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Effect of Carbonization on the number of fixed Carbon produced from Banan peel waste(Ambon, Kepok and Raja)

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Abstract : The number of fixed Carbon produced from every banana peel waste of Ambon, kepok, and raja was different due to the influence of carbonization temperature change. Carbonization temperature was varied into 400^{o}C; 500^{o}C; 600^{o}C; 700 ^{o}C and 800^{o}C. Fixed Carbon analysis included the moisture content, ash content and volatile matter. The change of carbonization also had impact on the number of carbon yield produced. The analysis result of highest carbon yield was temperature 400^{o}C on kepok banana peel of 45.99%, Ambon banana peel of 42.14%, and raja banana peel of 41.18%. Meanwhile, the analysis result of fixed carbon according to the standard of SII 0258-88 was temperature 700^{o}C on raja banana peel of 92.53%, kepok banana peel of 91.13%, and Ambon banana peel of 89.29%, with the percentage of moisture content 0.07%, ash content 3.14%, and 4.27% of volatile matter. In addition, the number of fixed carbon of kepok banana peel was 90.12% and Ambon banana peel was 88.86%. The score of analysis parameter conducted in the research was in accordance with SII 0258-88 that was about the carbon quality requirement of solid material, percentage parameter of fixed carbon produced minimal was 65%, Water Content maximal was 15%, Ash content maximal was 10%, and Volatile Matter maximal was 25%.
Keywords : Banana Peel Waste, Carbonization, Carbon.

Introduction

Banana (*Musacceae sp*) is a plant that easy to grow in tropical country like Indonesia. Almost in every place of Indonesia banana is easy to find. The potential of abundant stock of banana also contribute in producing waste since commonly people only use its fruit, its sheath, and its leaf while the banana peels are thrown as waste. The banana peel waste processing is not utilized maximally in order to get additional value. Banana production in Malang City has reached 482.87 ton/year. According to Basse (2000) if total number of banana peel is 1/3 of the total unpeeled banana, then the total of banana peels reachs 160.796 ton/year.

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Governement regulation No.18 Tahun 1999 concerning the activities of retrieves or reuses or recycles aim to change a waste into a product that can be used and safe for environment and human health.

Banana peel in common contains Vitamin C, B, Kalsium, Protein, and also enough fat. Chemical analysis result shows that banana peel composition mostly contains water of 68.90 % and the rest is carbohidrate of 18.50 %. Meanwhile one of bio-chemical components contained in banana peel is cellulose (Hewwet *et al*., 2011). It is a main component of plant cell wall with molecul formula $(C_6H_{10}O_5)n$. cellulose is carbon compound consist of more than 1000 unit of Glucose banded to Beta 1.4 of glicoside in straight chain (Desvaux,2005).

(Saleh, 2004) says that the use of organic material such as banan peel can be used as adsorbent. At present many techniques are developed reated to the process of adsorbent creation particularly from organic material, which does not rewired high cost and very effective. In general it is used to eliminate the contamination of heavy metals in environment. Adsorben is solid substance may absorb such component from a fluide phase (Saragih, 2008). Mostly adsorbent is highly porous material and adsorption occur particularly on the porous wall or on such location in that paticle. Therefore, pores commonly very small then inner surface area in some large orders are bigger than outer surface and may reach 2000 m^2/g. the separation occurs due to the difference of mollecul mass or due to the difference of polaity that causes some mollecul attach on that surface tighter than other mollecul.

Carbon is made by breaking the cellulose into carbon. It is a porous solid containing 85 – 95 % of carbon, produced from material with carbon content by heating at high temperature thus obatianed very large surface, where the size is about 300 – 2000 m^2/gr. Wide surface from structure active carbon pores can be developed, this structure provides cative carbon an ability to adsorb the gassess and steams of gass and also may elaborate substances from liquida (Kirk – Othmer, 1992).

Huajun Zheng. *et al* (2013) in his research entitle "*Banana Peel Carbon Containing Fungsional Groups Applied to the Selective Adsorbsion of Au (III) from Waste Prentend Circuit Boards*" says that the type of carbon of banana peel consist of functional groups of –OH, -NH2 in which characterized by variable the carbonization temperature and its use for gold adsorbtion from PCB waste. The adsorbtion from banana peel carbon for gold (III) reach equlibrium point 30 minutes with pH 2.5. Moreover, isotermal adsorption shows the adsoption maximum capacity for Au (III) of 801.7 mg/g. the result shows that banana peel carbon has high ability in adsorbing Au (III) and other ability is adsorbing methal ion, for instance Cu (II), Ni (II) Fe (III) and Pb (II). *Banana Peel Carbon* that adsorbs Au (III) can be activated by back with HCl-triourea solution.

Research result conducted by Hadi Rinayu (2013) entitle "Pengaruh Komposisi dan Ukuran Serbuk Briket yang Terbuat dari Batubara dan Jerami Padi Terhadap Karakteristik Pembakaran", was obtained carbon yield from phyrolis procees of coals and straws about 68.54% and 24.61% whereas the score of heat is 6150.740 kal/g and 4751,184 kal/g. From the test result of optimum point experiment on briquettes with composition 50% of coals and 50% of straws in 35 mesh, the test parameters in accordance with Indonesian National Standard (SNI) 01-62535-2000 are moisture content of 5.176%, ash content of 26.231%, *volatile matter* of 12.484%, heat score of 5037,127 kal/g, *fixed carbon* 56.105%, density of 0.743 g/cm3, and for the burning rate is 4.14 g/minute on the 8^{th} minute. The computer simulation result for the temperature in burning time then the composition 0f 50% coals and %0% straws on 35 meshes is 743 K or 469^oC.

In the current study it will be made of carbon from various tyoe of banana peel waste some of them are banana peel of Ambon, Kepok, dan Raja. Its role as solid waste can be changed into useful thing for the environment and increasing the selling value. Our study wants to prove that banana peel waste can be changed into carbon. Some stages of carbon manufacturing process are dehidration, delignification, and carbonization. Due to carbonization temperature affects the carbon manufacture then carbonization temperature is used as variable change to find its influence on the number of *fixed carbon*. The analysis conducted is calculating the carbon yield and *fixed carbon* (C) by conducting moisture content test with procedures of ASTM D-3173, ash content test with ASTM D-3174, and *volatile matter* test with ASTM D-3175.

Experimental

The study is conducted in the aboratory of Chemical Engineering of Institut of Technology National Malang and in the Laboratory of State Politechnic Malang. The research stages are studying literature, preparing research, implementing research, collecting data, analysing data, discussion and writing report.

Research Procedures

Banana peel carbon manufacturing is conducted with preparing the material, dehidration, delignification, and carbonization. The carbon obtained is given a tets by calculating the carbon yield, the percentage of *moisture content* carbon, ash content, *volatile matter*, and the number of *fixed carbon* on each type of banana peel.

Preparation and Dehidration of Banana Peel

The sap on banana peel is eliminated by washing it clearly. After that, cut the banana peel into 1 – 2 cm and weigh it with initial mass (B_0). Next is conducting dehidration process with the aim of reducing the moisture content on banana peel. It is conducted by putting them in the oven at the temperature of 60˚C for 6 days. Dry banana peels then are put into desiccator for 15 minutes then weigh the mass. To calculate that the material mass has been constant then having dehidration process at the temperature of 110˚C for 1 hour, then the material is weighed as the final mass (B_1). The percentage of *moisture content* on banana peel is obtained from the difference of initial mass and final mass of material per initial mass.

$$(\%\ kadar\ air) = \frac{berat\ awal\ (B_0) - berat\ akhir\ (B_1)}{berat\ awal\ (B_0)} \times 100\%$$

Delignification

Delignification process aims to eliminate lignin on each type of dry banana peel. According to Cahyaningrum 2016, delignification processes is conducted by soaking dry banana peels with NaOH 1 M solution for 12 hours and washing them with aqudest then dry them in the oven with temperature 60^{o}C for 24 hours. After that soak them with H_2SO_4 1 M solution for 24 hours and wash them again with aquadest then dry them in the oven with temperature 60oC for 24 hours. Weigh the dry material until get the conctant mass.

Carbonization

The dry banana peel is weighed into 10 gram as initial mass (B_0) on *crusible* then carbonated in *furnace*. Carbonization temperature is defined as variable changes (400˚C, 500˚C, 600˚C, 700˚C, and 800˚C). After carbonization process put the *crusible* on desiccator the weigh the final mass (B_1). The carbon obtained is then minimized the particle size (*size reduction*) using hammer. The result is in the form of black carbon powder.

Results And Discussions

(a) (b) (c)

Figure 1. Dry Ambon Banana Peel (a), Dry Kepok Banana Peel (b), and Dry Raja Banana Peel (c)

Carbon Yield

To understand the initial condition of raw materials that may influence the carbon quality, then carbon yield test was conducted on them.

Table 1 Analysis Result of Carbon Yield Percentage per 10 gram

No	Type of Banana Peel	400°C	500°C	600°C	700°C	800°C
1	Banana peel of Ambon	42,14	32,988	28,817	23,483	17,744
2	Banana peel of Kepok	45,99	31,505	29,151	23,805	19,615
3	Banana peel of Raja	41,184	32,969	27,457	25,35	19,641

The analysis result of carbon yield toward the temperature was depicted on the Figure 2 below:

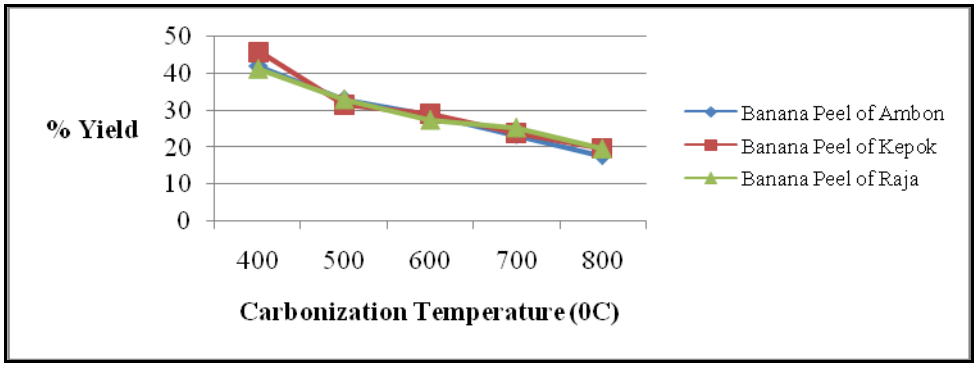

Figure 2. The Relation between Carbonization temperature (°C) on The Carbon Yield Percentage

In the figure 2 the highest percentage of carbon yiled for all type of banana peel (Ambon, Kepok dan Raja) was at the carbonization temperature 400°C, those were 42.14 % for banana peel of Ambon, 45.99 % for banana pee of kepok and 41.18% for banana peel of raja. Meanwhile, the lowest percentage of carbon yield was at carbonization temperature 800°C, those were 17.74 % for banana peel of Ambon, 19.62 % for banana peel of kepok and 19.64% for banana peel of raja.

The figure above showed that carbon yield decrease along with the increase of carboniczation temperature. In the range of carbonization temperature of 400 – 600°C it was caused by the hemicellulose depolymerization, the breaking of glycosidic bond from the component of cellulose and lignin was similar to the decomposition of several biomass such as protein or esther (Huajun Zheng 2013). After temperature 700°C the phyrolis on dry banana peel was occurred continually, and almost all groups of organic material inside were broken at this temperature. Carbon yield was used as one of the indicator to succes in carbon manufacturing.

The Percentage of Water Content

Table 2 Analysis result of the Percentage of Water Content per 1 gram

No	Type of Banana Peel	400°C	500°C	600°C	700°C	800°C
1	Banana peel of Ambon	0,032	0,118	0,148	0,107	0,761
2	Banana peel of Kepok	0,014	0,091	0,045	0,064	0,407
3	Banana peel of Raja	0,016	0,019	0,045	0,068	0,469

According to the standard of SII 0258-88 (1997) concerning the carbon quality requirement, the allowed percentage of water content maximally is 15%. From the analysis result in the figure 3 below, it was obtained the percentage of water content on *Banana Peel Carbon* occurred the water content increase along with the carbonization temperature increase. It was contradictory with the theory of water evaporation because

at the temperature of 100°C water started changing the phase into the steam where the higher the carbonization temperature then the decreasing of water content.

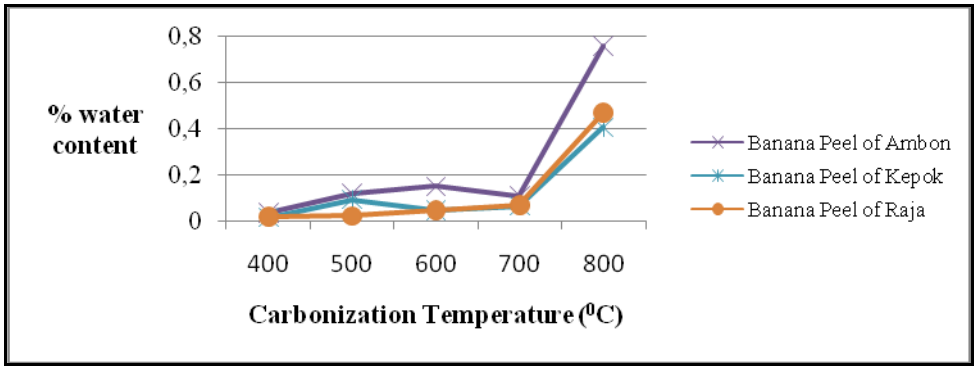

Figure 3 the Relation of Carbonization Temperature (°C) on the Percentage of Water Content

In the water content test the highest percentage obatined were at carbonization temperature 800°C for banana peel of Ambon 0.761%, banana peel of kepok 0.407% and banana peel of raja 0.469% whereas the lowest percentage of carbon water content were at the temperature 400°C for banana peel of Ambon 0.032%, banana peel of kepok 0.014% and banana peel of raja 0.016%. it was because the carbon produced at high temperature have more pores than at low temperature (Sastrodimedjo dan Simarmata, 1978 dalam Ade, 2015). The percentage of water content was contradictory with that theory because hygroscopic carbon (*Banana Peel Carbon*), thus the carbon was easy to adsorb the water from the air in cooloing process, baking process, as well as the storage process (Ade, 2015).

Moreover, from the analysis of water content test of banana peel before carbonization process had high percentage those were 80.34% for banana peel of Ambon, 76.83% for banana peel of kepok, and 70.83% for banana peel of raja.

Water content was one of the parameter in determining the carbon quality. Carbon with low water content would have high heat score. The higher the water content then the more heat required for eliminating the water content from banana peel material in order to be the steam thus the energy left inside the carbon become smaller (Hadi Rinayu, 2013).

Percentage of Ash Content

Table 3 Analysis result of the Percentage of Ash Content per 1 gram

No	Type of Banana Peel	400°C	500°C	600°C	700°C	800°C
1	Banana peel of Ambon	5,262	5,654	6055	6,424	6,816
2	Banana peel of Kepok	3,762	3,955	4,049	4,173	4,431
3	Banana peel of Raja	2,692	2,768	3,005	3,138	3,462

The testing result of ash content from all types of banana peel (Ambon, Kepok dan Raja) was depicted in figure 4 below:

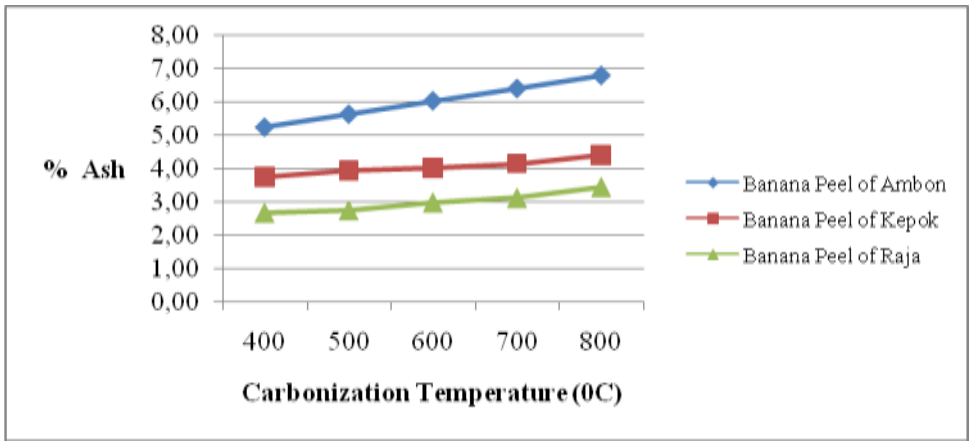

Figure 4 the Relation between Carbonization Temperature (^oC) on the Percentage of Ash Content

From figure 4 it showed the tendency of the graph about the relation between carbonization temperatures (^oC) on the percentage of ash content increased along with the increase of carbonization temperature. The highest ash content was at temperature 800^oC with the percentage for banana peel of Ambon 6.816%, for banana peel of kepok 4.431% and for banana peel of raja 3.462%. If comparing with SII 0258-88 concerning the carbon quality requirement, the parameter of ash content was produced maximally 10% then the sample produced has met the standard of SII.

At temperature 800^oC high ash content was obtained due to the ash was the number of residu after the organic material burned in which the main component of the material is organic and unorganic substances. Ash contained in solid fuel was mineral (unorganic) that cannot be burned and left behind after the burning process. Ash caused the pores blockage in carbon thus the surface width of carbon becomes reduced (Erwin Junary, 2015).

Percentage of *Volatile Matter* Content

Table 4 Analysis Result of the Percentage of *Volatile Matter* per 1 gram

No	Type of Banana Peel	400^oC	500^oC	600^oC	700^oC	800^oC
1	Banana peel of Ambon	5,924	5,370	4,744	4,183	3,584
2	Banana peel of Kepok	6,402	5,834	5,279	4,630	4,139
3	Banana peel of Raja	5,640	5,139	4,689	4,266	3,737

Volatile substance (*volatile matter*) in carbon was compounds except water, ash and carbon. Volatile substance consisted of the element of hydrocarbon, methan, and carbon monoxide. The testing result of volatile substance content was depicted in figure 5 below:

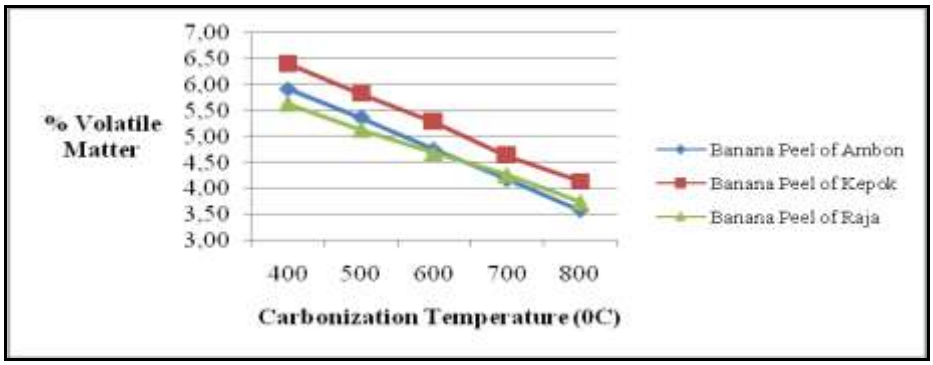

Figure 5 the Relation between Carbonization Temperature (^oC) on the Percentage of *Volatile Matter*

The figure 5 showed the tendency downward trend along with the increase of carbonization temperature. It can be seen that the lowest percentage of *volatile matter* was at temperature 800^{o}C those were 3.584% for banana peel of Ambon, 4.139% for banana peel of kepok and 3.737% for banana peel of raja. Meanwhile, the highest percentage was at carbonization temperature 400^{o}C those were 5.924% for banana peel of Ambon, 6.402% for banana peel of kepok and 5.640% for banana peel of raja.

If comparing to the SII 0258-88 concerning the carbon requirement, the parameter of *volatile matter* content produced maximally is 15%, then all samples of banana peel had met the standard of SII0258-88.

Figure 5 above showed that it was in accordance with the theory where the higher the carbonization temperature then the decreasing the volatile substance. It was because volatile matter was in maximum temperature of phyrolisis (Nurhayati, 1976). According to Hendra and Darmawan in Sudrajat 2008, the number of *volatile matter* content was affected by time and carbonization temperature. When the time and temperature of carbonization (banana peel) was increased then the more evaporated substance wasted, thus the content of evaporated substance that still on the carbon would influence the carbon adsorption. The higher the temperature the more eavporated substance cover the carbon, thus the carbon pores that initiall closed would be open and increasing the ability of carbon adsorption.

Percentage of *Fixed Carbon* Content

Table 5 Analysis Result ofthe Percentage of *Fixed Carbon* per 1 gram

No	Type of Banana Peel	400^{o}C	500^{o}C	600^{o}C	700^{o}C	800^{o}C
1	Banana peel of Ambon	88,782	88,858	89,054	89,287	88,839
2	Banana peel of Kepok	89,823	90,119	90,625	91,133	91,023
3	Banana peel of Raja	91,652	92,073	92,262	92,528	92,332

Bond carbon (*fixed carbon*) content was the carbon fraction bond inside the carbon beside water, ash and *volatile matter*. The score of bond carbon content was obtained through the calculation of sample mass (100%) substructed by the number of water content, ash content, and *volatile matter* content. The bond carbon was solid fuel left in stove after the volatile substance of material was destilated.

The testing result of *fixed carbon* on carbon was depicted in figure 6 below:

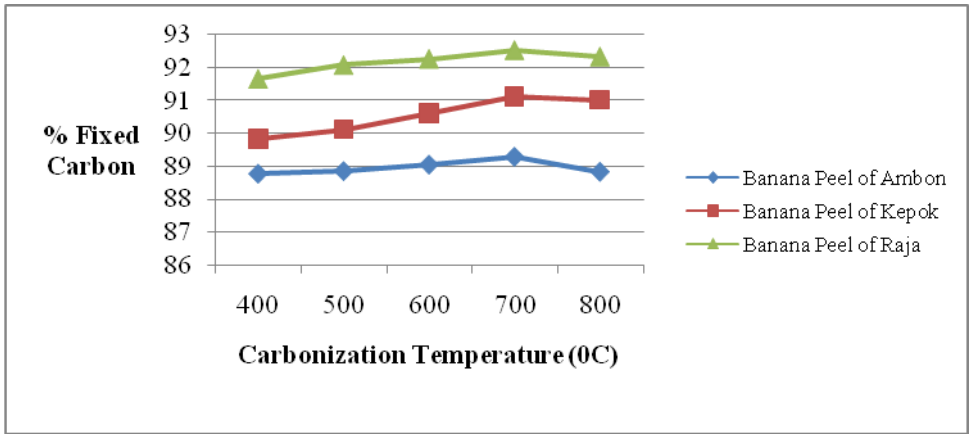

Figure 6 the Relation Between Carbonization Temperature (^{o}C) on the Percentage of *Fixed Carbon*

From figure 6 it can be seen that most of *fixed carbon* had increase along with the increase of carbonization temperature. The highest percentage of *fixed carbon* was at 700^{o}C those were 92.528% for banana peel of Raja, 91.133% for banana peel of kepok and 89.287% for banana peel of Ambon. It was accordance with the statement of (Sjostrom, 1995 in Erzam 2017) that was the highest temperature will increase the carbon content because the dehidration was more perfect and the elimination of volatile products. In

addition, the content of carbohidrate and hard viber on banana peel of raja had highest percentage among other types that was 59% and 3.33% per 100 gram of banana peel.

Moreover, *fixed carbon* at temperature 800^{o}C had decrease into 88.839% for banana peel of Ambon, 91.023% for banana peel of kepok, 92.332% for banana peel of raja. It was because banana peel was the organic material that will be unravel after temperature 700^{o}C, and almost all groups of organic natural material wil be broken/damage at this temperature.

Comparing to the SII 0258-88 concerning the carbon quality requirement, the parameter of percentage of *fixed carbon* produced minimal is 65%, then all samples of banana peel had met the standard of SII. The following was the result of each test based on the optimum percentage of *fixed carbon* from Banana peel carbon of Raja

Table 6 Test Comparison of Banana peel carbon of Raja at temperature 700^{o}C with standard of SII 0258-88

No	Analysis	Percentage of Raja BPC (%)	SII 0258-88 (%)
1	*Moisture Content* BPC	0,068	15
2	Ash Content BPC	3,138	10
3	*Volatile Matter* BPC	4,266	25
4	*Fixed Carbon* BPC	92,528	65

Conclusions

The number of *fixed carbon* optimum was obtained at carbonization temperature 700^{o}C with total 92.528% for Banana peel with yield 25.35%.

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