DANISH TECHNOLOGICAL INSTITUTE

Logistics and storage of torrefied biomass
Safety aspects

Resultat-Kontrakt (RK) Report

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1. Introduction

Torrefaction of biomass is a promising and widely discussed pre-treatment method to reduce the costs for bioenergy chains, especially logistics. Different studies have indicated that the supply chain for fuel pellets made from torrefied biomass (black pellets) is more cost efficient compared to conventional biomass pellets (white pellets) [1-7].

The utilization of torrefied biomass in “real life” situations in coal-fired power plants have been tested and reported by major European power producers – The utilization of torrefied biomass in existing handling and storage facilities and associated issues have been reported recently [8-10].

The supply chain of torrefied biomass has been illustrated by Gårdbo [6] as shown in Figure 1 and is generally the same as for wood pellets logistics.

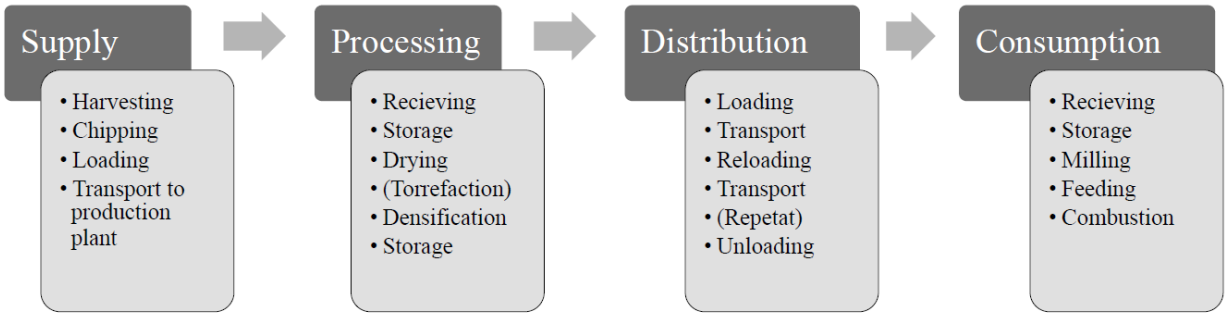

Figure 1. Value chain of energy carriers made from torrefied biomass [6].

From a safety perspective conveying, storage, loading and unloading, milling and feeding operations of torrefied biomass are the most relevant points in the value chain. Torrefied biomass is usually compacted into pellets after torrefaction to improve its handling properties by reducing dust emissions and increasing its bulk density.

Potential safety issues along the value chain of energy carriers made from torrefied biomass are similar as for wood pellets, and mainly related to self-heating, dust emissions, off-gassing and oxygen depletion. Proper handling and monitoring along the value chain are required to minimize the risk for damage and financial losses.

2. Product safety

Safety information on torrefied biomass is essential when designing handling, storage and feeding equipment as well as operation and safety instructions and emergency procedures for torrefied biomass. This information is available regarding a variety of commercial fuels [11], but there is little information regarding safe handling and storage of torrefied biomass. A recent report by Willén et al. [12], reviews recent results from dust explosion and self-ignition characteristics of torrefied biomass.

2.1 Material Safety Data Sheet (MSDS) for torrefied biomass

Torrefied biomass is a relatively new product and global trade as a commodity fuel require safety specifications and registrations. Material safety datasheets are important components of product stewardship and occupational safety and health. MSDS are primarily not intended for use by the general consumer but focusing instead on the hazards of working with the material in an occupational setting.

There are national and international standards for MSDS and they provide information on the composition, potential hazards, emergency measures, physical and chemical properties, toxicology and transport and regulatory information. MSDS for torrefied biomass are currently under development by the torrefaction industry. The consortium behind the European commission financed, research project SECTOR has recently drafted an MSDS that is currently under discussion within the torrefaction industry [13].

2.2 Determination of hazard potentials

Biomass treatment plants with potential dust emissions are usually falling under ATEX regulations. This is also valid for the production and handling of torrefied biomass fuels. Methods for the determination of off-gassing potential [15,16], self heating [17,18] and self-ignition/flammability tests [12] of biomass pellets have been described previously. Test methods developed for wood pellets can also be used for testing pellets made from torrefied biomass.

2.2.1 Self-heating, self-ignition and flammability of torrefied biomass

Torrefaction occurs in an oxygen depleted environment and the product is potentially reactive when getting in contact with oxygen which can result in self-heating and in worst case self-ignition. Torrefaction technology providers are aware of this potential problem, and have taken technical measures to make their products less reactive when exposed to air (i.e. quenching the reactivity with spraying water and adjusting the temperature and atmosphere during and after the torrefaction reaction). Commercial fuel pellets made from

torrefied biomass have been optimized towards a low reactivity and can usually be regarded as safer.

There is little empirical data on the self-heating of torrefied biomass stored on large piles or heaps, however there are indications that self-heating of torrefied biomass stocked on large piles or heaps can occur when it gets in contact with humid air, most likely following the same mechanism known for the self-heating occurring in coal piles. Different studies have been made investigating self-heating of coal stockpiles [19-21], indicating that the transport of oxygen and water to the coal pile and the transport of heat away from the pile by diffusion and convection play a crucial role. The studies indicate that ventilation (wind) and shape of the pile (angle of repose) are important factors to be taken into consideration [21]. It is most likely that the measure preventing self-heating in coal piles are also valid for the storage of torrefied biomass due to their similar characteristics. Further studies about this subject are in progress at the moment.

Flammability parameters and self-ignition temperatures of torrefied wood dust have been studied previously by Willén et al. [12] and are presented in Table 1 and Table 2.

Table 1. Flammability temperatures [12]*

	Minimum Ignition Temperature in a dust cloud (°C)	Minimum Ignition Temperature on a layer (°C)
Torrefied wood dust	460	330
Wood dust	420	340
Peat dust	470–590	305–340
Lignite dust	410–450	230–250
Coal dust	590–760	270–450

Table 2. Self-ignition tests made in an isothermal oven [12]*

Cell size (cm^3)	Lower temp. resulting in ignition (°C)	Higher temp. without ignition (°C)	Ignition temperature TSI (°C)	Induction time (min)
50	190	185	187.5	54
150	170	165	167.5	71
350	160	155	157.5	130
1500	145	140	142.5	317

*) It has to be noted that the presented results are valid for a certain type of torrefied biomass and that these parameters vary according to species, torrefaction technology and temperature.

2.2.2 Off-gassing and oxygen depletion

Generally, thermal treatment drives out potential hazardous off-gassing products from biomass that are known problem within the wood pellets industry. Off-gassing and oxygen depletion from black pellets is therefore minimal compared to conventional wood pellets [22]. Differences between different technologies and raw materials used for thermal treatment of the biomass need to be further evaluated.

2.2.3 Dust and Dust explosion

Dust explosion hazards in atmospheric pressure bins and handling equipment are usually provided for by arranging the discharge of explosion pressure through explosion discs or relief vents and by using explosion suppression systems [11]. Torrefaction technology providers have tested their materials for dust explosion potentials and designed there plants accordingly to ATEX regulations to reduce the risks of fires and explosions [23].

Willén et al. have studied the explosion parameters of different dusts [11,12] as shown in Table 3.

Table 3. Explosion parameters of different dusts [12]*.

	Explosion pressure Pmax (bar g)	Rate of pressure rise Kmax (m*bar/s)	Limiting Oxygen Concentration LOC (%)
Torrefied wood dust	9.0	150	11
Wood dust	9.1-10.0	57-100	10-12
Peat dust	9.1-11.9	120-157	13.5
Lignite dust	9.4-11.0	90-176	13-15
Coal dust	8.9-10.0	37-86	14

Torrefied wood dust is classified as a class St1 dust, as most biomass fuel dusts [12]

*) It has to be noted that the presented results are valid for a certain type of torrefied biomass and that these parameters vary according to species, torrefaction technology and temperature.

3. Logistics and utilization of torrefied biomass

Power producers are generally positive towards torrefied biomass fuels. However, secure supply of sufficient amounts of torrefied biomass, consistently high product quality (i.e. outdoor storage stability, dust emissions) and foreseeable and competitive pricing have been a barrier for market introduction so far.

Safe handling of torrefied biomass in existing systems originally designed for coal are of great importance for the end user. Power producers have tested and identified potential issues related to the use of torrefied biomass in their power plants [8-10].

Foreseen issues to handle pellets from torrefied biomass in existing coal power plants are mainly related to dust formation and ignition risks.

3.1 Shipping of torrefied biomass

The most cost efficient method for long distance shipping of torrefied biomass i.e. from North America to Europe is ocean shipping, preferably in bulk carriers similar to the ones used for wood pellets today.

Currently torrefied material does not have a safety classification under International Maritime Organization (IMO) yet and can therefore not be transported by ocean vessels without special permission since the product has similarities with charcoal, which is prohibited to be transported in bulk [10]. Short distance transport of torrefied biomass is made by train, truck and boats similar as for wood pellets.

The torrefaction industry is currently working on the safety classification of energy carriers made from torrefied materials to ease transportation formalities and connected insurance issues.

3.2 Unloading and transfer to conveyor

The utilization of torrefied biomass in existing handling and storage facilities at major European power plant operators and associated issues have been reported recently [8-10, 24].

Vatenfall has made tests with torrefied biomass in their Reuter West plant in Berlin and concluded that unloading and conveying of torrefied biomass is possible using the existing systems in a coal power plant – only minor adaptions in dust suppression systems and in the underloader grabs were required. Dust formation during conveying of torrefied biomass was regarded as minimal/irrelevant [8].

Controlling dust emissions when conveying, loading and un-loading at the power plant site has been mentioned by several end-users as an important issue [9]. Dust emissions are

generally closely related to pellet durability that need to be sufficiently high to limit the risk for dust emissions.

DONG Energy has tested torrefied biomass pellets in their Studstrup plant, north of Aarhus and has not observed any significant dust formation during unloading [24].

3.3 Conveying

Conveying of torrefied biomass at the plant site has been reported to be un-problematic [8, 24]. Coal conveyors can be used for torrefied biomass; however, dustfall was at some points higher than in coal operation [8].

Most power plant providers are concerned about dust and monitoring dust concentrations when using torrefied biomass is recommended to minimize potential risks.

3.4 Storage at coal yard

Outside storage of torrefied pellets at a coal yard exposes them to sun, rain, wind and frost that can alter the product, result in emissions such as dust or leachate. Experiences from storage tests at hard coal yards have shown high COD (chemical oxygen demand) values for the leachate, so that a ground insulation was required [8]

Risks for self-heating, ignition and degradation during outside storage are currently under investigation and depend on multiple factors such as climate, pile size and shape as well as pellet quality. Safety measures valid for coal yards should be applicable to torrefied biomass pellets. Degradation of torrefied pellets due to climatic effects increase the risk for dust formation for subsequent conveying operations

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