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Combined use of solar energy and waste heat from CHP for drying of biogas digestate

Digestates contain on average between 90 and 98% of water as well as important horticultural nutrients and are therefore often directly spread over the fields. Due to political reform of 1st January 2009 the amended renewable energy act stipulates the use of the heat from combined heat and power units (CHP) to process the digestates as a fertilizer [1]. If the residual heat from CHP is not enough for drying, a combination of solar energy and waste heat describes a innovative solution.

Keywords
Digestate, biogas, solar dryer

Abstract
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At the end of the year 2009 approximately 4 700 biogas plants will be operating in Germany therefore in the last five years the number of the biogas plants will have doubled. Due to the increasing number of biogas plants the amount of digestate, accumulated as a byproduct of the fermentation process, will also be increasing. In Germany the closeness of biogas plants is regionally different, leading to an accumulation of plant nutrients in certain regions. As well as using substrates from their own farms some farmers are buying in additional substrates for their biogas plants leading to an accumulation of nutrients on these farms. To affect this accumulation the plant nutrients are conducting away from the farms. Digestate contains important plant nutrients, but just 2-10 % of dry matter (DM) [2], and for this reason it is not economical to transport the digestate over long distances [3].

A feasible alternative by reducing the moisture content and therefore enhancing the DM content at the same time maintaining the plant nutrients in the digestate would be to dry the digestate, therefore reducing transportation costs considerably. By using solar drying and a combined heat and power plant (CHP) it is possible to harness the existing energy available and therefore increase the profitability of the biogas plant.

The aim of this research was to investigate the drying behavior of digestate in a combined solar/waste heat dryer.

Hybrid solar/waste-heat dryer

The investigations for determining the drying behavior took place in Kupferzell, in the rural district of Hohenlohe, Germany, at a biogas plant using renewable primary products for fermentation employing a hybrid solar/waste-heat dryer. The biogas plant has a capacity of 2 200 m^3 shared between two fermenters. The dryer has a similar construction to a greenhouse with a total drying area of 480 m^2. The waste heat from the CHP

($320\ kW_{el}$) is transferred through the heat exchanger into the drying hall. In addition the exhaust gas from a micro turbine ($65\ kW_{el}$) is channeled into the hall by means of an air duct on the gable wall, which is also connected to a ventilation flap positioned over the hall entrance. The discharged air is guided by four unregulated ventilators. The drying plant is controlled using PLC (Programmable Logic Control). During the drying process the digestate is turned over by an electric mole according to a predetermined time schedule. The turn over frequency is calculated by the PLC based on the climatic data. Turning over of the digestate is necessary to avoid crustification on the surface.

Experimental setup

To determine the drying behavior of the digestate, twenty samples arranged in a grid pattern were taken. The dry matter analysis of the samples was conducted in a drying chamber at a temperature of 105°C ± 3°C (DIN EN 12880) and the organic dry matter content was determined at 550°C ± 5°C (DIN EN 12879) in a muffle furnace.

Climatic data such as temperature, solar radiation and relative humidity of the air outside were acquired every four minutes. To determine the total content of nitrogen (N), ammonia (NH_4-N), phosphate (P_2O_5), potassium oxide (K_2O), magnesium oxide (MgO) and calcium oxide (CaO) a chemical analysis was conducted before the start of the drying process and again at the end of the drying process.

On the 10th of May 2009 the drying hall was filled with 100 t of digestate and after 21 days of drying on the 30th of May 2009 was discharged. The chemical composition of the digestate at the beginning and end of the drying process is shown in **table 1**.

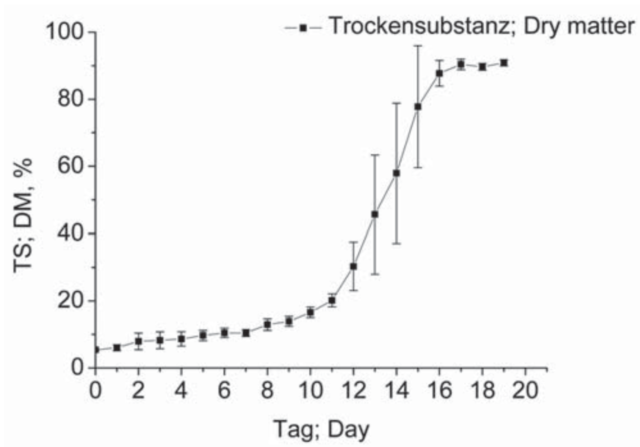
Drying behavior of the digestate

Figure 1 shows the increase of the dry matter during the process. During the first twelve days of drying the drying rate of the substance was less than that from after the twelfth day of drying. After twelve days of drying the digestate was found to be inhomogeneous above the drying area, indicating a high standard deviation. After a total of seventeen days of drying nearly no water could be detracted from the substance, whereby any further drying resulted in a homogeneously dried digestate, indicated by a decrease in value for standard deviation.

In **figure 2** the spatial distribution of the dry matter is shown for various days during the process. On examining the figures, it is evident that there are large differences in the dry matter content during the drying process particularly between 21 and 83 % of dry matter.

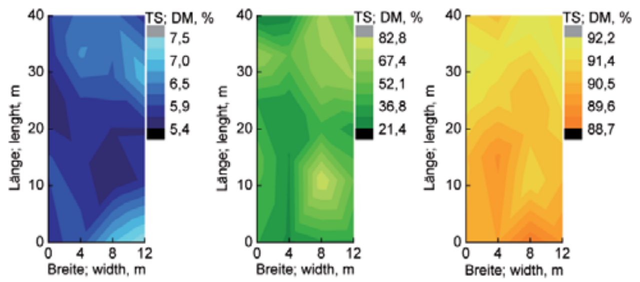
The climatic data during the drying process are shown in **figure 3**. To dry 100 t of digestate, 215 MWh of thermal energy was required, which corresponds to 9.1 MJ per kg of extracted water. About 65 % of the energy used originated from the CHP (139 MWh), as well as 20 % of solar energy (43 MWh) and 15 % (33 MWh) of energy was generated by the micro turbine but was operating for only ten days during the processing time.

Fig. 1



Development of the dry matter contents during the drying of digestate in a solar/waste heat drying plant

Fig. 2



Horizontal distribution of the dry matter contents in the hall: left at the first day, middle after 14 days, right after 21 days

Table 1

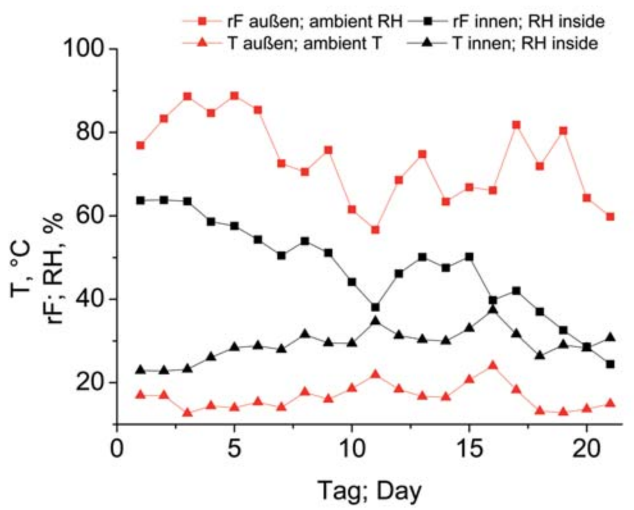
Composition of the digestate before and after drying

Parameter	Gärrest Frisch/ *digestate fresh* (TS/DM = 5,4)		Gärrest getrocknet/ *digestate dried* (TS/DM = 90,9)	
	kg/t	% TS/DM	kg/t	% TS/DM
N	3,9	6,9	22,7	2,5
NH_4-N	1,6	2,8	0,4	0,04
P_2O_5	2,4	4,2	40,4	4,4
K_2O	8,1	14,4	105,9	11,6
MgO	0,9	1,6	16,8	1,8
CaO	2,6	4,6	45,2	4,9

Conclusions

It has been demonstrated that the employment of waste heat from a CHP can be used as a basis for producing dried digestate to be used as fertilizer. Due to the reduction of the digestate mass, farmers can now reduce their storage capacity, whereby the application of the digestate can generate an ad-

Fig. 3



Climate data at the average from the 10 mai 09 till 30 mai 09

ditional source of income. The results indicate that it is possible to dry with the waste heat from a CHP digestate. The solar energy and the energy from the micro turbine affect the drying process positively but represent just a small part of the total energy input.

Literature

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