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Production of energy pellets from wet harvested greenery

Wet harvested greenery can be processed to energy pellets to be burned or gasified for sustainable energy supply. The harvest of the forage and the preservation in plastic tubes are known processes with low energy consumption. The mechanical dewatering of the silage with screw presses requires a higher energy demand with 0.26 to 2.02 GJ/T_{DM}. The dry matter content can be reduced with screw presses by 4 to 21 percentage points depending on the kind of forage. The drying process requires an energy demand of 4.73 to 13.7 GJ/t_{DM}. The total energy demand of the complete processing line corresponds to 65 % of the heating value of the pellets.

Keywords
Pellets, energy, energy crops

Abstract
Landtechnik 66 (2011), no. 1, pp. 42-45, 2 figures, 1 table, 6 references

In order to utilize available biomass potential in a most comprehensive and ecologically sustainable manner, it is suggested to gasify or burn energy pellets generated from wet harvested greenery. The process chain in question consists of preservation, drying, pelletizing, and burning or respectively gasifying. The following aspects are unknown variables in the process of energetic utilization of freshly harvested forage as well as maize and whole plant silage:

- process-related technical parameters
- required equipment and logistic
- economic and ecological perspectives

Considered the climate conditions of Central European, greenery is mainly harvested wet or wilted and cannot be stored unpreserved. Here, ensiling is a preservation method for greenery, widely established in agriculture, by which the wetness of the material is maintained to a great extend. Hardly any intelligence about further processing of wet silage into dry solid fuel has yet been established.

Facilities for the drying of greenery are generally suitable for drying silage. However, so far such drying facilities were mainly used for drying of fresh greenery for later use as animal fodder. The drying facilities for fodder are designed in such a way that allows for grossly maintaining nutrients and minerals when dewatering the material. When using greenery as a base for fuel, potentially ecologically hazardous compounds as nitrates, potassium, sulphur, and chlorine are unwanted, though. Thus is the question, whether by mechanical dewatering the hazardous compounds can be removed through the extracted liquid and which energy savings can be achieved by mechanical dewatering prior to the actual drying process.

Since there was hardly any intelligence about the individual preparation steps, machines, and performance parameters, tests had to produce the relevant parameters under conditions in step with actual practice [1].

Establishment of process parameters

Test materials used in the following investigations were wilted grass (1st and 2nd cut), barley and rye as whole plants, and ensilaged maize. Chuff lengths were 4-20 mm at diverse dry mass contents (DM-content). In the process chain from harvesting to energetic utilization of greenery, the relevant parameters for the process steps harvesting, ensilaging, dewatering, drying, and compacting were established.

The primary energy demand was determined by matching respective efficiency factors with energy consumption. It was the goal of the investigation to establish benchmarks for the individual process steps. In harvesting, the required work time and fuel consumption were measured for the partial processes cutting, swathing, and chuffing. After harvesting, the greenery was filled into silage bags with 2.4 m diameter, using a G 6700 ag-bagger, driven by a tractor with 103 kW nominal power output. The mass flow in filling was between 40 and 75 t/h. Since the mass flow of the harvester was clearly higher than the mass flow of the bagger, the greenery had to be stored interim and later be supplied to the bagger using a wheel loader (132 kW).

Table 1

Measured energy values in comparison to values from literature

Gut/*Crop*	Verfahrensabschnitt/ *Process step*	Prozessenergieaufwand / *Process energy demand*						
		Messung/ *Measurement*					Literatur/ *Literature*	
		Verbrauchsenergie/ *Energy consumption*				Primärenergie[3]/ *Primary energy*	Primärenergie/ *Primary energy*	Quelle/ *Source*
		n[1]	Diesel/ *Diesel* l/t_{DM}	Kohle/ *Coal* GJ/t_{DM}	Strom/ *Electricity* kWh/t_{DM}	Gesamt/ *Total* GJ/t_{DM}	Gesamt/ *Total* GJ/t_{DM}	
Mais/*Maize*	Ernte/ *Harvest*	1	2.57	-	-	0.11	0.07	[2]
	Silierung/ *Ensiling*	1	2.32[2]	-	-	0.11	0.015	[2]
	Abpressen/ *Mechanical dewatering*	9	-	-	28.7–42.2	0.28–0.41	-	
	Trocknung/ *Drying*	42	-	4.1-7.19	47.4–123.3	4.73–8.68	7.52	[3]
	Pelletierung/ *Pelletizing*	8	-	-	41–131	0.39–1.27	0.5	[4]
	Gesamt/ *Total*	-	-	-	-	5.62–10.58	-	
Roggen/*Rye*	Ernte/ *Harvest*	1	4.98	-	-	0.22	0.08	[2]
	Silierung/ *Ensiling*	1	1.52[2]	-	-	0.07	0.029	[5]
	Abpressen/ *Mechanical dewatering*	43	-	-	28-179	0.27–1.7	-	
	Trocknung/ *Drying*	17	-	3.7–4.0	59.9-60.2	4.43–4.7	-	
	Pelletierung/ *Pelletizing*	30	-	-	62-217	0.60–2.11	0.5	[4]
	Gesamt/ *Total*	-	-	-	-	5.59–8.8	-	
Gras/*Grass*	Ernte/ *Harvest*	1	8.70	-	-	0.36	0.31	[2]
	Silierung/ *Ensiling*	1	4.34[2]	-	-	0.19	0.08[4]	[2]
	Abpressen/ *Mechanical dewatering*	38	-	-	27–208	0.26–2.02	-	
	Trocknung/ *Drying*	25	-	7.4–11.5	93.9–178.6	8.61–13.7	12.46	[3]
	Pelletierung/ *Pelletizing*	18	-	-	67–309	0.65–3.0	0.5	[4]
	Gesamt/ *Total*	-	-	-	-	10.07–19.27	-	
Gerste/*Barley*	Ernte/ *Harvest*	-	-	-	-	-	-	
	Silierung/ *Ensiling*	-	-	-	-	-	-	
	Abpressen/ *Mechanical dewatering*	12	-	-	88–120	0.86–1.17	-	
	Trocknung/ *Drying*	19	-	9.23	158	11.14	-	
	Pelletierung/ *Pelletizing*	9	-	-	65–108	0.63–1.05	0.5	[4]
	Gesamt/ *Total*	-	-	-	-	12.63–13.36		

[1] Messwiederholungen/*Repeated measures.*
[2] Schlauchpressenantrieb und Befüllung/*Tube press drive and filling.*
[3] Primärenergetische Nutzungsgrade: Steinkohle 95,5 %; Braunkohle 96,9 %; Dieselöl 89,4 %; Elektroenergie 37,0 %/ *Primary-energetic levels of utilization: hard coal 95.5 %; brown coal 96.9 %; diesel oil 89.4 %; electric energy 37.0 %.*
[4] Nur Werte vom Horizontalsilo/*Only values of the horizontal silo.*

A screw extruder type Avz with a nominal power of 5.5 kW and type DZvv with a nominal power of 45 kW by Anhydro GmbH were used for mechanical dewatering. Grass and rye silage was dewatered after bag-storage in October; maize silage in April of the following year. The dewatered material was subsequently supplied with a wheel loader to the feeder conveyor of a drum dryer type UT 67/2 at the greenery drying facility Selbelang, and dried down to a dry mass content of 87-96 %.

The solid fuel was compacted with a pellet press type 39-1000 by Amandus Kahl GmbH & Co. KG with a constrainer mesh width of 8 or 15 mm. The fuel value of the dried solid fuel was determined experimentally with an IKA type C 200 bomb calorimeter by burning under excess pressure oxygen. Tablets were produced for measuring.

Results and discussion

At harvesting, the primary energy demand was at 0.11 GJ/t_{DM} in maize silage; 0.22 GJ/t_{DM} in rye whole plant silage; and 0.36 GJ/t_{DM} in wilted grass silage (**table 1**). Particularly in rye, the measured value was clearly above the values known from literature. The demand of diesel fuel for the filling of the silage bags, including the supply by wheel loader was 1.52-4.34 l/t_{DM} (**table 1**). The drive utilized for the ag-bagger used 1.72 l/t_{DM} for wilted grass, 0.88 l/t_{DM} for whole plant silage, and 0.98 l/t_{DM} for maize silage. Supplying the ag-bagger with a wheel loader approximately doubled the diesel fuel consumption for this process step and is thus not recommended for practice.

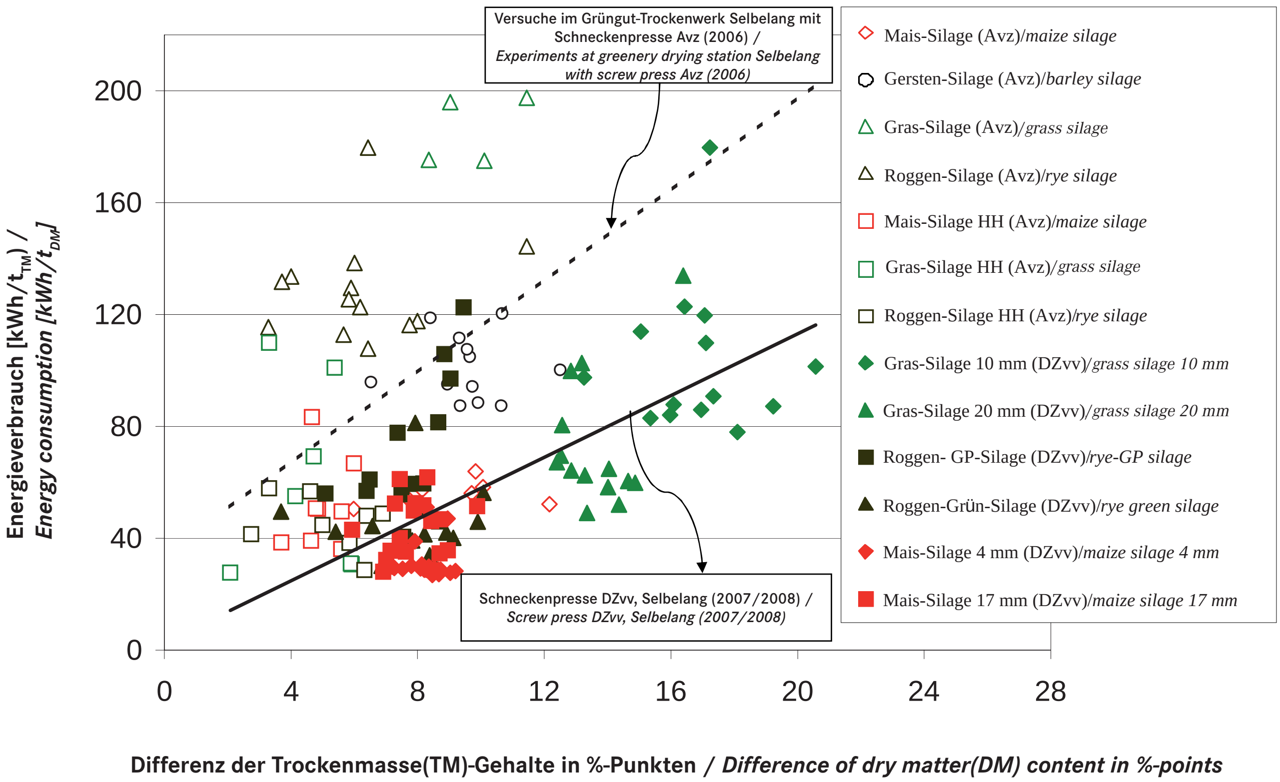
The highest dry mass differences in mechanical dewatering were achieved for grass silage with 11-21 percentage points (**figure 1**); however this effect was caused by the high water content of the silage. Rye and maize silage were only at ca. 4-10 percentage points in dry mass difference, using the DZvv screw extruder.

There was a high variability in measured values at energy demand (**table 1**). Due to the function principle of the screw extruder, a close correlation between dewaterizing effect, mass flow, and energy demand could be established [6]. Increases in dewatering effect consequently lead to an increase in energy demand (**figure 1**). The specific energy demand also seemed to depend on the type of material, but was primarily related, however, to dependence on throughput. The dry mass content in squeezed liquid varied between 9-15 % in grass and 15-17 % in rye. In maize silage, 13 % were achieved on average.

The ratio of nutrients (N, P, K, Ca, Mg, S, Cl) in the squeezed liquid, relative to the genuine ratio in silage varied from 1.5-40 %. Chlorine, in this respect, was in the lead. From maize silage, there were up to 40 % of the originally contained chlorine extracted through the removal of liquid.

The most energy demanding process of the entire process chain was the drying of the pressed cake (**table 1**). In order to dry the compressed silage down from a DM-content of 45 % to about 90 %, a directly fired drum dryer typically used in agri-

Fig. 1



Specific energy consumption of screw presses depending on the dewatering degree cultural drying plants required approximately 4-11.5 GJ/t_{DM} in heat energy and about 50-180 kWh/t_{DM} electric energy. In total this resulted in a primary energy demand of 4.4-13.7 GJ/t_{DM}.

By way of mechanical dewatering of the silage with screw extruders (**figure 2**) the energy demand for drying could be reduced. In order to e.g. increase the dry mass content of silage by 20 % absolute, the screw extruder required about half as much primary energy (1.1 GJ/t_{DM}) as the respectively used drum dryer (2.3 GJ/t_{DM}).

Pelletizing required 0.39-3.0 GJ/t_{DM} primary energy (**table 1**). The measured values were higher than respective references in the literature. This fact and the high variability point to a hidden potential for optimization of the pelletizing process. The minimum fuel value of the pellets was 16.8 GJ/t_{DM} in grass silage, 16.3 GJ/t_{DM} in rye whole plant silage, and 16.5 GJ/t_{DM} in maize silage.

Conclusions

Without any doubt, the most important results of this investigation are the issues related to overall energy demand. Under the existing practical conditions, the primary energy demand for harvesting, ensiling, mechanical dewatering, drying, and pelletizing totals to 5.59-19.27 GJ/t_{DM}, depending on the type of material. The average value of all variants is at 10.74 GJ/t_{DM}. Thus, for the production of the pellets, about 65 % of their eventual fuel value is consumed. Mass loss is not yet considered in this calculation. Energy efficiency of the investigated process chain for the production of pellets from ensilaged energy plants, thus, does not meet potential expectations.

Fig. 2

The dry matter content of silage can be reduced with relative low primary energy demand by the aid of screw presses. Photo: ATB

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