Pilz, Andreas; Döhling, Frank; Kirsten, Claudia; Weller, Nadja and Zeng, Thomas

Pelletizing and energy related use of hay from landscape preservation

In the field of heat production, high quality biomass fuels are experiencing an increased demand. Thus, currently unexplored raw materials are gaining considerable interest. Based on the decreasing animal livestock in the past years, hay which is no longer required as fodder becomes available for energy related use. Building upon the extensive knowledge base for wood pellet production and utilization, the current work illustrates how and to which extent available know-how can be applied to fuel production from hay. The adaption of selected parameters led to fuel pellets with good physical-mechanical properties. However, during combustion tests in a dedicated pellet boiler high emissions above required emission thresholds have been measured. Though employed additives resulted in significantly reduced emissions, further primary and secondary emission control measures are still necessary to comply with regulations and thresholds.

Keywords

Alternative solid biofuels, energy related use, hay from landscape preservation, pelletizing, pellet boiler, combustion

Abstract

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Due to the sharp decline in livestock production in the region Havelland [1], a large part of the available grassland is not used for animal feed production any longer. However, for nature conservation and landscape management purposes these areas must be cultivated (e. g. mown) at least once a year. The obtained landscape preservation hay can be utilized in small and medium-sized combustion units to meet some of the local heat demand of the nearby region. However, the combustion of hay in small combustion units is technically demanding. So far there is no standard approach for using this biomass in practice.

Pelletizing hay from landscape preservation

The pelletizing of hay is state of the art for feed pellet production [2; 3]. However, for the production of fuel pellets from landscape preservation hay the process must be adjusted. Especially the requirements on physical-mechanical properties are different between feed and fuel pellets.

In Europe a pellet diameter of 6 mm has been established for the use in pellet boilers [4]. Consequently, a die with 6 mm press channel diameter is used. The particle size of the milled raw material should not exceed the press channel diameter. Therefore, milling before pelletizing is necessary. The used raw material was provided in square bales and was initially coarsely shredded with a straw mill. Afterwards the fine milling was done by hammer mill (mesh size 4 mm). The ground material was then preconditioned in a mixer using water to adjust the moisture content to 10–18.5 wt.-%. Aim of the investigations was to examine the influence of moisture content on pellet properties. Additionally the effect of mineral additives as a measure for optimizing combustion properties was investigated. Additives can also have an effect on the production process and the physical-mechanical properties. The following additives were tested:

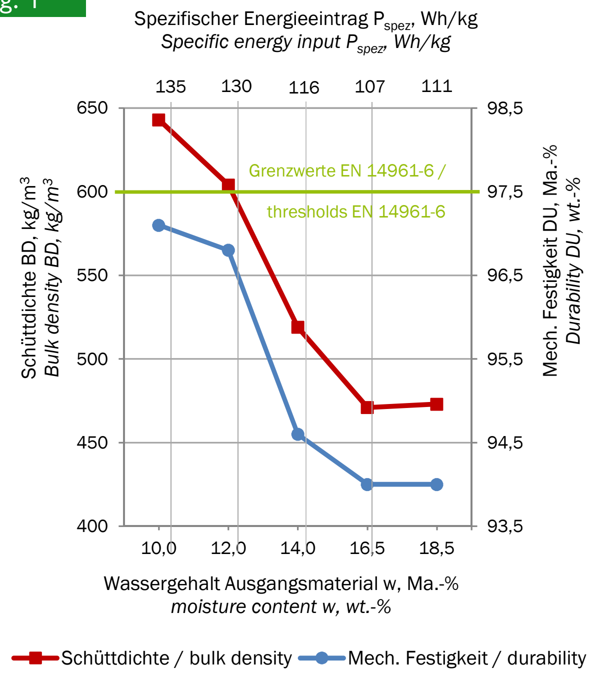
- Calcium carbonate: $CaCO_3$ and
- Kaolin: $Al_2Si_2O_5(OH)_4$.

The additives were added in form of a suspension during the pre-conditioning. The settings of the process parameters were kept constant and all experiments were carried out with the same pilot-scale test facility.

Water acts as a binding agent between the particles and can improve the physical and mechanical pellet properties. However, this process is dependent on the characteristics of the raw material. Water can also reduce the friction in the press channel, thus resulting in a lower specific energy input required for the pelletizing. The specific energy input describes the mass-based energy input for the production of pellets.

The specific energy consumption decreased significantly with increasing water content from 135 Wh/kg at 10 w-.% to 107 Wh/kg at 16.5 wt.-% (**Figure 1**). However, increasing water content from 10 wt.-% to 16.5 wt.-% resulted in a decline of bulk density from of 643 kg/m^3 to 471 kg/m^3. Also the durabil-

Fig. 1



Influence of raw material moisture on physical-mechanical properties and energy input

Table 1

Pellet properties of raw material with additives

Additiv *Additive*	**Schüttdichte** *Bulk density* kg/m³	**Mechanische Festigkeit** *Durability* Ma.-%	**Spezifischer Energieeintrag** *Specific energy input* Wh/kg
Ohne/*Without*	604	96.8	130
1 Ma.-% $CaCO_3$	682	97.8	-[1)]
3 Ma.-% $CaCO_3$	698	98.2	156
1 Ma.-% Kaolin/*Kaoline*	688	97.6	131
3 Ma.-% Kaolin/*Kaoline*	701	98.0	110

[1)] nicht bestimmt/*not determined*

ity decreased with the higher water content. With 94 wt.-% at 16.5 wt.-% water content the durability was significantly below 97.5 wt.-%, the standard set in DIN EN 14961-6 (Class A) [5].

For the test series shown in **Figure 1**, the lowest water content resulted in the highest durability and bulk density. However, the values for the durability were below the standards set in DIN EN 14961-6 making a further optimization necessary. Generally, a high energy input for the production of high-quality pellets (e.g. according to DIN EN 14961-6) is necessary. However, the specific energy input for obtaining comparable product properties was approximately 20 % below the required specific energy input for wood pelletizing (softwood, 168 Wh/kg [6]).

In addition pelletizing tests were carried to test the effects of additives on combustion and emission behavior. The amounts of added mineral additives are listed in **Table 1** (based on the dry matter). For better integration of the additives, the moisture content of the raw material was defined at 12 wt.-%.

The addition of mineral additives improved the bulk density and durability of the tested landscape preservation hay significantly (**Table 1**). Additives can act as a hardening agent and promote the formation of particle connections during the pelletizing process. A comparatively small increase in the specific energy input has a positive effect on the densification behavior and the physical-mechanical pellet properties. A similar effect is known when bentonite is used as additive, the pellet quality increases in combination with water [7]. For other biomass, such as Miscanthus mineral additives can have a negative effect on the physical-mechanical pellet properties [8]. The hay pellets produced with mineral additives comply with the physical and mechanical requirements of DIN EN 14961-6.

Combustion of landscape preservation hay

For the use of non-woody solid biofuels in combustion units legal regulations concerning emission thresholds have to be considered – the German 1st Ordinance on the Implementation of the Federal Immission Control Act for small scale combustion plants up to 100 kW (1st BImSchV [9]) and the German 4th Ordinance on the Implementation of the Federal Immission Control Act > 100 kW requiring a permit (4th BImSchV [10]).

According to § 3, Abs. 1, No. 8 of the 1st BImSchV small scale combustion units fired with straw and similar herbaceous biomass substances like hay have to pass a type test including the measurement of dioxin/furan-emissions. As these type tests are complex, costly and time consuming no authorized small scale combustion units (< 100 kW) for hay fuels are available at the moment.

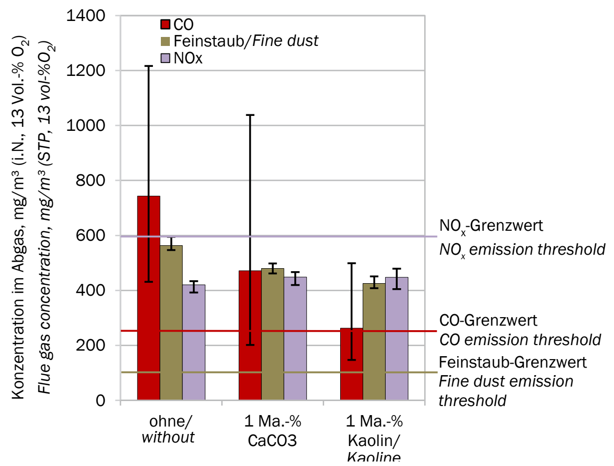
For combustion units with higher thermal power the legal authorities usually base the emission thresholds on the Technical Guidelines on Air Quality Control (TA Luft) but final decisions will be made at their sole discretion. In case that primary measures are not sufficient to meet the emission requirements secondary measures (e.g. an appropriate flue gas cleaning system) have to be installed.

Due to the absence of combustion units designed for hay pellets, combustion experiments were carried out using a common pellet boiler usually used for the combustion of straw pellets with a nominal thermal output of 30 kW. To evaluate the combustion properties of hay, pure hay pellets without additives and hay pellets with additives (1 wt.-% Kaolin and 1 wt.-% $CaCO_3$, respectively) were used. The pellet charges were manufactured by an experienced wood and animal feed pelletizer.

During the combustion process pure hay pellets showed a comparably high slagging tendency, which could be significantly minimized by the use of the mineral additives. Regarding the emissions of CO, NO_x and fine dust, which are relevant for regulatory approval, clear differences between the pure hay pellets and the charges with additives could be observed (**Figure 2**).

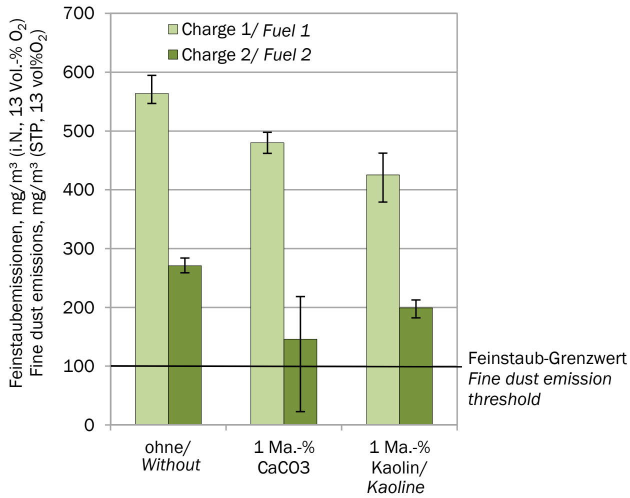
The use of additives had a positive effect regarding the emissions of CO and fine dust whereas NO_x-emissions re-

Fig. 2



CO-, NO_x- and fine dust emissions of hay pellets (batch 1) with and without additives burned in a small scale combustion unit. Emission thresholds according to the German First Ordinance on the Implementation of the Federal Immission Control Act

Fig. 3



Fine dust emissions of two different hay pellet fuels. Emission thresholds according to the German First Ordinance on the Implementation of the Federal Immission Control Act

mained almost unaffected at a level of about 440 mg/m³ (STP, 13 vol.- % O_2). All emission values were based on dry flue gas. Therefore the NO_x-emissions of all hay pellet variations were clearly below the emission threshold of 600 mg/m³ (STP, 13 vol.-% O_2). Even though the application of additives caused a reduction of fine dust emissions up to 30 % this was not sufficient to meet the required emission threshold of 100 mg/m³ (STP, 13 vol.-% O_2). In fact the emission threshold was exceeded by the factor of 4 to 5. Also the CO-emission threshold of 250 mg/m³ (STP, 13 vol.-% O_2) of the type test was exceeded by all three fuel-variations. Typically CO-emissions can be reduced by an optimized combustion management especially by a further adaption of the combustion air supply.

To account for site and management specific characteristics of the biomass two different hay batches were compared with regards to their combustion- and emission behavior. In contrast to batch 1, fertilized with liquid manure, batch 2 was derived from an extensively managed site with no fertilizer application. Due to the absence of fertilizer and due to other site-related factors the concentration of elements critical for the combustion and emission behavior of batch 2 was clearly lower than in batch 1. The different batches and variations were analyzed according to existing European standards for biofuels (http://www.energetische-biomassenutzung.de).

Furthermore it could be observed that under constant boiler adjustments hay pellets of batch 2 (fuel 2) had a much lower slagging tendency than pellets of batch 1 (fuel 1). This also affected the CO emissions positively, which were below the emission threshold (measurement values not shown). During the combustion of the two hay batches different levels in emissions of fine dust were observed (**Figure 3**). Fine dust emissions of batch 1 (fuel 1) were approximately twice as high as emissions of batch 2 (fuel 2). The application of additives resulted in a reduction of fine dust emissions for both hay batches (fuels). Besides these measures of mitigation an adaption of the control parameters of the used combustion unit should be aspired.

Conclusion

The pelletizing of hay is a manageable process from a technical point of view. With respect to adapted water content good physical-mechanical properties of the manufactured pellets could be achieved however existing standards could not be met entirely. Compared to the production of wood pellets the production of pellets from hay resulted in a 20 % lower specific energy input. However, since the experiments were conducted on a pilot-scale pellet press with a lower production capacity the specific energy input was above the level of an industrial production plant. In order to minimize the specific energy input and the production costs further optimization regarding raw material and process parameters is necessary. The use of mineral additives has led to an improvement of the mechanical-physical pellet properties so that existing fuel standards could be met.

Furthermore, it could be shown, that the chemical composition of the biofuels had a strong influence on their combustion and emission behavior. An enhancement of the combustion behavior can be achieved by the use of mineral additives. However, the fine dust emission threshold as described in the 1st BImSchV for repeated measurements was clearly exceeded. Therefore the combustion of hay pellets in small scale combustion units < 100 kW according to the 1st BImSchV without an adequate flue gas cleaning system is legally prohibited at the moment.

Nevertheless, fuel optimization by new technical approaches, for example the florafuel- or the BtE-process should be kept in mind. Concerning primary and secondary emission-reduction measures different research projects are currently conducted, so that over the next few years first technical approaches for the implementation of those technics may be applicable. In the light of the above, in the short to medium term promising processes and technical solutions will be available to enable the use of hay in small-scale combustion units (< 100 kW).

For combustion plants with a higher thermal power range (> 100 kW), which can only be operated with a legal permission, the usage of hay as a fuel is possible provided that an appropriate flue-gas cleaning system, e.g. cyclone separator, electrostatic precipitator, fabric filter or flue-gas scrubber will be installed. As for the small-scale units it cannot be assumed that fine-dust emission thresholds can be met without secondary emission-reduction measures.

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Authors

Dipl.-Ing. (FH) Andreas Pilz, Dipl.-Ing. Frank Döhling, Dipl.-Ing. Claudia Kirsten, Dipl.-Ing. Nadja Weller and **Dipl.-Ing. (FH) Thomas Zeng** are researchers in the working group "Innovative solid biofuels" (head of department: **Dr.-Ing. Volker Lenz**) at the Deutsches Biomasseforschungszentrum, Torgauer Straße 116, 04347 Leipzig, e-mail: Andreas.Pilz@dbfz.de

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