

METHOD AND APPARATUS FOR PROCESSING EMPTY FRUIT BUNCHES (EFB)

FIELD OF THE INVENTION

The present invention relates to a method of processing empty fruit bunches (EFB) to convert the empty fruit bunches (EFB) into useful byproducts including fuel products.

BACKGROUND OF THE INVENTION

In many oil palm growing countries such as Malaysia, Indonesia and Nigeria, large amount of palm oil are produced on a yearly basis. During the production of palm oil and palm kernel oil in palm oil mills, millions of tonne of fresh fruit bunches are relieved of the oil bearing fruits which are discarded as empty fruit bunches (EFB), felled oil palm trunks (OPT) and pruned oil palm fronds (OPF) which are termed as biomass. The quantity of biomass created during the production of palm oil is very large and massive which has limited use in contributing to the production chain. In Malaysia, an estimated 20 million tonne of empty fruit bunches (EFB) are produced as waste, annually.

Since the empty fruit bunches (EFB) have yet to be fully utilized economically, the empty fruit bunches (EFB) are normally disposed using conventional method such as putting the empty fruit bunches (EFB) under the trees for mulching where the decomposition of the empty fruit bunches (EFB) produce fertilizers. The maintenance of this method consumes unproductive cost and energy. The empty fruit bunches (EFB) are also disposed by being burnt in boilers as fuel. However, the burning of the empty fruit bunches (EFB) gives rise to ineffective burning in the boiler due to its composition. The unused empty fruit bunches (EFB) are also normally disposed by burning these residues in the open which create environmental problems where due to the composition, it generates air pollution which is damaging to the environment. Another common way to dispose the empty fruit bunches (EFB) is by using land filling method. The handling of the empty fruit bunches (EFB) in this land filling method consumes unproductive cost and energy. Furthermore, the dumping of the empty fruit bunches (EFB) can cause additional emission of methane into the environment.

The conventional methods of disposal as described previously give rise to potential environmental issues such as air pollution and soil pollution which is damaging to the environment. The land filling method requires a large footprint which proves costly and entails wastage of land.

An European patent application no. EP 1,990,399 A1 discloses a method for treatment of the empty fruit bunch (EFB) material of palm oil trees comprising (a) an optional pretreatment of the EFB material thereby forming an optionally pretreated EFB material, and (b) torrefying the optionally pretreated EFB material thereby forming a torrefied EFB product. The invention further provides a particulate torrefied EFB product comprising pellets with a bulk density of 0.75-0.90 kg/l, a carbon content in the range of at least about 50 wt.% relative to the total weight of the particulate torrefied EFB product, and a caloric value in the range of 20-26 MJ/kg.

In view of the large amount of residues namely the empty fruit bunches (EFB) produced in palm oil plantations, most of the residues are commonly disposed of. There is a need for a method and apparatus to convert the empty fruit bunches (EFB) to the end products such as fuel which are economically useful. This also is in consideration of the depleting conventional fossil fuel resources which lead to the need for alternative energy (fuel) which are cheap, renewable and environmentally friendly. Many of the conventional methods of disposing the empty fruit bunches (EFB) create damaging environmental pollution problems. To minimize pollution, there is a need for an effective method and apparatus to successfully process the empty fruit branches. Many conventional biological process plants operates at a high production cost which produce end products which are not significantly useful in economical sense to justify the high production cost. The present invention was developed in consideration of these needs.

SUMMARY OF THE INVENTION

In one aspect, the invention provides a method of processing empty fruit bunches (EFB), comprising the steps of :

- depositing empty fruit bunches (EFB) into a process chamber;
 - processing the empty fruit bunches (EFB) to yield byproducts;
 - subjecting the byproducts of the processed empty fruit bunches (EFB) to heating and condensation processes at different stages; and
 - collecting the byproducts of the processed empty fruit bunches (EFB) at the different stages of the heating and condensation processes;
- wherein the byproducts comprise carbonaceous solid fuel product, liquid chemical product, and a flammable gas product.

In another aspect, the invention provides a bioreactor for managing a process of converting empty fruit bunches (EFB) into byproducts, comprising:

- a vertical process chamber for processing the empty fruit bunches (EFB);
- a combustion chamber for heating a flow of air directed to the process chamber;
- wherein the flow of hot air in a jacket of the process chamber heats up the empty fruit bunches (EFB) to produce hot vapours;
- a distillation apparatus for condensing hot vapours generated from the heating of the empty fruit bunches (EFB) to produce byproducts;
- wherein the byproducts are collected at the different stages of condensation processes;
- wherein the byproducts comprises carbonaceous solid fuel product, liquid chemical product, and flammable gas product.

The empty fruit bunches (EFB) suitably from palm oil plants are used to be processed and converted into useful and environmentally friendly byproducts.

The invention provides a solution which allows all process variables to be effectively controlled and manipulated to convert the empty fruit bunches (EFB) into environmentally friendly byproducts of carbonaceous solid fuel, liquid chemical product, and flammable gas product. The process of converting the empty fruit bunches (EFB) into a variety of byproducts is called pyrolysis. Pyrolysis is simply defined as a thermal

cracking of organic materials in the absence of oxygen or any other reagents, to produce a solid residue, known as char, a liquid fraction and gases.

The raw waste material EFB is a ligno-cellulose material which contains a considerable quantity of lignin. The weight of each piece of EFB ranges from 2-6 kg with a moisture content range of 5-10%.

The raw material empty fruit bunches (EFB) are deposited into a process chamber of a bioreactor through a bucket elevator when the empty fruit bunches (EFB) are subjected to heating at a predetermined temperature without the presence of oxygen. A combustion chamber heats a flow of air which is directed to the process chamber. In the combustion chamber, there is at least one burner to burn a supply of liquefied petroleum gas (LPG) which comes from a set of cylinders. The burning of the LPG supply ignites the combustion chamber to heat the air which is directed to the process chamber through a jacket until it reached a pre-determined temperature. The EFB are subjected to heating by the flow of hot air flowing through the jacket of the process chamber by conduction and radiation. The temperature inside the process chamber is maintained at predetermined temperature. Hot vapors are generated from the heated EFB after the predetermined temperature is reached. The generated hot vapors are directed to a set of distillation apparatus for a series of condensation. Each series of condensation of the hot vapors produces byproducts namely liquid chemical and flammable gas product. The byproducts are collected by a separate tank.

The distillation apparatus comprises an impingement filter, a heat exchanger and a cyclone separator. The impingement filter is located after the process chamber in order to remove any solid particle in the hot vapor generated from the process chamber. The hot vapors strike against the sheet of the impingement filter and then condensed as liquid chemical and water. The liquid chemical and water are discharged through a valve and collected by a first collection tank. The remaining hot vapors are then are directed to the heat exchanger where the vapors are passed through a set of copper tubes where most of the liquid material including water vapors is condensed into liquid chemical and water. The liquid chemical and water are discharged through a valve in the heat exchanger and collected in a second collection tank. The remaining hot vapors from the heat exchanger are directed to the cyclone separator where they are subjected to a final condensation

process. Any liquid material remaining in the hot vapors is condensed and collected in a collection third tank. The gas coming out of the cyclone separator is almost free of any liquid or solid material and directed to exit the bioreactor for open air for burning or directed to return to the combustion chamber to be used for heating. The gas directed to return to the combustion chamber is subjected to a process of condensation in an impingement filter to collect any remaining liquid material available in the gas. Any remaining liquid material is collected in a fourth collection tank.

A hot air blower is positioned at the topmost point of the vertical process chamber to facilitate the flow of heated air from the combustion chamber to the vertical process chamber. The combustion chamber is positioned at the bottom of the vertical process chamber. The blower is connected to a hot air vent. The heated air flowing from the combustion chamber to the process chamber is directed out of the bioreactor through the hot air vent facilitated by the blower.

A screw conveyor is positioned directly below the process chamber to collect the remaining heated empty fruit bunches (EFB) which are reduced to a solid carbonaceous fuel material. The screw conveyor is driven by a motor and directs the carbonized solid fuel product to be collected in a fifth collection tank.

A cooling tower is connected to the heat exchanger and screw conveyor through a series of water pipe connection. The cooling tower provides a supply of water through a water pump to cool the heat exchanger and screw conveyor. A water tank is positioned at the top of the bioreactor which provides a supply of water to the cooling tower.

The remaining heated empty fruit bunches (EFB) in the process chamber are reduced to a solid carbonaceous fuel material. The carbonized product has the potential to be used as a fuel due to its high calorific value in the range of 5700 – 6000 kcal/kg. This fuel may be used directly in boilers (fluidized bed type) for heating purposes and does not require any pulverizing. As the fuel's fire retention time is lower, it burns well without any problem until the burning level is completed. The fuel liberates more heat at a lesser time. The burning of this fuel is not environmentally hazardous. The residues from the burning of the fuel have a low ash content of not more than 16% and have a high potash content of up to 40% which can be used as a high value fertilizer in any plantations. The major

advantage of the fuel produced from the carbonized product is the total absence of sulphur in its compound unlike the other coke materials made from coal or petroleum products.

The mixture of liquid chemical and water is collected in all of the collection tanks. Water and the liquid chemical are separated by gravity. The liquid material product ranges from 7-10% of the mixture collected in the collection tanks, depending on the nature of the palm oil plant, its origin and the soil conditions in which it grows. The liquid material, when coated over steel surfaces, dries to give a continuous well adherent film. The film has sufficient corrosion protection properties that it can be used as binder for making protective coating for example paints. The liquid material comprises phenol up to 26% of the content, methyl ester of hexanadecanoic acid up to 31% of the content and 1-tetradecanol up to 23% of the content. Further processing of the liquid material is required to separate the compounds in the liquid material. If separated, phenol for example will be commercially valuable chemical. The separated methyl ester of hexanadecanoic acid and 1-tetradecanol may be used to produce bio diesel.

The gas at the end of the condensation process flowing out from the cyclone separator is returned to the combustion chamber to be recycled in burning in the combustion chamber. The flammable gas contains methane, ethane, propane-pentane, carbon monoxide, carbon dioxide, and nitrogen. The supply of excess flammable gas may be used together with the LPG supply for burning in the combustion chamber. The usage of flammable gas reduce the usage of LPG for burning which is an added advantage in saving cost for the whole process.

In an embodiment, an agitator is fitted in the conical portion of the vertical process chamber which directs the carbonized empty fruit bunches (EFB) into the screw conveyor. The agitator which is a vibrating setup made of mild steel twisted rods provides agitation to the flow of the carbonized empty fruit bunches (EFB) in the scenario where the flow of the carbonized product may be blocked in the conical portion of the process chamber due to the high volume of the carbonized product flowing from the process chamber. This ensures the continuous flow of the carbonized empty fruit bunches (EFB) to the conveyor.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more clearly understood from the following description of the embodiment thereof, when taken in conjunction with the accompanying drawings. However, the embodiment and the drawings are given only for the purpose of illustration and explanation, and are not to be taken as limiting the scope of the present invention, the scope of which is to be determined by the appended claims.

In the accompanying drawings, like reference numerals are used to denote like parts throughout the several views.

Figure 1 is a plan view of a bioreactor to conduct the process of converting the empty fruit bunches (EFB) into byproducts;

Figure 2a is a tabulated result of an analytical report which determines the properties of carbonized fuel which is processed from the carbonized soil fuel product;

Figure 2b is a tabulated result of an analytical report which determines the composition of the flue gas after the burning of the carbonized solid fuel product; and

Figure 3 is a tabulated result of an analytical report which determines the composition of the flammable gas.

DETAILED DESCRIPTION OF THE EMBODIMENT

The present invention relates to a method of processing empty fruit bunches (EFB) to convert the empty fruit bunches (EFB) to byproducts using a bioreactor system.

Figure 1 illustrates all the components of a bioreactor 100 to conduct a pyrolysis process to convert the empty fruit bunches (EFB) to desired byproducts. The empty fruit bunches (EFB) with total weight of 1 tonne and 5-10% moisture are periodically deposited to a vertical process chamber 1 through a feed hopper 14 of a bucket elevator 2. The vertical process chamber 1 has a diameter of 1 meter and height of 6 meters. The process chamber 1 has a jacket 1a through its height in which a flow of hot air is passed to form the heating medium of the process chamber 1. The heating of the empty fruit bunches (EFB) through the jacket 1a is done in a sealed process chamber 1 without the presence of oxygen.

A combustion chamber 5 which is cylindrical in shape with a diameter of 1,720 mm and 2,000 mm long made of 4 mm thick mild steel sheet is ignited through a set of burners for which liquefied petroleum gas (LPG) supply is coming from a set of gas cylinders 4. Ten cylinders with 14.7kg capacity of LPG are connected to supply LPG to the burners in the combustion chamber 5. The set of burners has the capacity of burning up to 16kg of gas per hour. The walls of the combustion chamber 5 are lined with refractor and insulating bricks to avoid heat loss. The heated air exits from the combustion chamber 5 through a highly insulated 8 inches of diameter outlet pipe connection which is connected to the heating jacket 1a of the process chamber 1 at the bottom of the process chamber 1.

The heated flow of air from the combustion chamber 5 maintained at 680°C is directed or sucked into the heating jacket 1a of the process chamber 1 by operating the air blower 9 driven by a blower motor 10. In other words, the inlet temperature from the combustion chamber 5 into the vertical process chamber 1 is 680°C. The temperature inside the process chamber 1 increases steadily and reaches until 400°C and the temperature in the process chamber 1 is then maintained at 400°C. The heat is transferred from the flow of heated air in the jacket 1a to the empty fruit bunches (EFB). The jacket 1a is fitted with ribs throughout the height of the process chamber 1 in order to obstruct the flow of heated air which would result in a higher residential time for the hot air

leading to an efficient heat transfer in the process chamber 1. During this stage, the empty fruit bunches in the process chamber 1 subjected to the heat at temperature of 400°C start to release hot vapors. The heated flow of air passes from the combustion chamber 5 through the jacket 1a of the vertical process chamber 1 and escapes through the hot air vent 13 at an outlet temperature of 260°C.

The hot vapors are directed to the impingement filter 8 through a gas pipe connection 16a. The temperature of the hot vapors released from the vertical process chamber 1 to the impingement filter 8 is 230°C. At the impingement filter 8, the fine material, water and liquid chemical in the hot vapor is condensed and the condensed liquid is collected in a collection tank 18b. The remaining vapor then flows from the impingement filter 8 to the heat exchanger 6 through a gas pipe connection 16b. The flow of hot vapor passes through a set of copper tubes in the heat exchanger 6 where the liquid chemical and water in the hot vapor is further condensed after the hot vapor comes into contact with the set of copper tubes. The liquid chemical product is collected in a collection tank 18c. The remaining hot vapor flows to a cyclone separator 20 through a gas pipe connection 16c for further condensation. Most of the remaining liquid chemical in the hot vapor is condensed in the cyclone separator 20 when the vapor strikes against the wall of the cyclone separator 20, where the fine particles and liquid chemical remaining in the vapor are collected and discharged at the bottom of the cyclone separator 20 to a collection tank 18d. After the remaining liquid chemical is condensed, only gas remains from the flow of hot vapor. The cyclone separator 20 also helps to increase the velocity of the gas.

After passing through the cyclone separator 20, the gas line is provided with two options with two gate valves. One gate valve is connected to a gas pipe connection 16d where the gas is burned in the open atmosphere by a burner 23 which is positioned at a vertical height of 2 meters from the heat exchanger 6. The other gate valve directs the gas to a gas pipe connection 16e which is connected to the combustion chamber 5 where the gas is to be burnt along with the LPG supply for heating the flow of air at the start of the whole process of the bioreactor 100. The gas pipe connection 16e is connected to an impingement filter 21 for the purpose of filtering any fine particles and liquid chemical in the gas through condensation before the gas is directed to the combustion chamber 5 for

burning. Any remaining fine particles and liquid chemical is collected in a collection tank 18e.

The remaining heated empty fruit bunches (EFB) in the process chamber 1 are reduced to solid carbonaceous fuel material product. The carbonized solid fuel product is directed from the bottom conical portion 1b of the process chamber 1 to a collection tank 18a through a screw conveyor 3 for the purpose of collection. The screw conveyor 3 is driven by a motor. An agitator 22 is fitted in the conical portion 1b of the process chamber 1 which directs the carbonized empty fruit bunches (EFB) into the screw conveyor 3. The agitator 22 which is a vibrating setup made of mild steel twisted rods provides agitation to the flow of the carbonized empty fruit bunches (EFB) in the scenario where the flow of the carbonized products may be blocked in the conical portion 1b of the process chamber 1 due to the high volume of the carbonized product flowing from the process chamber 1. This ensures the continuous flow of the carbonized empty fruit bunches (EFB) to the collection tank 18a.

A cooling tower 7 is connected to the heat exchanger 6 through an inlet water pipe connection 17a. The cooling tower 7 provides a supply of water through a water pump 12 to cool the heat exchanger 6. The water is discharged from the heat exchanger 6 through an outlet water pipe connection 17b to be returned to the cooling tower 7. The temperature of the hot vapor at the inlet of the heat exchanger 6 is 230°C. By providing a supply of water at a temperature of 30°C at a flow rate of 100 L/minute to the heat exchanger 6, the outlet temperature of the condensed liquid is 30°C.

A water tank 19 located at the top of the bioreactor 100 supplies water to the cooling tower 7. Water is supplied to the water tank 19 by water pumps 12 through pipe connections 17e, 17f connected to a sump. The water tank 19 also supplies water for cooling the screw conveyor 3 through an inlet water pipe connection 17c and exits from the screw conveyor 3 through an outlet water pipe connection 17d. The water from the screw conveyor 3 is returned to the cooling tower 7 through the outlet water pipe connection 17d which is joined to the outlet water pipe connection 17b.

At the end of the pyrolysis process in the bioreactor 100, the composition of the collected byproducts are as follows; 370kg of solid fuel byproduct, 390kg of liquid chemical product and 240kg of flammable gas.

Figure 2a is a tabulated result of an analytical report which determines the properties of carbonized fuel which is processed from the carbonized product obtained from the processed empty fruit bunches which has undergone the pyrolysis process using the bioreactor 100. The carbonized product from pyrolysis process is used as fuel due to its high calorific value in the range of 5,700 – 6000 kcal/kg. The fuel can be used directly in the fluidized bed type boilers for heating. The advantage of this fuel is that it does not require any pulverizing. As its fire retention time is lower, it burns well until the burning level is completed. Two types of carbonized fuel processed from two types of empty fruit bunches (EFB), C-41 and C-39 are analyzed in Figure 2a. From Figure 2a, the ash content of both C-41 and C-39 is less than 16%, which is significantly low. The conventional coal has as much as 40% of ash content after burning which contaminates and pollutes the environment. The low ash content of the carbonized fuel processed from the carbonized solid fuel product offers a more environmentally friendly option. The small amount of ash is put to further good use. Because of the high potash content in the ash composition (40.8% in dry basis) as stated in Figure 2a, the ash obtained after burning the fuel can be used as a high value fertilizer in palm oil plantations or any other plantations. The range of the content of sulphur (S) is 19-25 mg/kg or 0.002%-0.003%. The content of sulphur (S) in the carbonized solid fuel product is almost negligible. The major advantage of the carbonized fuel is the negligible amount of sulphur in its composition, unlike the other conventional material made from coal or petroleum products.

Figure 2b is a tabulated result of an analytical report which determines the composition of the flue gas after the burning of the carbonized solid fuel product. From the information in Figure 2b, the flue gas analysis indicates clearly that the contents of the toxic gases emitted from the burning of the carbonized products to produce the carbonized fuel are within permissible limits. The burning of this fuel is not environmentally hazardous. The content of carbon monoxide (CO) is significantly low at 170ppm.

Figure 3 is a tabulated result of an analytical report which determines the composition of the flammable gas which flows out from the cyclone separator 20. The flammable gas product comprises a volume of 30% of nitrogen, 9.87 % of methane, 1.26 % of ethane, 0.50 % of propane-pentane, 42.37% of carbon dioxide and 16% of carbon monoxide. The flammable gas is returned to the combustion chamber 5 to be burned to provide heat for the pyrolysis process in the bioreactor 100. The flammable gas has a calorific value of 1,400kcal/kg. The supply of the flammable gas from the pyrolysis process decreases the quantity of used LPG for burning in the combustion chamber 5. Some of the remaining flammable gas from the cyclone separator 20 is released from the bioreactor to be burned in the open atmosphere.

The invention may be embodied in many ways other than those specifically described herein, without departing from the scope thereof.

CLAIMS

1. A method of processing empty fruit bunches (EFB), comprising the steps of :
depositing empty fruit bunches (EFB) into a process chamber;
processing the empty fruit bunches (EFB) to yield byproducts;
subjecting the byproducts of the processed empty fruit bunches (EFB) to heating and condensation processes at different stages; and
collecting the byproducts of the processed empty fruit bunches (EFB) at the different stages of the heating and condensation processes;
wherein the byproducts comprise carbonaceous solid fuel product, liquid chemical product, and a flammable gas product.
2. A method of processing empty fruit bunches (EFB) according to Claim 1, further comprising:
controlling any one or more of the treatment process of combustion, heating, condensation and cooling to optimize the process conditions.
3. A method of processing empty fruit bunches (EFB) according to Claim 1 or 2, further comprising:
supplying a flow of heated air to a heating medium in the process chamber allowing the empty fruit bunches (EFB) to be indirectly heated in the absence of oxygen to produce said liquid chemical product.
4. A method of processing empty fruit bunches (EFB) according to Claim 3, wherein the flow of heated air is channeled to a jacket of the process chamber to facilitate an indirect heating of the empty fruit bunches (EFB) through conduction and radiation.
5. A method of processing empty fruit bunches (EFB) according to Claim 3 or 4, wherein the flow of air is heated and maintained at a predetermined temperature of at least 400°C.
6. A method of processing empty fruit bunches (EFB) according any of Claims 1 to 5, wherein the excess from the liquid chemical product is further treated with condensation.

7. A method of processing empty fruit bunches (EFB) according to any of the preceding claims, wherein excess flammable gas product at the end of the treatment process is heated up and returned to the process chamber.

8. A method of processing empty fruit bunches (EFB) according to any of the preceding claims, wherein excess flammable gas product at the end of the treatment process is released and burn in open air atmosphere.

9. A method of processing empty fruit bunches (EFB) according to any of the preceding claims, wherein the solid fuel product is substantially sulphur-free.

10. A method of processing empty fruit bunches (EFB) according to any of the preceding claims, wherein the liquid chemical product comprises any one or more of phenol, methyl ester of hexanodecanoic acid and 1-tetradecanol.

11. A method of processing empty fruit bunches (EFB) according to any of the preceding claims, wherein the flammable gas product comprises nitrogen, methane, ethane, propane-pentane, carbon dioxide and carbon monoxide.

12. A bioreactor (100) for managing a process of converting empty fruit bunches (EFB) into byproducts, comprising:

a vertical process chamber (1) for processing the empty fruit bunches (EFB);

a combustion chamber (5) for heating a flow of air directed to the process chamber;

wherein the flow of hot air in a jacket (1a) of the process chamber heats up the empty fruit bunches (EFB) to produce hot vapours;

a distillation apparatus for condensing hot vapours generated from the heating of the empty fruit bunches (EFB) to produce byproducts;

wherein the byproducts are collected at the different stages of condensation processes;

wherein the byproducts comprises carbonaceous solid fuel product, liquid chemical product, and flammable gas product.

13. A bioreactor (100) according to Claim 12, wherein the distillation apparatus comprises:

- impingement filter (8);
- heat exchanger (6); and
- cyclone separator (5);

wherein byproducts are subjected to further treatment at different temperatures and process conditions to yield additional byproducts.

14. A bioreactor (100) according to Claim 12 or 13, further comprising at least one collection tank (18a, 18b, 18c, 18d, 18e) to collect the byproducts.

15. A bioreactor (100) according to any of Claims 12 to 14, further comprising a screw conveyor (3) for collecting the carbonaceous solid fuel product from the vertical process chamber (1).

16. A bioreactor (100) for managing a process of converting empty fruit bunches (EFB) into byproducts according to any of Claims 12 to 14, further comprising a water cooling tower (7) for cooling the components of the bioreactor.