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# Development of Briquette Stove to Increase Heating Efficiency and Flame Stability of Sago Waste Briquette

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**Abstract.** Experimental studies on the effect of adding an adjuster on the heating efficiency and flame stability of sago waste briquettes have been carried out. The adjuster keeps the burning distance constant thereby increasing the combustion heat of the fuel. The infrared thermometer is used to determine the evolution of the combustion temperature in the briquette and the combustion load (water in the pan). The results show that the addition of a success adjuster increases the performance of the briquettes and the stove so that it becomes more effective and efficient, where the combustion temperature increase and the water boiling time is faster. Moreover, the results showed that the stable burning distance makes the briquettes always get stable heat so that the used fuel is more effective, where all parts of the fuel can burn and transfer heat to the pan. From the molecular perspective, it can be seen that the stability of the burning distance is able to weaken the Van der Waals bonds of the carbon chain, increasing the reactivity of fuel molecules and the fuel is easy to absorb heat and is flammable.

## INTRODUCTION

With decreasing world energy reserves, increasing global energy demand accompanied by an increase in the world's population, the energy crisis has become one of the most serious problems today [1]. Therefore, alternative fuel sources are needed to increase energy security [2]. Biomass briquette fuel is a source of energy that can be used as an alternative fuel, and various types of briquette fuels have been discovered and researched, such as sawdust and charred palm kernel [3], charcoal particles and sawdust agglomerates [4, 5], vegetable market waste, and sawdust [6], palm kernel shells [7], etc.

On the other hand, research and development on briquette stoves have also been carried out [8, 9, and 10]. In general, the development of briquette stoves is carried out to produce high combustion efficiency. Some of the important factors that influence the performance of the briquette stove are burning time, flame temperature, combustion air quality, and variations in the inlet holes [11]. Furthermore, there is heat and flame stability which are

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also very important factors that must be considered. Related to this, several studies have been carried out, and the efficiency obtained varies widely around 24 - 33% with different heating values [12, 13]. Unfortunately, the results of these studies found that the heat generated from the combustion of briquette fuel was not optimal [14, 15]. This is because the burning distance between the briquette flame and the object being burned is always changing and not constant. Therefore, to maintain the maximum burning distance, research was carried out on the flame contact distance and the height of the gas burner [16, 17]. However, the results found that if the burner distance is shorter it produces exhaust gas and the reactor does not burn efficiently because some smoke appears from the gas stove. Meanwhile, if the burner is too high, it will reduce the stove's efficiency due to an increase in the distance between the flame and the lower part of the object being burned [18, 19].

Based on the brief review above, it can be seen that one of the factors causing the decline in stove efficiency and briquette fuel performance is the change in the contact distance between the flame and the object being burned. Therefore, the development of the stove carried out in this research aims to stabilize the burning distance between the flames to increase the efficiency and performance of the fuel burner and the briquette stove.

However, researches on the development of briquette stoves only focus on stove performance and its application. Therefore the fundamental scientific information about the effect of flame distance and the mechanism of the carbon atom as the main component of briquette fuel from biomass has not been revealed. The unique characteristics of atom carbon and the complexity of chemical processes make the effect of atom carbon in the combustion performance of briquettes is difficult to know through the applied research method [20]. The molecular structure of carbon atoms has the potential to increase the heat flow of flame [21]. Moreover, the composition and density of carbon atoms make it function as a good conductor so that when it receives heat, the fuel molecules are an allotrope of carbon be composed of a single layer atoms (see Fig. 1) become reactive and flammable. Therefore, considering the importance of scientific information about the burning distance and the effect of carbon atoms in the combustion process, thus more research that is detailed and observations are carried out.

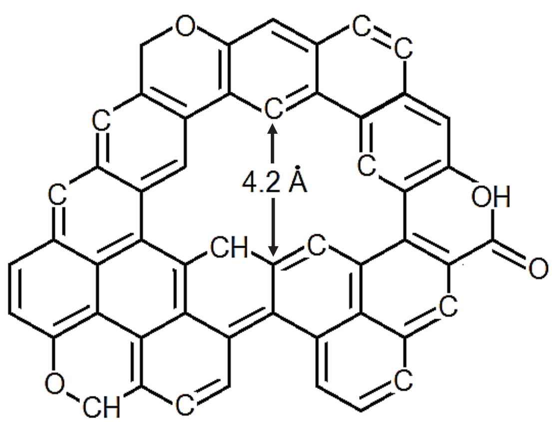


**FIGURE 1.** The molecular structure of charcoal briquette [22]

## MATERIAL AND METHOD

The main material for briquette fuel is obtained by converting the sago waste into honeycomb briquettes. The briquette diameter is 20 cm, 11 cm high with 14 holes (see Fig 2). Figure 3 shows the results of the development of a briquette stove, where an adjuster has been added to a new stove that functions to maintain a constant burning distance of about 5 cm.

The experimental apparatus is shown in figure 4. In the first stage, the briquettes are ignited and allowed to burn until extinguished to determine the effective flame time of the briquettes. In the second stage, the briquettes are turned on boiling the water, and every 30 minutes the temperature is measured using an infra-red thermometer, and during the water heating process, the effective burning distance of 5 cm is always kept constant by turning the adjuster.

The temperature data measured during the water heating process are the top surface temperature of the briquette ($T_1$) and the bottom temperature of the pan ($T_2$). The results of temperature data measurements are with and without adjuster shown in Table. 1. However, to get valid and accurate data, the data collection process was repeated five times.

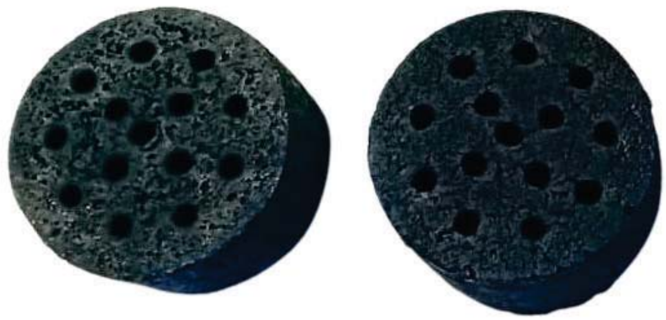

**FIGURE 2.** Sago waste briquette

**TABLE 1.** Effect of the adjuster on temperature changes

| Adjusting time (minutes) | Temperature ºC | | | |
|---|---|---|---|---|
| | With adjuster | | Without adjuster | |
| | $T_1$ | $T_2$ | $T_1$ | $T_2$ |
| 30 | 525 | 115.6 | 520 | 115.5 |
| 60 | 636 | 117.6 | 580 | 117.3 |
| 90 | 735 | 117.9 | 625 | 117.2 |
| 120 | 742 | 117.4 | 615 | 116.4 |
| 150 | 731 | 117.7 | 605 | 115.8 |
| 180 | 825 | 118.1 | 605 | 115.5 |
| 210 | 765 | 117.5 | 550 | 114 |

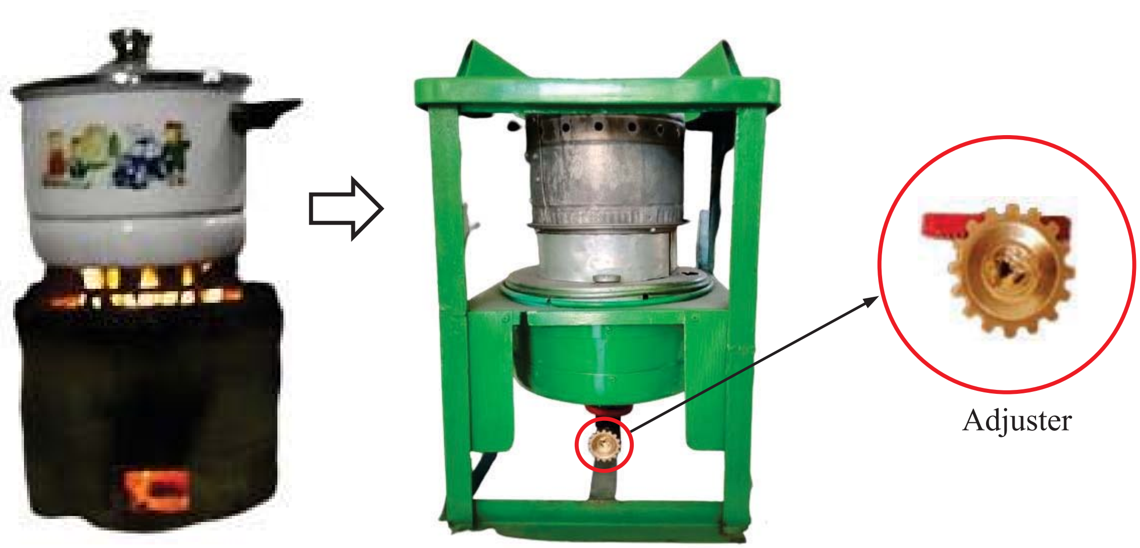


**FIGURE 3.** Development of a briquette stove model with an adjuster.

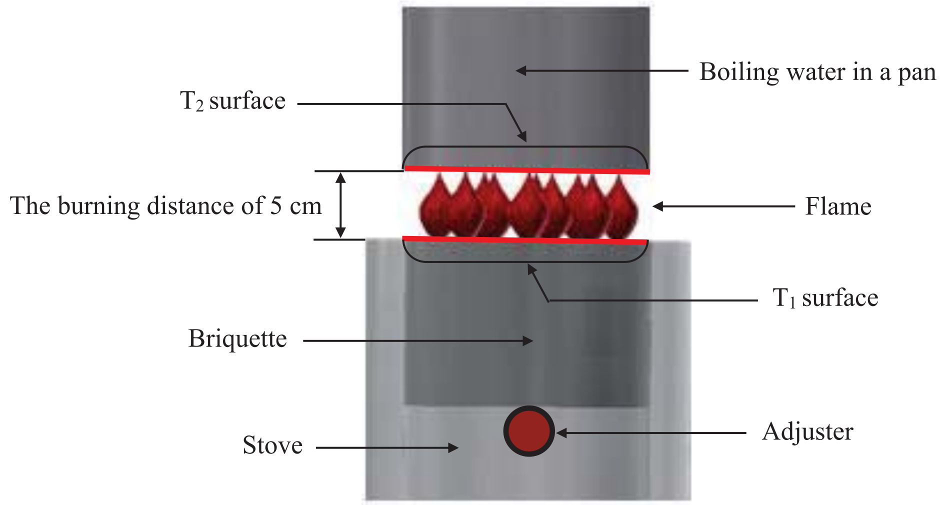


**FIGURE 4.** Experimental scheme

## RESULT AND DISCUSSION

From Fig. 5, it can be seen that without using the adjuster the flame looks smaller, opaque and the flame is uneven when compared to the flame of the stove with the adjuster (see Fig. 6) which is bigger, brighter, and the 14 briquette holes all emit flame. This shows that a stove with an adjuster produces better performance than a stove without an adjuster. Moreover, this shows that the power is greater and the flame is brighter, indicating that the fuel molecules are more reactive, so they absorb heat easily and are easily flammable. In general, for 210 minutes the burning time of the flame looks stable and constant. This phenomenon shows that the addition of an adjuster has a positive impact. Furthermore, this phenomena shows that a stable burning distance has a large effect on fuel and stove efficiency.

However, to maintaining the burning distance, the adjuster serves to make the use of briquettes more efficient. When the briquette burns for 30 minutes, the bottom of the briquette burns first because it burns earlier. When the height of the briquette decreases, the distance between the surface of the briquette and the pan increases. When this happens, the briquette flame does not touch the bottom of the pan. If this is allowed to do so, the heat generated from the combustion process will be inefficient and ineffective because the heat received by the water in the pan is reduced. This analysis shows that the burning distance must always be kept constant so that the heat received by the pan can be maintained and even increased.

**FIGURE 5**. Flame stability of the briquette stove without used an adjuster.

**FIGURE 6.** Flame stability of the briquette stove using an adjuster.

This is very possible because Fig. 7 and Fig. 8 shows that in general, it appears that the stove that uses the adjuster shows a trend that there is an increase in temperature in the two parts being measured, namely at the top of the briquette surface (T1) and the bottom of the panic surface (T2). As for the stove without an adjuster, it can be seen that the temperature trend continues to decrease starting at the 60th minute for T1, and at the 90th minute for T2.

However, from the observations in Figure 7, it was also found that with the adjuster, it was seen that at minute 30 the briquette temperature was reached 525 ºC and continued to increase. Furthermore, it is seen that in the 150th minute there was a temperature fluctuation where there was a decrease in temperature to 731 ºC and then it increased again until it reached a maximum temperature of around 825 ºC at 180 minutes. Meanwhile, without the adjuster, it can be seen that there is an increase in temperature from 520 ºC at the beginning of the combustion time until it reaches a maximum temperature of about 625 ºC at 90 minutes. After that, there is a decrease in temperature to 550 ºC.

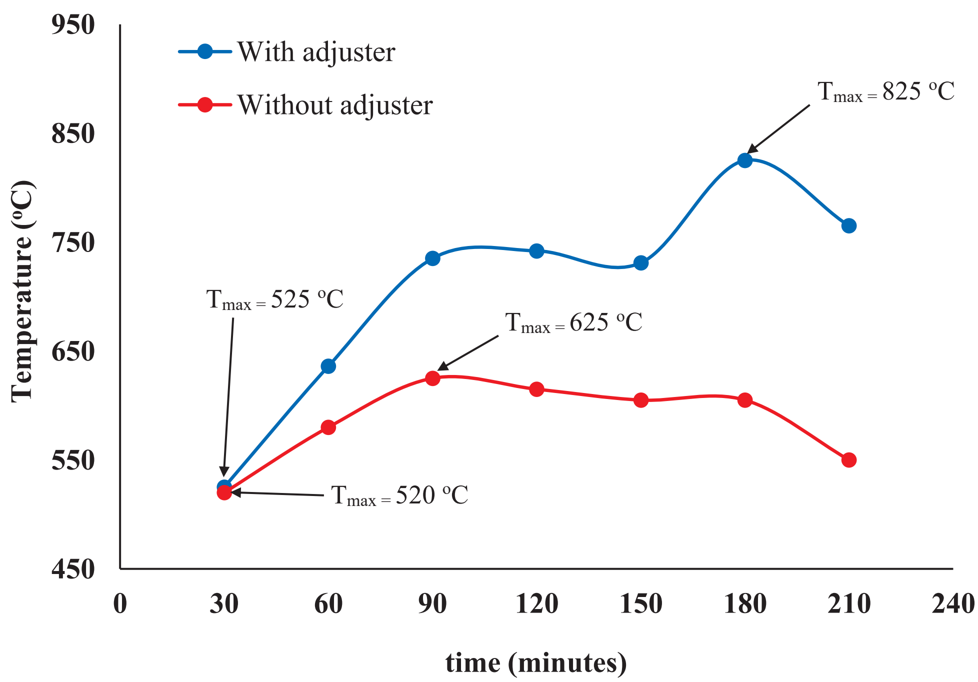


**FIGURE 7.** Evolution of the upper surface temperature of the briquette ($T_1$)

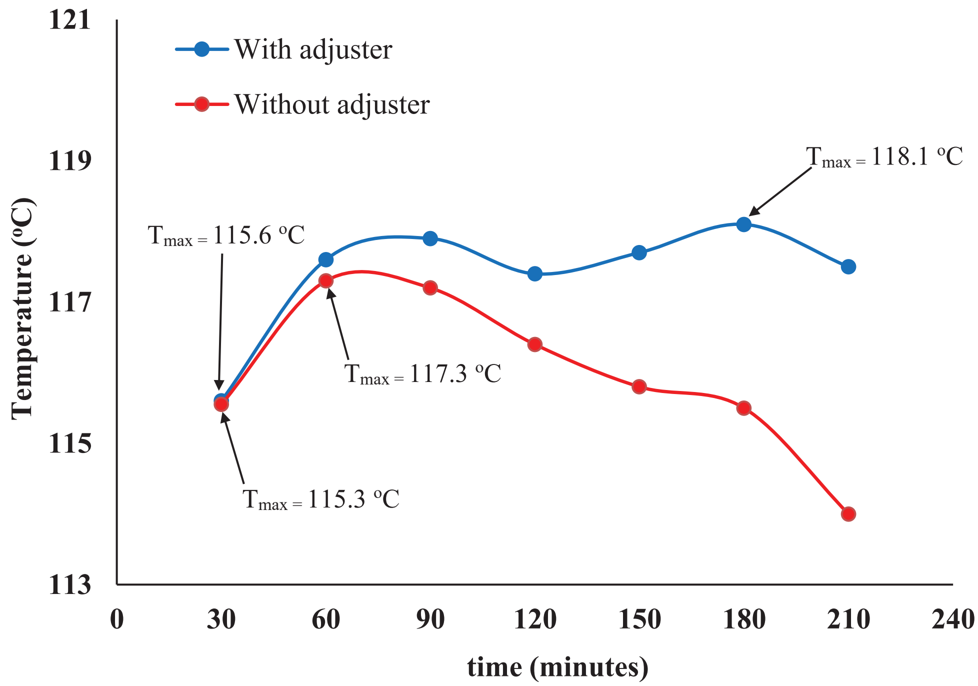


**FIGURE 8.** Evolution of the bottom surface temperature of the pan ($T_2$).

However, the same phenomenon occurs in figure 8. On the stove, with the adjuster, it can be seen that starting from the 30th minute the temperature increase continues to increase but decreases at 120 minutes at a temperature of 117 oC before finally reaching a maximum temperature of about 118 ºC at 180 minutes. While on the stove without an adjuster, it can be seen that there is an increase in temperature from 115.7 ºC to 117.3 ºC, where this occurs at minute 0 to minute 60. After that, it is seen that at minutes 90 to 210 minutes the temperature continues to decrease until it reaches 114 ºC.

These results indicate that the time interval for using the adjuster every 30 minutes cannot be applied evenly during the combustion time because of the potential to reduce fuel efficiency and effectiveness. This analysis is very possible because the heat accumulation received by the briquettes makes the bottom of the briquette potentially depleted at different times. By increasing the burning time, the more the briquettes receive heat so the bottom of the briquettes has the potential to burn and run out faster. However, in general, it was found that the use of an adjuster was successful in improving the performance of briquette fuel and the stove, which was proven when 5 liters of water was boil at a faster time, which is about 11.4 minutes.

On the other hand, from a molecular perspective, it can be analyzed that the molecular structure of briquette fuel is composed carbon chains with similar with graphene [23]. Furthermore, this shows that the molecular structure of the carbon chain functions as a good conductor so that the heat flow in the briquette can propagate properly. Moreover, the Van der Waals binding force between the carbon chains triggers the reactivity of the fuel molecules so that the fuel is flammable, and this analysis complies with the results of previous studies using crude vegetable oil as fuel [24]. This is very possible because the Van der Waals force is a weak bond so that when the briquette fuel receives heat, the carbon chains vibrate, collide with each other and cause the distance between the carbon chains to move apart. This analysis is in accordance with the results of previous studies that were discussed with different perspectives [25]. As the distance between the carbon chains increases, the Van der Waals bonds weaken. Furthermore, when the carbon atoms expand it causes the electrons to become more reactive because the electrons gain more space to move and have the potential to be excited [20]. This analysis is evidenced by the briquette flame that gets brighter during the combustion process when compared to the flame without using an adjuster (see Fig 5 and 6), and this result is consistent with previous studies and discussed from a different point of view [26]. Moreover, when the carbon atoms become more reactive, it causes the binding of the fuel molecules to weaken, easily absorb heat, and burns. This analysis is confirmed by an increase in temperature during the fuel combustion process (see Fig 7 and 8).

## CONCLUSION

Experimental studies on the effect of adding an adjuster on the performance of the briquette stove fuel of sago waste have been successfully carried out. Therefore, there are several main findings that can be concluded in this study, including:

1. The use of an adjuster is very important because it manages to keep the burning distance constant. Therefore, it must be considered in maintaining the stability of the flame so that the combustion heat becomes more efficient and effective.
2. The molecular structure of the briquette fuel that is composed of a dense network of carbon atoms functions as a good conductor, causing the heat of the briquette flame to propagate rapidly and resulting a more stable and brighter flame.
3. The density between carbon atoms makes effective collisions between atoms easy to occur when the atoms receive heat so that the fuel molecules more reactive, easily absorb heat, and burn.

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