Politechnika Wrocławska

Biomass torrefaction technologies

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IP Pardubice
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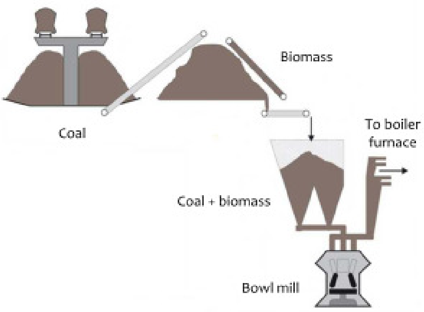
Wydział Mechaniczno-Energetyczny

Co-combustion

- Co-combustion of biomass is an important technology for CO_2-neutral electricity generation.
- Co-combustion of biomass is practiced in numerous plants, especially in Denmark, Belgium, Czech Republic, Poland.
- Typical co-combustion plants in the power plant sector are in the electrical output range of 50 MW to 700 MW.
- The majority of the plants are equipped with pulverized coal firing systems. However, biomass co-combustion is also implemented in fluidized bed systems (BFB and CFB) and in other boiler designs.

Co-combustion



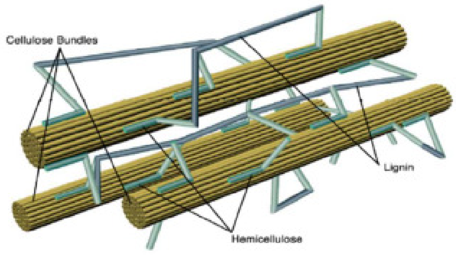
Source: Internet

Direct co-combustion:
Biomass and coal are burned in the same boiler, using the same or separate mills and burners, depending principally on the biomass fuel characteristics. Coal and biomass can be mixed before milling or coal and biomass are fed and milled by separated supply chains.

Co-firing in PF-fired boilers requires milling. Therefore the biomass has regularly to be dried and sometimes pelletized, that it can be milled to sufficient fine particles.

Co-firing in PF-fired boilers requires pretreatment of fuels, e.g. torrefaction.

Basic information of torrefaction

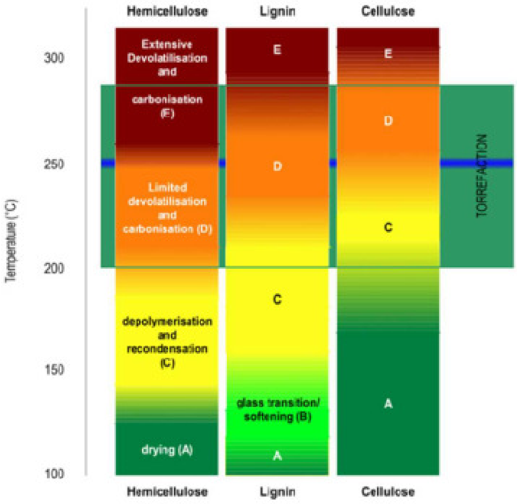


Source: [6]

Lignocellulosic biomass typically contains approx. 80% volatile matter and 20% fixed carbon on dry mass basis.

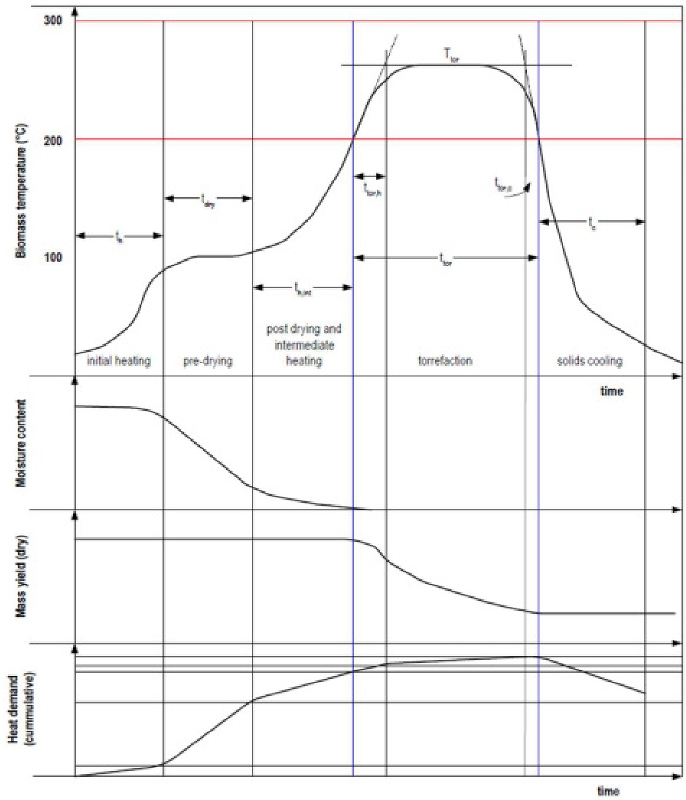
During the torrefaction process, solid biomass is heated in the absence of or drastically reduced oxygen to a temperature of approx. 200-350°C, leading to a loss of moisture and partial loss of the volatile matter in the biomass. With the partial removal of the volatile matter (about 20%), the characteristics of the original biomass are drastically changed.

Basic information of torrefaction



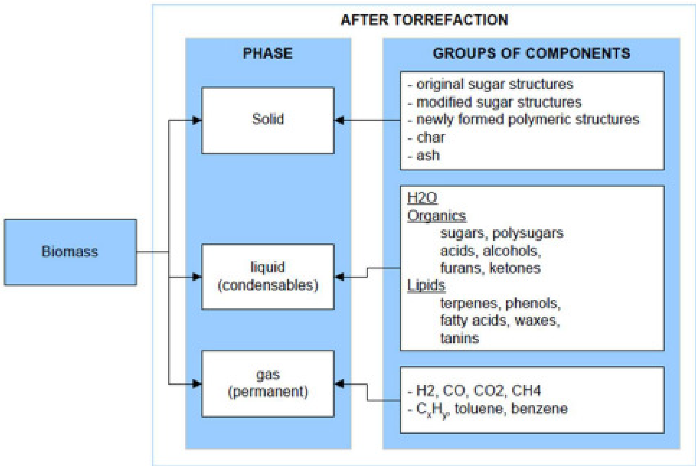
Source: [4]

During the torrefaction process, the tenacious fibre structure of the original biomass material is largely destroyed through the breakdown of hemicellulose and to a lesser degree of cellulose molecules, so that the material becomes brittle and easy to grind. The material then changes from being hydrophilic to becoming hydrophobic. With the removal of the light volatile fraction that contains most of the oxygen in the biomass, the heating value of the remaining material gradually increases.



Stages in the heating of moist biomass

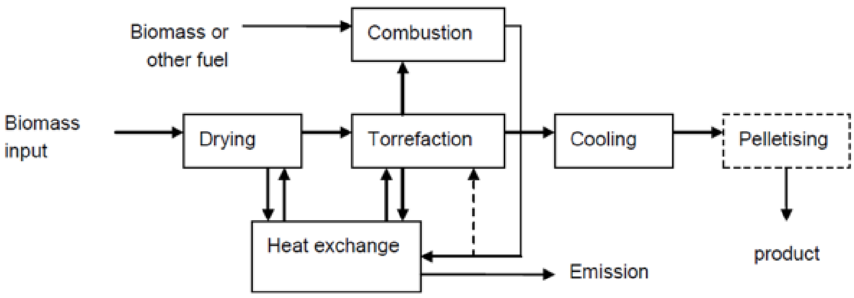
Source: [4]



Products formed during torrefaction of biomass

Source: [5]

Process diagram



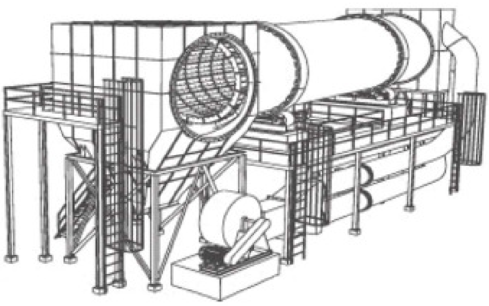
Overview of heat integration options

Source: [5]

Overview of reactor technologies

Reactor technologies	Companies involved
Rotating drum	CDS (UK), Torr-Coal (NL), BIO3D (FR), EBES AG (AT), 4Energy Invest (BE), BioEndev/ ETPC (SWE), Atmosclear S.A. (CH), Andritz , EarthCare Products (USA)
Screw reactor	BTG (NL), Biolake (NL), FoxCoal (NL), Agri-tech Producers (US)
Herreshoff oven/ Multiple Hearth Furnace (MHF)	CMI-NESA (BE), Wyssmont (USA)
Torbed reactor	Topell (NL)
Microwave reactor	Rotawave (UK)
Compact moving bed	Andritz/ECN (NL), Thermya (FR), Buhler (D)
Belt dryer	Stramproy (NL), Agri-tech producers (USA)
Fixed bed	NewEarth Eco Technology (USA)

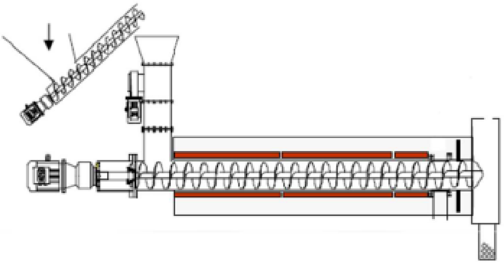
Rotating drum reactor



The rotating drum is a continuous reactor and can be regarded as proven technology for various applications. For torrefaction applications, the biomass in the reactor can be either directly or indirectly heated using superheated steam of flue gas resulting from the combustion of volatiles [5].

Source: [5]

Auger screw type reactor



A screw type reactor is a continuous reactor, consisting of one or multiple auger screws that transport the biomass through the reactor. The reactor technology can be considered as proven technology, and can be placed both vertically as well as horizontally [5].

Source: [5]

Torbed reactor

The particles to be processed are held in a shallow bed suspended by jets of the process gas stream that is forced through stationary angled blades at high velocity. The process gas stream impacts on and minimises the insulating microscopic gas layer around each particle. As a result, the heat and mass transfer rate is greater than in other types of reactor which means faster, more effective processing.

Source: www.torftech.com

Conclusion

- Issues with biomass as fuel: Low LHV, high moisture, low energy density, non-homogeneous, hygroscopic, poor grindability
- Torrefaction addresses most of these issues, delivering a fuel comparable to coal
- Torrefaction: thermochemical treatment process at 200-350°C to separate water, VOCs & hemicellulose in woody biomass
- Torrefied biomass:
  - Higher energy, lower moisture content; better grindability
  - Transport, handling & storage advantages due to higher bulk & energy density, homogeneity, hydrophobic property
- A competitive fuel when co-firing with coal in power plants.

Bibliography

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3. P.C.A. Bergman, Combined torrefaction and pelletisation. The TOP process, ECN-C--05-073, July 2005
4. P.C.A. Bergman. A.R. Boersma. R.W.R. Zwart. J.H.A. Kiel. Torrefaction for biomass co-firing in existing coal-fired power stations, ECN-C--05-013, July 2005
5. J. Koppejan, S. Sokhansanj, S. Melin, S. Madrali, Status overview of torrefaction technologies, IEA Bioenergy Task 32 report, FINAL REPORT, December 2012
6. J.S. Tumuluru, S. Sokhansanj, Ch.T. Wright, R.D. Boardman, J.R. Hess, Review on Biomass Torrefaction Process and Product Properties and Design of Moving Bed Torrefaction System Model Development, 2011 ASABE Annual International Meeting, August 2011

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Torrefaction of Agro-Biomass

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Agro Biomass

The principles of qualifying biomass for energy purposes in the domestic legislation have been laid down, first of all, in the Regulation of the Minister of Economy of 14 August 2008 on the detailed scope of the obligation to acquire and present certificates of origin for cancellation, pay the substitution fee, purchase electricity and heat produced from renewable energy sources and the obligation to confirm the data concerning the amount of electricity produced from in a renewable energy source (Journal of Laws of 2008 no. 156 item 969 as amended). Pursuant to the definition included in § 2 item 1 of this regulation, biomass is fixed or liquid substances of plant or animal origin that undergo biodegradation, originating from products, waste and residues from agricultural and forest production as well as the industry processing their products and parts of remaining waste which undergo biodegradation and cereal grains that do not fulfill the quality requirements for grains in intervention buying-in, as specified in Article 4 of Commission Regulation (EC) no. 687/2008 of 18 July 2008 establishing procedures for the taking-over of cereals by intervention agencies or paying agencies and laying down methods of analysis for determining the quality of cereals (Official Journal of the EU L 192 of 19.07.2008, p. 20, it applies to four kinds of cereals, i.e. wheat, corn, sorghum and barley) and cereal grains that are not subject to intervention buying-in.

Source: biomasapartner.pl

Agro Biomass

In accordance with the present regulations, agro biomass includes biomass:

- originating from energy cultivations;
- being waste or residue of agricultural production and industry processing its products (thus no product of agricultural production can be qualified and no product from industry processing agricultural products, which is to prevent competition between the food market and biomass for energy purposes);
- in the form of cereal grains that do not fulfill the quality requirements for grains in intervention buying-in and cereal grains that are not subject to intervention buying-in;
- from waste from industry processing forest products, combusted at the place of their generation – e.g. mixture of coniferous and deciduous wood and bark burnt directly in the unit functioning within the sawmill ;
- biomass being a different type of waste undergoing biodegradation, excluding waste and residues from forest production as well as the industry processing its products.

Source: biomasapartner.pl

Agro Biomass in Poland

Wheat straw

Rape straw

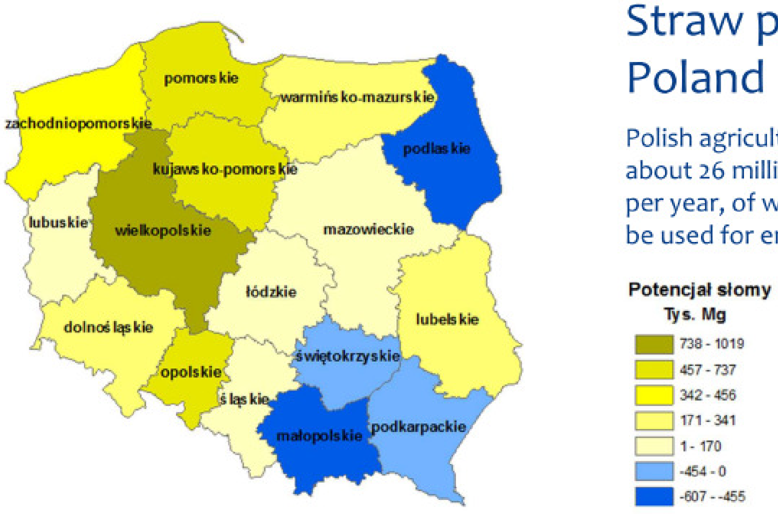
Corn stover

Corncob

Palm Kern Shell
(imported biomass)

Straw potential in Poland

Polish agriculture produces about 26 million tons of straw per year, of which about 40% can be used for energy production.



Source: www.bioenergiadlaregionu.eu

Biomass for research

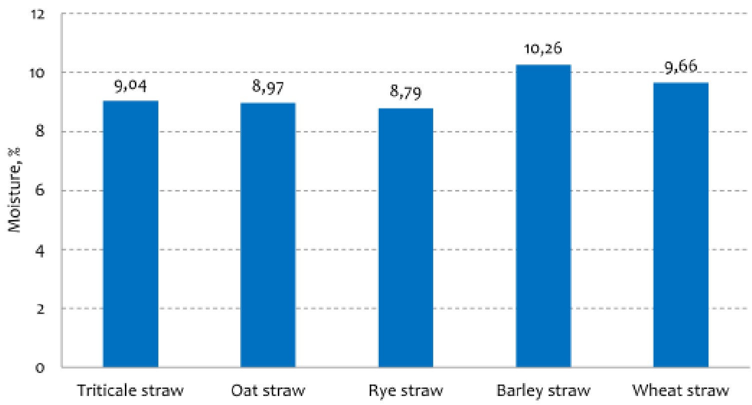
Triticale straw Oat straw Rye straw Barley straw Wheat straw

Measuring of moisture content

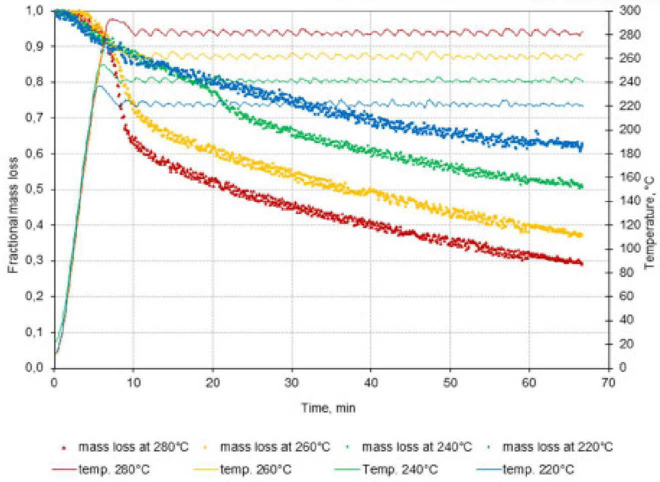
Laboratory dryer

Polish Norm PN-80/G-04511
Solid fuels – moisture content determination

Comparison of moisture content



TGA analysis



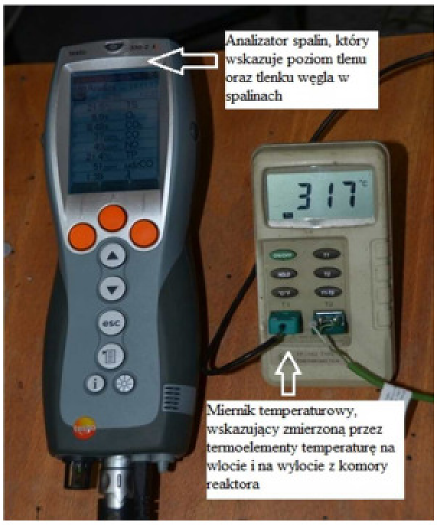
Mass loss of wheat straw depending on temperature and time

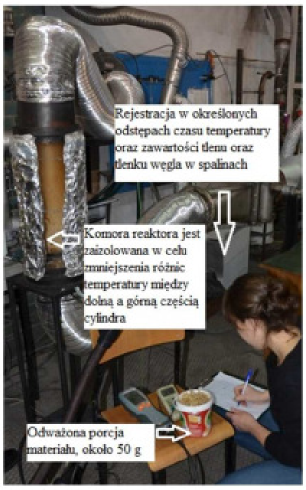
Test stand for torrefaction

1. Inverter
2. Protection of the inverter
3. Temperature recorder
4. Exhaust fan
5. Flue gas analyzer
6. Base of the reactor
7. Reactor
8. Gas cooler
9. Combustion chamber

Rotating bed

Wideo





Wideo

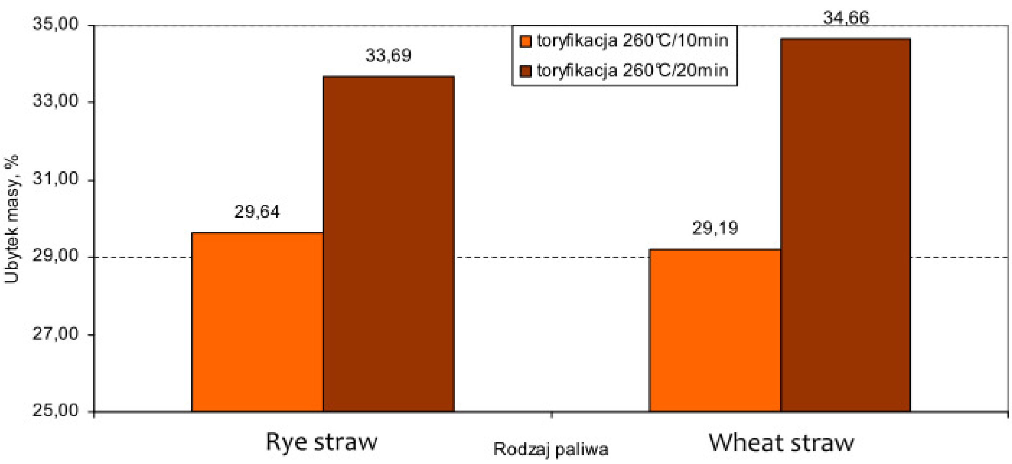
Wheat straw

0 – Fresh,
1 – Torrefied at 10 minutes,
2 – Torrefied at 20 minutes,
3 – Torrefied at 40 minutes,

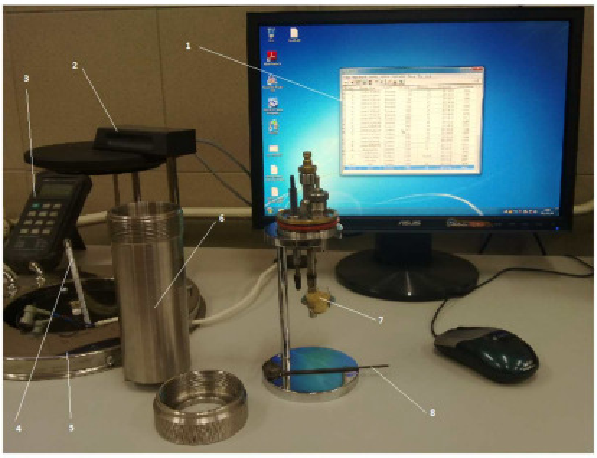
Rye straw

0 – Fresh,
1 – Torrefied at 10 minutes,
2 – Torrefied at 20 minutes,

Comparison of mass loss



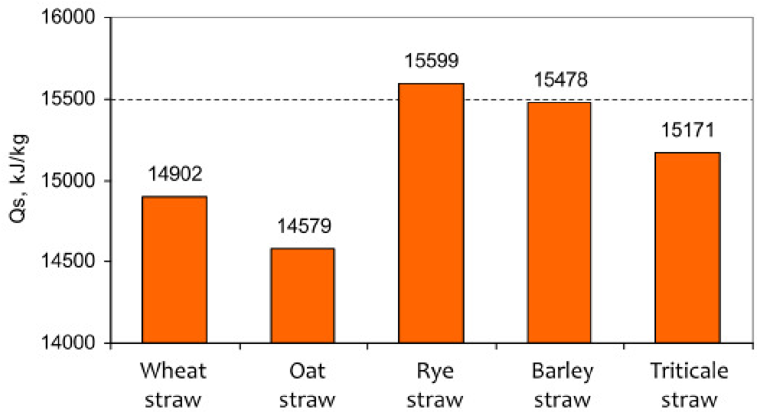
Measuring heating values



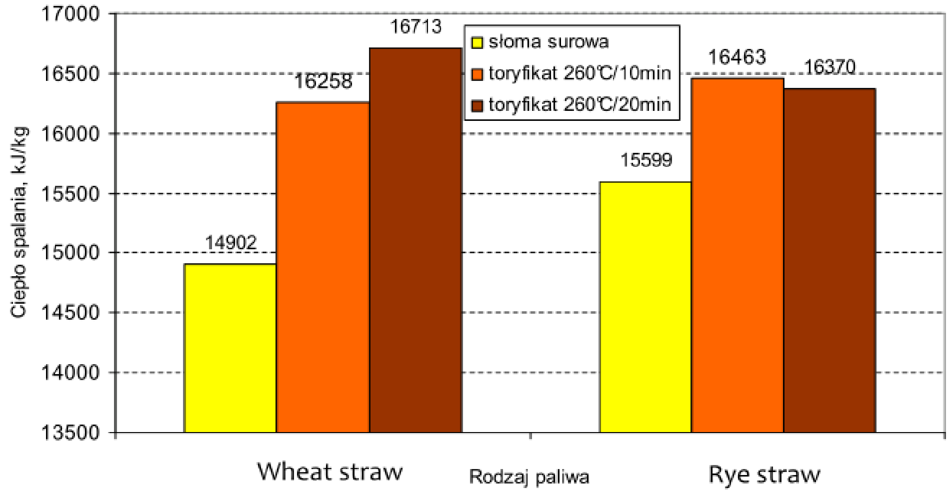
KL-12M bomb calorimeter

Polish Norm PN-81/G-04513
Solid fuels – determination of heat of combustion and calculation of calorific value.

Higher heating value of biomass



Comparison of HHV



Measuring of volatile content

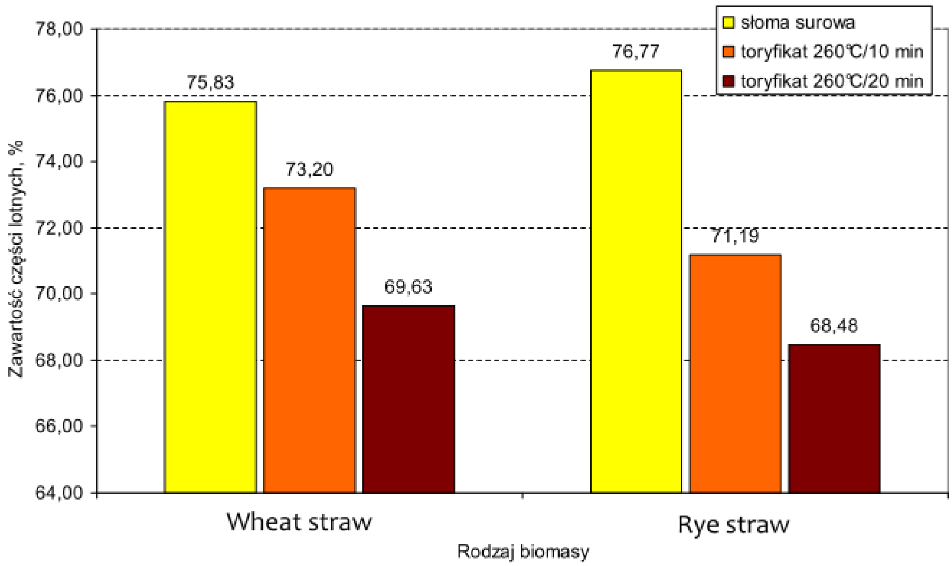
Polish Norm PN-81/G-04516
Solid fuels – determination of volatile matter content by gravimetric method.

Laboratory furnace

Digital laboratory scales

Biomass sample before (left) and after (right) test

Comparison of volatile content

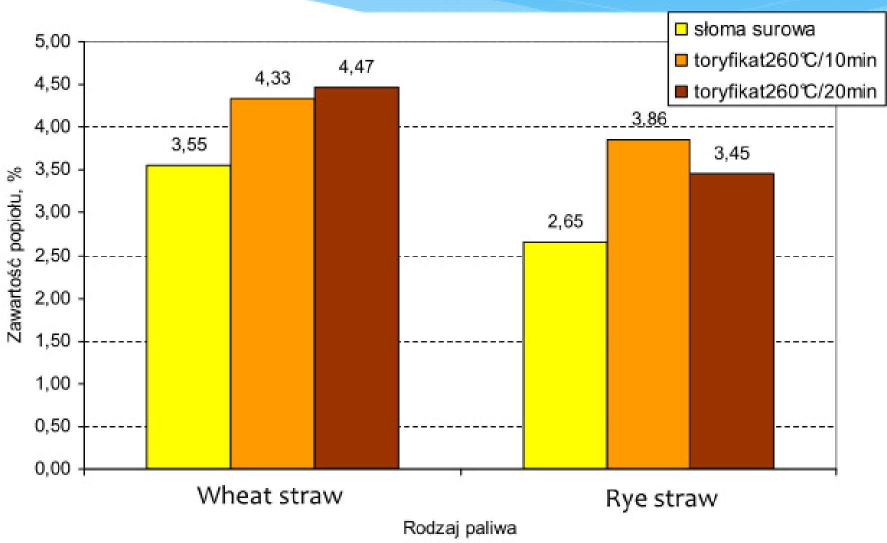


Measuring of ash content

Polish Norm PN-80/G-04512
Solid fuels – determination of ash content by gravimetric method.

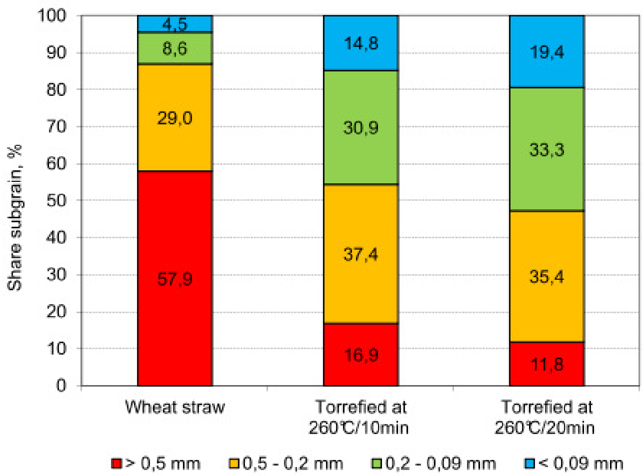
Biomass sample before (left) and after (right) test

Comparison of ash content

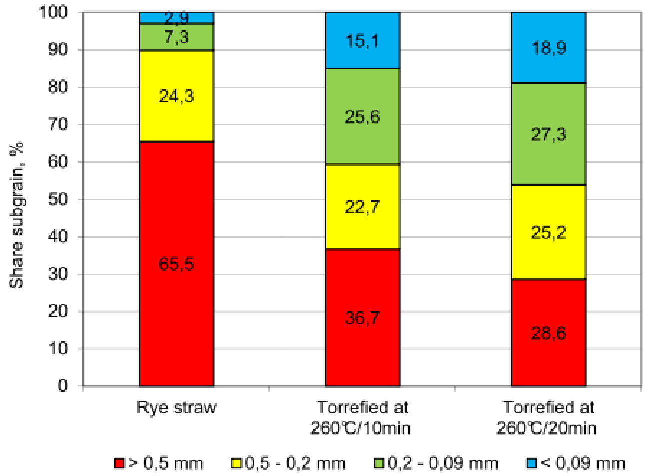


Analysis of milling process

Influence of torrefaction on the grindability



Influence of torrefaction on the grindability



Conclusion

Torrefaction belongs to the processes of thermal valorisation of lignocellulose biomass.

The process makes possible to produce torrefied biomass (called BioCoal) being a solid fuel of improved properties in comparison to raw biomass.

The most important advantages of BioCoal include higher degree of fuel coalification, increase in calorific value, better grindability and hydrophobic nature of torrefied material.