. It found that had the moisture content of 0.00%, volatile matter content of 79.03%, ash content of 2.30%, fixed carbon content of 54.28%, and heating value of 4217.1 calories per gram, had properties that could be used to make the fuel. Then, mixed the corn kernel residues with emulsifiers such as cassava starch at the ratio of 10:0:1, 10:1:1, and 12:1:1 and then compressed the briquettes. The compressed briquettes were obtained to test the chemical properties and the combustion such as heating value, moisture content, volatile matter content, fixed carbon content, ash content, and the combustion duration. The results of this research found that the compression of the corn kernel residues at the ratio of 10:1:1 is the most suitable proportion due to easy compression, high strength, and low ignition time. It had the moisture content of 0.00%, volatile matter content of 75.05%, ash content of 1.41%, fixed carbon content of 54.77% heating value of 3923.2 calories per gram, and the combustion duration of 111.67 minutes.

Keywords: Fuel Briquettes, Corn Kernels, Residues, Chemical Properties, Combustion Duration

1. Introduction

Nowadays, the research finding on alternative energy is currently an interesting issue [1, 6]. Important factors are the cheap, sufficient, sustainable energy and easily procured fuel in the locality, including the method without complications to apply it [2, 5]. One source of the better alternative energy is renewable energy from bio-briquettes [3, 4, 5]. It is saving and slowing down to use fossil fuels, reducing the climate change by a result of the increase of carbon dioxide in the atmosphere [2, 3, 5, 8, 11], reducing the impact of increasingly biomass dumping that affecting the economic, social and environmental balance [2, 5, 12, 13]. The benefits of reusing biomass are beneficial to rural and industrial sectors, either directly and indirectly [3, 5, 12]. All results are useful in the national and global levels [2, 8, 12].

Thailand has currently to be popular to use biomass as renewable energy widely. Since, Thailand is an agricultural country which has the abundant variety of the agricultural productivity that can be used in the form of the biomass energy (8, 9) such as firewood, rice hulls, bagasse, manure, straw, agricultural residues, wastes from agrarian processing plants, others [3, 6, 7, 12]. These raw materials will be used as the fuel in the direct combustion process and then utilized heat for electricity production or biogas production by biochemical reaction process using microbial activity [9, 11]. In the past, most of the biomasses were left to organic fertilizer within the cultivation area. The farmers sometimes eliminated them by incineration, which results in pollution to the environment [10]. In fact, all biomasses are quality fuel and provide heating energy levels that can be utilized [11, 12]. Due to the recession of energy sources, therefore, searching for alternative energy sources with potential and sufficient quantity is as important [14, 15].

Chiangrai Frozen Foods Company Limited is the industrial factory (about frozen sweet corn) in Thailand. This factory has a problem with some of the corn kernels. They were trapped by a sieve and a machine to separate the kernels from the water; nevertheless, the poor quality of corn kernels mixed with wastewater through downstream of the production line. Many corn kernels have been separated. Some corn kernels were sold to farmers for animal feed, and some parts were left and unused, resulting in spoilage and bad smell. Therefore, if there is management of agricultural residues from corn, that will also reduce the problem. Thus, the management of agricultural residues from the processing found that it can be extruded to fuel rods, which reduce the number of useless corn residues as waste. From the mentioned importance and problems, therefore, the author conducted to study the residue of corn kernels as fuel briquettes with the case study in Chiangrai Frozen Foods Company Limited, to apply knowledge and results of research to solve problems in the management of corn kernels for the factory.

2. Research Objectives

The objectives of this research was the feasibility of using corn kernel residues from the plants to manufacture the frozen sweet corn to make the fuel briquettes.

3. Research Methods

This research was the experimental research that experimented with making the fuel briquettes (16) with the residue of corn kernels from Chiangrai Frozen Foods Company Limited's processing. The analysis was to study the properties of fuel briquettes on both parts (chemical [17] and combustion properties [17, 18], and to study the most suitable emulsifier proportion (cassava starch) of fuel briquettes [19] from the corn kernels.

3.1 Sampling Method

A sampling of sample group was used to make fuel briquettes that were sweet corn kernels by purposive sampling [20], to select the poor quality of corn kernels remaining from the processing.

3.2 Fuel Briquettes

Mixed 10 kilograms of the corn kernels residues from the processing with the emulsifier (water of cassava starch by preparing starch and water at the ratio of 1 kilogram of starch per 1 liter of water) [5, 21, 22, 24], then compressed the briquettes as fuel rods using steel pipes (diameter of approximately 5 centimeters), and then compressed the rod fuel briquettes to a length of approximately 20 centimeters as a cylindrical fuel. Finally, the fuel briquettes were dried in the sun to reduce humidity and the fuel to be hard and combinable for 5-10 days [23, 26].

3.3 Analysis of the Chemical Properties of Corn Kernels

Laboratory analyses of chemical properties by the Environmental Center, Suan Dusit University were as follows: moisture content, ash content, volatile matter content, fixed carbon content, and calorific or heating value of corn kernels [27].

3.4 Analysis of the Chemical Properties of Fuel Briquettes from the Corn Kernels.

Laboratory analyses of Thai Industrial standard Institute (TISI) by the Environmental Center, Suan Dusit University were as follows: moisture content, ash content, volatile matter content, fixed carbon content, and heating value according to the American Society for Testing and Materials (ASTM) method [5, 18, 25, 26].

3.5 Analysis of Combustion Properties of Fuel Briquettes from the Corn Kernels (Determination of the Combustion Duration).

The fuel briquettes were ignited in a brazier using approximately 20 milliliters of 95% ethyl alcohol per ignitable time. Then, turned on the fan to blow into the ventilator of the brazier as the actual combustion state, and counted with the timer when the fuel briquettes began to burn until the fuel briquettes burned up completely [26, 28].

3.6 Processing

To compare the chemical properties of the fuel briquettes from the corn kernel with the TISI [24, 29, 31], and compare the emulsifier proportion of fuel briquettes from the corn kernels [29].

4. Results

Results of the Analysis of the Chemical Properties from the Corn Kernel

The chemical properties of the corn kernels were analyzed, found that the moisture content had 0.00%, the ash content had 2.30%, the volatile matter content had 79.03%, and the fixed carbon content had 54.28%. Moreover, the analysis of corn kernel had the heating value of 4217.1 calories per gram (Table 1).

4.1 Results of the Analysis of the Chemical Properties of Fuel Briquettes from the Corn Kernels.

The chemical properties and the combustion duration of fuel briquettes with the residue of corn kernels from Chiangrai Frozen Foods Company Limited's processing which the laboratory experiments (Table 2) were as follows:

4.2 Moisture Content

The analysis of the chemical properties of fuel briquettes from the corn kernels found that the fuel briquettes from the corn kernels had the moisture content of 0.00%. The TISI had given the moisture content standard no more than 8%. This moisture content was within the mentioned standard.

4.3 Ash Content

The analysis of the chemical properties of fuel briquettes from the corn kernels found that the fuel briquettes from the corn kernels had the ash content of 1.41%. The TISI had given the ash content standard no more than 8%. This ash content was within the mentioned standard.

4.4 Volatile Matter Content

The analysis of the chemical properties of fuel briquettes from the corn kernels found that the fuel briquettes from the corn kernels had the volatile matter content of 75.05% which the TISI had given the volatile matter content standard no more than 25%. The volatile matter content was higher than the TISI standard because the fuel bio-briquettes from the corn kernels in this research were the green fuel that had not been through the carbonization process.

4.5 Fixed Carbon Content

The analysis of the chemical properties of fuel briquettes from the corn kernels found that the fuel briquettes from the corn kernels had a fixed carbon content of 54.77%. The TISI had given the fixed carbon content standard no less than 75%. This fixed carbon content was below the TISI standard.

4.6 Heating value

The analysis of the chemical properties of fuel briquettes from the corn kernels found that the fuel briquettes from the corn kernels had a heating value of 3923.2 cal/g which the TISI had given the heating value standard no less than 5,000 cal/g. This heating value was below the TISI standard.

4.7 Combustion Duration

The analysis of emulsifier proportion (cassava starch) at the ratio of 10: 1: 1 had the combustion duration of 111.67 minutes.

Table 1. Results of the analysis of the chemical properties from the corn kernels.

The chemical properties of the corn kernels				
Moisture content	Ash content	Volatile matter content	Fixed carbon content	Heating value
0.00%	2.30%	79.03%	54.28%	4217.1 cal/g

Table 2. Results of the analysis of the chemical properties of fuel briquettes from the corn kernels.

The chemical properties of fuel briquettes from the corn kernels				
Moisture content	Ash content	Volatile matter content	Fixed carbon content	Heating value
0.00%	1.41%	75.05%	54.77%	3923.2 cal/g

5. Discussions

The author had experimented with producing the fuel briquettes from the corn kernels using cassava starch as an emulsifier with three different ratios. The proportion of fuel briquettes from the corn kernels was the ratio of 10 kg of corn kernels: 1 kg of cassava starch: 1 liter of water. It was the most suitable proportion for the production of the fuel briquettes from the corn kernels due to it was an easy compression, high strength, and time use of low ignition, same as the research of Sriket et al., 2019. They had studied improving fuel potential of para rubber wood bottom ash as charcoal briquette with co-extruded materials using the mixture of 10 kg of extruded materials: 1 kg of tapioca starch: 1 L of water. The use of tapioca starch as a binder provided the best quality [24]. However, this research had also experimented with two different proportions of the fuel briquettes; nevertheless, they failed. That was the fuel briquette experiment with 10 kg of corn kernels: 0 kg of cassava starch: 1 liter of water found that it could not be molded as a fuel rod. Another experiment was the fuel briquette with 12 kg of corn kernels: 1 kg of cassava starch: 1 liter of water found that it could be molded as a fuel rod, but it is not stable and fragile briquettes same as the research of Tuates et al., 2016. They had designed the charcoal rice hulls and corn cobs as raw materials in the production of fuel briquettes with a lower and higher amount of starch differently, but the produced briquettes were weak and erratic [21].

In this research, the author used the cassava or tapioca starch as the binder corresponding with many types of research [5, 17, 18, 21, 22, 24, 27, 30, 31]. The cassava starch was commercially available as a binder. This material was cheaper than the other adhesives, and could be easily found in the local markets. Another advantage of cassava starch was its great thickening properties [21]. Zubairu and Gana (2014) said that charcoal from biomass sources

(corncobs) as charcoal briquettes was an effective way to manage solid waste and possible methods of alternative energy sources [30].

Moreover, the fuel briquettes of this research used the corn kernel residues that it has not yet been appeared in any study. So, the result of the survey of the fuel briquette properties was not enough. We should be continued the research to improve and develop the fuel briquette processing for reducing agricultural residues.

6. Conclusion

The analysis of the chemical properties and the combustion duration of fuel briquettes from corn kernels found that the most suitable proportion for the production was 10 kg of corn kernels: 1 kg of cassava starch: 1 liter of water. Because it was an easy compression, high strength, and combustion duration of 111.67 minutes, it had the moisture content within the standard that the TISI had given the moisture content standard no more than 8%. It had the ash content within the standard that the TISI had provided the ash content standard no more than 8%. However, the volatile matter content had not passed the standard in which the TISI had also given the volatile matter content standard no more than 25%. Due to the fuel bio-briquettes from the corn kernels in this research were the green fuel which had not been through the carbonization process. Moreover, the fixed carbon content had not passed the standard, which the TISI had given the fixed carbon content standard no less than 75%. Including the heating value had not also passed the standard, which the TISI had given the heating value standard no less than 5,000 cal/g.

References

1. Iskin I, Taha RA, Daim TU. Exploring the adoption of alternative energy technologies: a literature review. International Journal of Sustainable Society 2013;5(1):43-61.
2. ShervinZakeri M, Taghizadeh MM. Review on renewable energy, sustainable energy and clean energies. Technical Journal of Engineering and Applied Sciences 2014;4(3):120-123.
3. Romallosa ARD, Kraft E. Feasibility of biomass briquette production from municipal waste streams by integrating the informal sector in the Philippines. Resources 2017;6(12):2-19.
4. Maninder, Kathuria RS, Grover S. Using agricultural residues as a biomass briquetting: an alternative source of energy. IOSR Journal of Electrical and Electronics Engineering 2012;1(5):11-15.
5. Kpalo SY, Zainuddin MF, Manaf LA, Roslan AM. and Ahmad MR. Production and characterization of hybrid briquettes from corncobs and oil palm trunk bark under a low pressure densification technique. Sustainability 2020;12:1-16.
6. Helwani Z, Fatra W, Arifin L, Othman MR, and Syapsan. Effect of process variables on the calorific value and compressive strength of the briquettes made from high moisture Empty Fruit Bunches (EFB). IOP Conf. Series: Materials Science and Engineering 2018;345:1-9.
7. Tripathi N, Hills CD, Singh RS, Atkinson CJ. Biomass waste utilisation in low-carbon products: harnessing a major potential resource. npj Climate and Atmospheric Science 2019;35:1-10.
8. Kaur A, Roy M, Kundu K. Densification of biomass by briquetting: a review. International Journal of Recent Scientific Research 2017;8(10):20561-20568.
9. Barz M, Delivand MK. Agricultural residues as promising biofuels for biomass power generation in Thailand. Journal of Sustainable Energy & Environment Special Issue 2011:21-27.
10. Chew KW, Chia SR, Yen HW, Nomanbhay S, Ho YC, Show PL. Transformation of biomass waste into sustainable organic fertilizers. Sustainability 2019;11:1-20.
11. Kadziuliene Z, Jasinskas A, Zinkevicius R, et al. Miscanthus biomass quality composition and methods of feedstock preparation for conversion into synthetic diesel fuel. Zemdirbyste-Agriculture 2014;101(1):27–34.
12. Liu S, Gao Y, Wang L, Xu B, Deng M. Research progress of biomass fuel upgrading and distributed utilization technology. IOP Conf. Series: Earth and Environmental Science 227: 1-8, 2019.
13. Rezny L, Bures V. Energy transition scenarios and their economic impacts in the extended neoclassical model of economic growth. Sustainability 2019;11:1-25.
14. Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R. The role of renewable energy in the global energy transformation. Energy Strategy Reviews 2019;24:38–50.
15. Owusu PA, Sarkodie SA. A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering 2016;3:1-14.
16. Voicea I, Voicu G, Cardei P, Vladut V, Gageanu I, Daraban A. Theoretical and experimental research on the process of biomass briquetting. U.P.B. Sci. Bull., Series D. 2016;78(3):203-214.
17. Falemara BC, Joshua VI, Aina OO, Nuhu RD. Performance evaluation of the physical and combustion properties of briquettes produced from agro-wastes and wood residues. Recycling 2018;3(37):1-13.
18. Ajimotokan HA, Ehindero AO, Ajao KS, Adeleke AA, Ikubanni PP, Babata YLS. Combustion characteristics of fuel briquettes made from charcoal particles and sawdust agglomerates. Scientific African 2019;6:1-9.

19. Festus AN, William MW, Steven JS. Effect of emulsifiers on the physical properties of native and fermented cassava starches. Journal of Agricultural and Food Chemistry 1996;44(9):2595-2599.
20. Tongco MDC. Purposive sampling as a tool for informant selection. Ethnobotany Research & Applications 2007;5:147-158.
21. Tuates AM, Ligisan AR, Caparino OA. Physico-chemical and thermal properties of fuel briquettes derived from biomass furnaces as by-products. Journal of the Japan Institute of Energy 2016;95:859-867.
22. Emerhi EA. Physical and combustion properties of briquettes produced from sawdust of three hardwood species and different organic binders. Pelagia Research Library 2011;2(6):236-246.
23. Navalta CJLG, Banaag KGC, Raboy VAO, Go AW, Cabatingan LK, Ju YH. Solid fuel from Co-briquetting of sugarcane bagasse and rice bran. Renewable Energy 2020;147:1941-1958.
24. Sriket W, Kaewjuea W, Kaosol T. Improving fuel potential of para rubber wood bottom ash as charcoal briquette with co-extruded materials. Thai Environmental Engineering Journal 2019;33(1):51-57.
25. Saikia M, Bikash B. Development of quality testing methodologies of fuel briquettes. Recent Advances in Bioenergy Research 2014;3:40-47.
26. Ikelle II, Chukwuma A. Comparative Thermal Analysis of the Properties of Coal and Corn Cob Briquettes. IOSR Journal of Applied Chemistry 2014;7(6):93-97.
27. Sulaiman MA, Adetifa BO, Adekomaya SO, Lawal NS, Adama OO. Experimental characterization of maize cob and stalk based pellets for energy use. Engineering Journal 2019;23(6):117-128.
28. Thulu FGD, Kachaje O, Mlowa T. A study of combustion characteristics of fuel briquettes from a blend of banana peelings and saw dust in Malawi. International Journal of Thesis Projects and Dissertations (IJTPD) 2016;4(3):135-158.
29. Abdulkareem S, Hakeem BA, Ahmed II, Ajiboye TK, Adebisi JA, Yahaya T. Combustion characteristics of bio-degradable biomass briquettes. Journal of Engineering Science and Technology 2018;13(9):2779-2791.
30. Zubairu A, Gana SA. Production and characterization of briquette charcoal by carbonization of agro-waste. Energy and Power 2014;4(2):41-47.
31. Kongprasert N, Wangphanich P, Jutilarptavorn A. Charcoal briquettes from Madan wood waste as an alternative energy in Thailand. Procedia Manufacturing 2019;30:128-135