

Analysis of the way of pretreatment before transportation of palm biomass fuel

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Received Mar. 10, 2022

Revised May. 14, 2022

Accepted Jun. 1, 2022

Abstract

With the increasing concern about the environment, renewable energy development is imminent, and biomass utilization is an essential part of it. In many regions (e.g., Southeast Asia), palm kernels are a very economical feedstock for biomass energy production. However, the collection and transportation of palm kernels are complicated, which is not conducive to the further development of this industry. This paper analyzes the current situation of collection and transportation of palm kernels in Southeast Asian countries using basic analysis methods. Meanwhile, the characteristics of palm fruit bunches as biomass fuel and its transportation and handling methods are briefly introduced and analyzed concerning the fuel demand of biomass power generation projects. The shortcomings of the current methods were identified, and relevant directions for improvement were proposed. It is hoped that it can improve the transportation efficiency of palm fruit bunches as a feedstock for biomass power generation and provide a reference basis for the collection and transportation of palm fruit bunches biomass.

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Keywords: Biomass fuel, Palm fruit bunches, Mode of transport handling

1. Introduction

As a new thing, biomass straw power generation has the advantages of renewable and low pollution compared with fossil energy, and has been developing rapidly in recent years, and is a key renewable energy project in China. To promote the development of biomass power generation technology, the State promulgated the Renewable Energy Law and implemented preferential feed-in tariffs for biomass power generation and other related policies, which led to the rapid development of biomass power generation, especially straw direct-fired power generation [1].

The coal-fired coupled biomass power generation technology conversion project makes full use of the investment and infrastructure of coal-fired power plants and is a low-cost, low-risk flexible way to utilize renewable energy, which can not only reduce the dependence of traditional power plants on fossil fuels but also reduce the emission of traditional pollutants (SO₂, NO_x, etc.) and greenhouse gases (CO₂, CH₄), with positive social and economic benefits. In addition to the biomass direct-fired power generation projects, biomass-coal coupled power generation projects will also flourish, leading to a further increase in demand for biomass fuels and improvement in fuel quality, which makes the corresponding biomass fuel pretreatment and supply chain particularly important [2].

Biomass fuel is a clean energy source, mainly from agricultural and forestry waste such as wood chips, rice husk, straw, and palm fruit bunches. Biomass power plant fuels are currently locally sourced and local fuels are used. Generally, fuels are loaded and transported into the plant in bulk, especially in Guangxi and coastal areas of China where biomass fuels can be collected in small quantities, but the demand is quite large. Considering the supply quantity, cost, and long-term, stability of biomass fuels, overseas Southeast Asian countries such as Malaysia, Indonesia, Laos, Cambodia, Vietnam, and Myanmar are therefore being investigated for biomass Fuel and transportation processing research, to solve the problem of fuel shortage in biomass power plants near Guangxi and the coast [3].

This study aims to find a transportation method that can improve the efficiency of transporting palm fruit bunches as a feedstock for biomass power generation. In this paper, we analyze palm bunches' collection methods, find the advantages and disadvantages of each of the two palm bunch transportation methods, and propose relevant improvement measures. Furthermore, the feasibility of using palm bunches for biomass power generation is determined by analyzing the cost economy of palm bunches.

2. Research method

In Southeast Asia, the production of palm oil is an important industry. Both Malaysia and Indonesia have the largest area of oil palm cultivation in the world, at $485.4 \times 10^8 \text{m}^2$, and the oil palm industry has become their mainstay [4]. In this section, the feasibility of palm bunches as biomass fuel will be analyzed using the basic analysis method.

After the palm matures the fruit is separated from the stem and the empty fruit bunches (EFB) left behind after the palm fruit is first pressed become a waste product. Every year, millions of tons of EFB, aged trunks, and leaves are produced [5]. Due to the scarcity of land and the backwardness of the bioenergy industry, these fuels are not utilized and are left to decay naturally, and most of them are discarded to palm plantations and burned as fertilizer, which not only pollutes the environment but also wastes resources, while these discarded oil palm wastes are excellent fuel materials for biomass power plants and are relatively cheap to acquire. At present, research on the use of this waste is ongoing, so some biomass fuel projects may import fuel from Malaysia and Indonesia in the future, especially Malaysia is surrounded by sea on three sides, with 54 ports and 19 deep-water terminals, the port terminal transportation system is more developed, so that the cost of biomass fuel shipping to China's coastal areas is not high [6].

Oil palm is an oil plant with an economic life span of 17 a~25 a. Adult trees can reach 10 m, with branches and leaves 4 m~6 m long. Its empty fruit bunches, trunks, and leaves are very good biofuels. As shown in Table 1, the ash content of oil palm empty fruit bunches (dry basis) is 5.4%, the volatile matter is 75.6%, solid carbon is 19%, and the calorific value is up to 20310 kJ/kg, and the total S is 0.08%.

Table 1. Composition analysis data of oil palm empty fruit bunch [7]

Test parameters	Testing method	Unit	Result
Total moisture (sampling base)	NTA8200-BPM 4-02 (Test method for total moisture of fuel)	%	11.6
Ash (dry basis)	NTA8200-BPM 4-01 (Test method for fuel ash)	%	5.4
Volatile (dry basis)	NTA8200-BPM 4-04 (Test method for fuel volatile matter)	%	75.6
Solid carbon (dry basis)	BY DIFFERENCE (fixed carbon data by subtraction)	%	19.0
Total sulfur (dry basis)	ISO 334:1992 (Determination of Total Sulfur in Solid Fossil Fuels)	%	0.08
Chloride (Kilobase)	ISO 587:1997 (Standard for Determination of Chloride by Ashka Mixture)	%	0.02
Gross Calorific Value (dry basis)	NTA8200-BPM 4-05 (Test method for calorific value of fuel)	kJ/kg	20310
Na	AAS (Spectrometer for Sodium)	%	0.32
K	AAS (Spectrometer for potassium)	%	2.49

As described in Table 1 [7], the advantages of palm fruit bunches as biomass fuel are:

- a) they are concentrated in oil palm crushing mills, so there is no need for scattered acquisition;
- b) the calorific value generated by combustion is higher than that of general biomass fuels;
- c) the quantity of raw materials is large, a large number of palm fruit bunches are produced every day and there is no shortage of raw materials;
- d) the fruit bunches are rich in crude fiber, which is conducive to combustion;
- e) since palm fuel does not contain S and P, it does not produce SO_2 and P_2O_5 during combustion, thus it does not cause acid rain, does not pollute the atmosphere and does not pollute the environment, it greatly meets the trend of environmental sustainability in the world today and in the future;
- f) it can relieve the rising cost of fuel and reduce carbon emissions, and palm fuel is economical and inexpensive [8].

Pictures of oil palm biomass fuels are shown in Figure 1 (These pictures are collected from the Internet).



Figure 1. Processing of palm fruit bunches

3. Methods and facilities for pretreatment of EFB before transportation

3.1. EFB fuel acquisition methods and processing

Biomass fuel should be easy to obtain, low cost, and meet the principle of long-term supply, biomass fuel collection should be set up in a fuel processing supply base, the base should be selected in the area of oil palm plantation and several oils crushing plant distribution is relatively concentrated, convenient transportation area, close to the port, or reliable berthing 10,000 tons of bulk cargo ship deep water port, can form a transport chain with the fuel processing base, and establish a partnership with the oil crushing plant, each base Each processing base covers 4~5 oil crushing plants, mainly collecting a large number of empty fruit bunches produced by nearby oil palm crushing plants, supplemented by collecting aging trunks and leaves from nearby palm plantations, according to different situations, it is more economical to take the form of direct acquisition and cooperative processing[9]. The oil palm trunk can be harvested, sawn, after certain fumigation treatment, directly transported to the domestic fuel base, but for the empty fruit bunches and branches and leaves, considering their transportation costs, the following two forms can be used:

3.1.1. String flattening, packing and conveying

Considering that the palm fruit is ripe in October-November every year, and the rainy season in Malaysia and Indonesia is October-December every year, so the empty palm fruit bunches just harvested contain a lot of water, in addition, the empty fruit bunches are very loose, bulk transport volume, high transportation costs, so it is necessary to squeeze out some of the water from the empty fruit bunches and flatten and pack them for transportation [10].

Research has learned that the current market for empty bunches of fruit extrusion processing equipment is mainly screwed extruders. The working principle of the screw extruder is: the empty fruit string of palm from the drum above one end of the inlet into the drum, the material in the spiral rotating blades to move along the axial direction to the discharge end, in the changing pitch, screw and adjust the baffle in the role of extrusion, to complete the mechanical dehydration of materials, the empty fruit string containing 65% to 80% moisture extrusion and dehydration to the flat empty fruit string containing about 40% moisture, flat empty fruit The bunches are passed to the horizontal baler for baling, and the baled bunches are shipped to China [11]. The bunches are shipped to domestic biomass power plants or fuel storage bases for further processing. The extruded filtrate enters the receiving tank through the filter drum and flows out from the outlet, and is collected in the collection tank for oil-water separation, precipitation and filtration, and the filtered oil is recovered, and the filtered water is sent to water treatment for recycling. The spiral extruder adopts mechanical dewatering, which greatly reduces the energy consumption in the process of material drying [12].

The process flow of palm empty fruit string extrusion treatment is empty fruit string → belt conveyor → spiral extruder → horizontal baler → baling shipping. The main equipment needed for the whole process is a belt conveyor, screw extruder, and baler. System equipment is conventional domestic mature equipment, many companies can produce [13];

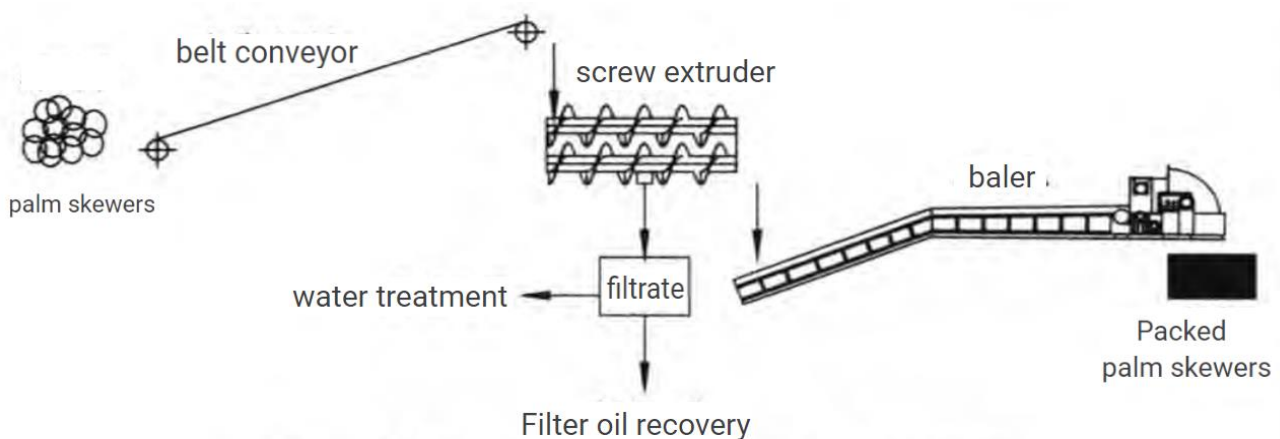


Figure 2. Process flow chart of palm empty fruit bunch extrusion processing

3.1.2. Fruit bunches and discarded aged palm trunks, branches and leaves are mixed and granulated, packaged and transported

In cooperation with the local oil mill, a crushing, drying, compressing and baling production line can be set up using the steam from the oil mill to produce biomass EFB solid fuel, and the processed fuel will be transported by car to the port for shipment to China [14]. The process of pelletizing empty palm fruit bunches is as follows: empty fruit bunches → belt conveyor → spiral extruder → crusher → dryer drying and mixing → pelletizer pressing and forming → cooling and packing → loading → shipping, as it is shown in Figure 3 [15].

Palm fruit bunches are large in size, the pre-processing of granulating into fuel is to first reduce the volume size, and squeeze out part of the water, for the next granulation process to do sufficient pretreatment. It is necessary to crush the palm fruit into small particles first, which is suitable for crushing palm fruit shells crusher, palm fruit shells crusher can distribute conveyor belt, first place the material on the feeding conveyor belt, and then transport the material to the crusher bin, start the crusher, by the knife shaft series of crushing, can get the output of 6 mm ~ 10 mm palm fruit shells small particles. After extrusion, the palm nutshell pellets still contain more water and need to be dried to remove the water, and the water of the dried palm nutshell pellets is <15%.

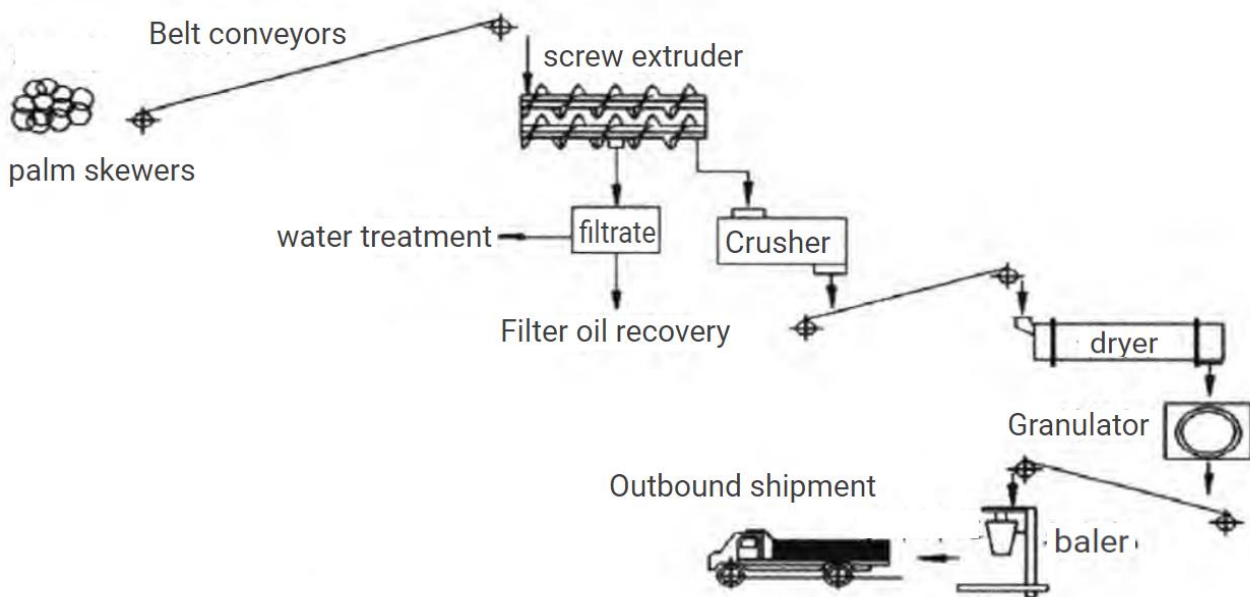


Figure 3. Process flow chart of palm empty fruit bunch granulation treatment

Pulverizer, dryer, and forming machine are the core equipment of the system process, but the high energy consumption and high cost of this system processing is a common problem at present [16].

3.2. Layout of fuel processing bases

The fuel processing supply chain consists of fuel supply, coastal terminal fuel transfer yard, and domestic fuel yard. The fuel processing base should be located in the relative center of the amount of oil crushing plants or plantations, close to the port, with a certain scope of integration, and on the main traffic road; the coastal terminal fuel transfer yard should be close to the international freight port, or a deep-water port where 10,000-ton bulk carriers can berth and can form a transportation chain with the fuel processing base. The fuel transfer site should be close to an international cargo port or a deep-water port where 10,000-ton bulk carriers can berth and form a transportation chain with the fuel processing base [17].

3.3. Construction of fuel processing base

The fuel processing base should have convenient conditions such as an open site, far away from residential areas, convenient transportation, and reasonable material direction. The fuel yard is transported into the plant by car and sent directly to the open-air stockyard or dry material shed, where the fuel is stacked in zones according to its characteristics [18].

A special fuel import/export area is set up near the open yard area, and a fuel management room, a waiting area, and a truck scale (the truck scale measures and weighs the fuel) are arranged in conjunction with the fuel

transportation entrance/exit. According to the quality of fuel such as moisture content, the foreign material can be sent to the dry material shed directly for storage or sent to the open field for stacking and drying first; the bulk material with high moisture content will be stacked in the open field first and then added to the dry material shed after drying, and the road around the processing plant is circular to facilitate logistics transportation[19].

The fuel processing base of the extrusion process of palm fruit bunches consists of metering devices, fuel open yard, dry material shed, extruder, baler, conveying system, fire control, sewage treatment, and discharge system. The fuel processing base for the palm empty fruit bunch pelletizing process consists of a metering device, fuel open yard, crushing system, drying system, compressing and baling, finished product warehouse, conveying system, fire control, and other systems.

The outdoor fire hydrant system is adopted for the open-air temporary yard, and the outdoor fire hydrant network is arranged in a ring around the open-air temporary yard, and the above-ground fire hydrant is set [20]. Outdoor firefighting pool and fire pump are set. Smoke detectors are set in the dry material shed. For the granulation process, a finished product warehouse should be set up. The indoor finished product warehouse should be equipped with ventilation and fire-fighting devices, and the water content of the finished granulated product should not exceed the specified range, otherwise, the moisture will easily become moldy and rotten, or cause a fire in the warehouse; fire sprinklers should be set up in the warehouse to form a fire block, and the entire fire block should be covered according to the sprinkler interval, and heat-sensing automatic alarm devices should be set up to promptly detect the change of temperature inside the fuel online. The temperature change of the internal fuel is sensed and alarmed [21].

4. Cost analysis

The total cost of pre-treatment of biomass palm empty fruit bunches is fuel acquisition or processing cost + transportation cost; the comprehensive cost of biomass oil palm empty fruit bunches = land transport unit price × land transport distance + acquisition unit price + processing cost + shipping cost; through the inspection of Malaysia and Indonesia, oil palm empty fruit bunches have not yet formed a large-scale market, there is no uniform price, but the overall acquisition cost and transportation cost is relatively low. In addition to this, it has the following cost advantages:

- a) Palm fruit bunches and their compressed pellets can be used as biomass fuel instead of wood chips and straw, with low investment and short construction period [22];
- b) It can be mixed with coal to reduce consumption and carbon emissions at the same time, which is especially suitable for industries that use coal as fuel. It is especially suitable for industries using coal as fuel, such as power generation and cement;
- c) Palm waste combustion does not contain S, P, does not corrode the boiler, can extend the service life of the main equipment, the enterprise will benefit greatly [23];
- d) Palm waste is clean and sanitary, easy to feed, reduce the intensity of workers' operations, greatly improve the operating environment of power plants, will reduce the cost for labor.

5. Conclusions

Oil palm empty fruit bunches are abundant in Malaysia, Indonesia, and other places, which can be described as "piled up like a mountain". In the pre-treatment of oil palm empty fruit bunches as the main fuel for biomass boiler combustion, the transportation pre-treatment program adopts the extrusion process of palm empty fruit bunches, which is more feasible in terms of fuel calorific value, cost, operability, and the comprehensive cost is about 320-yuan/ht. The comprehensive cost is about 320-yuan/ht, which can be equal to the cost of domestic local material; if the oil palm empty fruit bunches are coupled with coal and mixed combustion, and the requirements for calorific value, moisture, and particle size of biomass fuel are high, the transport pretreatment program adopts the process of granulation of palm empty fruit bunches, which is more feasible and the comprehensive cost is higher.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

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