LEX LOCALIS-JOURNAL OF LOCAL SELF-GOVERNMENT
ISSN:1581-5374 E-ISSN:1855-363X
VOL. 23, NO. S6(2025)

LOCALIZING SOY FIBER PRODUCTION FROM TOFU DREGS TO REDUCE IMPORT DEPENDENCY: A PILOT STUDY USING COAL-FUELED TECHNOLOGY

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Abstract: Tofu dreg has excellent potential as a source of dietary fiber and is used as a raw material for the Food and Beverage industry to produce added value products. Indonesia is an importer of soy fiber. Commanditaire Vennootschap (CV) Samudra Alfath and Pamulang University collaborated to produce soy fiber for a pilot project and research and development. The research objective was to compare the efficiency of coal energy, gas fuel, and diesel in processing tofu dreg into soy fiber. The soy fiber production process began with heating a thermal oil heater (TOH) with coal for two hours to heat the oil to an output temperature of 190^0 C to produce hot air, which was directed to a rotary dryer for the drying process of tofu dreg which has gone through the pressing process into the fiber, which was ground in a hammer mill to get 80 mesh. The results from 1 ton of tofu dregs per day produced 150 kilograms of soy fiber. The comparison of the use of fuel for processing 1 ton of tofu dregs, namely 150 kilograms of coal, 184.5 liters of diesel, and 148.9 kilograms of gas, with a coal production cost of IDR 728,700; IDR 2,573,676 of diesel fuel; IDR 2,754,587 of gas.

Keywords: business sustainability, Soy fiber, tofu dregs, saving the environment

Introduction

Based on the Statistical Database of Food and Agriculture Organization companies in 2016, Indonesia was ranked 13th as the largest soybean producer globally, mainly used for daily food. According to the Central Bureau of Statistics (BPS), soybean production in Indonesia in 2018 was 982,598 tons/year. The Central Bureau of Statistics (BPS) survey showed that Indonesia's average tempeh and tofu per capita consumption was 0.304 kg per week in 2021. The average consumption per capita for tofu was 0.158 kg, and tempeh was 0.146 kg per week in 2021. Ironically, the higher demand for soybeans, around 67.28% or 1.96 million tons, must be met from imports. When processing tofu, 120% of tofu dreg comes from processing dry soybeans (The Indonesian Food and Product Authority (POM), 2009). Approximately 1 kg of tofu dreg is produced for every kg of dry soybeans made into soy milk or tofu. More specifically, 53% of the initial dry mass of soybeans is found in tofu, 34% tofu dreg, and 16% whey. 72% protein is found in tofu, 23% in tofu dreg, and 8% in whey. The average yield of soybean oil was 82% protein, 16% tofu dreg, and <1% whey. Although the actual composition depends on the specific process and soybean variety, fresh tofu dreg contains 76-80% water content, 2.6-4.0% protein, and the remaining percentage is for other solids. When dried, tofu dreg contains 25.4-28.4% protein, 9.3-10.9% oil, 40.2-43.6% insoluble fiber, 12.6-14.6% soluble fiber, and 3.8-5.3% soluble carbohydrates. Therefore, tofu dregs have high fiber, protein, and oil content [13].

Tofu dreg is proven to be a high-quality by-product with several nutritional components such as dietary fiber, polysaccharides, isoflavones, small molecule peptides, and so on [12]. In addition, tofu dreg contains a high total fiber content, which is 28.4%. Human dietary fiber needs are about 38 g/day for men and 25 g/day for women. Thus, tofu dregs have excellent potential as a source of dietary fiber.

A high-fiber diet provides several benefits, including lowering cholesterol concentrations and blood pressure, aiding weight loss, improving glucose and insulin responsiveness, maintaining a healthy digestive tract, and lowering the risk of cancer [2, 7]. It affects laxation, lowers blood cholesterol, and lowers glucose throughout the year.

In general, soy fiber can be used as a food additive in bakery products such as bread without causing significant color changes. Soy fiber has a high vegetable protein because it is made from one hundred percent soybeans. Thus, it can be a meat substitute for vegetarians and tastes like meat [9].

Dietary fiber, as stated earlier, adds various functional properties to food products and health benefits. Due to its water-holding and fat-binding abilities, dietary fiber is combined with various meat products to increase cooking yields and minimize fat content [4]. Low-fat and low-sodium meat products and restructured meat products are made with dietary fiber from a variety of sources plus additional components [1, 4, 6].

Indonesia was still dependent on imports (Food preparation) of soy fiber, as can be seen from the data in Figure 1.

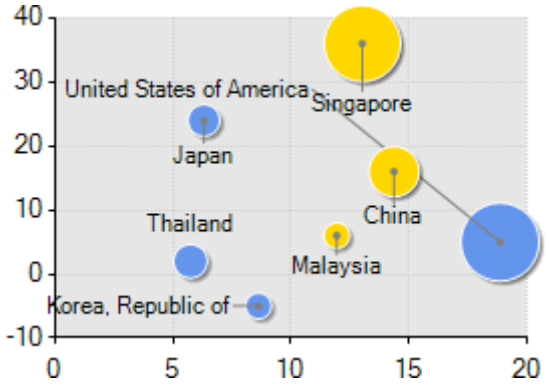

Figure 1. Imported Food Preparation Data (*Soy Fiber*) 2021
(Source: *https://www.trademap.org/Index.asp*)

Indonesia still relies on food (soy fiber) originating from the United States, China, Singapore, Malaysia, Korea, Japan, and Thailand. The largest importing countries of food (soy fiber) to Indonesia are the United States 18.9%, China 14.4%, Singapore 13%, Malaysia 11.9%, and Korea 8.6%.

There are several ways to dry tofu dregs to make fiber, from heating the machine to grinding the fiber to equalize the desired particle size. In this experiment, researchers used coal as fuel to heat oil to produce hot steam. The solid fuels found on our earth come from organic substances. Solid fuels contain elements such as charcoal or carbon (C), hydrogen (H), acid or oxygen (O), nitrogen (N), sulfur (S), ash, and water. All of them are bonded in chemical compounds. Examples of solid fuels are wood, coconut shells, coal, and so on.

Coal is a dark brown combustible rock produced when soil and water plants accumulate, buried during geographic ages transmitted by heat and pressure. It takes a long time to form a thick, extensive layer of coal deposits where the soil sinks slowly. It is then slowly buried underground as the soil sinks, the sand covers it, and plants thrive on it. The advantage of coal compared to other fuels is the abundance of electric power. It is reliable

energy, has lower costs, and has more significant fuel reserves than oil and gas. However, there are other energy options besides coal, including gas and diesel. Coal is a fuel with a high calorific value and elemental carbon content, and a high proportion of volatile parts characterizes biomass. In the case of coal-charcoal burning is the longest and most decisive stage of the combustion process. In the case of biomass combustion, the crucial steps are the devolatilization and combustion of volatile parts [3, 5].

Natural gas is a mixture of several hydrocarbon compounds formed from organic fossils buried in the earth's crust for millions of years. The formation process occurs naturally in a fairly long-time span. Natural gas is composed of light hydrocarbons, mainly methane (CH4). Natural gas is generally used as industrial and residential fuel as well as fuel for the petrochemical industry. There are two types of gas fuel sold in Indonesia, namely LPG (*Liquefied Petroleum Gas*), which is better known as LGV (*Liquid Gas Vehicle*), and CNG (*Compressed Natural Gas*), which is known as NGV (*Natural Gas Vehicle*). The two types of fuel have different forms. LPG/LGV is in liquid form, while CNG/NGV is in gas form [10]

A diesel is crude oil separated in the distillation process and produces a diesel fraction with a boiling point between 250^{o} C to 300^{o} C, cetane number 43, and sulfur content between 3000 to 3500 ppm. As a fuel, diesel fuel has specific characteristics: colorless/ sometimes yellow and smelly. It will not evaporate at normal temperatures. It has a higher sulfur content when compared to biodiesel, and Pertamina dex has a *flash point* between 40^{o} C to 100^{o} C, spontaneously ignites at a temperature of 300^{o} C, and generates high heat of approximately 10,500 kcal/kg.

CV Samudra Alfath, in collaboration with Pamulang University, was the first Indonesian company to produce soy fiber using coal material. Soy fiber from dry tofu dreg can be used for food and beverage industry materials.

This research aimed to compare the efficiency of coal energy, gas fuel, and diesel fuel processing tofu dreg into soy fiber.

Methods/Experimental

The pilot project was carried out at Pamulang University, whose experiments were carried out by CV. Samudra Alfath involved lecturers and students of Pamulang University. The materials used were tofu dregs with water content between 84-86%, coal, gas, diesel, and oil. The tools used are a series of machines consisting of a *Thermal Oil Heater* (TOH), a Screw Press, a Z-Elevator, a Rotary Dryer, a Hammer Mill, and its equipment.

Experimental Engine Heating with Coal Fuel

a. Ensure the oil in the thermal oil heater engine unit is full and not lacking
b. Check the oil level by opening the oil storage tank valve with a minimal oil indicator
c. If the oil does not come out when the minimum indicator valve is opened, add oil until the oil comes out of the valve
d. 60 kg of coal is put in the furnace
e. Turn on the fire in the thermal oil heater furnace manually
f. Wait until the coal becomes embers takes 2 hours
g. Turn on the oil transfer pump on the thermal oil heater system by pressing the 'on' button on the panel. Make sure the oil circulation line valves are open
h. Set the temperature of the oil entering and leave the thermal oil heater furnace
i. When the fire has been on, turn on the blower by pressing the 'on' button on

the thermal oil heater control panel

j. Control the temperature of the hot air that will be used for the drying process by looking at the temperature on the heat exchanger panel
k. Keep the fire burning and ensure it does not go out
l. After the heat exchanger panel temperature reaches the desired temperature, the drying process and the input material into the dryer can be carried out.

Calculation of Engine Heating with Gas Fuel

a. Ensure the oil in the thermal oil heater engine unit is full and not lacking
b. Check the oil level by opening the oil storage tank valve with a minimal oil indicator
c. If the oil does not come out when the minimum indicator valve is opened, add oil until the oil comes out of the valve
d. Open LPG tank valve opened
e. Turn on the burner thermal oil heater
f. Wait for heating TOH up to 5 minutes
g. Turn on the oil transfer pump on the thermal oil heater system by pressing the '*on'* button on the panel. Make sure the oil circulation line valves are open
h. Set the temperature of the oil entering and leaving the thermal oil heater furnace
i. When the fire has been on, turn on the blower by pressing the 'on' button on the TOH control panel
j. Control the temperature of the hot air that will be used for the drying process by looking at the temperature on the heat exchanger panel
k. Keep the fire burning and ensure it does not go out
l. After the heat exchanger panel temperature reaches the desired temperature, carry out the drying process and put the input material into the dryer.

Calculation of Engine Heating with Diesel Fuel

a. Ensure the oil in the thermal oil heater engine unit is full and not lacking
b. Check the oil level by opening the oil storage tank valve with a minimal oil indicator
c. If the oil does not come out when the minimum indicator valve is opened, add oil until the oil comes out of the valve
d. Open the diesel tank valve
e. Turn on the burner thermal oil heater
f. Wait for heating thermal oil heater for up to 10 minutes
g. Turn on the oil transfer pump on the thermal oil heater system by pressing the '*on'* button on the panel. Make sure the oil circulation line valves are open
h. Set the temperature of the oil entering and leaving the thermal oil heater furnace
i. When the fire has been *on*, turn on the blower by pressing the '*on'* button on the TOH control panel
j. Control the temperature of the hot air that will be used for the drying process by looking at the temperature on the heat exchanger panel
k. Keep the fire burning and ensure it does not go out
l. After the heat exchanger panel temperature reaches the desired temperature, carry out the drying process and put the input material into the drying machine.

Soy Fiber Production Process with Coal, Gas, Diesel Fuel

Production stages include raw material (*tofu dreg*) pressed to reduce the water content and materials other than fiber. The material that comes out of the press is called *cake*. The cake is then dried directly with hot air at a controlled temperature and time. Hence, the energy transfer occurs, which causes the water contained in the cake to evaporate. Hot air is generated by contact or heat exchange of hot oil produced from fuel (coal, gas, diesel) with clean air. Clean air is passed through the hot oil flow in the pipe, where the heat exchange occurs from the oil to the air. Soy fiber is then milled to a fineness of 80 mesh. The results of the manufacture of soy fiber were analyzed by testing the water content. The flow chart of the research procedure is presented in Figure 2.

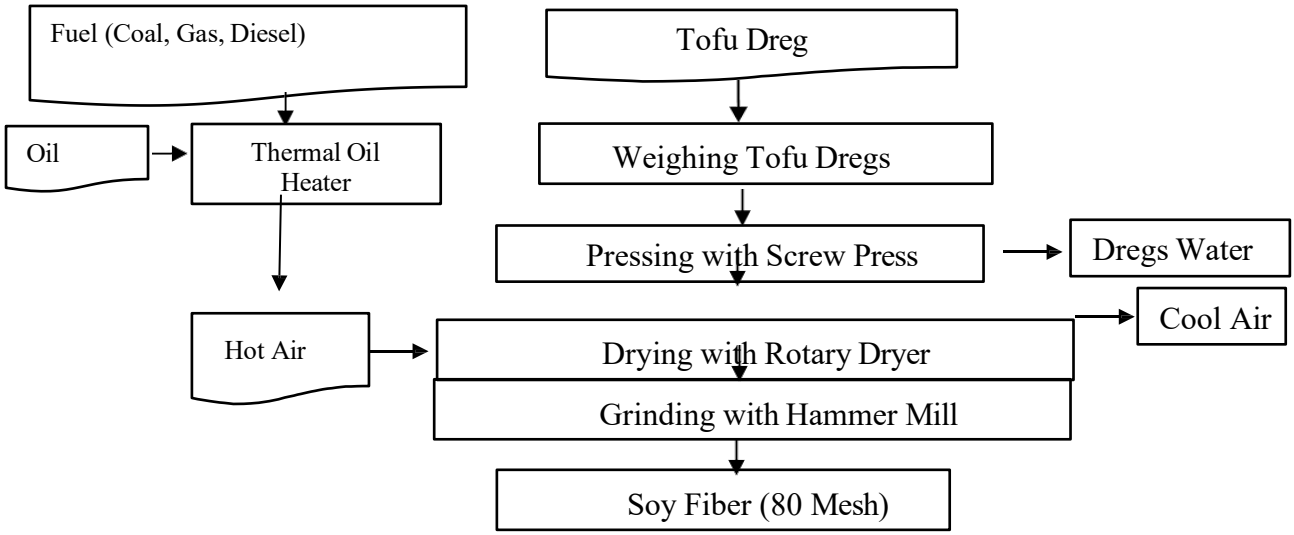

Figure 2. Flowchart of Soy Fiber Production Process

Results and Discussion

The expansion of the tofu industry had a positive impact on the food business but had a negative impact on the environment due to increased waste. Tofu dreg produced 25 percent to 35 percent [8]. Due to its foul smell, organic matter content, and tendency to rot, large amounts of tofu dreg will pollute the environment if it is not treated and utilized effectively. Soy Fiber is a novel product and a pleasant taste derived from the fiber and protein found in the cell walls of soy cotyledons.

Soy protein and fiber, such as soy flour, soy protein concentrate, and isolated soy protein, are widely used in the food business. Soy protein is commonly used in infant formula, nutritional products, and supplements. It is one of the raw materials used in the meat processing business, such as sausages. Soy protein is exceptional, equal to or better than animal protein. Soy fiber is widely used in baking and nutrition. Soy fiber provides essential health benefits usually associated with dietary fiber, such as increased laxative and cholesterol-lowering ability [11]. However, Indonesia is still dependent on imports of soy fiber.

A soy fiber production machine is a series to produce soy fiber with raw materials from tofu dregs. These machines consist of a screw press, Z-Elevator, rotary dryer, hammer mill, and thermal oil heater (TOH). TOH engine fuels are coal, LPG, and diesel. The series of soy fiber production processes in general, namely the raw

material of tofu dregs, is fed to a screw press machine to remove or reduce the water content in the material. The material is then dried using a rotary dryer. The material is dried with hot air from the thermal oil heater. Then, the dried soy fiber is milled and put into a grinding machine until it reaches a size of 80 mesh and accommodated in a cyclone with a negative pressure system.

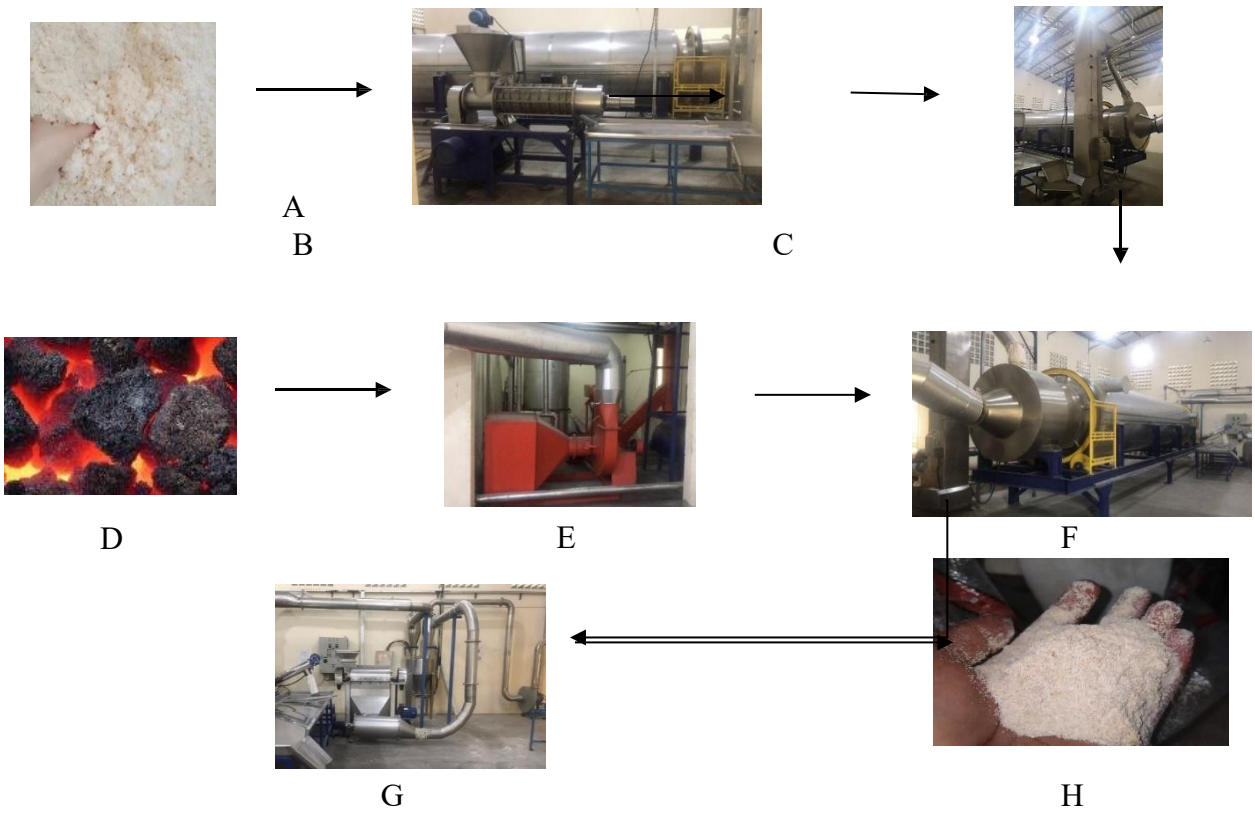

Figure 3. Soy fiber production process with machine technology
(A. Tofu dreg, B. Screw press, C. Z-Elevator, D. Coal Fuel, E. Thermal Oil Heater, F. Rotary Dryer, G. Hammer Mill, H. Soy Fiber)

One ton of tofu dregs consists of approximately 84-86% water. After being pressed, it will decrease to 74% with a weight of 632.33 kg, then it will be transferred to a rotary dryer with a hot air temperature of 170° C inlet, 70° C output, and a rotational speed of 12 rpm. Tofu dregs passed through a rotary dryer in the first round to produce a moisture content of 70-72% and fiber of 291.84 kg. In the second round, the fiber is put back into the rotary dryer by taking into account the minimum output temperature of the rotary dryer, 60-70° C, and a minimum TOH temperature of 190° C, and produces 169.67 kg. The fiber is fed continuously in the third round to get soy fiber with a moisture content of 10-14%. Furthermore, the yield of the result is 12-15%; then, soy fiber is milled with a hammer mill to produce a uniform particle size of 80 mesh. The production process time of 1 ton of tofu dregs from pressing until it becomes soy fiber with a moisture content of 10-14% is 4 hours and produces 150.17 kg of soy fiber.

Thermal Oil Heater (TOH) is a tool to generate heat energy using Thermal Oil Fluid as a heat conductor and can work up to a maximum temperature of 300° C. The TOH working pressure only comes from the Heat Transfer oil pump. Coal, LPG, and diesel are used as fuel to heat oil. Hot air is generated by contact or heat exchange of hot oil with clean air. Clean air is passed through the hot oil stream in the pipes; where there is a heat

exchange process from oil to air using controlled temperature and time so that energy transfer occurs, which causes the water contained in the cake to evaporate and obtain a moisture content of 10-14%. Based on the production process, 1 ton of soy fiber uses 150 kg of coal fuel. Comparing the use of other fuels such as gas and diesel to produce soy fiber requires 44.28 liters of diesel fuel/hour, and the gas requirement is 36.46 kg/hour with a TOH heating value of 409131.4 kcal/hour.

Table 1. Calculation of Fuel Needs and Prices for Processing 1 Ton Tofu Dregs

No	Fuel	Calorific value	Fuel Needs	Price/kg	Start-Up Time	Processing Time	The price of fuel for 1 ton of tofu dregs
1	LPG	11,220 kcal/kg	36.46 kg/hour	IDR 18,500/kg	5 minutes	4 hours	4 hours 5 minutes x 36.46 kg/hour x IDR 18,500/kg = IDR 2,754,587
2	Diesel	9240 kcal/kg	44.28 kg/hour	IDR 13,950 /kg	10 minutes	4 hours	4 hours 10 minutes x 44.28 kg/hour x IDR 13.950/kg = IDR 2,573,676

The time to start heating the TOH engine uses coal for 2 hours, while the use of diesel fuel is about 10 minutes, and gas is 5 minutes. For the process of forming soy fiber with a rotary dryer, the processing time is not directly affected by the type of fuel, only at the beginning of the start-up, so that the production process time is considered the same, namely 4 hours for 1 ton of tofu dregs. Thus, it requires 184.5 liters of diesel and 148.9 kg of gas. Based on the costs incurred for using various fuels to process 1 ton of tofu dregs into soy fiber, coal is IDR 728,700; IDR 2,573,676 for diesel fuel; IDR 2,754,587 for gas.

Conclusion

Based on the analysis results, soy fiber production with a production capacity of one MT/four hours could increase the selling value of tofu dregs. The fuel used to heat oil was coal. In production, 1 ton of soy fiber used 150 kg of coal compared to other fuels. Then, it took 184.5 liters of diesel and 148.9 kg of gas with a coal production cost of IDR 728,700; diesel fuel IDR 2,573,676; gas IDR 2,754,587. Based on the production time efficiency, using LPG was faster, but using coal was cheaper in terms of cost efficiency. Before being released into the air, exhaust gases from coal combustion have passed through a water sprayer to clean small particles from combustion fumes.

Abbreviations:

Carbon	(C)
Food and Baverage	(FnB)
Hydrogen	(H)
Nitrogen	(N)
Oxygen	(O)

Pamulang University	(UNPAM)
Sulfur	(S)
Thermal Oil Heater	(TOH)

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