PERFORMANCE CHARACTERISTICS OF COCOA SKIN LIQUID SMOKERSIN DIFFERENT WATER CONTENT CONDITIONS

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ABSTRACT

The purpose of this study was to design and make pyrolysis (pyrolysisator) makers of liquid smoke cocoa skin from stainless steel 3 mm thick and to test the performance of the tool on raw materials of brown leather under different conditions (moisture content 10 percent, 15 percent, 20 percent and 25 percent). The method of making uses the design directly in the production process of the Faculty of Engineering, Ekasakti University. The results of the design and manufacture, obtained a pyrolisator with a volume capacity of 27 liters equipped with tar reservoir pipes, condenser pipes of stainless steel for cooling, liquid smoke reservoirs and heat sources derived from combustion of LPG gas. The test results of tool performance such as yield and working capacity of the tool (ml / minute) were analyzed using a Completely Randomized Design with a real level of 5%, if significantly different it was further tested with a 5% BNJ Test. From the results of testing the tool obtained the performance capacity of liquid smoke generating devices for moisture content of 10%, 15%, 20% and 25% respectively 6.33; 4.67; 6.00; and 7 ml / minute and after being tested statistically significantly different. While the yield of liquid smoke each is 20.00 percent, 24.00 percent; 33.33 percent and 44.00 percent are also statistically significantly different.

Keywords: Performance, Pyrolysis and Liquid Smoke Cocoa Skin

INTRODUCTION

Cocoa farmers generally only use cocoa beans during harvesting, while cocoa skin is usually used as animal feed ingredients and the rest is left to become waste around the plantation area. Cocoa pod waste produced in large quantities will be a problem if it is not handled properly because this solid waste production reaches more than 60% of the total fruit production, this will be a great potential to pollute the surrounding environment, for that we need a solution with liquid smoke making (Harsini and Sosilowati, 2010).Liquid smoke can be obtained by condensing or condensing biomass from the pyrolysis process. Liquid smoke is a mixture of solutions from wood smoke suspensions in water made by condensing or condensing the results of wood pyrolysis (Darmadji, 1996). This pyrolysis process produces gas, solids and liquid smoke. Smoke is produced by incomplete combustion which involves decomposition reactions of polymer constituents into low molecular weight organic compounds due to the influence of heat which includes oxidation, polymerization, and condensation reactions. During combustion, components of wood including cellulose, hemicellulose and lignin will undergo the pyrolysis process to produce various compounds including phenols and derivatives, carbonyl (ketones and aldehydes), acids, furans, alcohols, lactones, polycyclic aromatic hydrocarbons and so on. The most important component in contributing to the fuming reaction are three compounds, phenol, acid and carbonyl (Girrard, 1992).Several studies on the production and utilization of liquid smoke have been carried out, among others, the development of liquid smoke generating devices from rice husks to produce organic insecticides (Putri et al., 2015), making liquid smoke from rubber shells as latex coagulants (Prasetyowati et al., 2014), chemical components of liquid smoke resulting from pyrolysis of oil palm solid waste (Haji, A. G et al., 2013), making liquid smoke from coconut fiber by non pyrolysis technique (Fatimah, 2011), activity test and antibacterial liquid smoke originating from cinnamon bark and peanut shells (Yefrida et al., 2009).The pyrolysis process involves various reaction processes namely decomposition, oxidation, polymerization, and condensation. The process that occurs during pyrolysis according to the increase in temperature is: removal of water from wood at a temperature of 120-150oC, pyrolysis of hemicellulose at a temperature of 200-250oC, pyrolysis of cellulose at temperatures of 280 - 320oC and pyrolysis of lignin at 400oC. This pyrolysis at 400oC produces compounds that have high organoleptic quality and at higher temperatures there will be a condensation reaction for the formation of new compounds and oxidation of condensation products followed by linear increases in tar compounds and polycyclic aromatic hydrocarbons (Girard, 1992; Maga, 1988, in Darmadji , 2002).The chemical components of wood which decompose during the pyrolysis process are hemicellulose, cellulose and lignin. Hemicellulose is the first to undergo pyrolysis to produce furfural, furan, acetic acid and homologs. Pyrolysis of pentosan forms furfural, furans and their derivatives along with a long series of carboxylic acids. Together with cellulose pyrolysis hexose forms acetic acid and homologs. Lignin in pyrolysis produces compounds that play a role in the smell of smoke from smoked products. These compounds are phenols and phenolic ether such as guaiakol (2 methoxy phenol) and its homologs and derivatives. The next process is cellulose pyrolysis producing acetic acid compounds, and carbonyl compounds such as acetaldehyde, glyoxal and akreolin. Lignin pyrolysis will produce phenol compounds, guaiakol, syringol together with homologs and their derivatives.Liquid smoke has functional properties as an antioxidant, antibacterial and forming colors and distinctive taste. These functional properties are related to the components contained in the liquid smoke. Liquid smoke has the ability to preserve food ingredients because of the presence of acidic compounds, phenol derivatives, and carbonyl (Darmadji, 1996). To produce liquid smoke that is of high quality and optimum liquid smoke yield, a pyrolisator is needed which can increase the quantity and quality of liquid smoke. The pyrolisator that was designed by the researchers had previously been in the form of a cylindrical column originating from a stainless steel plate, the remaining oil drums which were generally easily corroded. Syafri et al. (2011) made the design of tools for making liquid smoke from stainless steel plates, the capacity of tools for coconut shell material, coir, and chaff respectively 1.25; 0.45; and 0.32 kg / hour. Reny et al. (2015) developed a liquid smoke generator from rice husk, a pyrolysis time of 2 hours and produced 1.3% liquid smoke yield. In this study, a pyrolysis device was designed using stainless steel. The purpose of producing this is to measure the performance of a 27-liter pyrolysis device with a heat and rust resistance. The performance of the tool was tested using cocoa fruit skin with different moisture content which is widely found in West Sumatra and has not been utilized optimally.

RESEARCH METHODS

This research was carried out by bringing raw materials from brown skin from Padang Pariaman Regency, and the process of producing brown liquid liquid smoke was carried out in the mechanical engineering production laboratory of the Faculty of Engineering, Ekasakti University, a lathe welding workshop in the city of PadangTools and materialsThe tools used include thermometer IR temperature 600oC sellery brands, brand value vacuum pumps, San-EI brand water pumps model SE 125A, 230 watts of electric power, pump suction power 42 liters / minute, digital scales, tools to make pyrolysis tanks (pyrolysis) namely stainless steel pan volume 32 liters, diameter 30 cm, 30 cm high and 5 mm thick equipped tar tar size 10 x 12 cm, stainless steel pipe diameter 0.75 inches, length 1.5 meters connecting pyrolyzer tank with condenser, for pipes the condenser uses a stainless steel pipe 0.75 inches in diameter 8 meters long with 12 circle diameter of 30 cm, for the operation it uses the win gas brand 0100 gas stove, and 2 liquid smoke containers from plastic and glass. The materials used are cocoa peel with a moisture content of 10%, 15%, 20% and 25% as measured by the MBI-TM-20 type multi-digital moisture content measuring device. .Research methodologyThe research method is carried out by conducting a literature study of the design of the pyrolisator that had been carried out by previous researchers. Syafri et al., (2011) conducted a pyrolysis design of 3 mm thick stainless steel plate with a diameter of 50 cm and a height of 80 cm. The combustion process takes 5.5 - 6.5 hours and the yield of liquid smoke for coconut shell is 21.74%. Devison (2015) designed a pyrolyzer with a capacity of 60 kg, a diameter of 60 cm and a height of 90 cm. The yield of liquid smoke for coconut shell was obtained 43.93%. Rahmi et al., (2018) carried out the design of a liquid smoke generator engineered from a 12 kg LPG gas cylinder that was able to produce liquid smoke for coconut shells, corn cobs, coconut husks, and cocoa pods. The capacity of the equipment in the condition of running water for coconut shells, corn cobs, coconut husks, and cocoa pods is 0.55 each; 0.08; 0.05; and 0.09 kg / hour. While the yield yield of each is 45.05; 8.73; 8.44; and 18%. Based on the results of these studies, an experiment was conducted to design a portable, rust-resistant liquid smoke maker. The manufacture of liquid smoke devices using several tools includes smoke pipe pyrolysator, cooling pipe, liquid smoke cooling drum, vacuum pump and liquid smoke storage container.The stages in making liquid smoke consist of preparation of raw materials using cocoa skin with a moisture content of 10%, 15%, 20% and 25%. The experiment was designed using an experimental method with a completely randomized design (CRD) of one factor. Each treatment at different moisture content was repeated with three replications at each different moisture content. If it is significantly different, further testing is done with a 5% BNJ test using a statistical program8. Each raw material is filled with 2 kg and closed tightly. The LPG gas stove is ignited, the material in the container will heat up and undergo the pyrolysis process. Smoke will come out of the container and into the condenser pipe which contains running water and finally remove the liquid from the condensation that drips into the container. The pyrolysis process is stopped until there is no condensation liquid dripping into the container. To speed up the flow of liquid smoke using a vacuum pump.The stages of conducting research include:a. Manufacture of pyrolysis and condenser devicesThe stages in making the pyrolisator began with the design of the material preparation pyrolyzer, assembling the tool and testing the tool. The specifications of the tool are as follows:1. The pyrolysis tube is made of 27 kg stainless steel volume added with a cap that is impermeable and added with a chimney at the top. Tube diameter 30 cm, tube height 30 cm and plate thickness 5 mm.2. The smoke distribution pipe is made of 2 mm thick stainless steel pipe, 0.75 inch diameter and 1.50 m long3. The stainless steel tar box is 2 mm thick, 10 x 12 cm in size4. Spiral pipe condenser pipe, where the condenser in the form of a drum containing 50 liters of water is flowed using a San-EI brand water pump model SE 125A, 230 watts of electric power, pump suction power 42 liters / minute to 100 liters of water filled drum so that it occurs circulation of water that keeps the condenser cool. The pipe used is made of 2 mm thick stainless steel, 0.75 inch diameter, 30 cm spiral coil diameter and 12 spiral circles.5. The combustion stove used is the gas type 0100 win gas stove with a gas source of 3 kg LPG gas.6. The pyrolyzer lid locking bolt uses an airtight cover with a screw system. The lid of the pyrolisator is also equipped with a thermometer brand sellery maximum temperature 600oC, and the cap tone is also equipped with heat-resistant rubber to avoid smoke leakage on the tube connector and lid of the pyrolisator.7. There are 2 pieces of liquid smoke poured through stainless steel pipes from plastic containers, or glass.8. To speed up the withdrawal of liquid smoke from the pyrolysis tank, it is assisted by using a brand value vacuum pumpb. Standard Operating Procedure Use of liquid smoke maker1. Prepare 2 kg of raw material for cocoa peel moisture content of 10%, 15%, 20% and 25%. Each raw material is first cleaned, reduced in size from 2 to 4 cm, dried in the sun, and measured in its water content using the MBI-TM-20 type multi-digital water content measuring device.2. Put the cocoa peel ingredients with different moisture content into the pyrolyzer and close it tightly so that the condition is completely airtight.3. Check the pyrolysis pipe connection is really strong and does not leak and the vacuum compressor pump can work safely4. Make sure enough cooling water and the circulating water pump runs smoothly5. Turn on the heating source (gas stove), while paying attention to the temperature movement on the temperature gauge according to what is desired and pay attention to the time of pyrolysis until the first smoke comes out and the liquid smoke comes out.6. During the pyrolysis process, make sure enough water flows and inundates the condenser spiral pipe so that the condensation event can take place perfectly7. The pyrolysis process is considered complete if there is no more liquid smoke coming out from the pyrolysis tank.8. After the pyrolysis phase is complete, a cooling process is carried out by waiting until the temperature drops (room temperature), after the temperature drops, the lid is opened valve and weigh the activated charcoal pyrolysis results, including measuring the volume of liquid smoke, tar by opening tar reservoir on the pyrolysis pipe flow and the weight of charcoal obtained.9. Clean and trim the pyrolysis device and condenser when it's finished making liquid smoke.c. Calculation of yield results from the pyrolysis process (Luditama, 2006).

1. Liquid smoke recovery

$$\text{Liquid smoke recovery} = \frac{\text{liquid smoke mass}}{\text{Ingredient mass}} \times 100\%$$

2. Charcoal recovery

$$\text{Charcoal recovery} = \frac{\text{Charcoal mass}}{\text{Ingredient mass}} \times 100\%$$

3. Tar recovery

$$\text{Tar recovery} = \frac{\text{Tar } mass}{\text{Ingredient Mass}} \times 100\%$$

4. Missing Ingredient Recovery

Loss of material weight= Ingredient$Mass$ - (liquid smoke $mass$ + charcoal $mass$ + tar $mass$)

$$\text{Missing Ingredient Recovery} = \frac{\text{Loss of Material weight}}{\text{Ingredient weihgt}} \times 100\%$$

5. Analysis of tool performance

Tool performance capacity = total liquid smoke (ml) / Burning time (minutes)

RESULTS AND DISCUSSION

a. Designing Liquid Smoke Making Equipment

The design of the liquid smoke maker can be seen in Figure 1. The design of the tool is based on the existing liquid smoke maker and the study of literature. The results of designing and manufacturing obtained a pyrolyzer with a volume capacity of 27 liters equipped with coolant, a container of liquid smoke and heat sources derived from gas stoves and vompa vacuum

Figure 1.Construction of liquid smoke making equipment a).Pirolisator tube b). Smoke channel pipe, c). Condenser, d).Liquid smoke container. e). Vacuum pump

b. The process of making liquid smoke.

The process of making liquid smoke is done using raw materials of brown skin with different moisture content. Each raw material is put into a pyrolyzer with a 2 kg amount of material filled in the pyrolysis tube. The material in the pyrolyzer is heated to the boiling point of the organic compounds in the material so that the phase turns into steam / gas. The steam / gas that has come out from the material will flow to the top of the pyrolyzer and exit through the pipe then flow into the condenser for the condensation process. Liquid smoke that has turned the solid phase into a liquid phase exits through the condenser and enters the storage tube. Charcoal as a residue will be left inside the pyrolisator. Besides that there are also other ingredients that cannot be condensed or missing ingredients and tar. Trials of each ingredient were carried out three times. The trials that have been carried out can know several things, among others (data in Table 1): 1. The first smoke coming out of the pyrolyzer after the pyrolysis process runs between 10-20 minutes and the temperature of the pyrolyzer above 600C. 2. Liquid smoke first comes out after the pyrolysis process runs between 20-70 minutes and the temperature of the pyrolysisator is above 700C. The difference in time and temperature of each ingredient due to differences in water content of each cocoa skin raw material is seen from the amount of water content and raw material density. c. The yield of pyrolysis

The trial of liquid smoke producing equipment was carried out on four cocoa skin ingredients with different moisture content carried out 3 times to produce liquid smoke, tar, charcoal and missing material, shown in Table 2.

Table 1. Trial average yield of liquid smoke generator

No	Material	The first smoke came out		First Liquid Smoke Exits		Length of Pyrolysis (minutes)
Times (menute)			Temp (^{o}C)	time(menute) /Temp. ^{o}C)		
1	Cocoa pods .10%	10,00 c	85 a	20 a	125 a	60 d
2	Cocoa pods .15%	13,33 ab	75 b	48 b	100 b	90 c
3	Cocoa pods 20%	16,67 bc	70 bc	55 c	80 c	105 b
4	Cocoa pods 25%	20,00 a	65 c	70 d	72 d	120 a

From table 1 above shows the fastest time of the first smoke coming out on cocoa peel raw material water content of 10%, it is thought to be caused by the water content in a little so as to accelerate the release of smoke. This will be related to the first liquid smoke coming out. Materials with high water content will be slower to reform the components contained in the cocoa skin material so that it affects the time of pyrolysis. Statistically after further testing showed that the differences in water content on cocoa skin raw materials showed significant differences between treatments.

Table 2. Average Results of Design Test Tools for Various Moisture Content of Fruit Skin Raw Materials cocoa

Moisture content of cocoa pods	Amount of material (kg)	T (^{o}C)	Liquid smoke component			
			Liquid smoke (%)	Tar (%)	Chrcoal (%)	Loss ingredient (%)
Cocoa pods ka.10%	2	200	20,00 a	6,00 c	50,00 a	24,00 a
Cocoa pods ka.15%	2	200	24,00 b	7,00 bc	45,67 ab	23,33 b
Cocoa pods ka 20%	2	200	33,33 c	8,00 b	42,00 bc	16,67 c
Cocoa pods ka 25%	2	200	44,00 c	12,00a	39,00 c	5,00 d

Table 2 shows that the results of the pyrolysis test on four types of raw materials produced liquid smoke yields which were 44.00% highest for 25% cocoa pods and 20% lower for 10% brown skins. These results indicate that the design build a pyrolyzer from 27 kg stainless steel gives maximum yield for brown leather material 25% moisture content so that the designed pyrolisator has a high performance with a yield of liquid smoke yield up to 44.00%. The high yield of brown skin liquid smoke of 25% moisture content compared to other materials is also shown from the pyrolysis temperature up to 200oC.

Pyrolysis temperature greatly influences the yield of liquid smoke produced, from the experiments that have been conducted showing that the higher the temperature in the pyrolyzer will decompose the organic components in the material into liquid smoke to the maximum, so that the liquid smoke produced will also increase the yield (Devison , 2015). Increasing the yield of liquid smoke for each increase in temperature due to each addition of heat in the pyrolysis process will describe many substances contained in the material, so that condensed smoke increases.

Organic compounds in the material can be released if the temperature of the material has reached and exceeds the boiling point. Compounds in liquid smoke have different boiling points, the phenol group has the highest boiling point of 285oC, the acid group has the highest boiling point 176oC and the carbonyl group with the highest boiling point 97oC (Astuti, 2000 in Devison, 2015). To find out more about the content of liquid smoke, it is necessary to analyze the characterization of liquid smoke content in each ingredient.

d. Tool Performance

In this study, besides the calculated yield, the work capacity of the tool was also calculated. The working capacity of the pyrolysis device is determined by the amount of liquid smoke produced per unit of time as shown in Figure 2

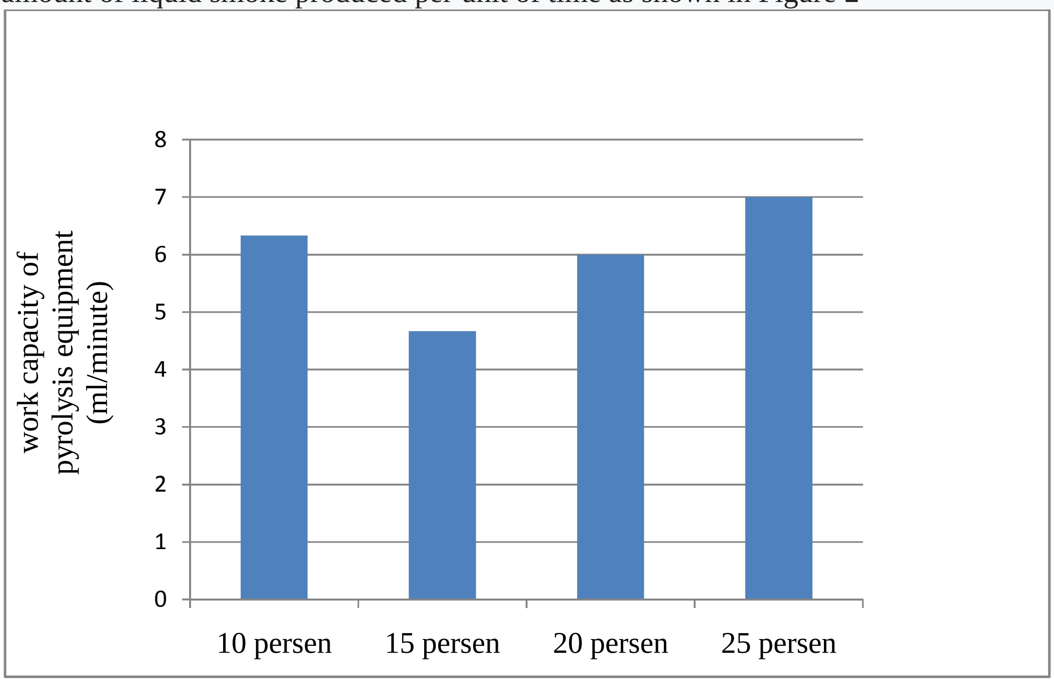

Figure 2. Capacity Diagram for Four Liquid Smokers for Cocoa Skin Raw Materials at different moisture content

Based on Figure 2 above, it is known that the performance of the liquid smoke maker of cocoa skin at the highest moisture content of 25% is followed by lower water content in cocoa fruit skin with a value of 7.00; 6.00; 4.67 and 6.33 ml / minute. The liquid smoke yield produced by the pyrolysis process will be influenced by the moisture content of the raw materials used, including water content and raw material density. The lower the density of the raw material the more liquid smoke will be produced. As shown in Table 3 the 10% cocoa skin moisture density is the highest among the raw materials of cocoa skin with lower moisture content so that the highest performance of the tool is obtained.

Table 3. Data on Water Content and Density of Each Cocoa Skin Raw Material with levels different water

No	Raw Material	Water content (%)	Density (gr/mL)
1	Cocoa pods	10	5,00
2	Cocoa pods	15	4,17
3	Cocoa pods	20	3,00
4	Cocoa pods	25	2,27

The low water content of cocoa skin raw material is 10% moisture content. According to Nisandi (2007), the water content of a good raw material for the pyrolysis process of liquid smoke is recommended not to exceed 8%. The increase in water content in the material will reduce the content of phenol, acids and formaldehyde in smoke (Guillen et al, 1999 in Sari et al., 2006).

The heat source in pyrolysis also affects the yield produced. The heat source in this study only comes from the bottom side of the tube so that the heat received by the material in the pyrolyzer is uneven. The density and cavity in the tool also affect the distribution of heat in the material. This results in the process temperature not being reached and the pyrolysis process not perfect. The process of decomposing and discharging liquid smoke components in the material requires even distribution of heat in the pyrolyzer so that the temperature of the desired material for the pyrolysis process of the material will run perfectly so that the liquid smoke in the material will be maximally removed (Devison, 2015).

CONCLUTION AND RECOMMENDATIONS

a.Conclusion

From the research that has been done, it can be concluded that the liquid smoke generator engineered from 3 kg LPG gas cylinders has been able to produce liquid smoke from cocoa pods. The capacity of the equipment in running water conditions for cocoa fruit peels at a moisture content of 10%, 15%, 20% and 25% respectively is 6.33; 4.67; 6.00; and 7 ml / minute and after being tested statistically significantly different. While the yield of liquid smoke each is 20.00 percent, 24.00 percent; 33.33 percent and 44.00 percent are also statistically significantly different

b.Recomendations

1. Design combustion so that the heat source in pyrolysis does not only come from under the pyrolyzer but from various directions so that the combustion process becomes more perfect so that the capacity of the tool and yield can be increased
2. Using an accurate temperature measuring device so as to produce a recording of the temperature of the pyrolysis process that is appropriate and in accordance with the actual conditions in the pyrolyzer.

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REFERENCES

Darmaji,P. (1996) Aktivitas Anti bakteri Asap Cair yang Diproduksi dari Bermacam-Macam Limbah Pertanian, Laporan Penelitian Mandiri, DPP-UGM, 16: 19 - 22.

Darmadji,P. (2002). Optimasi Pemurnian Asap Cair dengan Metode Redistilasi. Proseding Seminar Nasional, PATPI.

Devison. (2015). Rekayasa Pirolisator Berkinerja Tinggi Untuk Peningkatan Rendemen Asap Cair. Thesis Program Studi Teknologi Pertanian Universitas Andalas, Padang.

Fatimah Feti. (2011). Komposisi Dan Aktivitas Anti bakteri Asap Cair Sabut Kelapa Yang Dibuat Dengan Teknik Pembakaran Non Pirolisis. Agritech 31(4): 305 – 311.

Girrard,J,P. (1992). Technology of Meat and Meat Product. Ellis Hardwork, New York.

Haji, A. G. (2013). Komponen Kimia Asap cair Hasil Pirolisis Limbah Padat Kelapa Sawit. Jurnal Rekayasa Kimia dan Lingkungan 9(3) : 109 - 116.

Harsini and Susilowati,2010 "Pemanfaatan kulit buah kakao dari limbah perkebunan kakao sebagai bahan baku pulp denga proses organosolv," *J. Ilmu. Teknik.Lingkungan.*,**vol. 2, no. 2**, 80–89

Luditama C., 2006. Isolasi dan Pemurnian Asap Cair Berbahan Dasar Tempurung dan Sabut Kelapa secara Pirolisis dan Destilasi. Skripsi Fakultas Teknologi Pertanian IPB. Bogor.

Prasetyowati, Muhammad Hermanto, Salman Farizy. (2014). Pembuatan Asap Cair dari Cangkang Buah Karet Sebagai Koagulan Lateks.JurnalTeknik Kimia 20 (4):14 - 21.

Rahmi E.P, Anwar Kasim, Emriadi, AlfiAsben, 2018. Karekteristik Kinerja Alat Pembuat Asap Cair I Biomassa Pertanian. *AgricaEkstensia. Vol. 12 No. 1 Juni 2018: 45-50*

Nisandi.(2007). Pengolahan dan Pemanfaatan Sampah Organik Menjadi Briket Arang dan Asap Cair. Proseding Seminar Nasional Teknologi.Yogyakarta.

Putri, R. E, Mislaini., Lisa S. N. (2015). Pengembangan Alat Penghasil Asap Cair Dari Sekam Padi Untuk Menghasilkan Insektisida Organik. Jurnal Teknologi Pertanian Andalas 19(2):30-36.

Sari,R,N.,dkk. (2006). Rekayasa Alat Penghasil Asap Cair Untuk Produksi Ikan Asap. Jurnal Pasca panen dan Bioteknologi Kelautan dan Perikanan, Jakarta 1 (1): 65 - 73.

Syafri Edi, Sri Aulia Novita. (2011). Rekayasa Alat Pembuat Asap Cair Dengan Limbah Pertanian Sebagai Bahan Baku. Prosiding Seminar Nasional. POLITANI Payakumbuh.

Yefrida, Farrah Aprilina, Indri Ticel Leone, Refilda, MarniatiSalim. (2009). Uji Kativitas Anti Bakteri Asap Cair Yang Berasal Dari Batang Kayu Manis Dan Kulit Kacang Tanah. Jurnal Riset Kimia 2 (2) : 190 - 194.