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Development of liquid smoke production process as a latex coagulant by utilizing a refrigeration machine

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Abstract. This study aims to obtain a method of producing liquid smoke as a latex freezing material using a pyrolysis reactor equipped with a counter flow condenser with a cold water cooling medium. The raw materials as local wisdom studied were coconut shells and oil palm shells, abundant in South Sumatra. The condensation process uses a shell and tube type heat exchanger with counter flow. The raw materials were pyrolyzed with time variations of 180, 240 and 300 minutes. The production of liquid smoke with a pyrolysis duration of 300 minutes has the highest yield values of 36,66% and 29,74%, respectively, for the the raw materials of oil palm shell and coconut shell. The average amounts of tar separated from liquid smoke in a settling tank are 8.13% and 8.08%, respectively, for raw materials of oil palm shell and coconut shell.

1. Introduction

Indonesia is known as the Equatorial Emerald, an island nation and a country with abundant natural resource potential. Potential natural resources that are quite large include coal, oil and gas, Coal Bed Methane (CBM), geothermal, oil palm and rubber plants. Indonesia is estimated to have the opportunity to increase production while also increasing export volumes. estimated to reach 2.2% per year. In an effort to take advantage of these opportunities, Indonesia still faces various problems related to poor quality. To overcome this problem, several policies and developments need to be researched comprehensively [1].

Rubber plant (Havea brasiliensis) is one of the important plantation commodities and also a source of non-oil and gas foreign exchange for the Indonesian country. Most of Indonesia's rubber fields are smallholder plantations that contribute significantly to national natural rubber production. Indonesian rubber plantations spread across Sumatra island (70%), Kalimantan island (24%) and Java island (4%). In fact, Indonesia has the potential to become a major producer of global rubber if various major problems faced in managing rubber plant products can be overcome and agribusiness developed professionally. Expansion of the area of rubber plantations in Indonesia is expected to continue due to the relatively stable and high condition of world rubber prices. This needs the support of the government to achieve higher productivity and quality [1].

Rubber tree sap or commonly called latex is a rubber raw material used for manufacturing various kinds of tools for domestic or outdoor use such as shoe soles, car tires and various other products. One way to convert liquid rubber into crumb rubber is to use liquid smoke. Technology to make liquid smoke is needed especially by small farmers.

In general, rubber farmers in Indonesia still use frozen materials such as vinegar and potassium alum which can damage the quality of rubber. Besides damaging the quality of the latex produced, its use also produces a very bad odor that can interfere with the comfort of life of the people around the processing location. Currently, for the freezing of rubber tree sap is used liquid smoke produced from the raw materials of coconut shell or oil palm shell that can prevent and kill bacterial growth and also function as an antioxidant. The use of 1 liter of liquid smoke concentrate can freeze 200-250 liters of latex or the equivalent of 75 kg of dry rubber.

One method for producing liquid smoke is by pyrolysis of raw materials in the form of coconut shells, oil palm shells, rubber-wood or rice husks in a pyrolysis reactor. The gas produced from the reactor is then channeled through a long pipe to a condenser. In the condenser, the gas resulting from the pyrolysis process changes phase from gas to liquid or condensate [2]. The condensate liquid is then stored in a settling tank to separate tar from liquid smoke.

Tar which has a greater density will settle to the bottom of the tank while the condensate above it which has a lower density is liquid smoke (liquid smoke). There are three types of liquid smoke along with its benefits, namely: Grade-3 liquid smoke that is used in rubber processing to remove odors and wood preservatives to be resistant to termites, Grade-2 liquid smoke that is used for preserving smoked food (for example smoked meat or fish smoke) so it's safer than the use of formalin, and Grade-1 liquid smoke that is used as a preservative for fast food like meatballs, noodles, and tofu.

2. Literature Review

2.1 Refrigeration System

The refrigeration system can be applied to the field of refrigeration and air conditioning. At present the application covers a very broad range of fields, ranging from household, agricultural, to the gas, petrochemical, petroleum and even industrial uses such as manufacturing and construction. The fields of refrigeration and air conditioning are interrelated, but each has a different scope. In air conditioning not only covers the field of cooling but also includes heating, but both of them equally discuss the problem of air humidity, air quality and its distribution [3].

Refrigeration is the process of releasing heat from unwanted places. The heat taken from food aims to maintain the quality and taste of the meal. While the heat taken from a room aims to maintain human comfort in it. There are so many applications in the industrial world where heat has been released from several places or materials for the desired purpose [4].

In general, the field of refrigeration covers a temperature range up to 125 K, whereas processes that take place below 125 K are often called cryogenics (Cryogenics). This difference is due to the typical phenomena that occur at temperatures below 100 K, where in this temperature range gases such as nitrogen, oxygen, hydrogen and helium can melt [5].

The vapor compression cycle is the cycle most widely used in refrigeration systems. In this cycle the vapor is compressed, and then condensed into a liquid, then the pressure is lowered so that the liquid can evaporate again.

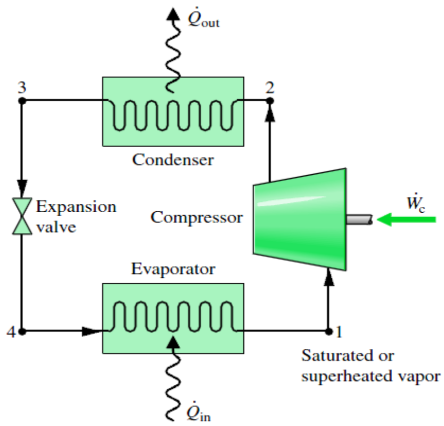

Figure 1. Vapor compression system

The standard vapor compression system can be seen in Figure 1 above. The cycle of a standard vapor compression system is as follows:

1-2 : Adiabatic and reversible compression, from saturated vapor to condenser pressure. This process takes place in a compressor where refrigerant vapor with low pressure and temperature enters the compressor through the suction line. The refrigerant vapor is then compressed in the compressor cylinder so that the temperature and pressure of the refrigerant vapor coming out of the compressor through the discharge line rises. The process that occurs in a compressor is assumed to be an isentropic process and the amount of compression work can be expressed by the following equation [6]

$$q_w = (h_2 - h_1) \quad (1)$$

with:

q_w = the amount of compression work (kJ/kg)
h_1 = enthalpy of refrigerant when entering the compressor (kJ/kg)
h_2 = enthalpy of refrigerant when exiting the compressor (kJ/kg)

2-3 : Release of reversible heat at a constant pressure, causing a decrease in heat further (desuperheating) and condensation of refrigerant. This process takes place in the condenser where the high temperature and pressure refrigerant vapor entering the condenser is condensed so that the refrigerant vapor undergoes phase change from the gas to liquid. The amount of heat released in the condenser can be expressed by the following equation [6].

$$q_c = (h_2 - h_3) \quad (2)$$

with:

q_c = The amount of heat released by the condenser (kJ/kg)
h_2 = Enthalpy refrigerant when entering the condenser (kJ/kg)
h_3 = Enthalpy refrigerant when exiting the condenser (kJ/kg)

3-4 : Non-reversible expansion at constant enthalpy, from saturated liquid to evaporator pressure.

4-1 : Addition of reversible heat at constant pressure, which causes evaporation of mixture refrigerant to saturated vapor refrigerant. This process occurs in the evaporator where the mixture refrigerant entering the evaporator absorbs heat from the cooled room or media. The amount of heat absorbed by the refrigerant in the evaporator is expressed by the following equation [7].

$$q_e = (h_1 - h_4) \quad (3)$$

with:

q_e = the amount of heat absorbed by the evaporator (kJ/kg)
h_1 = enthalpy of refrigerant when exiting the evaporator (kJ/kg)
h_4 = enthalpy of refrigerant when entering the evaporator (kJ/kg)

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2.2 Liquid Smoke

Liquid smoke is the result of condensation of pyrolysis vapor of raw materials containing lignin, cellulose, hemicellulose and other carbon compounds. Liquid smoke is produced by the pyrolysis process, ie compounds which evaporate simultaneously will be condensed in the cooling system. During the condensation process a coarse smoke condensate will be formed which will separate into three phases, that is, the soluble phase in water can be directly used, while the purified high-level tar phase extract can be used again for the production of liquid smoke and is usually called the primary tar fraction [8].

Liquid smoke can be applied in various ways such as mixing, spraying, dipping or mixed directly into food, soaking and injection. Besides heating liquid smoke to produce smoke-containing vapors is one of the methods used for food smoke.

Lots of materials that can be used as raw materials for making liquid smoke include wood, coconut shells, oil palm shells, coconut fiber, and cassava stems.

2.2.1 Coconut shell

Coconut shell is the hardest part of coconut fruit. Located next to the coir with a thickness of 3-5 mm and serves as a rotector of coconuts from damage from external influences. Coconut fruit needs to consist of fruit flesh of 30%, fiber of 33%, shell of 15%, and coconut water of 22%.

Coconut shells have as much lignin and a small amount of cellulose. The content of hemicellulose of coconut shell is almost the same as wood, and the water content varies according to environment, and fruit maturity. Coconut shell derived from ripe fruit in a dry state of air with a water content of about 6-9%.

The contents of lignin, cellulose, hemicellulose, and water of Indonesian coconut shell are 23.84%, 30.44%, 25.64% and 14.00%, respectively. The chemical composition of Indonesian coconut shell can be seen in Table 1 below.

Table 1. Chemical composition of Indonesian coconut shell [9]

Chemical composition	(%)
Lignin	23.84
Cellulose	30.44
Hemicellulose	25.64
Water content	14.00

2.2.2 Oil Palm shell

Oil Palm is a material for the processing of palm oil that produces a lot of waste, especially in the form of shells. As industrial waste, palm kernel shells are produced by oil processing plants up to tens of tons every day. In fact, this shell can be used as raw material for processing liquid smoke.

The most cultivated oil palm plantation in Indonesia is Elaeis Guineensis because this species has higher productivity. Based on the thickness of the shell, oil palm is divided into three types, namely: Dura, Pisifera, and Tenera. Dura is an oil palm whose fruit has a thick shell. Pisifera is oil palm that does not have a shell so it does not have a core that produces economical oil and sterile female flowers. Therefore Pisifera very rarely produce fruit while Tenera is a cross between female Dura and male Pisifera. This species is considered a superior seed that produces thin fruit skin and fertile female flowers [10].

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3. Research Methodology

The research method chosen was experimentation by designing pyrolysis equipment for raw materials of coconut and oil palm shells and liquid smoke resulting from the pyrolysis process will be applied to the freezing process of liquid rubber sap (Latex).

3.1 Research Flowchart

The research began with the preparation of research equipment, which is a pyrolysis reactor equipped with a condenser which is cooled by cooling water from a refrigerated water tank. The next step is testing the equipment and continuing with the collection of test results on the raw material for coconut shells and oil palm shells. Then, data analysis and processing are carried out before drawing conclusions and suggestions as the final stage. The stages of research conducted can be seen in the research flowchart shown in Figure 2 below.

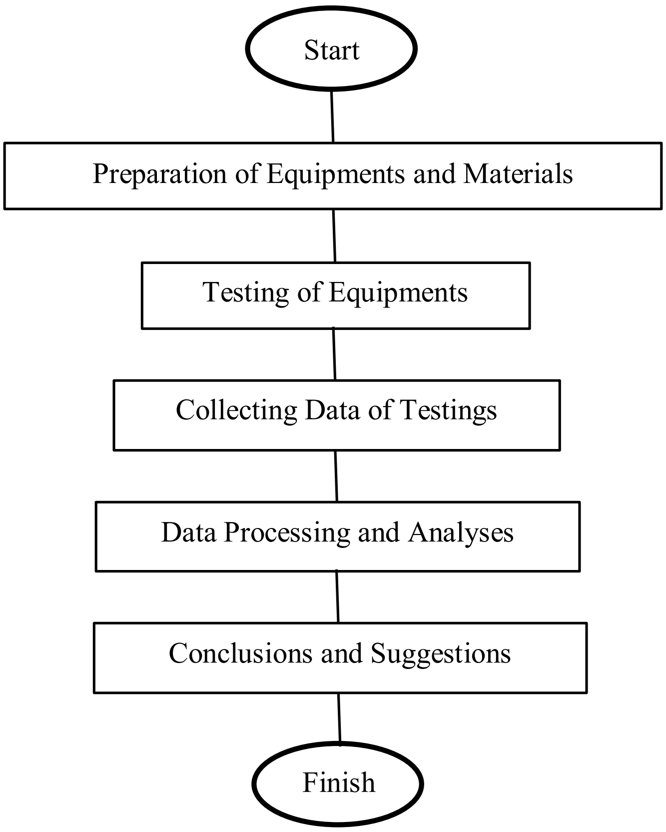

Figure 2. Research flowchart

3.2 Research Equipment

The equipment used in this study is a pyrolysis reactor equipped with a condenser cooled by cold water coming from a cooling water tank cooled by the evaporator pipes of a refrigeration machine. The temperature of the cooling water can be controlled through the evaporator pipes from the refrigeration machine which are passed into the cooling water tank. The vapor from the pyrolysis reactor will be condensed in the condenser and then the condensate from the condenser will be flowed to the settling tank to separate the tar from liquid smoke. The arrangement of equipment used is shown in Figure 3 below.

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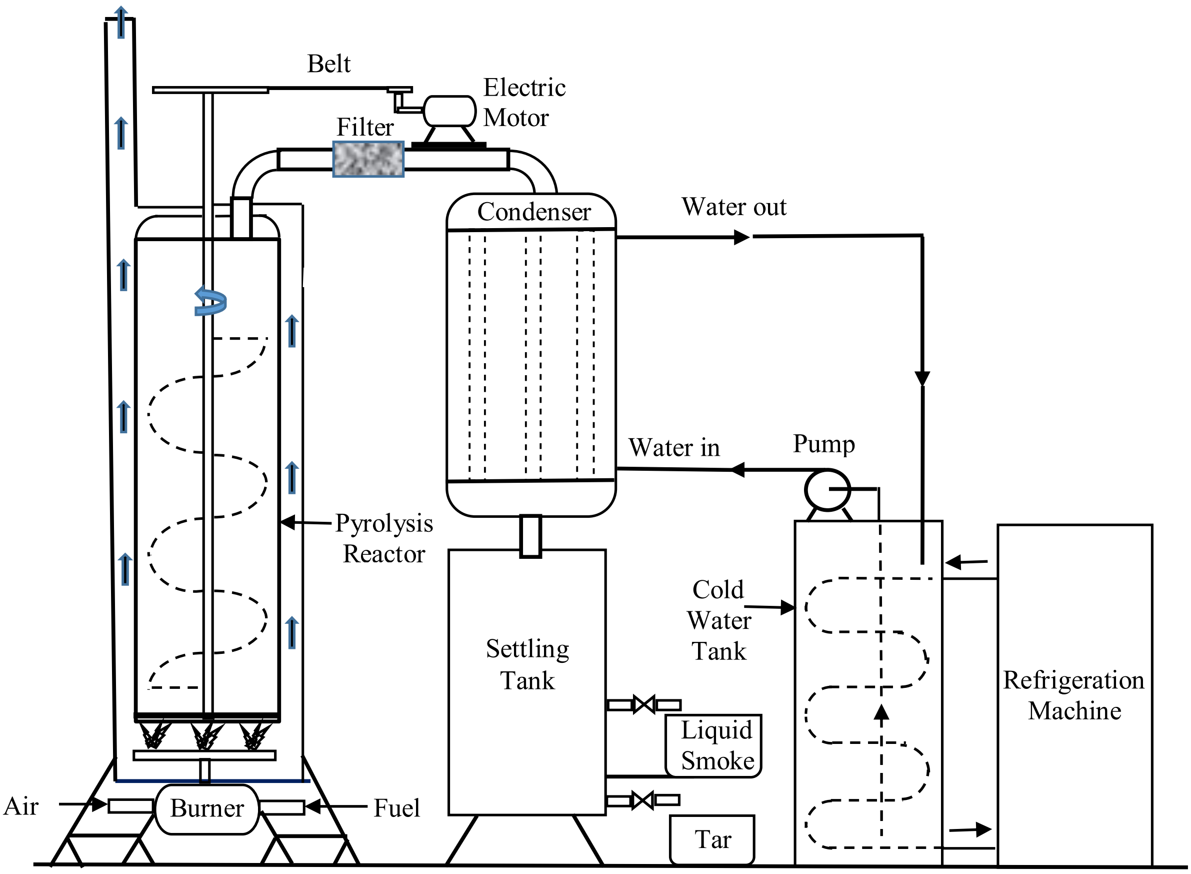

Figure 3. A pyrolysis reactor equipped with a condenser cooled with evaporator pipes of refrigeration machine

4. Results and Discussion

In this study, the raw materials used are coconut shells and oil palm shells. The two raw materials were pyrolyzed with time variations of 180, 240 and 300 (min). The fuel used is LPG gas and the amount of raw material for each cycle is 25000 (g) and the resulting liquid smoke is presented in Table 2 below.

Table 2. Data from the pyrolysis of raw materials of coconut shells and oil palm shells on the pyrolysis duration of 180, 240 and 300 (min).

No.	Raw Materials	Raw material weight (g)	Duration of Pyrolysis (min)	Total Distillation (cc)	Total Liquid Smoke (cc)	Tar Percentage (%)
1	Coconut Shell	25000	180	6987	6422	8.09
		25000	240	8175	7516	8.06
		25000	300	8439	7758	8.07
2	Oil Palm Shell	25000	180	8598	7898	8.14
		25000	240	10046	9229	8.13
		25000	300	10412	9565	8.13

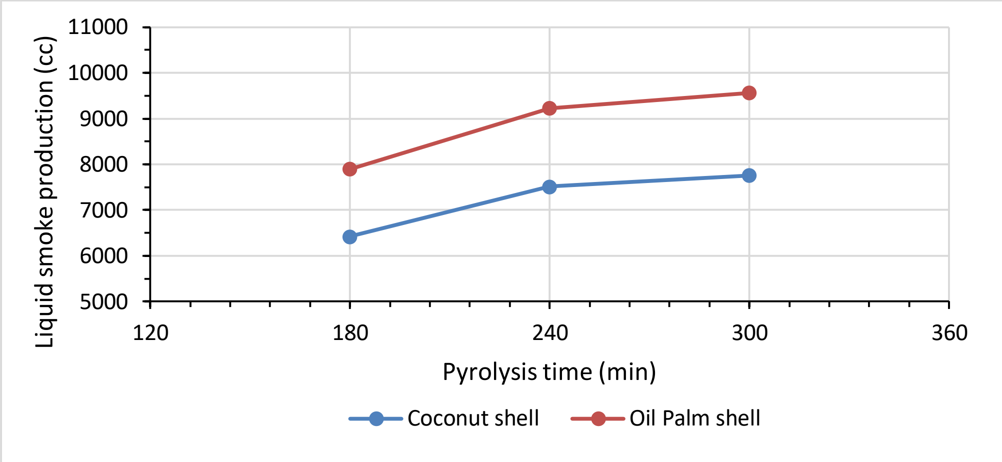

Figure 4. The effect of varied pyrolysis time on liquid smoke production for raw materials of coconut shell and oil palm shell at average pyrolysis temperature of 305°C and raw material weight of 25000 g.

Figure 4 shows that an increase in pyrolysis time from 180 (min) to 300 (min) resulted in an increase in the production of liquid smoke for the raw material of coconut shells and oil palm shells by 20.80% and 21.11%, respectively. It can also be seen that the percentage increase in the production of liquid smoke decreases between 180 to 240 minutes compared to between 240 to 300 minutes ie. from 17.04 down to 2.22 and from 16.85 down to 3.64, respectively, for raw materials coconut shells and oil palm shells. This is due at the 300th minute, the element of liquid smoke is almost completely out of the raw material.

The production of liquid smoke in the pyrolysis process with a pyrolysis duration of 300 minutes has the highest yield values of 29.74% and 36.66%, respectively, for the raw material of coconut shell and oil palm shell. In addition, the production of liquid smoke in the process of pyrolysis with a duration of 180 minutes has the lowest yield values of 24.62% and 30.27%, respectively, for the raw material of coconut shell and oil palm shell, as shown in Figure 5 below.

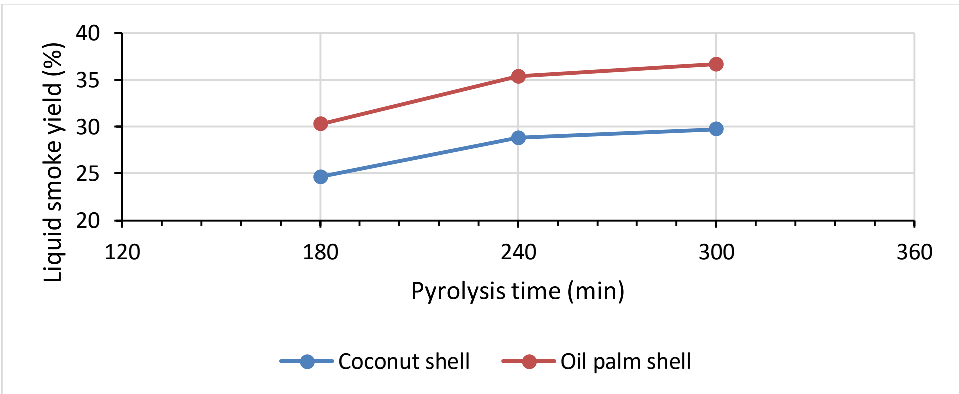

Figure 5. The effect of varied pyrolysis time on liquid smoke yield for raw materials of coconut shell and oil palm shell at average pyrolysis temperature of 305°C and raw material weight of 25000 g.

The total production of liquid smoke is highly dependent on the type of raw material used and the length of the pyrolysis process. This is consistent with the results of research conducted by Budaraga, et al. (1996) on the raw materials of coconut fibre, coconut shell and cinnamon [11]. The average amount of tar separated from the distillation liquid from the pyrolysis process of raw materials for coconut shells and oil palm shells is 8.07% and 8.13 as shown in Figure 6 below.

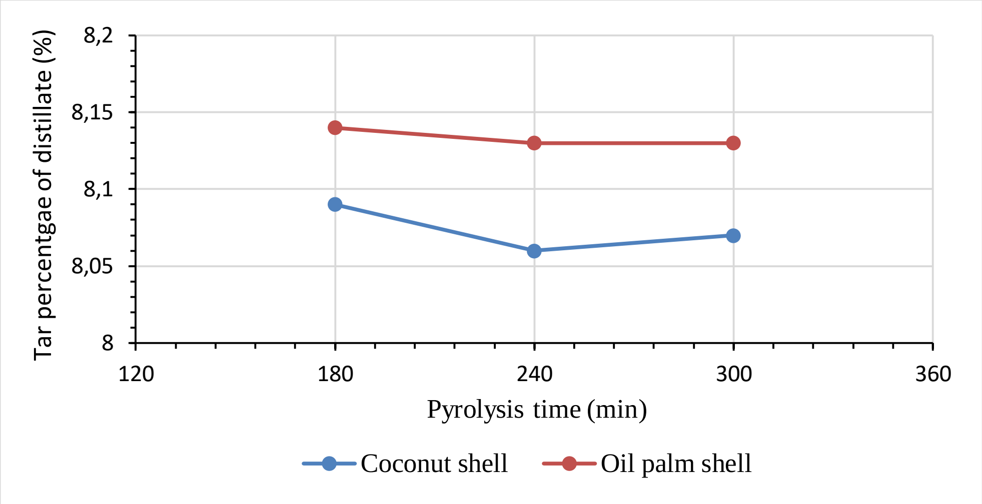

Figure 6. The effect of varied pyrolysis time on tar percentage of distillate (%) for raw materials of coconut shell and oil palm shell at average pyrolysis temperature of 305°C and raw material weight of 25000 g.

5. Conclusions

From the results of research on the development of the liquid smoke production process utilizing a refrigeration machine can be concluded as follows: 1). The raw material of oil palm shell has more potential to produce liquid smoke compared to the raw material of coconut shell, in the pyrolysis process. 2). The highest yield of liquid smoke occurred at a pyrolysis duration of 300 minutes, that is 29.74% and 36.66% for the raw materials of coconut shells and oil palm shells, respectively. 3). Condensate derived from the condensation process on vapor originating from the pyrolysis process of raw material of oil palm shell consists of liquid smoke of 91.87% and tar of 8.13%. 4). Condensate derived from the condensation process on vapor originating from the pyrolysis process of raw material of coconut shell consists of liquid smoke of 91.93% and tar of 8.07%.

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