Assessment of the biological activity of waste – a comparison of anaerobic test methods in Germany and in the UK

Anke Bockreis*, Wolfgang Müller, Iris Steinberg***

* Technische Universität Darmstadt, Fachgebiet Abfalltechnik, Darmstadt
** IGW Ingenieurgemeinschaft Witzenhausen Fricke & Turk GmbH, Witzenhausen

Bewertung der biologischen Aktivität von Restabfall– ein Vergleich von anaeroben Testmethoden in Deutschland und England

Abstract

In Germany, the parameter AT4 (respiration activity determined over the course of 4 days in laboratory testing) and GB21 (gas formation determined over the course of 21 days in laboratory testing) were implemented in the German legislation (Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (Abfallablagerungsverordnung, 2001) in order to describe the biodegradability of the waste and to determine the efficiency of the mechanical-biological pre-treatment. In comparison to the situation in Germany, two different methods for assessment of the biodegradability of waste were developed in the UK (Godley et al. 2005). The BM100 is an anaerobic methanogenic digestion test, which runs for up to 100 days. The DRI is a test method in order to evaluate the aerobic dynamic respiration. In the paper the differences of the anaerobic test methods are discussed. Different kinds of pre-treated waste from different treatment steps were analysed with both methods and the advantages and disadvantages of both methods were investigated. In order to compare the waste treatment systems in Germany and the UK, it is necessary to know the limitation of each method.

Keywords

Biodegradability, mechanical-biological treatment, aerobic/anaerobic test methods (AT4, GB21, DRI, BM100)

1 Introduction

Due to the guidelines of the EU-landfill directive, the share of biodegradable waste on landfill sites has to be reduced. Over a period of 15 years, beginning with the volume of waste produced in 1995, a reduction of the organic substance of a total of 65 % can be achieved within three steps. Member states which disposed more than 80 % of their waste on landfill sites in 1995 may apply for an extension of 4 years. The directive does not include specifications for a method of determination for the biodegradable organics nor for the proof of the reduction (EU-landfill directive 1999).

In Germany, waste may be stored on landfill sites if – after suitable pre-treatment – they meet the criteria of the ”TA Siedlungsabfall” (technical instruction for utilization, treatment and other disposal of municipal solid wastes) or rather the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements. This is to guarantee that only waste with a low biological activity and a correspondingly low potential for gas and seepage water formation is deposited.

In the UK, a weight-related assessment is carried out in order to determine the organic share in the waste, which is to say that the assessment is conducted on the basis of an allocation of waste fractions and their organic share. The specified organic share, however, does not describe the biological degradability, but merely the native-organic share. If the efficiency of the treatment plant is to be determined, the combination of the organics' separation (e.g. in the high calorific fraction) and the reduction in the biological treatment step of the corresponding plant is determined. The difference of the organics in the input and the separated share equals the remaining organics share, which can either be deposited or treated further. (NIESAR ET AL., 2005; ENVIRONMENT AGENCY UK, 2000).

2 Biological Methods for the Assessment of the Activity

2.1 Test Methods in Germany

In the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (2001) two parameters were specified for the determination of biological degradability. On the one hand, there is the aerobic test AT4 for the determination of the oxygen consumption over a course of 4 days. The determination gives information about the present biological activity, which is understood to be an advantage over the physical-chemical process. On the other hand, the determination of the gas production rate is specified in the digestion test GB21. By this, the anaerobic degradability of a substrate is tested at laboratory scale in an uninfluenced bench test under optimized conditions. The analysis period amounts to 21 days. The digestion test is conducted on the basis of the DIN 38414 Part 8 (DEV S8) – determination of the rotting behaviour of sludge and sediments.

If a waste is mechanically-biologically pre-treated, either the AT4 or the BG21 has to be determined or one of the two allocation values of AT4 (5 mg/g DM) or GB21 (20 Sl/kg DM) has to be met.

2.2 Test Methods in the UK

In the UK, the test methods are published in the technical instructions for the assessment of mechanical-biological pre-treatment (ENVIRONMENT AGENCY UK, 2005). For the determination of biological activity, an aerobic test (DR4; Dynamic Respiration) and an anaerobic test (BM100) were specified. The BM100 is a gas production test, which runs over a determination period of up to 100 days. This test is substantial for the determination of the organics reduction. Due to the long determination period, this test is unsuitable for process accompanying investigations. For that purpose the DR4 was suggested, which determines the breathing activity over a course of 4 days. The BM100 is supposed to determine the gas production potential of a waste sample as exactly as possible. With the help of a correlation yet to be developed of the BM100 with the DR4, the DR4 could possibly be used as the only test for the description of the biological activity and therefore also for the description of a treatment plant's efficiency (input-output-balance of the organic share).

2.3 Comparison of the Methods of the Anaerobic Tests

The following table shows the comparison of the two anaerobic tests BM100 and GB21 and their specifications.

Table 1 Comparison of the method instructions BM100 and GB21

	BM100	**GB21**
Sample conditioning	sieving < 5 mm, sorting of fraction > 5 mm into different fractions (biodegradable constituents (=BMW), glass, metals, inert material, plastics) Drying of the BMW-sample at 70°C until dry mass content of 87- 93 m.-%, shredding	sorting of inert material (glass, stones, metals) with later considerations of the sorted weight fractions shredding of original samples (without inert material) < 10 mm
initial weight	amount of sample corresponding to 20 g ignition loss of BMW fraction	50 g processed sample (WM)
seeding sludge	50 ml	50 ml
further addings	200 ml specific medium	tap water until total sample amount of 300 ml
setting pH-value	setting of the medium for pH 7.5	pH must be between 6.8 and 8.2, setting with means of alkalization (caustic soda or potash solution) or hydrochloric acid
temperature	35°C in water bath	35°C room temperature
reference batch	--	check of seeding sludge by adding cellulose
test period	100 days	21 days in consideration of lag phase
consideration of a lag phase	--	consideration of percentual share of the rise
information about result	Sl/kg IL BMW (BMW = biodegradable share)	Sl/kg DM

Key: WM: wet mass IL: ignition loss

DM: dry mass Sl: standard litre

As table 1 shows and the names imply, the two methods BM100 and GB21 differ the most regarding the test period. While the result of GB21 is available after a test period of 21 days plus the duration of the lag phase (depending on the kind of waste sample and pre-treatment), the result of the BM100 is available only after 100 days. Another big difference is the kind of processing before the insertion into the test equipment: dry waste is used in the BM100 whereas in the GB21, the waste is used in its original condition. The influence of the insertion weight on the ignition loss in the BM100 and on the wet mass in the GB21 results in clear differences of the insertion weight. The average insertion weight of the input samples in the BM100 amounts to 40 g DM compared to 20-30 g DM in the GB21. A further difference is the adding of a medium (a nutrient solution with a set pH-value of 7.5) for a potentially better buffering of the test in the BM100 and the adding of tap water in the GB21.

For the check of the seeding sludge for inhibitions or too much activity (according to the guidelines of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements) a reference batch is conducted which is to say that cellulose is added to the seeding sludge. The gas production of this reference batch has to be 400 Sl/kg minimum.

3 Test Results and Discussion

For the comparison of the two anaerobic test methods, different investigations were conducted in order to evaluate the basic findings of both test methods.

The following tests were conducted according to their respective target setting:

1. Adding of cellulose in order to check the buffering capacity of the medium used for the analysis of the BM100 compared to the adding of water in the GB21.
2. Comparison of different waste samples through parallel BM100 and GB21 determinations

In order to compare the results directly, the BM100 results were converted to the reference value Sl/kg DM total sample instead of Sl/kg IL BMW.

3.1 Investigations on the Buffering Capacity of the Medium, Tap Water and Seeding Sludge

For the check of the adding of medium, 1 g of cellulose was added in the BM100 whereas in the GB21 tap water was added. Figure 1 displays the sum curves of the gas production of the different batches.

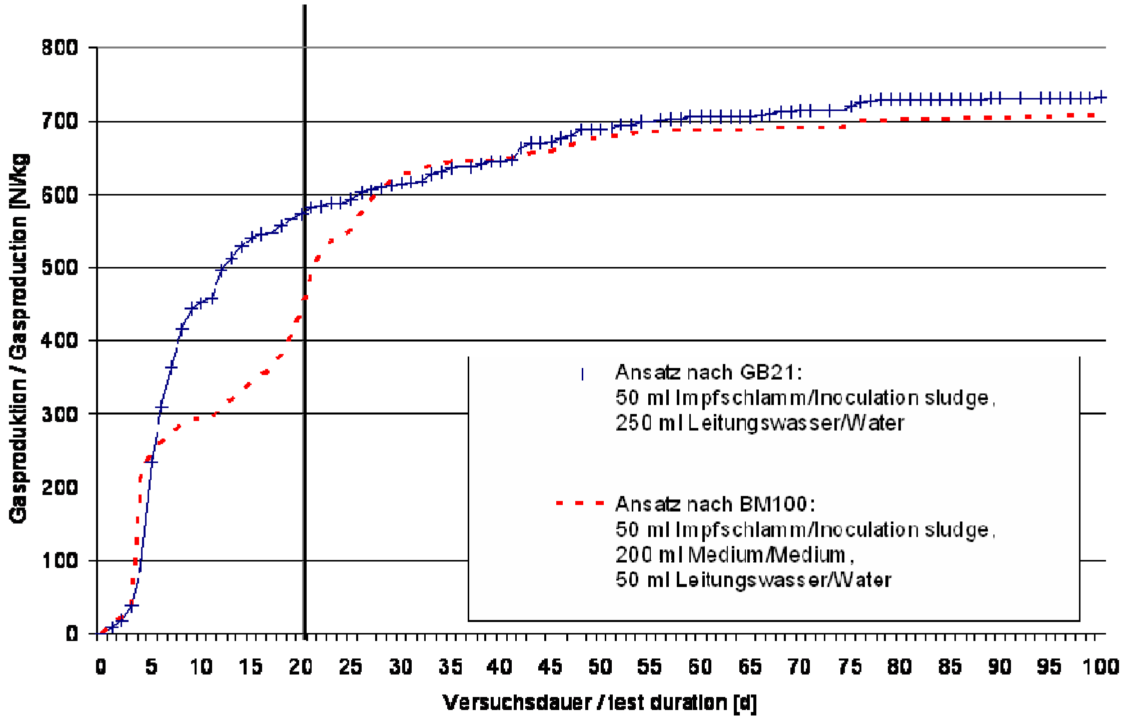
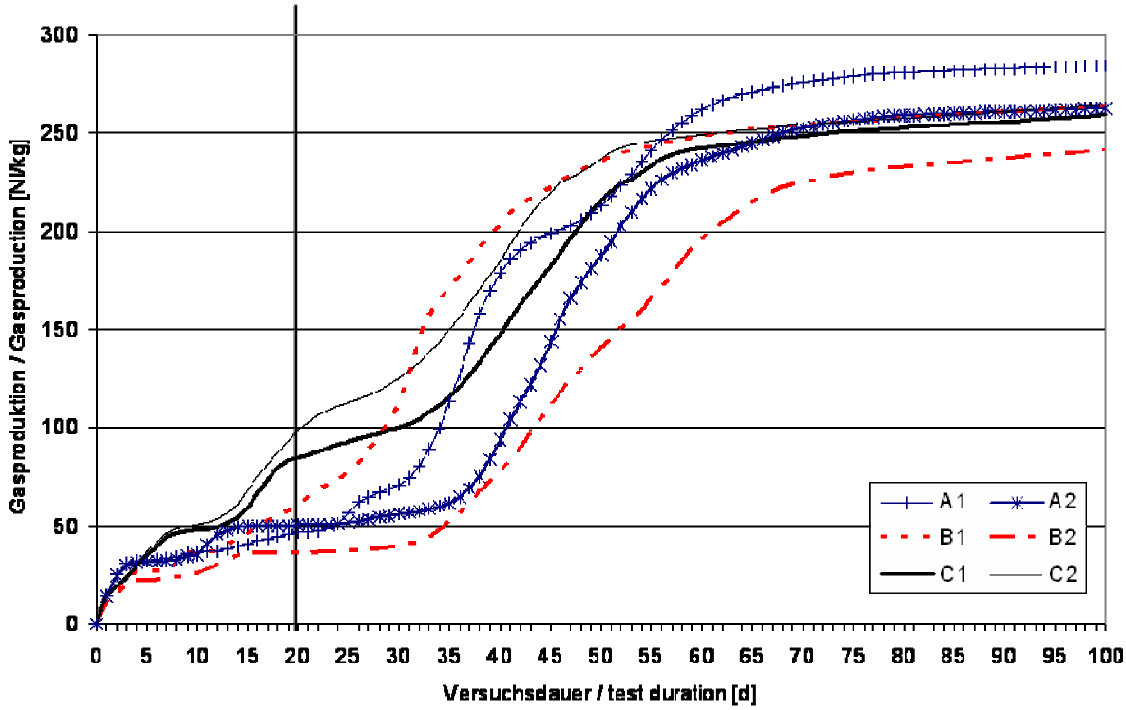


Figure 1 Adding of cellulose into medium, tap water and seeding sludge in different compositions

A difference in the gas production caused by the application of medium instead of tap water can only be witnessed in the starting phase. The batch with the main share of tap water runs with a more even rise than the batch with the medium. After a test duration of about 30 days, both batches run parallel and show a similar amount of gas production. Further investigations also showed more even curves for the batches with the medium compared to tap water, but all in all it can be concluded that the batches with medium and tap water lead to the same results when adding of cellulose. Both batches were – as is required in the GB21 batch – suitable for the check of the seeding sludge because after 21 days, both showed gas production of more than 400 Sl/kg.

In order to validate these findings on batches with waste samples, 50 g WM of a fresh waste sample were each added instead of cellulose to the same batches in the double batch as described above. Additionally, investigations with a higher amount of seeding sludge were conducted for a better buffering if necessary. The results are displayed in figure 2.



A1	A2	B1	B2	C1	C2
Test A1: batch acc. to GB21 50 g Sample, 50 ml Inoculation sludge, 250 ml Tap water	Test A2: batch acc. to GB21 50 g Sample, 50 ml Inoculation sludge, 250 ml Tap water	Test B1: batch acc. to GB21 50 g Sample, 50 ml Inoculation sludge, 200 ml Medium, 50 ml Tap water	Test B2: batch acc. to GB21 50 g Sample, 50 ml Inoculation sludge, 200 ml Medium, 50 ml Tap water	Test C1: modified batch 50 g Sample, 250 ml Inoculation sludge, 50 ml Tap water	Test C2: modified batch 50 g Sample, 250 ml Inoculation sludge, 50 ml Tap water

Figure 2 Adding of samples to medium, tap water and seeding sludge in different compositions

It can be witnessed that due to the high reactivity of fresh waste, all batches immediately start with the gas production. Between the 5^{th} and 60^{th} test day, the batches show great deviations from one another and the double batches of the samples lie, at least partially, at greater distances from each other; in the BM100 batch, for example, they deviate about 60 %. During a test period of 100 days, the courses of all batches have approximated each other again and the standard deviation of all batches amounts to 14.7 %. The double batches deviated from one another approx. 10 % in all three variations during 100 days.

3.2 Parallel Batches BM100 und GB21

In order to compare the two anaerobic tests with each other, 3 different samples from a treatment plant (input material = fresh waste, material after 3 weeks of composting and

6 weeks of composting) were each included according to the method instructions. Figure 3 displays the results of each of the double investigations.

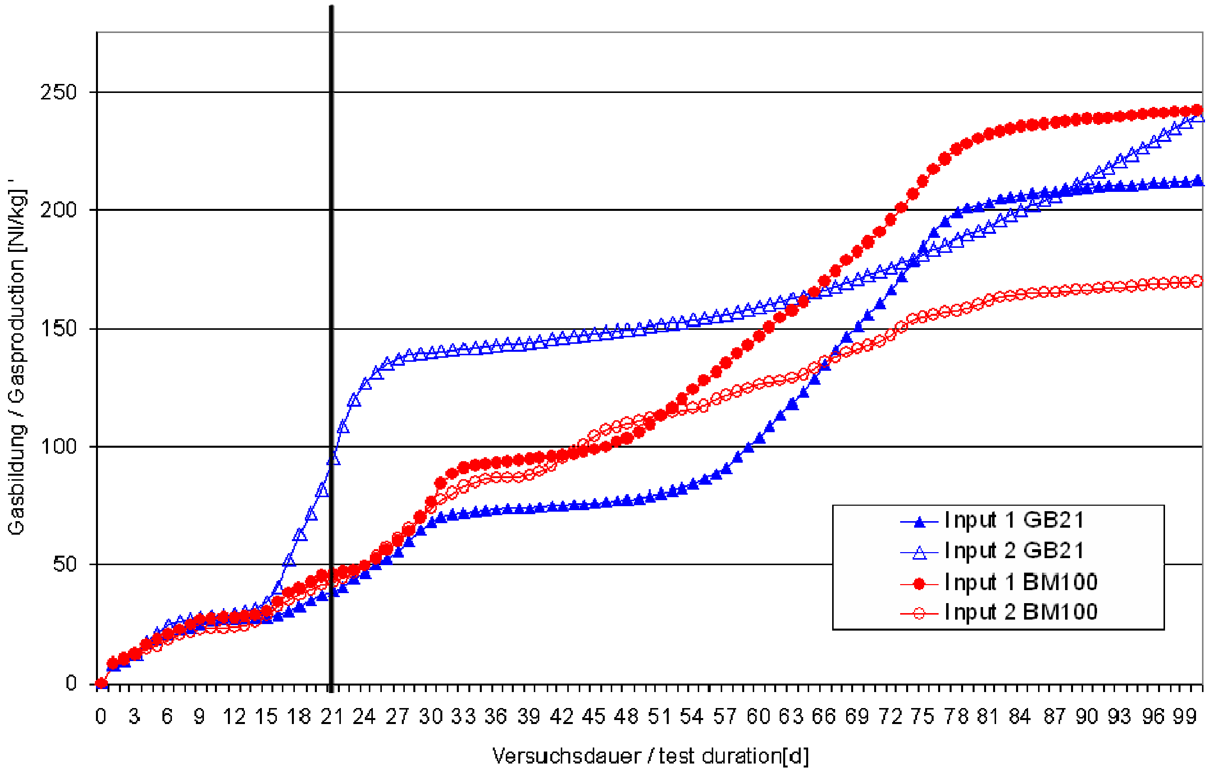


Figure 3 Comparison of input samples each in double batch BM100 and GB21

It is clear that both double batches of the input samples run differently not only among each other but also to each other over the course of the test period. Without considering the lag phase, the batches in the GB deviate by a factor of 2.5 to one another on day 21 while the batches in the BM deviate by about 6 % and diverge further from approx. day 50. The analysis of the gas production on day 100 shows that the batches which have been prepared according to the GB21 method deviated by about 13 % from one another, whereas the batches of the BM100 deviated by about 30 %. While the curves of both input samples according to BM100 and input 1 GB21 continued to rise more slowly from approx. day 80 onward, the rise of input 2 GB21 is still steeper so that here an increased gas production must be expected.

Both methods show a comparably strong scattering regarding the fresh samples. An advantage of one method over another during a test period of 100 days cannot be ascertained.

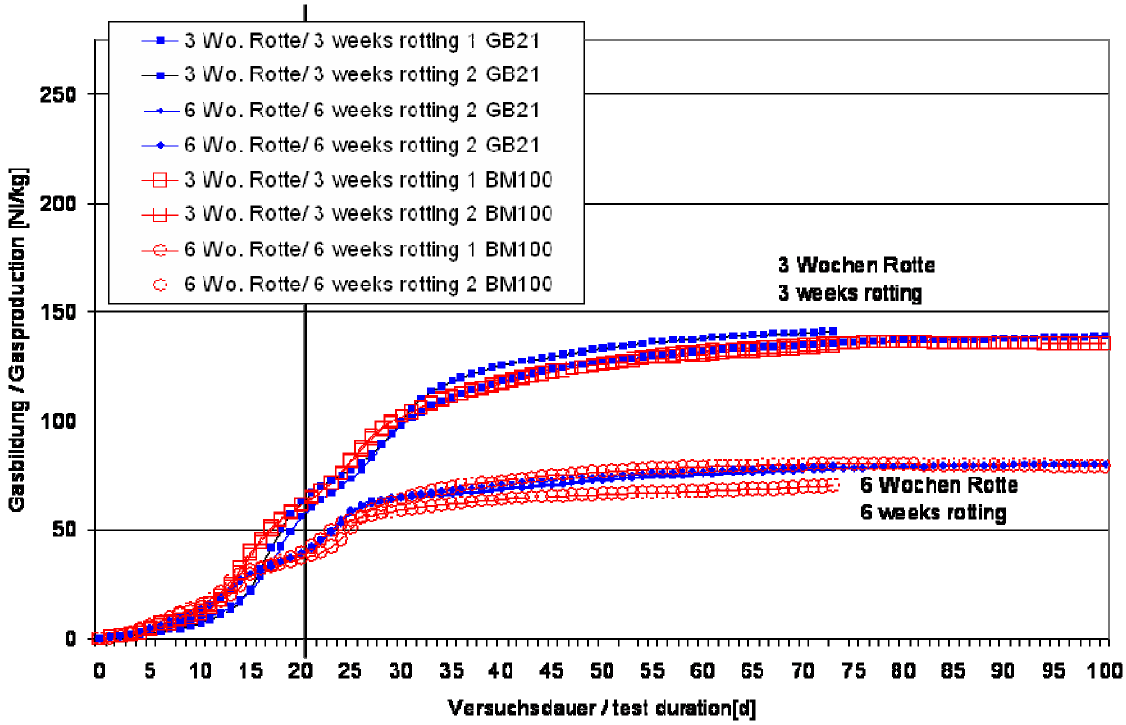


Figure 4 Comparison of 2 different samples each in double batches BM100 and GB21

Looking at the behaviour of the rotted samples in figure 4, it becomes clear that the longer the waste was treated in a plant, the more even the courses of the curves become in comparison to the courses of the input samples (see figure 3). Furthermore, the decrease of the samples' reactivity due to longer treatment time is noticeable. Due to the parallel course of both double batches to each other and also in between the methods, it can be stated that there is no mentionable difference in the result analysis of both methods, if the long test period of 100 days is taken into consideration for both methods.

Due to the relatively short test period of 21 days in the GB, the lag phase has to be taken into account in the result finding. The following figure shows the values of the gas production read directly after 21 days and the results in consideration of the lag phase.

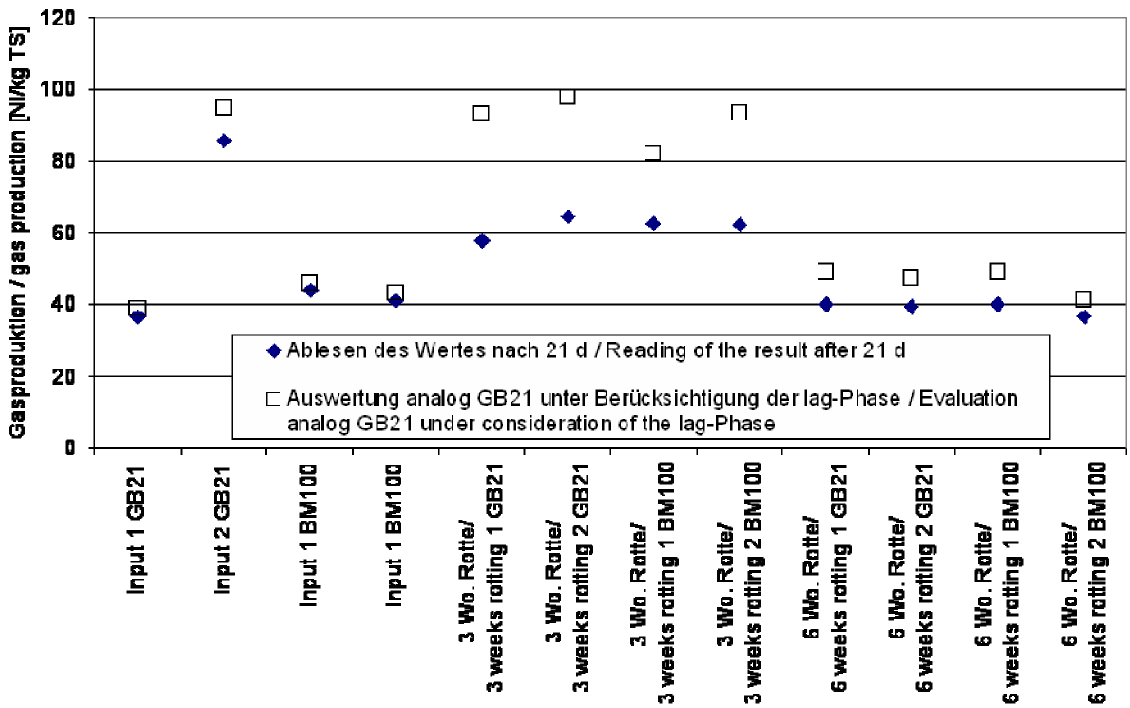


Figure 5 Comparison of values read directly after 21 days and results in consideration of lag phase

Especially with the samples that have been rotting for 3 weeks, there is a clear difference between the direct reading and the result that considered the lag phase – independent from the two methods of approach of the GB21 and BM100. In these samples, the biological anaerobic degradation did not commence immediately as it did with the input samples. In view of the short test period of 21 days of the GB21 in contrast to the BM100, the necessity of taking the lag phase in GB21 into consideration is justified.

4 Summary

In the UK as well as in Germany, methods were developed to determine the biological activity of waste samples before the landfilling. Among other things, the two anaerobic tests were introduced, the GB21 in Germany and the BM100 in the UK. In this paper, both methods were compared and the differences and similarities were investigated via parallel batches. Generally, it can be stated that both methods may lead to the same results, which is to say that the methods in themselves do not differ much from another if the rather long period of 100 days accounts for both of the methods. The major difference, however, lies in the test period of 21 or respectively 100 days and the accompanying effort. There is no mentionable advantage from the application of a medium in the BM100 over tap water used in GB21.

Along with the results of further investigations, which are not included in this paper, it can be said that despite the taking into consideration of the lag phase in the GB21, the

GB21 is less suitable for the evaluation of fresh waste samples or in other words, if fresh waste is used, the test period should be prolonged. Input samples can run very differently in multiple batches too, so that no confirmed statement can be derived. But even with a test period of 100 days as it is in the BM100, an end of biological activity by using fresh samples does not always seem foreseeable. If the waste is pre-treated, the courses of the gas production in multiple batches approximate further and further so that a test period of 21 days is sufficient to capture the remaining biological activity of a pre-treated sample.

5 Literature

AbfAblV	2001	Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (Abfallablagerungsverordnung AbfAblV), Section 1 of the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment in the version dated 20.02.2001, 31.01.2001 Federal Law Gazette Part I, No. 10, p. 305-324, Bonn, 27.02.2001
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5.1 Authors' Addresses

Dr. Anke Bockreis, Dr. Iris Steinberg
Technische Universität Darmstadt - University of Technology
Institut WAR, Fachgebiet Abfalltechnik
Petersenstr. 13, D-64287 Darmstadt
a.bockreis@iwar.tu-darmstadt.de
www.abfalltechnik.net

Dr. Wolfgang Müller
IGW Ingenieurgemeinschaft Witzenhausen Fricke & Turk GmbH
Bischhäuser Aue 12, D-37213 Witzenhausen
www.igw-witzenhausen.de