Biomass Pellet

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Abstract

This article reviews biomass pellet by focusing on biomass and its potential as an alternative energy, biomass's properties, biomass pellet production processes, fuel properties of biomass pellet, biomass pellet standards, and economics of biomass pellet production.

Keywords: biomass pellet, biomass pellet production processes, economic, biomass pellet standards

Introduction

Nowadays the world is confronting the decrease of petroleum quantity. The amount of biomass from agricultural residues is adequate to be used as alternative energy. However, the use of raw biomass, which is the biomass without undergoing the improvement process, has some disadvantages. For example, the high moisture content in raw biomass causes instability of combustion. A problem also occurs when raw biomass is moved from its source to the storage area. With the big size and heavy weight of raw biomass as well as its different shape, length, and size, the transportation takes a lot of time, while each time of transportation, a small quantity of biomass can be moved. Moreover, there is a problem in the design of combustion chamber. However, all mentioned problems can be solved with pelletization that is a way to improve raw biomass by using enough compressive force on particles contributing to the form of pellet. Pelletization causes improved biomass to have the same size and shape, contributing to the decrease of its volume, storage area, and a cost of transportation. This article explains the details of biomass potential as an alternative energy, its properties, production process, its fuel properties, biomass pellet standards and economics of biomass pellet production.

Biomass

Biomass is renewable materials from plants or animals. The term "Biomass" also includes agricultural residues such as wood scrap from lumber industry; animal excrement; and residues from agricultural processing, communities, and production process in agriculture industry.[27] Crude oil, natural gas, and coal that come from the deposit of dead plants and animals are not biomass.

Agricultural crop includes sugarcane, cassava, corn, and oat[4]. Agricultural residues include ricestraw, cassava root, ear of corn, soybean trash[7] grass[19, 28] wheat straw[28] barley straw[28] stalk corn[13] grape component[16] sorghum trunk[13] and palm olive.[17] Wood and wood residues include fast growing trees and standing timber, residues from lumber factory and paper factory[27] Scotch pine[6,10] Norway sprout[6] molt bark[12] chestnut[16] eucalyptus[16] wood residues from forest[15] palm olive[17] sawdust[16]. Agricultural waste from industry includes husk from rice miller, sugar trash and sugarcane husk from sugar factory, waste from palm oil extraction,[27] coffee trash[16] from coffee extraction, rice bran from rice milling,[8] and bunch of palm fruit from crude palm oil extraction.[21] There are also garbage and excrement from animals and other living things.

Biomass is comprised of cellulose ($C_6H_{10}O_5$) and lignin ($C_{40}H_{44}O_6$) and can be divided into 2 types namely woody biomass such as branch, wood scrap, sawdust, and paper pulp residue; and non-woody biomass including husk, sugarcane husk, rice straw, spike, and dry animal excrement.[29] Each kind of biomass can have different components that are cellulose, hemicelluloses, lignin, flour, and protein. Trees and herbs have the main

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components that are cellulose, hemicelluloses, and lignin, while cereal is comprised of flour as major component.[27] Moreover, composition of each biomass was different depending on its origin and environment.

By considering the excessive amount of biomass to be alternative energy, it was found that the earth could store biomass on the ground for 1,800 billion ton and in the water for 4 billion ton. Ground biomass is compared to the energy content of 33×10^{12} GJ that is 80 times of the world's annual energy consumption.[27] This can be shown in Figure 1. By considering the potential of available biomass, it was found that the large portion of available biomass came from forest, especially wood residues from tree cutting and timbering with the energy content of 15×10^{9} GJ which is 36% of biomass resources[27] as shown in Figure 2. It could be seen that the earth consists of biomass as alternative energy apart from petroleum and coal. For the optimum benefit, there is a need to develop efficient technology of biomass.

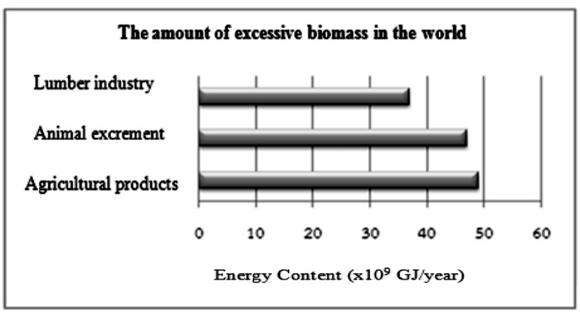

Figure 1 The amount of excessive biomass in the world.

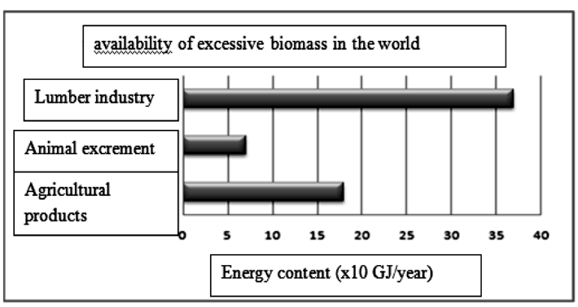

Figure 2 Availability of excessive biomass in the world.

Analysis of Biomass Properties

As mentioned, there are many kinds of biomass, and the main components of biomass are carbon, hydrogen, oxygen, nitrogen, sulfur, and chlorine (the components of carbon, hydrogen, and oxygen account for 97-99 percent of its mass). There are two methods to analyze biomass properties namely proximate analysis and ultimate analysis.

Proximate analysis method analyzes biomass components by considering on moisture (M), ash (A), volatile matter (VM), and fixed carbon (FC).[26] The property test follows the ASTM D3172 standard. The sample of fuel will be dried in the oven at the temperature of 105-110°C until its weight is constant. The lost weight compared to the origin weight of the fuel is the moisture of the sample. The dried sample is then heated in the container with the temperature of 900°C in closed container to get rid of combustible volatile matter. After that, the sample is combusted at the temperature of 750°C until the weight is stable, and it is the weight of its ash, while the lost weight is the amount of fixed carbon. The proximate analysis can be used for fuel comparison[29] and can be shown as the relationship equation below.[20]

$$FC + VM + M + A = 100\ \%\ \text{of mass} \quad (1)$$

Ultimate analysis method analyzes biomass properties by considering on component quantity of the biomass. The analysis focuses the quantity of nitrogen (N), carbon (C), hydrogen (H), sulfur (S), moisture (M), ash (A) and oxygen (O), and the relationship equation can be shown as[20]

$$C+H+O+N+S+M+A = 100\%\ \text{of mass} \quad (2)$$

The elemental analysis is similar to ultimate analysis, but there is minor difference. Elemental analysis method analyzes the quantity of sodium (Na), magnesium (Mg), silicon (Si) phosphorus (P), potassium (K) calcium (Ca), cesium (Sc), chromium (Cr), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb). These components are calculated to mass percentage as well[26]. The data of Thai agricultural residues were shown in Table 1-3.

Production Process of Biomass Pellet

Biomass pellet production process is developed from the process of the animal food industry. The process starts from putting biomass in the ring die press machine with the roller pressing the biomass through the small holes around the ring die. Later, the pressed biomass will be cut to pieces with the same length and become biomass pellet.[22] Nowadays, the pelletization process requires many steps namely gathering the biomass from agricultural area and other sources, dehumidifying, biomass milling, biomass modifying before pelletizing, pelletization, cooling, screening, and pellet's packaging.[3] The pelletization process and its machine are shown in Figure 3-4 and can be explained in details as follows.

Gathering the raw biomass from agricultural area and other sources.[16] This step uses tractor or agricultural utility cart to store it in the form of cubic, or sometimes it is rolled and stored in the raw material storage area. In case of many kinds of biomass existing together, it is categorized and stored in each container. Each will be mixed together with the consideration on the possibility and suitability before dehumidifying.

Dehumidifying means removing of the water from the biomass by controlling its moisture at 10-15 % by weigth.[3] This step requires the drying machine with the temperature range of 60 - 140°C depending on drying technique, drying media, raw material, temperature, and residence time. There are many kinds of drying machines such as rotary drum dryer, flash dryer, and spouted bed dryer.[14]

Biomass milling is a way to reduce the biomass size with the milling machine whose screen size is ¼ inches or about 3 millimeters. The size of biomass after being milled must not be bigger than the pellet's diameter. However, if the size is too small, the fuel pellet might be contaminated when it is formed.[3]

Pelletization is to form the milled biomass with pelletization machine. There are two kinds of this machine namely flat-die and vertical mounted ring-die. Before the pelletization starts, the water must be added to stimulate lignin in the biomass to absorb the water. After the lignin absorbs the water, the small particles of biomass will be combined together. The compressive force between roller and pellet mill die is required to form the pellet.[3]

(a)

(b)

Figure 3 (a) The ring die pellet press (b) The flat die pellet press[23]

Cooling is to reduce the temperature of the pelletized fuel as it has the high temperature and softness. It is necessary to reduce the temperature so that the fuel pellet will be hard and durable for the transportation. The temperature will be reduced from 90°C to 25°C.

Screening is a process to separate the fuel pellet from the dust that will be returned to the producing process. The separated fuel pellet will be moved to storage bag.[3]Thehigh quality biomass pellet contains the dust not more than 0.5% of the pellet.

Pellet's packaging is done automatically. This process is the last stage of pelletization before the fuel is distributed.

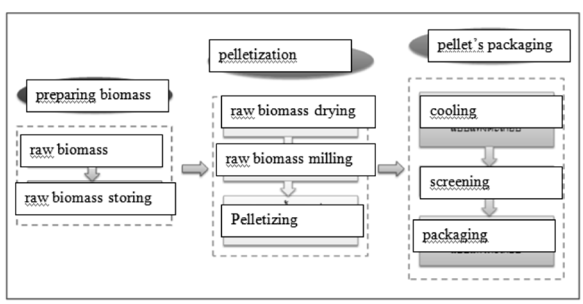

Figure 4 The chart of pelletization process

The parameters affecting the biomass pellet qualities

From the previous study, it was found that moisture, and particle size affected the qualities of biomass pellet.[22]Moreover, there is a lot of research further studying the effect of compressive force, temperature, storage time, die thickness, and hammer mill screen sizeon biomass pellet properties.

The moisture content of raw biomass has an influence on net calorific value, combustion efficiency,[15] bulk density, and durability index. In the case of bulk density, a higher moisture content cause a lower bulk density of biomass pellet. Moreover, durability index of biomass pellet decrease when moisture content of biomass pellet increase.[13]

It was found that a large particle size causes cracks and fracture in pellet.[18]

The hammer mill screen size has a role in specifying the size of the biomass after being milled. The pellet formed from the ground biomass has more mechanical durability than the pellet formed from the coarsely ground biomass.[13]

The die thickness refers to the thickness of the pelletization machine's part that is an iron plate with holes like the honeycomb. The die is used for pressing the raw biomass through to become pellet. There are two kinds of frame that are circle frame for vertical pelletization machine and ring die for radius pelletization machine. The thicker die results in enhancing of durability, the evidence was found in pellet of wheat straw, corn stover, and sorghum stalk.[13]

Compressive force is the force from the pressing head of pelletizing machine on the biomass. From the study, it was found that when the compressive force increased, the length and the density of the pellet were increased.[31]

The die temperature for the pelletization must be prepared before the process starts. The die is warmed beforehand at the temperature of 90°C to ensure that lignin starts melting and mix with other particles of the biomass, contributing to the ability to form the pellet.[10,19,22] Storage time of raw biomass is another important factor for pelletization. The raw biomass with long storage time causes more energy consumption to form the pellet than the fresh biomass with the short time of storage. It was also found that the pellet from the long time storage biomass had lower mechanical durability and higher bulk density than the pellet formed from the fresh biomass because the amount of fat and resin affecting the bulk density decreased.[24,30]

Specific Properties of Biomass Pellet

The specific properties of biomass pellet are shown in Table 4.From the table, each defined specific property is important and can tell its quality as follows:

The length and the diameter of the pellet is the pellet shape value which estimated amount of pellet. Moreover, the length and diameter can prevent jamming while the biomass is processed, packed, and transported.

The ash content reflects the maintenance frequency of the equipment taking the biomass pellet to be combusting fuel since the ash from the combusting process is composed of potassium, chlorine, and sulfur dioxide attached to the wall of the pipe and combustion room, causing the erosion of the tools.[2]

The moisture content represents the amount of water inside the pellet. The moisture plays an important role in the fuel combustion. If the moisture is high, the heat resulting from the fuel combustion will lose with the water evaporation.[2] Moreover, the moisture affects the storage of the pellet. If the moisture of the pellet is high, the pellet will be easily damaged by biodegradation. For example, there might be fungus, or rotten.

Bulk density indicates the hardness and energy content of the fuel pellet.

Heating value is the amount of heat which can be obtained when the pellet was combusted.

Standard of Biomass Pellet

The countries that develop the pelletization are in Western Europe. These countries are located in the cold climate region such as France, Italy, German, Sweden, and North America, so the biomass pellet is widely used for heaters in households. As a result, there is standard of biomass pellet in each country such as PFI in U.S.A., ONORM M1735 in Australia, SS 187120 in Sweden, DIN 51731 in German, CTI-R 04/5 in Italy, and ITEBE in France. The standard in each country is beneficial for commercial production for exporting the biomass pellet to overseas. Table 5 summarized the specification of pellet in each country.

Economics of biomass pellet production

Biomass pellet production is a biomass improvement technology, which is a way to produce a low energy density biomass in the form of higher energy density. To invest in the biomass pellet industry, there is the necessity to consider on the costs of raw material, labor, drying process, pellet production, transportation, and other services. From the study on the cost of biomass pellet production, the production cost can be proportioned to raw material 23%, drying process 8%, labor 18%, pelletizing machine 5%, energy 12%, maintenance 6%, packaging 13%, and other services 15% as shown in Figure 5.[22]

Considering on the size of biomass pellet factory, a small factory requires higher cost (production capacity: more than 10 ton/hour) as a big factory has high efficiency and capacity of the machine contributing to cost saving. In contrast, the small factory needs cheap raw material and labor cost but long term profit.[11] There is other research showing that the suitable size of the factory depends on the amount of raw biomass, while the production cost relates to transportation cost.[4] Therefore, the best way to manufacture fuel pellet from biomass is to construct the factory where the biomass is available and the biomass pellet is demanded; also, the size of the factory must be suitable for the amount of available biomass.

Conclusion

Biomass pellet is biomass or agricultural residues that undergo the processing to be small solid fuel with higher energy efficiency. Biomass pellet is produced by milling agricultural residues such as rice straw, sawdust, and leaves of sugarcane, palm, and other plant residues before forming them to fuel pellet. When the biomass pellet and the raw biomass are compared, biomass pellet has higher energy density and bulk density. To manufacture the efficient fuel pellet from biomass must consider on two things. The first one is factors affecting the formation of the pellet such as compression force, temperature, storage time, die thickness, and hammer mill screen size, and the second one is investment. From the study, it has been found that the suitable size of the biomass pellet factory depends on the amount of biomass, while the production cost relates to the transportation cost. Therefore, there should be further research on fuel pellet from biomass for the alternative energy benefits.

Table 1 Proximate analysis of Thai agricultural residues[26]

Element	Rice husk	Rice straw	Mize stalk	Sugar cane	Palm stem	Palm branch
N (%)	0.37	0.60	1.30	0.80	0.40	0.76
C (%)	38.00	44.40	44.20	44.90	42.97	43.31
H (%)	4.73	5.00	5.80	5.90	5.58	5.44
S (%)	0.09	0.10	<0.01	<0.01	<0.01	<0.01
O (%)	50.20	30.80	43.50	-	-	-

Table 2 Ultimate analysis of Thai agricultural residues[26]

Element	Rice husk	Rice straw	Mize stalk	Sugar cane	Palm stem	Palm branch
N (%)	0.37	0.60	1.30	0.80	0.40	0.76
C (%)	38.00	44.40	44.20	44.90	42.97	43.31
H (%)	4.73	5.00	5.80	5.90	5.58	5.44
S (%)	0.09	0.10	<0.01	<0.01	<0.01	<0.01
O (%)	50.20	30.80	43.50	-	-	-

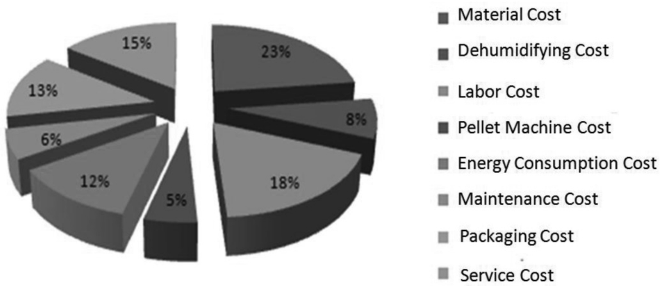

Figure 5 The proportion of biomass pellet production cost[22]

Table 3 Elemental analysis of Thai agricultural residues[26]

Element	Rice husk (mg/kg)	Rice straw (mg/kg)	Mize stalk (mg/kg)	Sugar cane (mg/kg)	Palm stem (mg/kg)	Palm branch (mg/kg)
Na	-	3,641	9.56	16.93	121.17	118.29
Mg	0.55	1.35	2.00	1.17	0.74	1.95
Si	6.66	4.30	2.68	5.30	0.73	3.01
P	43.13	54.96	111.77	45.42	29.30	81.84
K	2,395	2,799	9,611	5,141	1,481	2,952
Ca	570	1,221	1,954	1,767	2,075	3,560
Sc	-	0.24	-	-	-	-
Cr	997.33	559.42	112.26	63.49	-	-
Mn	3.2.04	852.27	43.98	125.86	5.89	12.11
Fe	2,127	2,594	446	356	8.31	35.65
Cu	210.76	6.70	7.50	4.26	1.64	4.07
Zn	38.23	29.46	65.73	40.98	19.26	21.21
As	0.76	1.04	0.04	0.49	-	0.03
Cd	-	0.06	-	0.01	-	-
Hg	0.98	-	0.04	-	0.84	-
Pb(%)	32.89	1.55	0.45	1.88	0.27	-

Table 4 The specific properties of biomass pellet[3]

Item	Properties
1. diameter of pellet	6-10 millimeters
2. length of pellet	10-30 millimeters
3. heating value	16.9-18.0 MJ/kg
4. moisture content	7-12 percent of mass
5. ash content	Approximately 0.5 percent of mass
6. bulk density	650-700 kg/cubic meter

Table 5 Comparison of biomass pellet standard in each country[1, 5]

Country	Standard	Heating value(MJ/kg)	Bulk density (kg/m^3)	Highest Moisture (% wt)	Ash amount (% wt)
Europe	CEN/TS 14961	16.9	-	10	0.7
Australia	ONORM M7135	18	-	10	0.5
German	DIN 51731	17.5-19.5	-	12	1.5
Sweden	SS 187120	≤16.9	≤500	12	1.5
U.S.A	PFI	-	641.7	8	1
Italy	CTI-R 04/5	>16.96	620-720	≤10	≤0.7
France	ITEBE	>17.02	>650	<10	<10

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