Chapter 2
Biomass Types for Pellet Production

Biomass is the totality of organic substances occurring in a natural habitat, a distinction being made between phytological and zoological mass [1].

Biogenic fuels represent the proportion of the total quantity of biomass which can be used as energy sources to provide electricity, heat or engine fuels. Bioenergy sources can be subdivided into solid, liquid or gaseous by means of their state of aggregation. Of these, only the solid biogenic fuels are of relevance for the pellet production (with a water content which is as low as possible).

2.1 Classification

Figure 2.1 represents the wide variety of assortments of biogenic solid fuels accruing as residues, byproducts or waste products both in agricultural and

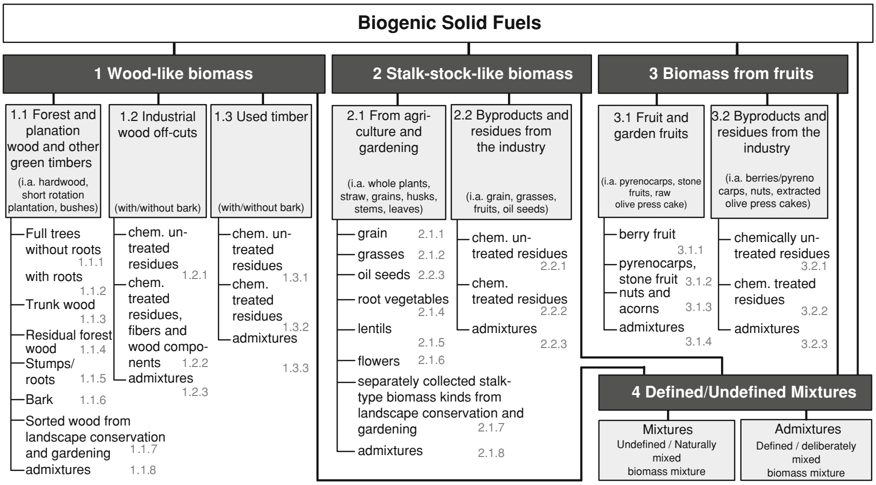

Fig. 2.1 Classification and specification of biogenic solid fuels to DIN EN 14961-

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forestry-related production and in the further industrial processing or at the end of a utilization chain. Energy plants from agricultural cultivation (e.g. short rotation plantation, miscanthus, whole cereal plants, can represent additional potentials for pellet production. Following European standard DIN EN 14961-1, biogenic solid fuels are classified into wood or stalk-stock-like biomass, biomass from fruits and defined/undefined mixtures.

2.2 Raw Materials and Technical Potentials

In Central Europe, mainly chemically untreated barkless industrial wood offcuts which, for instance, accrue as offcuts in sawmills or as byproducts of the wood processing industry in the form of chips, wood dust or cut wood pieces, are being used for producing wood pellets. Newly felled wood (forest wood offcuts or also lower-quality log wood pieces—so-called calamities—e.g. from forests with storm damage or bark beetle infestation) is used to an as yet rather small extent as raw material for the wood pellet production since it requires a more elaborate production process due to, among other things, its higher water content and the amount of bark involved. The use of plantation timbers from the cultivation of fast-growing types of trees such as poplars or willows with multi-annual harvesting cycles (short-rotation plantation) is currently being prepared in many places but has hitherto been implemented only at a few sites. In the medium or long term, an increase in the use of newly felled timber in the pellet production is expected in order to exploit further contingents of biomass. It is also expected that the demand for biofuels will continue to grow and the availability of non-wood-like raw materials (e.g. straw, miscanthus) will progress so that their often significant but hitherto unused potentials can be put to further use.

However, any further development and the exploitation of additional biomass contingents for producing pellets may contribute to a shortage of the limited resources of natural biogenic raw materials available which would lead to numerous rivalries for utilization and further intensify existing rivalries. On the one hand, competitive fields can be developed with regard to the utilization of the land area and cultivation of biomass which has an effect on the supply and the available potential in raw material. On the other hand, the rivalries will intensify further with respect to the different technical options for utilization of the biogenic energy sources, particularly the material utilization of wood as such. To identify rivalries in the utilization of bioenergy, four levels can be distinguished in which the indicators are evident in varying degrees depending on the basic parameters (Fig. 2.2). Active indicators are, for example:

– Availability of a conversion technology at time x
– Options of biomass use/material flows for selected concepts of technology

– Area rivalries in biomass cultivation for the provision of electricity, heat and fuel
– Raw material prices for energy utilization in competition with food cultivation and the material utilization.

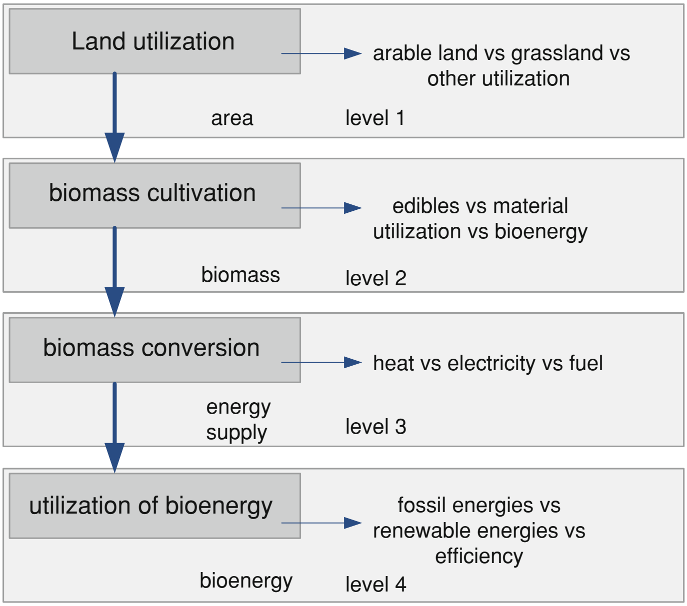

Fig. 2.2 Levels of utilization rivalries in the energy utilization of biomass

2.2.1 Methodical Approach

Following the results of the study "Sustainable Biomass Utilization Strategies in the European Context" [2], the relevant raw material potentials for the pellet production are derived for Germany and the EU countries. For the countries of Russia, Canada and the USA, the relevant biomass potentials are derived from existing studies of potentials [3–6].

The method for determining potentials is attributable to balancing material flows for determining the technically developable and energy-providing biomass potential, using the theoretical potential as a basis. The technical potential of raw material determined describes the proportion of the theoretical potential of the available biomass which, taking into consideration the given material utilization of biomass (food, feed and wood processing etc.) and structural and ecological restrictions (e.g. maintaining cycles of matter, areas claimed by biotope networks etc.) can be utilized with the available technologies.

The technical potential describes the proportion of the theoretical potential which can be utilized, taking into consideration current technical capabilities—i.e. available techniques of utilization, their efficiencies and with regard to the availability of sites [2].

With respect to the determination of technically available energy source potentials, only thermo-chemical conversion processes are considered in the biomass utilization of the raw material potentials considered and, accordingly, fuel-specific heating values are included. The basis for the determination of potentials are European and regional agricultural and forest and waste statistics, data by the FAO and numerous assumptions for the forward projection of the development [2]. Technical raw material potentials have been developed for the following biomass fractions:

- Forestry potentials
- Potential from felling = logwood + firewood + forest wood offcuts (harvest losses)
- Potential from unused growth = theoretical potential—felling
- Agricultural potential
- Potential from energy plant cultivation (short-cycle rotation plantation, miscanthus, whole wheat plants)
  - Potential from waste materials and byproducts
  - Industrial offcut potential from sawmills, wood composite, groundwood and pulp industry
  - Straw potential (grain straw, corn, rapeseed, sunflower straw)
  - Landscape conservation material.

2.2.2 Selecting Raw Materials

Due to the fact that the varied biogenic solid fuels have in some cases very different fuel characteristics, only the appropriate fuels can be used depending on their field of application. With regard to a qualitative use of the existing biomass types, it is possible to break these down into different input streams for pellet production—classified and specified according to European Standard DIN EN 14961-1 (Fig. 2.3). The potentials are subdivided into the following target markets:

- Wood pellets for the small-consumer market
- Wood pellets for the medium-sized and greater power range
- Other pellets, e.g. for use in the power station sector, partly also suitable in plants for agricultural fuels.

Figure 2.3 shows the import flows of the biomass potentials broken down into their qualitative fields of application. Wood offcuts represent a mixed fraction of woods from different tree components (including bark), like merchantable treetop wood, brushwood and short trunk segments.

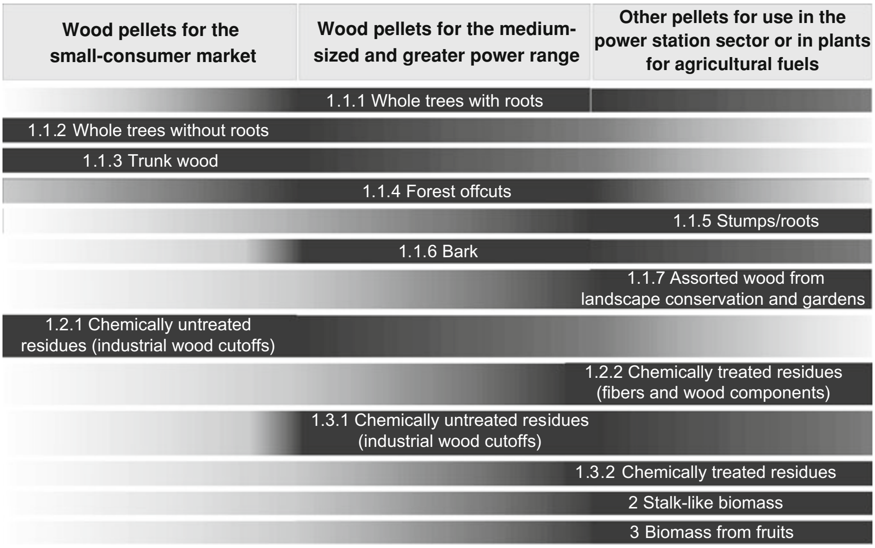

Fig. 2.3 Qualitative allocation of biogenic solid fuels (to DIN EN 14961-1) according to potential input flows for determining pellet potentials

Fractions not taken into consideration during the determination of potentials—stumps and roots, flowers, wild berries and garden fruit—do not appear as potential everywhere or are not available as such in the countries.

Due to the large number of different options for utilizing biomass, which will increase further in future—utilization rivalries—only 1/3 of the total technical forestry and agricultural fuel potential is taken into consideration for the fuel pellet production. The potential of industrial wood cutoffs is already being used most comprehensively today for the production of wood pellets and is, therefore, included with 50 % in the estimation of the wood pellet production potential.

2.2.3 Technical Potential

In the 28 EU countries, the technical potentials of raw materials for the pellet production varied between 500 and 750 TWh/a in 2010. This corresponds to a pellet production capacity of 100—150 million tons (Table 2.1). The greatest potentials for pellet production are largely found in the utilization of forest wood cutoffs and in the cultivation of energy plants for the production of wood pellets in the medium and higher power range or of other types of pellets (e.g. in the cultivation of whole grain plants).

With respect to the qualitative differentiation of the potentials according to fields of application, the potential for the production of pellets for use in small heating systems is currently about 200 TWh for the 28 EU countries. The pellet production

Table 2.1 Technical pellet production potentials for the 28 EU countries and Germany in 2010, derived from [2, 25]

		EU-28	Germany
Wood pellets for the small-consumer market	TWh/a	200	28–30
	Mio. t/a	40	5–6
Wood pellets for the medium-sized and greater power range	TWh/a	130–390	15–60
	Mio. t/a	25–80	3–12
Other pellet types	TWh/a	170	17–23
	Mio. t/a	35	3–5
Potential for pellet production (total)	TWh/a	500–750	60–110
	Mio. t/a	100–150	12–22
Pellet production plants	Number[a]	667–1 000	80–147

[a] with a production capacity of 150,000 t each

Table 2.2 Pellet production potentials for Russia, Canada and the US in 2010, derived from [3–6, 26]

		Canada	US	Russia
Forestry potential	TWh/a	0–80	170	250
Agricultural potential (energy crop cultivation)	TWh/a	400	630	400
Potential from remnants and byproducts	TWh/a	140	590	100
Potential for pellet production (total)	TWh/a	220–620	760–1,390	350–750
	Mio. t/a	44–125	150–280	70–150

potential for use in the medium-sized and higher power range was registering as continuous over the observation period and was between 130 and 390 TWh in 2010. The range of the potential can be explained by uncertainties and by the long-term high demand for biomass in the cultivation of energy plants. The technical potential for the production of other types of pellets is currently about 170 TWh.

The potential of raw materials available in Germany for the pellet production from agriculture and forestry and the wood processing industry including the chargeable assortment of unhewn timber is currently between 60 and 110 TWh (Table 2.2) according to moderate estimates. The greatest potentials of raw materials for pellet production are found in France,. Germany, Spain, Poland and Sweden (Fig. 2.4).

Taking into consideration regional studies of potential, significant potentials for use in the pellet production can be shown to exist in North America and Russia. Considering numerous options for utilizing biomass, the pellet produciton potential in North America ((USA and Canada) is between 1,000 and 2,000 TWh/a. In the US, considerable fuel potentials from industrial and agricultural remnants and byproducts are mainly found. Whereas Russia has a considerable forestry potential for use in the pellet production (Table 2.2).

In summary it is noted that the existing biomass potentials for pellet production in the EU, North America and Russia are hitherto not being fully tapped. In the long term, the potentials for pellet production are largely found in the field of

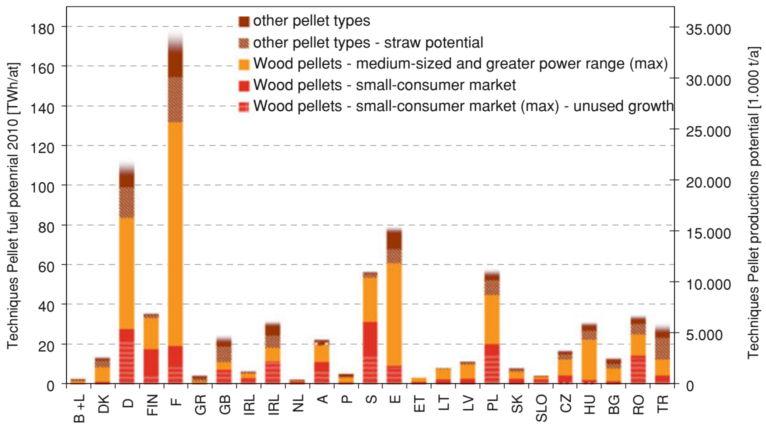

Fig. 2.4 Qualitative grading of the technical fuel potential for pellet production in 2010

utilization of forest wood cutoffs and of energy crop cultivation. Future prospects are that the potentials for pellet production will largely lie in the area of utilization of forest wood offcuts and of energy crop cultivation. In the long term, it its expected that the potential for production of wood pellets for the small-consumer market will drop slightly since, although the felling increases with increasing utilization of unhewn timber and thus the quota of wood cutoffs also increases, the potential from unused growth decreases. Furthermore, segments of wood cutoffs previously neglected in material utilization are increasingly put to other use due to the increasing competition for the utilization of low-cost timber quotas [7, 8]. The cultivation of energy crops, like the cultivation of short turnover plantations, can currently be considered only as an additional option for providing raw material for the pellet production. The basic conditions and stimuli for the agricultural cultivation of short turnover plantations must here be enhanced further in the short to medium term in order to be able to fulfill the current forecasts regarding the growth potential of the pellet market in Europe and world-wide with sustained quotas of raw material.

2.3 Characteristics of Raw Materials

2.3.1 Molecular and Elementary Structure

Knowledge of the chemical composition of biomass is of great significance for the assessment of the utilizability of the raw material for the pelletization and thermal utilization. In this context, a distinction can be made between the molecular structure of the biomass—which is mainly of relevance to the treatment of the raw

Table 2.3 Molecular structure of biogenic raw materials [9, 11, 10]

Components		Typical proportions and constituents
Fundamental substance:	Holocellulose	Cellulose (long-chain macromolecule) 20–55 % wood: 40–55 % Hemicellulose (short-chain, branched macromolecule) 10–40 % wood: 20–35 %
	Lignin	3-dimensional macromolecule 30–35 % softwood: 25–35 % hardwood: 18–32 %
Associated material;	Extracts	Fats, oils, resins, waxes proteins, starch, sugar, natural rubber dyes, tanning, bitter and odorous substances, camphor organic and inorganic acids, salts, minerals

material (e.g. for pelletization)—and the elementary structure, knowledge of which is of special value to understanding the thermal decomposition process.

With respect to the dry vegetable matter, biomass is composed of around 90 % carbon (C) and oxygen (O) and around 6 % hydrogen which are absorbed by the plant in the form of CO_2, O_2, H_2O or HCO_3. These three main components of the herbal substance are contained in all organic compounds (e.g. in lignin, cellulose, pectine, sugars, fats, starches snf proteins). The remaining parts of the dry substance serve to store the herbal nutrients. Up to 5 % of the dry matter can be associated with the important macronutrients (N, K, Ca and in lesser amounts P, Mg, S and Fe_1). In contrast, micronutrients only occur as trace elements in a concentration of between 0.001 and 0.03 % (Zn, Cu, B, Mn, Mo, Fe). Apart from a few exceptions, the nutrients are present uncombined in the phytomass (not combined with organic substances). The necessity and assignment of chlorine, silicon and sodium to plants has not yet been conclusively explained [1].

Considering the molecular structure of plants, solid types of biomass consist in about 95 % of the three biopolymers of cellulose, hemicellulose and lignin. The remaining proportion is composed of a multiplicity of associated materials, the so-called extracts (such as resins, fats, tanning agents, starch, sugar, proteins and minerals). The proportions of the chemical components related to dry matter vary in accordance with their specific type (Table 2.3).

Cellulose

Cellulose Cellulose, formed predominantly of linear glucose polymers, is the substance occurring most frequently in nature. It forms the structural substance of the plants and is the fundamental substance of the unlignified (non-woody) cell wall. Due to its high degree of crystallization, cellulose, inspite of having a relatively high number of hydrophilic groups, is not water soluble but acts hydroscopically (water-absorbing).Due to its molecular structure, cellulose imparts a high dimensional stability to the biomass, especially by providing tensile and flexural strength. In the case of wood and of most of the other biogenic raw materials, the tensile strength (cellulose content) is on average twice as high as the compressive strength (lignin content), resulting in the relatively high flexural strength of wood. Hardwoods form as a reaction to the tension-loaded side of the tree so-called tension wood which has particularly high strength.

Celluloses are used in the production of paper and insulating material from pulp and groundwood, and in the textile, cosmetics and food industry [9, 10].

Hemicelluloses

Hemicelluloses (also called polyoses) are polysaccharides with complex branching which support the plant multifunctionally, for example the supporting effect in the cellular membrane or as a backup, swelling and adhesive substance for cementing the cell walls. Hemicellulose always occurs as a substance associated with cellulose. Whereas in softwoods the fundamental building blocks of hemicellulose are represented by hexanes, in hardwoods it is the pentosanes which impart to them plastic properties (the wood becomes more flexible). Due to the amorphous molecular structure of hemicelluloses they easily absorb water but relinquish it only slowly and thus retard the drying out and dying back of the cellular tissue.

Hemicelluloses are obtained from agricultural products (e.g. corn cobs, oat spelts) and are used as, among other things, binding agent for activated coal or briquets, in the manufacture of paper (increasing its strength), in the food industry (thickening agent, jellification) [1, 9, 11].

Lignin

From the chemical point of view, lignin is described as a complex polymer chain of phenyl propane groups having thermoplastic properties. Lignin never occurs separately but always as a cellulose-associated substance. The reddish-brown substance lignin is the actual filling and lignifying substance of the plant which, due to its swelling effect (less than with cellulose) and cementing and stiffening effect is responsible for the compressive stability of the plant. Thus, a high lignin content ensures that the sprout of a plant will remain upright and can dry off even with a decreasing water pressure as is the case, for example, with the stalks of ripe cereal plants in the field. Wooden biomass types have much higher lignin contents than one year old plants (annual harvesting cycle) and can therefore also withstand high continuous stresses in spite of relatively low water contents. The lignin content also varies within a plant, depending on the type of biomass. Thus, the highest lignin values are typical of the lowest, highest and innermost parts of a trunk, of softwood branches, bark and compression wood1.[1] Being an organic substance, the natural lignin depletion begins with the harvesting of the plant/felling of the tree and can be accelerated by externnal factors (UV light, heat and moisture).

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[1] Compression wood is the reaction wood formed in conifers on the pressure-loaded side (e.g. due to the main wind direction). Compression wood is heavier, harder and denser than the normal wood.

Lignin occurs in large quantities as a byproduct of the pulp industry and is now being used both synthetically and for energy purposes [1, 9, 11].

Extracts

The minor constituents, associated substances and extracts include more than 500 different compounds. In some cases, the inorganic components of the plants (K, Ca, Mg, Fe, Mn etc.) are listed separately as "ash" in the chemical allocation of the elementary constituents whilst the extract substances then contain only purely organic components [11]. They are then allocated to the minerals.

Although extractives partly constitute only minimal proportions of the molecular substance of plants they can determine significant characteristics of the raw material such as, e.g. [10]:

– resistivity against fungi and insects (tanning agents, terpenes, phenols)
– odour (e.g. fir tree, pine) and colour (e.g. walnut, Douglas fir)
– water-repellent (resins, waxes, fats, oils),
– impregnability (poorer with resin-containing woods)
– flammability (with resin-rich woods).

Whilst the timbers of the temperate zones have between 1 and 10 % extractives, between 2 and 30 % by weight can be found in tropical timbers. Their mass-related concentration is typically 3–7%. There are 2 different groups of extractives. On the one hand there are the primary minor components (e.g. starch, sugar, fats, fatty oils and protein).which are mainly deposited as storage substances in the fall in order to be available in spring for sprouting. This is why deciduous trees have a higher proportion of extractives than evergreens (with the exception of the larch). On the other hand, there is the multiplicity of secondary minor components which include, for example, heartwood substances, minerals, dyes and tanning agents, resins, essential oils, irritants and toxic substances. Apart from a few exceptions, heartwood has more metabolites than sapwood [1, 10, 11].

Resins, Turpentines

Resins serve to close wounds in plant tissue, cure in air and are hydrophobic. Conifers have high resin contents. Turpentines are liquid extractives which occur in conjunction with resins and are toxic [11]. Both substances are used commercially as solvents, resin size, odorants or as turpentine oil [10]. In the case of highly resinous conifers, the extracts can be collected by ("bleeding") the trees, i.e. scratching the bark.

Terpenes

Terpenes are of chemically similar structure to resins. They protect the plant from the penetration of bacteria and fungi. Terpenes are also hydrophobic and consist of slightly volatile compounds [10].

Tanning Agents and Waxes

Both of these substances are contained mainly in the bark of trees for the thermal, mechanical and chemical protection of the herbal tissue. They increase the rsistivity of the plant against external penetrators such as fungi and insects [10].

Fats, Starches

Fats can be detected in increased concentration mainly in conifers in winter. Starches, on the other hand, are stocked up typically in the growth phase of deciduous trees and partly converted into fats during the winter.

Minerals

Minerals contain a large number of the macro- and micronutrients of the plants (e.g. P, Mg. S, K, Si) which handle different metabolistic functions. For example, the silicic acid (Si) content has an influence on the resistance against insects (especially in tropical types of trees) [9].

Table 2.4 lists the organic components and inorganic substances (ash) of various biomasses referred to dry matter. In comparison with stalk-type biomass (annual plants), woody raw materials have much lower protein contents.

Table 2.4 Molecular components of various biomasses (no information on lacking mass fractions) [1]

Fuel	Cellulose	Hemicellulose	Lignin	Resins/Fats	Protein	Ash
Wood fuels (in % b.w.)						
Fir	42.3	22.5	28.6	2.3	–	1.2
Pine	41.9	21.5	29.5	3.2	–	1.3
Spruce	41.0	24.3	30.0	k.A.		k.A.
Ash tree	40.2	25.0	26.0	2.2	–	1.3
Beech	45.4	22.2	22.7	0.7	–	1.6
Birch	40.9	27.1	27.3	2.2	–	1.8
Poplar	48.4	18.2	21.6	2.4	–	1..3
Willow	42.9	21.9	24.7	2.0	–	1.2
Stalk-type fuels (in % dry matter)						
Wheat straw	38	29	15	–	4	6
Prairie grass	37	29	19	–	3	6
Miscanthus	43	24	19	–	3	2
Sorghum bicolor	23	14	11	–	k.A.	5
Tall fescue	25	25	14	–	13	11
Corn straw	38	26	19	–	5	6

Regarding the information on the molecular and elementary composition of various raw materials in this chapter, it should be pointed out that this can vary greatly both between the types of biomass and within one type and even when considering different parts of a plant (e.g. trunk wood, bark, needles, leaves, roots). There can also be fluctuations in the elementary composition within one period of vegetation or in the various development sections of a plant. Site-related factors such as climate, weather and ground or plant cultivation measures (e.g. fertilization) have an additional influence on the substance of the plant. In the case of biomasses having a short growth phase, especially, (e.g. straw and whole plants), generalizing conclusions regarding the content of elements can only be drawn to a limited extent from the type of biomass.

2.3.2 Raw-Material Parameters for Influencing the Quality of Pellets

According to their definition in prEN 14588, pellets represent a compressed biofuel of pulverized biomass which have been compacted with or without additives, have normally a cylindrical shape with a length of 5–40 mm, and have broken ends [12].

From a technical point of view, almost all biogenic solid fuels are suitable to be palletized. However, optimal successes in pelletization are only achieved if the raw material is relatively constant in its particle structure/grain size distribution, the water content and the chemical composition [13]. In this context, the molecular composition of the biomass has a decisive influence on the natural suitability of the raw material for pelletization, whereas the water content and the physical/mechanical properties of the raw material characterize the processing effort required and the storability of the biomass. For these reasons, the chemical effects of the molecular mass of the raw material on the palletizing process are shown in summary in Table 2.5 and then their influence on the pellet production process, in particular, is explained. In addition, the significance of the water and bark fraction of the raw material was listed as a quality parameter.

Basic Substance

Whereas cellulose is composed of 48 % carbon (52 % O, 6 % H), lignin has even 64 % carbon (30 % O, 6 % H). Due to their great heterogeneity it is not feasible to provide adequate information on the chemical composition of hemicelluloses.The unequal molecular composition of the raw materials affects the overall carbon content of the bioenergry source and thus its energy content referred to dry matter. In principle, it was found that the heating value for needlewood was about 2 % higher on average compared with that for leafwood. This rise, and also the heating value of the needlewood bark which is higher again by another 2 %. Is attributable to the higher lignin content of the needlewood and partially also to the higher content of extractives. Both groups of materials are characterized by the fact that their partial heating value of appr. 27.0 and 35.9 MJ/kg, respectively, is distinctly higher than that for cellulose (appr. 17.3 MJ/kg) or hemicelluloses (appr. 16.2 MJ/kg) [1].

Table 2.5 Selected raw material parameters for influencing the pellet quality and the production process [1, 11, 16–18, 21, 23, 27]

Parameter	Effects
Molecular composition	
Basic substance	Mass fractions of cellulose, hemicellulose and lignin affect the carbon content of the raw material and thus the energy content (heating value), referred to dry matter, of the pellets.
CelluloseCellulose	A large number of hydrophilic groups will influence the water absorption and water reduction of the raw material (drying characteristics)
Hemicellulose	The amorphous structure promotes the water absorption of the raw material but retards the release of water and thus the drying time of the raw material particles (drying energy expenditure)
	Swelling and adhesion function supports the pelletizability of the raw material
Lignin	Natural pressing aid (arching, adhesive effect), increases the mechanical strength of the pellets
	The hydrophobic structure increases the stability of the pellets with respect to (air) humidity after the curing of the ligning in the cooler; sealing of the pellet surface
	High lignin content of the raw material can be recognized from the external gloss of the pellets
	LigninLignin depletion starts at appr. 150 °C (loss/reduction of adhesive effect) and thus influences the choice of technical drying (temperature level) of the raw material.
Starch, sugar Albumens	Natural pressing aids/bonding agents, support the bonding power of the material to be pressed through their adhesion–stability, mechanical strength (abrasion) of the pellets
	Throughput of the press/energy expended is partially optimized due to the lubricating function (e.g. with potato starch, but can also be partially reduced, e.g. with molasses (sugar).
Fats, oils	Lubricating function affects throughput of the press/energy expended
	Decrease in stability/mechanical strength of the pellets
Resins, waxes	Hydrophobic structure also increases the stability of the pellets with respect to (air) humidity (s.a. ligning)
	Natural pressing aids, support the bonding power of the raw material particles and thus the mechanical strength (abrasion) of the pellets.
	Temperature level of the raw material drying system affects bonding forces/adhesion (high temperatures promote risk of self-ignition due to easily volatile components)
	Wax layer/sheathing of fibrous raw materials (e.g. in cereal) lowers pelletizability (and affects the choice of milling technology
Terpenes	Easily volatile, partially poisonous gases (storage)
Minerals	Inorganic components affect ash content and ash fusibility of the pellets

(continued)

Table 2.5 (continued)

Parameter	Effects
s.a. K, Ca, Na,, Mg, Si[a] etc.	Si increases the abrasion and wear of the presses (edge runner, dies) and conveying systems.
Selected components	
Water	Water contentWater content affects the fiber length in milling and the expenditure for drying
	The optimum water content of the chips has a decisive influence on the strength of the pellets with respect to abrasion.
	The water content of the raw material determines the requirement/expenditure for drying
	The water content of raw material and fuel affects the storability (growth of fungi, storage losses, risk of self-ignition) of the material, the fuel mass and its heating value.
	Adding water as a bonding agent in pelletization improves the sliding of material which is too dry, whereas adding hot steam is used more for the thermal activation of the bonding agents native to the raw material or added.
Bark	The high content of lignin and extractives (tanning agents) makes raw material more sensitive to temperature and pressure effects/ lubricating function optimizes throughput of the press/energy expended
	High proportion of minerals increases ash content.

Lignin

Since lignin hardens (dries) progressively in dead plants and thus loses its bonding capacity, the lignin can be activated/softened in the pelletization by supplying heat. With relatively fresh raw material, an increase in temperature can be achieved partly merely by means of the friction and pressure effects of the material to be pressed in the die. The activation of the lignin can be supported technically (e.g. in the case of older raw material stored for a longer time) by feeding hot water or hot steam into the conditioner [14]. Due to the hydrophobic (water-repelling) structure of the lignin, however, a speedy absorption of the water (water integration) is limited [15]. The addition of hot steam (small volume of water, high input of heat) will, therefore, probably have a better effect on the activation of the lignin than adding hot water.In addition, the dwell times of the mixture of materials to be pressed are limited.

The dimensional stability and mechanical strength of the pellets will be achieved only if the material to be pressed is cooled rapidly immediately after pelletization in order to then cure the previously softened lignin and any bonding aids possibly added (s.a. cooler [16–18].

The licensing of chemically extracted lignin (from the wood pulp industry) for use as pressing aid in pellet production is handled in different ways and depends on the nationally applicable standards and the legal framework conditions. In Germany, only untreated bonding agents from biomass from agriculture or forestry are permitted if the pellets in heating systems fall within the scope of the first BImSchV (Federal Immission Control Act Ordinance) [19, 20].

Starch, Sugar, Albumens

Adhesion supports bonding of the raw material particles in pressing. Adding pressing aids based on cereal and potato starches or molasses increases the natural concentration of the extractives in the material to be pressed (strengthening of the mechanical strength of the pellets) and improves the sliding/lubricating function of the material to be pressed [14]. However, molasses can also lead to a reduction in the throughput of the press [21].

Fats, Oils

The lubricating and sliding action of the extractives can lower the energy expended in the pressing process and, at the same time, increase the throughput rate of material through the press [21].

Waxes

Without any pretreatment, biomasses which have raw material surfaces sheathed in a layer of wax (e.g. cereal plants) tend to be less easily pelletizable compared with woody biomasses. It is possible to dissolve the wax layer, for example, by means of a double screw extruder which unravels the fibers of the raw material instead of milling it in cutting or hammer mills (typical procedure for wood). This process can be supported with a parallel water steam treatment. As a rule, fibrous pellets have higher mechanical strength and a lesser fine fraction than comparable straw pellets from chaff [16].

Resins

As a consequence of the increase in temperature in the press during the pelletization (pressure, friction), the resinous components of the raw material are softened and support the mechanical strength of the pellets due to their adhesion (similar effect to lignin) [16].

Terpenes

When wood is stored, the very volatile nature of the terpenes can result in outgassing which, together with CO and hexanal, can lead to harmful concentrations in enclosed storage spaces [22].

Minerals

Mineral contaminations (e.g. with sand, stones etc.) of the raw material during storage or transportation can increase the natural content of mineral substances [23].

Water Content

Too high a water content of the source material reduces the physical/mechanical properties of the pellets and especially their strength (abrasion). The pellets may become fissured and swell up due to the steam vented immediately after emergence from the press. This reduction in quality may occur also with an inhomogeneous water content of the raw material before pelletization [24].

Bark Fraction

The higher proportion of extractives and mineral contaminants reinforces the associated effects. In most cases, however, the relatively high proportion of lignin in the bark can produce an improvement in the throughput rate of the pellet press even with low rates of admixture [21]. However, the admixture of the bark fraction represents a decisive quality criterion for the use of wood pellets since bark has a significantly higher content of heavy metals and ash.

Apart from the criterion for exclusion of the bark fraction, the regional and weather-related location of growth of a tree can also cause a naturally increased concentration of elementary contents such as alkalis/alkaline earths, (e.g. K, Ca, Mg) and metals (e.g. Si, Fe, Zn, Cd, Pb) which cause the raw material of wood to be graded as critical to unusable since they can lead to technical problems when used in small heating systems. For this reason, the quality assurance of the raw material input makes use of rapid-test methods and laboratory analyses which analyze and log the essential wood characteristics in their delivered state. The frequency of these quality verifications is regulated contractually; in addition, retained samples of each delivery of raw material should be taken in the pellet plant.

References

1. Kaltschmitt M, Hartmann H (2009) Energy from biomass—principles, techniques and methods, Springer, Berlin, (Publ.)
2. Thrän D et al. (2007) Sustainable biomass utilization strategies in the european context, institue for energetics and the environment (IE), University Hohenheim (UH), Federal Research Institute for Forestry and Timber Industry (BFH) and Öko-Institut e.V. (ÖI), on behalf of the Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU), Leipzig
3. Brsdley D (2006) Canada biomass-bioenergy report, Ottawa
4. Deutsches BiomasseForschungsZentrum gGmbH (2008) Global Biomass Potentials, Investigation and assessment of data, country specific energy crop potential, remote sensing in biomass potential research (unpublished study), Leipzig
5. Perlack RD et al. (2005) Biomass as feedback for bioenergy and bioproducts industry. The Technical feasibility of a billion-ton annual supply, U.S. Department of Agriculture, U.S. Department of Energy
6. Pöyry Forest Industry Consulting GmbH (2008) Global sourcing and logistics (unpublished study), Freising
7. Thrän D, Witt J (2008) Fuel markets and utilization rivalries. Symposium on "Power and Heat from Biogenic Solid Fuels" VDI Wissensforum GmbH, VDI Reports 2044, Salzburg, pp 53–64
8. Witt J, Buchhorn M (2008) Raw-material potentials for the wood pellet production. 4th symposium on wood pellets, NRW, Cologne
9. Liese J (1950) Wood conservation manual. 3rd edition, Springer-Verlag OHG, Berlin (Publ.)
10. Klenkhart R (2005) Chemistry of wood, chap. 4—chemistry of wood, wko portal of the chamber of commerce, Austria
11. Poehler Rotach E, Seubert Hunziker H (2001) Wood facts II—part 2: wood chemistry, scripts of the chair in wood sciences, ETH Zürich
12. prEN 14961-2 (2010) Solid biofuels. Fuel specifications and classes—part 2: wood pellets for non-industrial use, European Committee for Standardization
13. Kratzer M (2007) Increases in performance and quality by process optimization. Bühler AG, 7th industry forum on pellets, conference transcript, pp 123–125
14. Aeckersberg R, Schlaug W, Witt J. (2008) Optimization of the pellet production, final report of the FNR research report (FKZ 22006104) of the RWTH Aachen, Institute for Energy Technology and Environment, MANN Engineering GmbH
15. Leaver RH (2000) Wood pellet fuel and the residential market. Andritz Inc., Sprout Matador Division Muncy, USA
16. Hiendlmaier S (2006) The straws pellets fuel. Information letter straw pellets, CARMEN e.V
17. Lethigangas P (2001) Quality properties of pelletized sawdust, logging residues and bark Biomass and Bioenergy 20 pp 351–360
18. Meier D (2008) The art of pelletizing—experience from 25 years of wood pelletizing. 8th industry forum on pellets, conference transcript, pp 110–113
19. BImSchV (Federal Immission Control Act) (2003) First act for implementing the federal immission control law, article 1 of the act relating to the new version of the 1st and change of the 4th act on implementation of the federal immission control law—act on smsll and medium-sized heating systems—federal law gazette
20. BImSchV (Federal Immission Control Act) (2003) First act for implementing the federal immission control law (act on smsll and medium-sized heating systems—1st federal immission control act) of 26 Jan 2010. Federal law gazette, part 1, no 4, Bonn, 1 Feb 2010
21. Sternowski S (2007) Experience with mixed pellets and R&D Requirement from the point of view of the (Plant) Manufacturers. AMANDUS KAHL GmbH & Co, Technical conference by the FNR Gülzow

22. Granström K (2009) Emissions of hexanal and terpenes during storage of wood sawdust and pellets. Karlstad University, Department of Energy, Environmental and building technology, International Bioenergy conference, Jyväskyla
23. Witt J, Schlaug W, Aeckersberg R (2008) Optimization of the wood pellet production for small heating systems. 8th Industry Forum on Pellets, conference transcript, Stuttgart, pp 114–119
24. Kirsten C, Weller N, Pilz B (2010) Miscanthus pellets: opportunities, experience and problems in Germany, European Pellet Conference, World Sustainable Energy Days 2010, Wels (AT)
25. Witt J, Rensberg N et al (2009) Analysis of the current and future market potential of wood pellets in the german and european context, unpublished study, german biomass research center (DBFZ), Leipzig
26. Tveritinova E (2008) Analzsis of organic-waste-based bioenergy potential in the Russian Federation, University of Jyväskylä
27. Obernberger I, Thek G (2009) Production and utilization of wood pellets, series on thermal biomass utilization, vol 5. Institute for Process Technology, Technical University Graz

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