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Contents

Critical biomass attributes of the most common bioenergy and biofuel applications

Keywords

Biomass, Biofuel, Bioenergy, Moisture content, Bulk density, Bark content, Contamination, Ash, Lignin, Carbohydrate, Extractives.

Abstract

This primer presents critical attributes such as format and size; moisture content; bulk density; foliage/bark content; contamination; ash, lignin, carbohydrate, and extractive contents; and calorific value of the most common bioenergy and biofuel applications: direct combustion, gasification, pyrolysis, torrefaction, fermentation, and densification. The primer is aimed at forestry, wood processing, pulp and paper, and biomass professionals who are interested in basic information about these critical attributes.

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Introduction

Biomass comprises recently living organisms or their metabolic by-products (e.g., manure). When used for bioenergy and biofuels, biomass is considered a renewable energy source, unlike other natural resources such as petroleum, coal, natural gas, and nuclear fuels, which are considered non-renewable. Woody or forest biomass comprises mostly trees and shrubs. Currently, a large component of woody/forest biomass is utilized in high-value commodity products such as lumber, flooring, furniture, and paper. Consequently, bioenergy and biofuel operations utilize woody biomass comprising small-diameter trees, trees from underutilized species, shrubs, and harvesting and processing residues.

Recent increased demand for woody biomass has revealed a number of resource misallocation problems rooted in the mismatch between the biomass attributes and the desired feedstock attributes of various bioenergy or biofuel processes. Even in direct combustion applications such as biomass boilers and furnaces, feedstock attributes play a critical role in increasing their efficiency, feasibility, and environmental soundness. As more bioenergy and biofuel applications are being developed, both forest products companies that supply woody biomass and bioenergy and biofuel producers must become aware of the most important woody biomass attributes.

This primer provides basic information to forestry, wood processing, pulp and paper, and biomass professionals interested in critical woody biomass attributes required for the most common bioenergy and biofuel applications. The critical attribute values presented in this report are for guidance only; in practice, they should be confirmed with the manufacturers of each combustion or conversion technology.

Biomass attributes

Format and size

Biomass feedstock for bioenergy and biofuels has a multitude of formats, such as small and long logs, chunks, firewood, hog fuel, chips, construction and demolition waste, processing residue, and sawdust (Figure 1). While firewood, chips, and sawdust can be used directly as feedstock for combustion or biofuel applications, other biomass formats such as logs, branches, and chunks need further size reduction (comminution).

Conventional screening methods are used to estimate the size distribution of biomass. For larger biomass sizes such as logs and branches, these size distributions are measured through conventional scaling and volumetric determinations. In recent years, standards have been developed for size measurement and classification. Biomass size relates directly to the residence time, defined as the time necessary to complete the biomass combustion or conversion. Size requirements depend mainly on the feeding systems and capacities of combustion or bio-conversion technologies.

Moisture content

Moisture content (MC) is the percentage of water weight contained in biomass relative to the total weight of either the wet biomass (MC wet basis) or dry biomass (MC dry basis). MC wet basis is more commonly used by forestry and energy professionals whereas the MC dry basis is usually used by professionals in the sawmilling sector. High moisture content causes increased residence time and energy required to drive off moisture. It also affects biomass storage by contributing to self-heating and self-ignition. Moisture also decreases the bulk density and increases transportation costs, as wood increases in volume when wet. MC wet basis of forest residuals varies between 40% and 60% and can be lower than 10% for dry sawmilling residues, such as planer shavings (Badger 2002).

Figure 1. Biomass format and sizes.

Bulk density

Bulk density relates to biomass size and is defined as the total mass of biomass particles divided by the volume that the particles occupy. Bulk density is a limiting factor in biomass transportation, especially in regards to load size. Bulk density can be increased by reducing the biomass particle size through chipping or grinding, or by compressing the biomass into products such as bundles, pellets, and briquettes that are easier to transport and utilize. For example, wood pellets have a bulk density of 600 kg/m^3, wood chips (hardwood) 320 kg/m^3, wood chips (softwood) 250 kg/m^3, bark 320 kg/m^3, and sawdust 240 kg/m^3 (Van Loo and Koppejan 2007).

Foliage/bark content

The foliage/bark content is the percentage of foliage/bark in the biomass feedstock. The foliage of coniferous trees contains high amounts of nitrogen that could generate harmful nitrogen oxide (NOx) emissions during combustion. Also, due to its high mineral concentration, the foliage could increase the ash content of the biomass feedstock. The foliage/bark content can be reduced by allowing the leaves and bark to dry and fall off at the harvesting site, where they provide nutrients to the forest soils.

Contamination

Contamination refers to the percentage, by volume or by weight, of contaminants in biomass. The most common contaminants are soil, sand, and rocks (Figure 2); metal; other inorganic matter; and chemicals from preservative treatments or lead-based paints. For example, when piled on the ground, biomass (e.g., bark, hog fuel) can get mixed with large amounts of contaminants such as dirt and rocks. Contaminants can also include metal or plastic items from logging operations, such as de-barker and chainsaw chain links, plastic wrapping, wire, and ropes. Soil, sand, and gravel can cause mineral deposits on boiler pipes; rocks and metal debris can harm the chipping equipment; and chemical contamination of the feedstock can create harmful emissions. Logs submerged in salt water, or trees growing adjacent to salt water, may contain salts that can corrode the operating equipment and can emit dioxins during combustion. Road salt and dust suppressants can also contaminate residue piles. Contamination can lead to a higher-than-normal ash content and mineral deposits that can cause boiler problems. To reduce contaminants, strict handling practices should be instituted during biomass harvesting, collection, transportation, and storage.

Figure 2. Biomass contamination.

Ash content and composition

Ash is the inorganic component of biomass that remains after its complete combustion. The ash content is greater in hardwood than softwood species and varies between 0.5% in clean white wood and 8% in bark. Elements such as Si, Ca, Mg, K, and Na compose much of the ash in biomass (Van Loo and Koppejan 2007). Wood ash often contains 40–70% calcium oxide, 10–30% potassium oxide, and 5–10% magnesium oxide, as well as oxides of the other elements. Hardwood species tend to have more potassium than softwood (Ragland et al. 1987). These elements form minerals with low melting points that can condense into deposits on the heat transfer surfaces of boilers and can cause fuel and ash particles to agglomerate—a phenomenon known as slagging (Stanford University 2005). Also, the ash composition affects the fusion temperature of ash; low fusion temperatures can cause problems for the combustion equipment. Many operating problems in biomass plants are ash-related as high ash content can reduce boiler output, decrease heating efficiency, and increase ash removal and disposal costs.

Carbohydrate content

The carbohydrate content of woody biomass is a specific attribute of the distillation process in the production of bioethanol. Approximately two-thirds of the dry matter of wood is composed of polysaccharides (cellulose and hemicelluloses). Cellulose is the world's most abundant and important biopolymer; its molecules aggregate into microfibrils. Cellulose, comprising linear chains of glucose, is relatively inert during chemical treatments and soluble only in a few solvents. Hemicelluloses comprise branched carbohydrate chains; hardwoods and softwoods differ not only in the content of total hemicelluloses, but also in the hemicellulose constituents (Stenius 2000). Consequently, the distillation processes must be optimized for the cellulose and hemicellulose (carbohydrate) content of the biomass feedstock as it varies between different species. For example, lodgepole pine contains 68% carbohydrates, while quaking aspen 78% carbohydrates, by mass (Pettersen 1984).

Lignin content

Lignin is an amorphous, complex biopolymer—an integral part of the tree cell walls that, along with polymeric carbohydrates, gives trees their structural strength. Lignin is the most slowly decomposing part of dead vegetation. The lignin content of wood depends on the tree species (McKnight and Mullins 1981) and is generally higher in softwoods than hardwoods (32% in red cedar, 23% in red maple). When combusted, lignin yields more energy than cellulose; consequently, a high lignin content of biomass is a good combustion attribute. In pellet production, lignin plays a significant role as a natural binding agent.

Extractive content

Extractives are complex mixtures of low molecular-weight, organic material: sugars, inositols, amino acids, simple fats, carboxylic acids, terpenes, and phenolic compounds (Di Blasi et al. 2001). They are non-structural and soluble in neutral organic solvents or water (Stenius 2000). During drying, some of these extractives (e.g., terpenes) are emitted as volatile organic compounds (VOCs). They increase the energy value of biomass, but could be corrosive to the conveying or combustion equipment and can cause significant problems in storage (off-gassing, self-heating, auto-oxidation). Biomass could be stored in well-ventilated areas until some of the VOCs are released to reduce their negative effects; however, this reduces the calorific value and the amount of material available for tall oil and turpentine production (Stenius 2000).

Calorific (heating) value

The calorific value is the total amount of heat produced by complete combustion of one mass unit of fuel (MJ/kg, GJ/tonne). Higher calorific values or lower calorific values may be reported. The higher calorific value assumes that all the water vapour formed during the process is condensed back to liquid so there is no heat loss because of vaporization. The lower calorific value assumes that all the water contained in the fuel is vaporized. Therefore, it is a more realistic description of the energy content of biomass than the higher calorific value. However, higher calorific value is more frequently reported in the literature and varies between 18 and 23 MJ/kg, depending on wood species. Generally, softwoods have larger higher calorific values (21 MJ/kg for Douglas-fir) than those of the hardwood species (19 MJ/kg for maple), mostly due to higher resin and lignin content (Nielson et al. 1985). However, due to their higher density per volume, hardwoods are usually a better source of fuel (Röser et al. 2008).

Critical biomass attributes of the most common bioenergy and biofuel applications

Direct combustion

Direct combustion occurs when converting woody biomass to heat in a combustion chamber in which oxygen intake is controlled by vents and/or fans. Critical biomass attributes vary depending on the scale of the direct combustion technologies: from small scale (household size) to district heating and, further, to industrial applications.

Following are the most common direct combustion technologies and their critical biomass attributes in regards to biomass combustion.

Wood stoves and cordwood boilers

Wood stoves burn firewood, or cordwood, loaded manually and stoked in combustion chambers (Figure 3). Ash removal is done manually through an ash box. Combustion efficiency in stoves depends mostly on the firewood quality, but also on their design. Older stoves, installed in rural areas of Canada, have efficiencies under 50% and could emit a high amount of small particulate matter. Modern stoves are more efficient and may include emission control units which make them more suitable to urban environments.

Cordwood boilers are used to heat water in centralized residential/commercial heating systems. Cordwood is loaded manually in the combustion chamber several times a day. Electric fans control the burning of cordwood in the combustion chamber. Some cordwood boilers (e.g., GARN) have specially designed combustion chambers that ensure a more complete combustion and reduce the amount of ash and tars. Cordwood boilers with water tanks surrounding the combustion chambers can store hot water for several hours and may require stoking only twice a day.

The most critical attribute of firewood is the moisture content. Desirable moisture contents of less than 25% (wet basis) (Kofman and Kent 2009) can be attained by splitting the logs and storing the split cordwood in open sheds to take advantage of the prevailing air currents. Splitting the firewood is labour intensive; therefore, electric or hydraulic log splitters are used. Stacking firewood is often done manually with the objectives of optimizing the storage area and providing maximum exposure to the air currents and access to loading/unloading. In European countries, cylindrical or cubical fenced enclosures are becoming more popular. Kiln drying of firewood is also possible if affordable heat is available or the customer is willing to pay for it.

As different wood species reduce their moisture contents at different rates, they should be stored separately. Firewood stacks should be raised 20–30 cm from the ground and several feet of access space should be allowed between the rows (Folkema 1984). If possible, both ends of the firewood should be exposed to the wind. In the summer, seasoning of the wood is rapid; usually one summer is enough to bring the firewood to about 30% moisture content (Röser 2012). For firewood processed in the winter, the seasoning takes much longer, sometimes until the next fall. In wet climates, properly drying the cordwood could take more than 12 months. In order to reduce moisture content, proper storage is essential as sun, wind, and time are the most cost-effective means to reduce moisture content.

Wood density is also an important attribute of cordwood; high density wood species (hardwoods) are preferred in order to reduce the frequency of stoking the boilers and stoves. A less critical but still important attribute of firewood biomass is the salt content. When combusted, the salt accumulated in the firewood will generate dioxins—gaseous substances that are harmful when inhaled. Consequently, combustion of firewood made from logs that were submerged in marine waters (e.g., sink logs, driftwood) is not recommended.

Figure 3. Wood stove.

Pellet stoves and boilers

Wood pellets are small cylindrical "nuggets" of compressed, sawdust-size wood fibre, with standard diameters of 6 and 8 (±0.5) mm and lengths of up to four times their diameter. Their compact size and portability, high energy density, low moisture content (below 10%), and minimal net carbon output make wood pellets very appealing as a bioenergy source (Marinescu and Bush 2009). Pellet stoves are clean-burning, automated systems that require minimal maintenance (mainly ash removal) as they can acquire pellets from an internal or external storage using an auger. Most pellet stoves use a thermostat to regulate the temperature and are used in residential applications to heat a room or the whole floor of a house or apartment. Pellet stoves can achieve high efficiency values due to the high quality and energy content of pellets. Bylaws in some communities may prohibit the use of wood heaters due to air quality issues, but pellet stoves are usually allowed.

Pellet boilers (Figure 4) operate similarly to pellet stoves except that the combustion of pellets heats water in a boiler, which is circulated through a closed heating circuit. Pellet boilers are available in a variety of sizes, from household to district heating applications. The feasibility and reliability of the feedstock and adequate storage areas must be ensured, especially for larger installations.

The critical attributes of pellets are ash and moisture contents. The ash content is the attribute that distinguishes pellet grades. For example, Class A1 pellets must have less than 0.7% ash (Obernberger and Thek 2010). Low ash content improves combustion efficiency, decreases ash collection and disposal costs, and lowers dust emissions. The moisture content in pellets should normally be below 10% (wet basis) to reduce the risks of self-heating and degradation in storage (Obernberger and Thek 2010).

Stoker, bubbling fluidized bed, and circulating fluidized bed boilers

Biomass boilers are direct combustion technologies designed for district heating and industrial applications (heat, steam, and electricity production) that use wood chips, hog fuel, or pellets. Biomass boilers are automated and can have capacities that could exceed 300 MWe (EPA 2008). In biomass boilers, ash is generally removed automatically. The feedstock is typically stored in separate buildings, then moved by conveyor and metered into the burner. A variety of combustion systems are available (e.g., fixed and moving grates, fluidized beds) depending on the boiler size. Chip boilers are the most common heating technology for district heating at all scales in Europe. Most of the small- and medium-scale chip boilers in Europe are unmanned and controlled remotely via the Internet or cellular phones. The most common heat distribution system is based on circulating hot water through insulated steel pipes, and each consumer is connected through a heat exchanger to the distribution system.

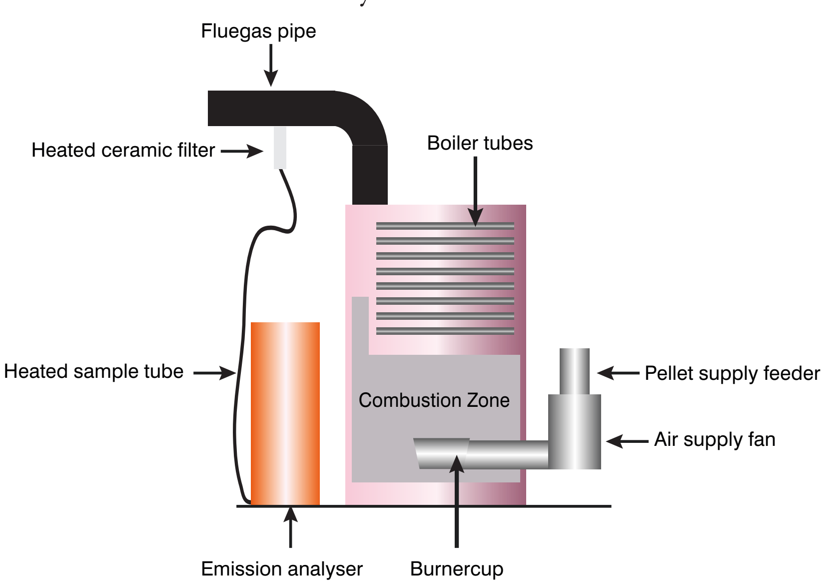

Figure 4. Pellet burner.

To ensure efficient and continuous combustion, the biomass needs to have uniform size and moisture content. Depending on the combustion technology and capacity, biomass boilers can accept moisture contents of up to 30% for stoker systems, although larger stoker boilers could deal with wetter biomass. Fluidized bed systems can accept biomass of up to 60% moisture content (Badger 2002). Some biomass boiler systems may use residual heat to dry the feedstock located in the loading area. The most common particle size for biomass stoker boilers is "4 inch minus" (i.e., up to 4 in. or 10 cm). Fluidized bed systems are less sensitive to particle size and can accommodate particles of 6 in. (15 cm) and greater (McKenzie and Stirgwolt 2010).

Particle size uniformity is also an important biomass attribute that could help increase boiler efficiency and combustion control. The European standard EN 14961-1:2010 offers guidelines regarding the percentage of fines (<3 mm or <0.1 in.) and oversize (>16 mm or >0.6 in.) particles. The degree of contaminant content is also very important for boiler performance, as soil, sand, and gravel can cause glassing on boiler pipes; rocks and metal can harm secondary hogging equipment; and chemical contamination of the feedstock can create harmful emissions.

Co-firing and co-combustion boilers

Co-firing/co-combustion boilers are direct combustion systems in which comminuted biomass such as fine wood powder is blown into the combustion chamber alongside or mixed with other fuels such as coal. Consequently, particle size and moisture content attributes are critical. These systems require fine particles up to 1.5 mm or 1/16 in. (McKenzie and Stirgwolt 2010). Size uniformity is also important to control combustion (residence time) and to provide a consistent fuel mixture; consequently, hammer milling is usually required. Low moisture contents around 10% are necessary to allow optimal size reduction (hammer milling) and combustion. No contamination with dirt, rocks, or metal is allowed (Badger 2002). Wood pellets meet all these constraints and currently constitute the preferred fuel for co-firing with coal.

Gasification

Gasification is a process that converts organic or fossil-based carbonaceous materials into carbon monoxide, hydrogen, carbon dioxide, and methane. This is achieved by reacting the material at high temperatures (>700°C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called producer gas, synthetic gas, or syngas and is a fuel with a calorific value of approximately 5 MJ/m^3, similar to that of wood, but much lower than that of natural gas (39 MJ/m^3). In order to be further utilized in combustion processes, the syngas needs to be cleaned and conditioned. After the cleaning, syngas can be burned directly in internal combustion engines; used in fuel cells; used to produce methanol and hydrogen; or converted, via the Fischer-Tropsch process, into a synthetic fuel. Several types of commercial gasifiers are available: counter-current or co-current fixed bed, fluidized bed, entrained flow, and plasma.

Biomass particle size is a critical attribute that helps ensure the uniformity of the gasification bed in fixed bed gasifiers. Uniformly sized fuel particles aid heat distribution by minimizing hot/cold spots in the bed, especially for gasifiers used in small-scale CHP applications (50–150 kWe). Also, fuel particle size affects the reliability of conveying the biomass fuel into the gasifier, as feed screws could jam if the particles are too big. The ideal size and format are those of wood chips 3 inch minus. Wood pellets between 6 and 8 mm in diameter and up to 12 mm maximum length also work well in gasifiers.[1] Similar to direct combustion systems, fluidized-bed gasifiers can handle larger size variability than fixed-bed gasifiers.

The moisture content also has a critical effect on the efficiency of gasification and on the syngas quality. High moisture content may decrease the gasification temperature and syngas cannot be produced efficiently. Optimal moisture content is usually between 10 and 15%[2] but larger gasification units, such as Nexterra[3], claim to accept moisture contents between 6% and 60%.

Pyrolysis

Pyrolysis is the thermo-chemical decomposition of organic material at elevated temperatures in the absence of oxygen. As opposed to gasification, pyrolysis employs relatively low temperatures (<700°C). Wood pyrolysis causes bond cleavage and produces fragments of the original polymers (cellulose, hemicelluloses, and lignin). The products of biomass pyrolysis are syngas, pyrolysis oil, and char. The yield of these products is directly related to the biomass composition. Pyrolysis oil is formed by rapidly heating biomass to drive off the organic volatile components, then condensing the fuel vapours. Pyrolysis oil is a thick, black, tarry fluid with up to 20% water by weight, the viscosity of heavy oil, and a slightly higher heating value (18–26 MJ/kg) than wood (Demirbas 2009). Pyrolysis processes are mainly classified into carbonization (very slow), conventional (slow), fast, and flash pyrolysis, depending on the operating conditions. The pyrolysis residence times are days, 5–30 min, 0.5–5 s,

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[1] Les Groom, Project leader, USDA Forest Service, Personal communication, September 2008

[2] Stephanie Trottier, Research scientist, Alberta Innovates, Personal communication, January 2012

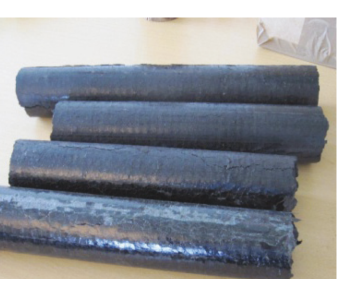
[3] Tyler Abrams, Senior account executive, Nexterra, Personal communication, March 2012

and <1 s in carbonization, conventional, fast, and flash pyrolysis, respectively (Demirbas 2009). Extreme pyrolysis, which leaves mostly a carbon residue, is called carbonization, whereas mild pyrolysis at lower temperatures is called torrefaction (see the *Torrefaction* section).

The extractive content of biomass feedstock is a critical attribute in the pyrolysis process. High variation in pyrolysis oil yields occur depending on the wood species and cause variations in the optimum liquid yields of up to 10% of the initial dry wood mass. Variations in syngas yield with wood variety are lower than for char and oil yields. Species with high extractive contents (e.g., western red cedar) generally produce lower pyrolysis oil yields than species with lower extractive contents (e.g., Douglas-fir, beech) (Di Blasi et al. 2001).

Fast pyrolysis processes generally require small and uniform particle sizes. According to Dynamotive, the desirable particle size is between 1 and 2 mm.[4] However, Pytec ablative pyrolysis technology was tested successfully with traditional wood chip sizes.[5] Similar to gasification, pyrolysis requires an optimum moisture content of the biomass feedstock. For example, Pytec technologies require 10% moisture content (Meier et al. 2007). High lignin content generates more char; consequently, softwoods are expected to produce more char than hardwoods. Also, due to their higher lignin contents, softwoods may require longer conversion times than hardwoods. Higher pyrolysis oil yields are expected from wood varieties with high lignin content such as softwoods (Demirbas 2009). However, high bark content of biomass may reduce the pyrolysis oil yield. According to the pyrolysis oil producer Envergent, pyrolysis oil yields are 70–75% for hardwood, 70–80% for softwood, 60–65% for hardwood bark, and 55–65% for softwood bark, by weight.[6]

Figure 5. Torrefied briquettes.



Torrefaction

Torrefaction of biomass can be described as a mild form of pyrolysis, at temperatures typically ranging between 200°C and 400°C. Torrefaction of biomass, combined with densification (Figure 5) produces a solid fuel similar in texture to coal, with high heating values between 19.8 GJ/t and 25.5 GJ/t.[7] In addition, torrefied biomass fuels are hydrophobic, sterile, and easier to grind into a powder than wood. These properties allow the torrefied biomass to be stored in open spaces without the concern for increasing moisture contents, biological decomposition, and self-ignition. Also, torrefied biomass can be readily mixed, ground, blown, and combusted with coal. Critical attributes of biomass feedstock for the torrefaction process are similar to those of the pyrolysis process (see the *Pyrolysis* section).

Fermentation for bioethanol production

Two chemical reactions describe the conversion of woody biomass to ethanol (Figure 6): hydrolysis, which uses acids and enzymes to convert the biomass to simple sugars, and fermentation, which converts sugars to ethanol by means of yeast or bacteria that feed on the sugars.[8] Ethanol, carbon dioxide, and cellular biomass are produced as the sugars are fermented. The ethanol production process starts with the biomass handling and size reduction (chipping to uniform particle size), followed by biomass pre-treatment and hydrolysis, in which the sugars are released and fermented. The ethanol is then recovered from the fermentation broth, typically by distillation.

The feedstock quality affects all the steps in the ethanol production process, but most critically it affects hydrolysis, which is also the most expensive step in the process. Researchers have been improving the efficiency of ethanol production by developing new enzymes, chemical processes, and mechanical processes (e.g., steam

[4] www.dynamotive.com/technology/fast-pyrolysis/
[5] www.pytecsite.de
[6] www.envergenttech.com/rtp.php
[7] www.torrefuels.com/technology.html
[8] http://www.eere.energy.gov/basics/renewable_energy/ethanol.html

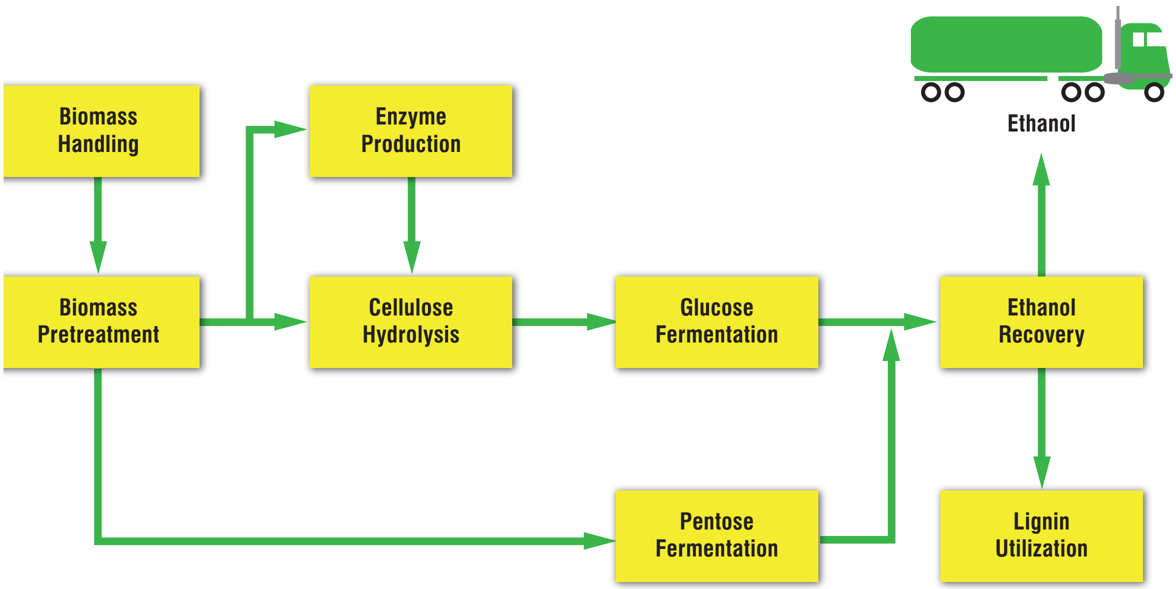


Figure 6. Bio-ethanol production process.

explosion),[9] and by converting cellulose into fermentable monosaccharide.

One of the most critical feedstock attributes is the cellulose content, which has a direct effect on the ethanol yield. Hardwood species, such as poplars, aspens, and willows, are preferred over softwood species because of their high cellulose and low lignin contents. However, these species may also have higher levels of xylans, which are difficult to ferment efficiently. Also, the presence of bark and lignin reduces the efficiency of the hydrolysis reaction; consequently, clean "white" wood chips (with little or no bark) are desirable (Sannigrahi and Ragauskas 2010). Similar to the chemical pulping requirements, a uniform wood chip size is very important for increasing the efficiency of the hydrolysis reaction. Contamination with dirt, rocks, and other foreign materials should be avoided as these can reduce the reaction efficiency dramatically.

Densification

Densification refers to the process of increasing the bulk density of materials. There are two densified woody biomass products on the market today: wood pellets and briquettes. Wood pellets are small cylindrical "nuggets" of compressed, sawdust-size wood fibre that are combusted in pellet stoves and boilers to generate heat (see the *Pellet stoves and boilers section*). Larger but less dense than pellets, briquettes are also made from wood particles that are compressed in a variety of shapes, from brick to cylindrical shaped (Figure 7). Briquettes are used mostly in industrial applications (biomass boilers), although some small-scale applications exist in farms and greenhouses.

Wood chips from hardwood (oak, birch, beech, willow, poplar) and softwood (pine, fir, spruce) species comprise the feedstock for pellet production. Most pellet producers prefer softwood chips because they are easier to mill into pellets than hardwood and contain more lignin, the natural binding agent that holds the wood particles together in pellets and briquettes. Regardless of species, stem wood is preferred over other parts of the tree (bark, roots, tops, and limbs), because wood pellets require homogeneity and predictability of burning characteristics. For example, wood pellets produced from tree branches and tops may have high ash and bark content, which would limit their access to markets where strict standards for these characteristics exist (European premium grade pellet markets). However, there is also a market for industrial pellets which are used by large-scale energy producers.

In Canada, sawmilling residues, such as planer shavings and sawdust, are the most utilized feedstock sources for wood pellet and briquette production. Because they are

[9] www.iogen.ca/cellulosic_ethanol/what_is_ethanol/process.html



Photos: Thinkstock

Figure 7. Wood pellets and briquettes.

a by-product of the lumber manufacturing process, sawmilling residues require little or no drying before entering pellet production.

The biomass feedstock for wood pellets and briquettes are evaluated based on the following critical attributes: particle size, moisture content, extractive content, lignin content, ash content, and contaminant content. Pellet standards and grades have been developed based on these critical attributes. Currently, there are no standards for briquettes. One of the most critical attributes is particle size and size distribution. A generally accepted feedstock for pellets (before the pellet press) should have a maximum particle size of 4 mm (up to ¼ inch) and less than 50% particles under 1 mm (Obernberger and Thek 2004). To achieve the desired sizes, biomass feedstock requires pre-processing through chipping and subsequent hammer milling.

To increase the efficiency of size reduction and pelletization processes, the biomass feedstock should meet specific moisture content values. The desired moisture content (wet basis) of the feedstock (before the pellet press) should be between 8 and 12% (Obernberger and Thek 2004). For wood chips with higher moisture content values, drying them in rotary or belt dryers before hammer milling is required. Drying costs could be substantial, reaching more than 20% of the total pellet production cost (Mani et al. 2006). To maintain or minimize feedstock moisture content, the feedstock should be stored in silos or warehouses rather than in outdoor piles. Also, if pellets are manufactured from logging residues, storing of branches, tops, and small logs in clean windrows is recommended to decrease the moisture content and contaminants. Although moisture content and particle size are perceived as critical attributes for briquette manufacturing, no rigorous information or standards are available to date. Anecdotal information from existing briquetting operations suggests that larger particle sizes and higher moisture contents may be acceptable, which could decrease the manufacturing costs of briquettes.

Extractives, such as terpenes, which are released as VOCs during drying and storing phases corrode the metal equipment (conveyor covers, chip dryer, hammer mills, pellet mills, silos). Extractives (e.g., resins) also tend to gum-up the hammer mills. Through a process of auto-oxidation, the unsaturated fatty acids and other extractives, they could contribute to the self-heating of wood pellets during transportation and storage (Arshadi and Gref 2005).

High ash content in wood pellets reduces heating value and, consequently, the combustion efficiency (Lehtikangas 2001). Also, high ash content increases the wear and tear of pellet manufacturing equipment and reduces the efficiency of the combustion equipment. Higher proportions of bark in the feedstock will result in greater ash content in the pellets. Although less than 1% ash content is required for premium pellets (for residential use in pellet stoves), less than 0.5% ash content is preferred to further reduce the need for ash removal. By contrast, industrial pellets are required to have less than 3% ash content (Obernberger and Thek 2004). Increased ash content in pellets could also be an indication of mineral impurities such as sand and dirt in the feedstock or a high content of inorganic compounds (e.g., calcium compounds in some hardwoods). Impurities in the feedstock can vary significantly depending on the method and the season in which they were handled.

Contamination of feedstock is a critical issue in wood pellet manufacturing. Contamination with soil, sand, and gravel increases wear on pelletizing dies and the ash content of produced pellets. Also, the presence of gravel and metal can harm secondary comminution equipment such as chippers and hammer mills (Ohmann et al. 2004). Contamination is more prevalent in feedstock sourced from logging residues and reclaimed landfilled materials; therefore, contamination of feedstock material should be avoided at all costs, throughout the forest to product supply chain.

The lignin content in biomass for wood pellets is one of the most critical attributes because lignin is a natural binder in the pelletizing process. Due to the friction between rollers and dies of the pellet mills, high temperatures are generated that melt the lignin in the wood. Molten lignin penetrates the wood fibres, increasing pellet durability and providing a shiny surface. Generally, softwoods have higher lignin content than hardwoods; therefore, to increase bonding in hardwood pellets, softwood feedstock is added. In Europe, it is common to use biological additives (e.g., maize and rye) of up to 2% to increase bonding characteristics of pellets and reduce operational costs (Obernberger and Thek 2004). For example, lignosulphonate may be added to feedstock to improve binding, but can increase the sulphur content and cause higher SOx emissions.

Summary

The main objective of this primer is to provide general information about the biomass attributes critical to the most common bioenergy and biofuel processes. Table 1 presents a summary of the biomass critical attributes investigated in this primer.

Table 1. Summary of critical biomass attributes[a]

	Direct combustion technologies					Thermo-chemical biofuel technologies				Densification technologies
Biomass critical attributes	Wood stoves/ cordwood boilers	Pellet stoves/ boilers	Stoker boilers	Fluidized bed boilers	Co-firing/ co-combustion boilers	Gasification	Pyrolysis	Torrefaction	Fermentation	Pelletization and briquetting
Size			Uniform size	Uniform size <10–15 cm	Uniform size <1.5 mm	Uniform size 2.5 cm × 2.5 cm × 0.6 cm	Uniform size 1–2 mm	Uniform size 1–2 mm	Uniform size	<4 mm, <50% fines (<1 mm)
Moisture content	15–20%	<10%	<30%	<60%	<10%	10–15%	<10%	<10%		8–12%
Proportion of bark/foliage/wood		L					L		L	L
Degree of contamination	L (salt)		L	L	L				L	L
Calorific value	H	H	H	H	H					H
Ash content		<0.5%[b]								<0.5%[b]
Carbohydrate content									H	
Lignin content							L[c]		L	H
Extractive content							L	L		L

[a] L= attribute value as low as possible desired; H = attribute value as high as possible desired.
[b] <0.5% premium pellets; <1% industrial pellets.
[c] Unless char and lignin are targeted products.

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