

## WASTE RECYCLING CONCEPTS IN THE BREWING AND FOOD INDUSTRY

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### ABSTRACT

Organic waste represents a disposal problem in the brewing and food industry but 30–50% of the energy demand of a brewery can be covered by means of special treatment and thermal recycling of spent grains. One possibility within a 'no-waste' concept is the thermal recycling of residual materials from the production process.

According to requirements, mechanical as well as thermal methods can apply. The degree of dewatering has a significant influence on the subsequent combustion process and on the total energy balance of the disposal process.

To design the combustion process it is necessary to carry out analyses in order to check the combustion behaviour of different residual materials. This is of particular importance for the common thermal recovery of different residual materials due to the different behaviour of the individual elements. In addition, the annual amount of accumulating residual materials is recorded accordingly, which gives the possibility to improve the internal material flow.

The combustion behaviour of different residues, such as brewers spent grain partly in mix with wood pellets and the optimum combustion parameters, were investigated in a 250-400kW pilot and demonstration plant, in which different biological residues of the brewing and food industry have been tested for their thermal recoverability. By using the fluidised-bed technology, residues, which are not appropriate for usual boilers due to their chemical/physical characteristics, can also be recycled.

This lecture deals with the findings gained from the thermal recovery of different biological residues, whereas particular attention is given to the associated emissions. The energy balance of the recovery of the process and the calculation of savings of CO<sub>2</sub> emissions by avoiding the use of fossil fuels are discussed. Comparative options of recycling are the generation of biogas from spent grains and effluent, which can also be integrated into an alternative waste recycling concept.

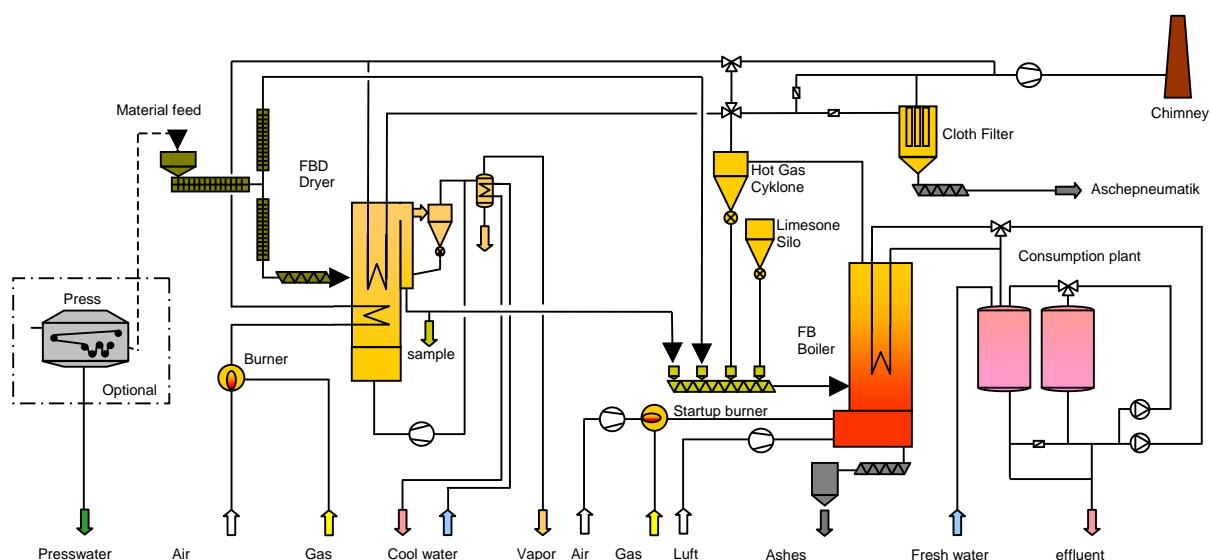
**Keywords:** *spent grains, combustion, energy, wastes*

## INTRODUCTION

The thermal utilisation of spent grains and other brewery wastes forms part of various attempts for environmentally friendly and economically sound concepts of waste recycling. The value of brewery wastes has been in discussion for over a decade and several successful applications are reported<sup>1-5, 7-13</sup>. Fluidised bed technology for combustion has been recently investigated and shows economic potential<sup>15,16</sup>. Other combustion technologies in place, with different incineration technologies for wastes, are also described<sup>14</sup>. This work shows a quick achievement approach of stable combustion conditions with spent grains. The work was carried out in a trial on a 250–400kW installation.

## Materials and Methods

Trials for the combustion were carried out forming part of an overall concept of avoiding wastes and emissions from a brewery<sup>15</sup> (**Fig. 1, 2**)



**Fig. 1 Pilot Plant Process Diagram**

Before the raw materials are used in the trial plant they are analysed for their chemical composition, tested with regard to the pressing and dewatering and drying behaviour. Finally the raw materials are incinerated in the fluidised bed combustion plant.

The pilot plant comprises a dewatering unit for the raw material, where the water level of wet wastes can be mechanically reduced to approximately 38% dry matter. Further dewatering happens in a continuous re-circulating dryer. This technology can process wet spent grains and other wastes. The trials were done with spent grains, pelletised or unpelletised. Wood pellets were used in comparison. In dry form the spent grains can be handled as disperse mixture or they are pelletised. The pellet form would enable transport to other sites and allow simple storage.

The thermal utilisation was tested in combustion trials with different compositions of the raw material.

The combustion procedure is typically split into three major phases. In the first phase the boiler is started and the plant reaches firing or ignition point. During this phase the primary air supply is adjusted in order to reach an acceptable ratio of CO/NO<sub>x</sub>. The primary air supply has to be carefully controlled. The target is to reach the next phase in a short period.

In phase two the system reaches an even heat distribution and secondary air feeding is adjusted to get a further settlement of the CO/NO<sub>x</sub> level. Limestone additions are used to reduce the emission of SO<sub>2</sub> in the exhaust gas. The duration of this phase is up to two hours. Phase three is the final phase of continuous combustion and generation of steam.



**Fig. 2 Photograph of pilot plant**

## Goals

The most important goal for this technology is to thermally dispose of brewery wastes without exceeding permitted emission limits of exhaust gases. The legal guideline Technische Anleitung Luft<sup>6</sup>, sets clear limits for the combustion in fluidised bed combustion plants regarding a plant capacity of <1MW thermal energy output (**Table I**).

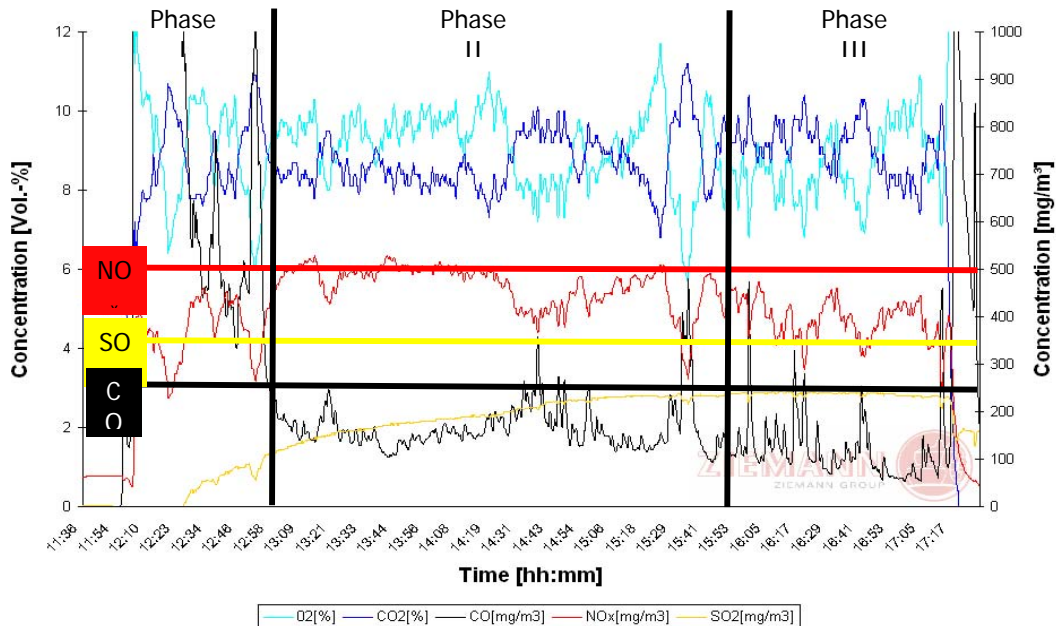
<b>TABLE I</b>		
<b>Limit Values in Emissions in Fluidised Bed Combustion according to TA Luft<sup>6</sup></b>		
<b>Emissions for fluidised bed combustion</b>	<b>Unit</b>	<b>Amount</b>
O <sub>2</sub>	% vol.	
N <sub>2</sub>	% vol.	70
CO <sub>2</sub>	% vol.	8-14
CO	mg/m <sup>3</sup>	< 250
NO <sub>x</sub>	mg/m <sup>3</sup>	< 400
SO <sub>2</sub>	mg/m <sup>3</sup>	< 350
Particles	mg/m <sup>3</sup>	< 20

The carbon monoxide level during the exposition to combustion air temperatures of approx. 850°C (depending on ash melting point) should be <250mg/m<sup>3</sup>. An addition of sufficient retention time in the fluidised-bed causes an almost complete oxidation of CO to CO<sub>2</sub>. The atmospheric fluidised bed combustion limits the formation of nitrogen oxides (thermal NO<sub>x</sub>) due to relative low combustion temperatures. With regard to the SO<sub>2</sub> limitation silica sand and lime sand are utilised in the fluidised bed. Sulphur and chlorides adhere to the CaO up to a specific extend (sulphur up to 90%, CL up to 60%) and are discharged with the bottom ash or separated together with the flue ash.

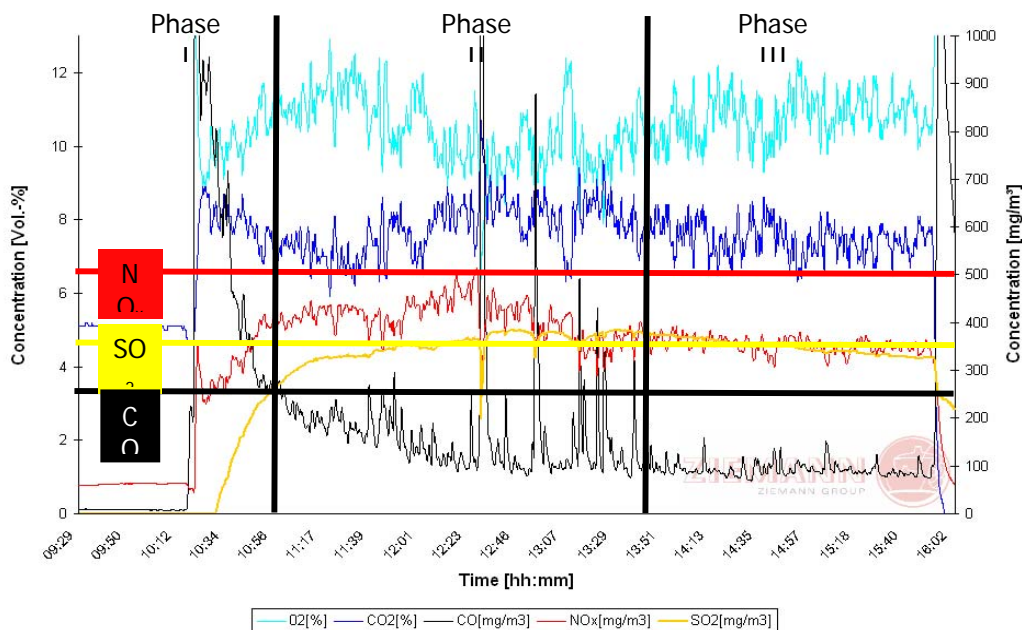
## Results

The results show that the mandatory values in the exhaust air can be achieved and do not interfere with surroundings. The combustion of spent grains can attribute a very significant part of the energy in a brewery. This can be as high as 50%. In the case of high-gravity brewing this ratio can even be higher.

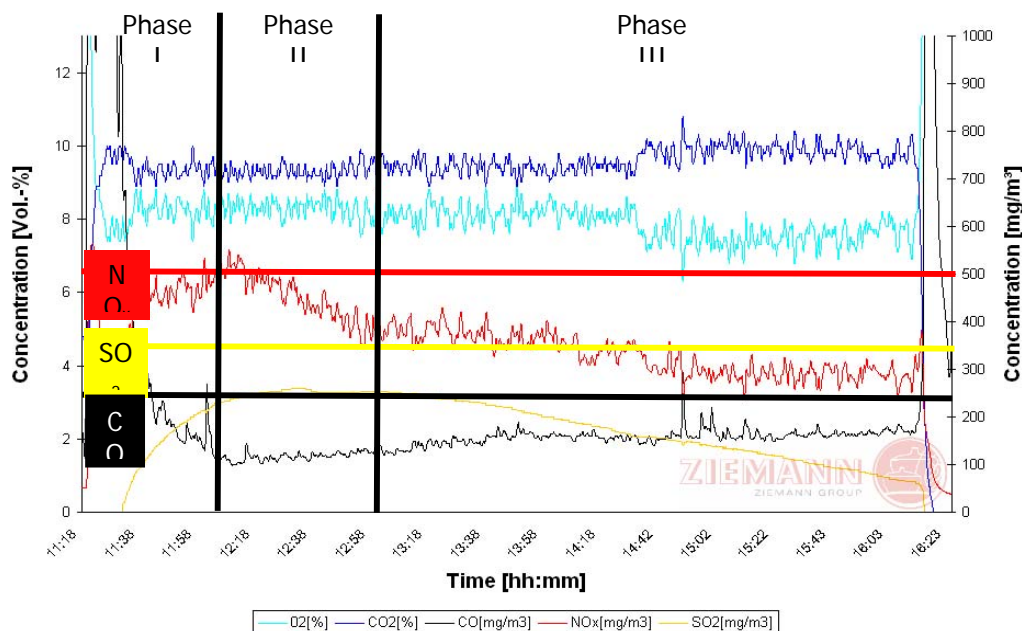
**Figs. 3,4,5** show the reached levels of emission gases in the exhaust flow in the phases described above. The limits for CO, NO<sub>x</sub> and SO<sub>2</sub> are indicated. In all cases the limits were not exceeded. CO is naturally beyond the limit in the beginning, when this cannot be avoided. The start-up phase is the most critical procedure during the firing of a biomass boiler and was therefore investigated in detail. The target here is to shorten this phase to a minimum. Phase II is used for the fine adjustment of airflow control and emissions. Short peaks of exceeding the limits may occur, while in phase III the limit values are kept.



**Fig. 3 Combustion trial with a mix of dried spent grains and wood pellets**



**Fig. 4 Combustion trial with dried disperse spent grains**



**Fig. 5 Combustion trial with pelletised dried spent grains**

In comparing the different raw materials, it is obvious that the use of a mix with wood pellets is not fully homogenous and therefore causes variations and does not reach a very smooth steady phase of continuous combustion. Even though the mix is well combustible the trial showed some irregularities. This was due to conveying, which needs to be carefully adjusted to the combustion performance. Pure spent grains in disperse form, as they were used in the second trial (**Fig. 4**) show a shorter start-up phase and more controllable behaviour in phases II and III. There were still some fluctuations in the incineration quality. Clearly the best results were achieved by using pelletised dry spent grains as in **Fig. 5**. Here the emission values were already stable and quickly achieved in phase I. The optimisation of the emissions during phase II were shorter and were very stable in phase III.

## DISCUSSION

The trials showed that it is possible to achieve steady conditions in fluidised bed combustion and achieve given limits in the exhausted gases at the same time. Spent grains are available continuously during the production process and in the time of energy demands in the brewery. The concurrent consumption of thermal energy and logistically close utilisation is advantageous because additional emissions through transports are mostly avoided. The transportation of combustion residues vs. wet wastes is minimal and reduces a logistic problem. Fluctuations of the distribution and sale revenues from spent grains are minimised. The dependence on primary fuel sources and energy prices is reduced. The ecological advantage can be used for emission calculations on a larger scale and leads to improved carbon dioxide footprints as the final customer requests more. The process is patented<sup>17</sup> in 33 countries and held by Ziemann.

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