Performance Test And Economic Evaluation Of Pyrolysis Furnace Small Scale-Worth The Business For Producing Liquid Smoke

A Indriati, D D Hidayat, and D A Darmajana

1 Development Centre of Appropriate Technology Indonesian Institute of Sciences, Jl. KS. Tubun No. 5 Subang West Java, Indonesia, 41213

Email: ashrindriati@lipi.go.id

Abstract. Liquid smoke is water which made of smoke as pyrolysis processing products. It can use in food products as a flavoring, texture, distinctive taste in food products such as meat, fish, and cheese. To produce liquid smoke safely and provide economic value, the effective and efficient a pyrolysis furnace that is indispensable. The study aimed to get the proper scale of the pyrolysis furnace and food grade liquid smoke which feasible for business. The research activities consisted of testing of the pyrolysis furnace, analyzing the content of liquid smoke, determining the effectivity of liquid smoke against various types of spoilage and pathogenic microorganisms and investigating market feasibility. Results of this study showed that the yield of pyrolysis was 42.26%, first distillation was 35.18% and second distillation was 34.33% of the raw materials used. The resulting liquid smoke indicated that no content of Polycyclic Aromatic Hydrocarbon (PAH). The liquid smoke concentration of 20%, 30%, and 40% was able to inhibit the bacteria E. coli, Salmonella, and Staphylococcus aureus; this meant that the liquid smoke was safe for use in food products. The feasibility analysis indicated that the liquid smoke business using the pyrolysis furnace was able to provide benefits and was feasible to run.

1. Introduction

Liquid smoke is a mixture of wood smoke dispersion solution of water produced by the liquid smoke condensation resulting from pyrolysis [1]. Liquid smokes were used extensively in food systems to provide flavor characteristics that were similar to natural smoked food products [2]. The liquid smoke may use to preserve quality and ensure the safety of foods [3,4]. There were many studies done due to liquid smoke. Results of the study showed that liquid smoke had many benefits. As a substitution substance, liquid smoke can replace phosphate in chicken nuggets processing, and replace borax or formalin in the production of beef meatballs [5]. As a pesticide liquid smoke inhibits the development of anthracnose disease, fusarium wilt [6], Pseudomonas solanacearum and Sclerotium rolfsii fungi in vitro [7]. In food processing liquid smoke may use for the binder, extends the shelf life of fish meatballs [8], preservative of wet noodles [9], antioxidants and antimicrobials, flavoring and distinctive taste of other food products [10] such as meat, fish, and cheese [11]. Due to the multifunction of liquid smoke, it has a business opportunity to be developed.

The raw materials used to produce a liquid smoke is coconut shell. In Indonesia Coconut is one of Indonesia's plantation potential. Based on the crop estate statistics of Indonesia 2015-2017, the area of coconut plantation was 32,755 Ha with the production of 2,871,280 tons [12]. One of the waste from coconut is coconut shell. To produce an economical product, one of the methods that used is through pyrolysis of raw materials containing hemicellulose, cellulose, and lignin that would be condensed to become liquid smoke. Coconut shell is more suitable for pyrolysis process as it provides lower ash content, and high volatile matter content [13].

The community will undoubtedly require the existence of appropriate technology to process the coconut shell into liquid smoke for both food and non-food purposes. The technology needed is a
technology that is safe, easy to operate and can provide benefits. The study aimed to determine the
smallest scale of business-worthy pyrolysis furnace and distillation apparatus and to obtain a food grade
liquid smoke.

2. Experimental method

2.1. Sites
The study conducted in February and July at the Development Center for Appropriate Technology-
Indonesian Institute of Sciences, Subang district-west java province.

2.2. Equipment and materials
Equipment used in liquid smoke production were scales, pyrolysis furnaces, blowers, condensing drums,
gas tanks, electrical pumps, plastic dippers, distillation apparatus, graduated cylinders, beaker glasses,
and glass jars.

Materials used for liquid smoke production were Kerosine, liquid petroleum gas, and coconut shell.
Coconut shells used as raw materials had a moisture content of 7.47% and with an ash content of 0.88%.
Kerosene used at the time of initial ignition, and liquid petroleum gas used during the distillation process.

2.3. Research methods
The experiment consisted of testing the pyrolysis furnace and refinement equipment manufactured, and
analysis the liquid smoke quality. Parameters observed regarding pyrolysis and distillation process
included of equipment specifications, capacity, and temperature of pyrolysis and refinement, as that for
the resulting liquid smoke consisted of volume, pH, and chemical content. Determination of liquid
smoke chemical content of liquid smoke conducted by Gas Chromatography-Mass Spectrometry
(GCMS) analysis and grading of that referred to researched done by Fauzan and M. Ikhhwanus [14].

2.4. The process of Liquid Smoke production

2.4.1. Pyrolysis
Etymologically the word pyrolysis came from Greek, i.e., pyro and lysis. Pyro meaning fire, and lysis
meaning to loosen. Pyrolysis, therefore, is the process of thermal decomposition in producing the gas, a
liquid, and the char. Pyrolysis usually understood to be thermal decomposition occurred in the oxygen-
free atmosphere, but oxidative pyrolysis is nearly always an inherent part of combustion processes [15].

The steps of liquid smoke producing was as follows. A quantity of 26.5 kg of coconut shell imparted
to the pyrolysis furnace then initiate the ignition using kerosene. The blower used to drain the hot smoke
through the pipe to the condensing drum. The flowing water in the condensing drum will absorb hot
smoke in the pipeline. The resulting liquid smoke will come out through the sheltered smoke exit place.
The liquid smoke produced from the pyrolysis process classified as grade 3.

2.4.2. Distillation
The first stage distillation conducted to obtain a liquid smoke grade 2. The way to get the liquid smoke
grade 2 was to impart the liquid smoke grade 3 into distillation apparatus. The heating process during
distillation used LPG fuel.

2.4.3. Redistillation
The second stage distillation carried out to obtain Liquid smoke grade 1. The way to get the liquid
smoke grade 1 was to place the liquid smoke grade 2 into distillation apparatus.

Results Analysis
Gas Chromatography-Mass Spectrometry (GCMS) performed To obtain the chemical content of
the Liquid smoke, while the financial feasibility analyzed by calculating variable components as follows.

3. Result and Discussion

3.1. Liquid Smoke Tools
The Tool used for the manufacture of liquid smoke comprised of pyrolysis and distillation equipment.
The schematic of the liquid smoke making apparatus presented in Figures 1 and 2.
In this experiment used a pyrolysis tool which had a capacity of 26.5 kg. The raw material used was coconut shell. Results of this experiment were 11.2 liters of liquid smoke that had a pH of 3 and the time required was 2 hours. Assumed that a density of liquid smoke was 1.009 gr/cm$^3$ [16], the yield of the liquid smoke was 42.26%. The yield was the ratio of liquid smoked amount pyrolyzed from the coconut shell. Yield measurement conducted on the condition of the reactor outside walls temperature of 201 ºC and environmental temperature of 27 ºC. The temperature measured using an infrared thermometer.

The pyrolysis process produced liquid smoke grade 3. This third-grade liquid smoke then further distilled for 8 hours and produced second grade. The yield was 9.32 lt, i.e., 35.18% with a pH of 2.425. Measurement of result done at a condition of highest temperature outer wall of the distillation apparatus of 81.7 ºC, fire temperature of 257 ºC and environment temperature of 24 ºC.

The last processing stage of liquid smoke was redistillation. The tools used together with previously distillation equipment. Results of redistillation were liquid smoke grade 1. The yield was 9.10 lt, i.e., 34.33 % with a pH of 2.425; the processing time was 4 hours. Measurement of result was conducted at a condition of highest temperature outer wall of the distillation apparatus of 84.4 ºC, fire temperature of 258 ºC and environment temperature of 26 ºC.

### 3.2. Liquid smoke generated

Liquid smoke obtained from each process, i.e., grade 3, grade 2 and grade resulting from the pyrolysis, distillation and distillation process respectively, then analyzed with Gas Chromatography-Mass Spectrometry (GCMS) The analysis data presented in Table 1.

| Peak | Name             | R. Time | Area  | Area (%) |
|------|------------------|---------|-------|----------|
| 1    | 2-Decyne-1-ol    | 0.021   | 35474 | 0.58     |
| 2    | Boric acid (H$_3$BO$_3$) | 1.336 | 237897 | 3.88     |
| 3    | 2-Propanone      | 1.395   | 53934 | 0.88     |
Table 2 showed that there was no content of Polycyclic aromatic hydrocarbons (PAH) in liquid smoke produced. PAH was one of the chemical components that might form on the manufacture of coconut shell liquid smoke. Some PAH compounds were carcinogenic compounds. PAH compounds were not present in liquid smoke generated in the pyrolysis temperature below 400 ºC. The combustion process occurred in the heat under 400 ºC had not formed PAH [8]. Food processing allowed to use liquid smoke with no PAH. Phenol and acid contained in liquid smoke had a function as an antimicrobial [8]. Due to that food preservation can use liquid smoke such as meatballs, noodles, and tofu [14].

3.3. Anti Microbial Test
First-grade liquid smoke is the best liquid quality and produced no harmful compounds to apply to food products [14]. Anti-microbial tests performed only at first-grade level with concentrations of 20%, 30%, and 40%. Determining the level of intensity based on an earlier study conducted by Harun al Rashid that stated the concentration of 30% was the best concentration for preserving the fresh anchovy [17]. Results of other earlier study reported that.
Concentrations level of 0%, 5%, 10% and 15% of liquid smoke tested on fresh fish had no inhibitory effect against Pseudomonas bacteria and 0% and 5% concentrations of that also had not been able to inhibit against E. Coli; inhibitory resistance of liquid smoke just occurred at the level of 5% and 10% against the Staphylococcus aureus bacteria [8]. In this study, the antimicrobial test performed by paper diffusion method against bacterial pathogens that contaminated food products such as E. coli, Salmonella, and Staphylococcus aureus. Inhibition zone of each bacteria shown in Figure 3.

![Figure 3. The inhibition zone against (a) E. coli (b) Salmonella, and (c) Staphylococcus aureus](image)

Figure 3 showed that a concentration of 20 %, 30 %, and 40 % respectively indicated the ability to inhibit E. coli, Salmonella, and Staphylococcus aureus. The results of the research on microbial inhibitory seen in Table 2.

![Table 2. The Liquid Smoke Resistance of various concentration level against E. coli, Salmonella, and Staphylococcus aureus](table)

| Concentration (%) | E. coli | Salmonella | Staphylococcus aureus |
|-------------------|---------|------------|----------------------|
| 20                | 13.00±2.65 | 14.67±5.03 | 33.00±2.00           |
| 30                | 15.00±1.00 | 17.67±3.05 | 34.67±2.08           |
| 40                | 17.50±0.50 | 24.00±1.00 | 40.00±1.73           |

Description: The different notation letters showed a significant difference in the significant level (α) of 5%.

3.4. Cost Determinations

3.4.1. Investment Costs

Investment costs represented all expenses incurred either in the form of production equipment and value for supporting apparatus. The calculation of investment costs on the manufacture of liquid smokes showed in Table 3.

![Table 3. The equipment of production](table)

| Name                          | Total unit | Unit cost (Rp) | Total cost (Rp) | Economic life (Rp) | Salvage value (Rp) | Depreciation (Rp) |
|-------------------------------|------------|----------------|----------------|--------------------|--------------------|-------------------|
| pyrolysis furnace             | 1          | 10,000,000,-   | 10,000,000,-   | 5                  | 1,000,000,-        | 1,800,000,-       |
| LPG thank                     | 1          | 400,000,-      | 400,000,-      | 5                  | 40,000,-           | 72,000,-          |
| electrical pump (120 Watt)    | 1          | 350,000,-      | 350,000,-      | 5                  | 35,000,-           | 63,000,-          |
| blower (1.6 A, 220 V, phase 1)| 1          | 350,000,-      | 350,000,-      | 5                  | 35,000,-           | 63,000,-          |
| Liquid smoke container        | 2          | 15,000,-       | 30,000,-       | 5                  | 3,000,-            | 5,400,-           |
| Plastic funnel                | 1          | 5,000,-        | 5,000,-        | 5                  | 500,-              | 900,-             |
| Plastic dipper                | 1          | 10,000,-       | 10,000,-       | 5                  | 1,000,-            | 1,800,-           |

Total 11,145,000,- 2,006,100,-

3.4.2. Operating Costs

Operational cost is the cost used to produce a liquid smoke product using a coconut shell as raw material. Monthly production costs calculated with the assumption of production ten times a month. The annual production costs were the product of the multiplication of monthly production costs by the number of
months per year. Operational costs consist of variable costs and fixed costs. The variable costs, fixed costs and total cost presented in Table 4, 5, and 6, respectively.

**Table 4. Variables costs**

| Name                          | Total unit | Unit cost (Rp) | Cost (1 month) (Rp) | Cost (1 year) (Rp) |
|------------------------------|------------|----------------|---------------------|--------------------|
| Maintenance of assets        |            |                |                     |                    |
| - Raw material               | 26,5 Kg    | 2,203.39,- /Kg | 583,898.31,-        | 7,006,779.66,-     |
| - 1-litre plastic bottle     | 91 pcs     | 2,000,- /pcs   | 182,000,-           | 2,184,000,-        |
| Pyrolysis process            |            |                |                     |                    |
| - Electric Pump (120 Watts)  | 2 hours    | 132,- /kwh*    | 2,640,-             | 31,680,-           |
| - Electric Blower (1,6 A, 220 V, phase 1) | 2 hours    | 387.2,- /kwh*  | 7,744,-             | 92,928,-           |
| Distillation process         |            |                |                     |                    |
| - LPG                        | 1,6 Kg     | 13,750,- /kg   | 220,000,-           | 2,640,000,-        |
| - Electrical Pump (120 Watts) | 8 hours    | 132,- /kwh*    | 10,560,-            | 105,600,-          |
| redistillation process       |            |                |                     |                    |
| - LPG                        | 1 Kg       | 13,750,- /kg   | 137,500,-           | 1,650,000,-        |
| - Electrical Pump (120 Watts) | 4 hours    | 132,- /kwh*    | 5,280,-             | 63,360,-           |
| Total                        |            |                |                     | 1,149,622.31,-     |

*Electricity Base Tarif Rate B-1

**Table 5. Fixed costs**

| Name   | Total unit | Unit cost (Rp) | Cost (1 month) (Rp) | Cost (1 year) (Rp) |
|--------|------------|----------------|---------------------|--------------------|
| Labour | 2 persons  | 500,000,- /month | 1,000,000,-         | 12,000,000,-       |

**Table 6. Total costs**

|                  | Total cost (1 year) (Rp) |
|------------------|--------------------------|
| Variable costs   | 14,274,347.66,-          |
| Fixed costs      | 12,000,000,-             |
| Total costs      | 26,274,347.66,-          |

3.4.3. *Cash inflow (Proceed)*

The assumption of making liquid smoke used a queuing system; the working hours was 8 hours per day; total consumed time per batch process, i.e. 26 kg of raw materials, was 14 hours (2 days); production frequency was 20 days a month; monthly cash flow was 2,727,000 rupiahs (9.09 x 10 x 30,000 rupiahs). Therefore, based on the existing price of first-grade liquid smoke on the market, the determining annual cash flow presented in Table 7.

**Table 7. The annual cash flow**

| Cash Flow Component | Total |
|---------------------|-------|
| Revenue             | Rp, 32,724,000,- |
| Total cost          | Rp, 26,274,347.66,- |
| Gross profit        | Rp, 6,449,652,- |
| Tax 1%              | Rp, 64,496.52,- |
| Net profit          | Rp, 6,385,155.82,- |
| Depreciation        | Rp, 2,006,100,- |
| Cash inflow         | Rp, 4,379,055.82,- |

3.4.4. *Feasibility Analysis*

Business feasibility analysis conducted to determine the financial feasibility of a business. Table 8 showed the results of the feasibility analysis.

The payback period is the period required to recover the cost of an investment. The result of the analysis found that the return period obtained of the liquid smoke making was 2,545 months. The earlier
study [18] stated that business defined as feasible if the value of payback periods equaled to that of economic life. Therefore liquid smoke producing in this study was reasonable to run.

The net present value (NPV) is a measurement of profit calculated by subtracting the PV of cash outflows from the PV of cash inflows over a period and. The profitability Index is the proportion of payoff to the investment of a proposed project. Results of the analysis showed that the net present value of 5,454,686.88 which was positive and more than 1; and profitability index of 1,489 indicated that liquid smoke using the existing equipment could provide benefits and was feasible to run.

The internal rate of return (IRR) is used to compare and decide between capital costs. The IRR is the interest will bring a series of cash flows (positive and negative) to a net present value (NPV) of zero (or to the current amount of value of cash invested). Table 9 showed that the analysis result of IRR was 27.81%. It was more than 10% discount rate. Therefore the business run was acceptable.

### Table 8 Feasibility Analysis

| Method  | Total       |
|---------|-------------|
| BEP unit | 126.18 liter |
| BEP     | Rp, 3,785,298.55,- |
| PP      | 2,545 months |
| NPV     | Rp, 5,454,686.88 |
| PI      | 1,489 |
| IRR     | 27.81% |

4. Conclusion
The maximum capacity of a pyrolysis furnace per batch was 26.5 Kg of coconut shell. The yield of the pyrolysis process, distillation, and redistillation was 42.26%, 35.18%, and 34.33% respectively. The resulting liquid smoke showed that there was no PAH content. Therefore, it was safe for use on food products. Liquid smoke with a concentration of 30% was the best concentration for inhibiting *E. coli*, and *Salmonella* bacteria and the level of 40% was the best concentration to inhibit against *Staphylococcus aureus*. Feasibility of business tests showed that liquid smoke using the existing equipment could provide benefits and was feasible to run.

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