Problems with treatment of solid digestate and approaches to their solution

- **Jacques G. Fuchs** (FiBL, CH-Frick)
- **Konrad Schleiss** (UMWEKO GmbH, CH-Grenchen)
- **Ulrich Galli** (Terra Nova Umweltberatung GmbH, CH-Breitenbach)
- **Arthur Wellinger** (Nova Energie GmbH, CH-Aadorf)
- **Alfred Berner** (FiBL, CH-Frick)

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Problems with treatment of solid digestate and approaches to their solution

- Introduction
- Properties of solid digestate with respect to ist agricultural use
- Effects of inadequate storage or treatment of solid digestate
- Preliminary experiments on solutions
- First experiences in practice
- Conclusions

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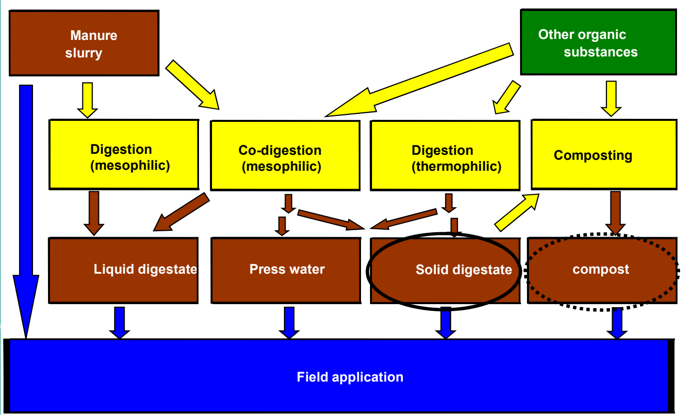
Introduction: Pathway of organic substances



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Properties of solid digestate with respect to its use in agriculture

- **Nutrient content**
  - **Total nutrient content of solid digestate ≈ compost**
  - **NH_4 content of solid digestate >> compost**
- **Organic matter**
  - **Organic substance in solid digestate ≈ young compost**
  - **Stability of the organic substance in solid digestate << compost**
- **phytotoxicity**
  - **Phytotoxicity of solid digestate >> compost**

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Solid digestate: agronomic considerations

- **Properties of fresh digestate:**
  - High availability of nutrients (mainly nitrogen)
  - Limited improvement of soil fertility
  - High phytotoxicity
  - Material unstable, in the process of rotting
- **Consequences for its use:**
  - Use mainly in arable crops, less in horticulture
  - Application only at times when crops can take up nitrogen
- **Open questions:**
  - Is it possible to store solid digestate? How?
  - Can solid digestate be stabilized and improved with post-treatment?
  - How can the content of Nmin be retained in post-treatment?

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Consequences of inadequate storage or treatment of solid digestate

- High danger that ammonia is lost as gas.
  - N availability in soil after application

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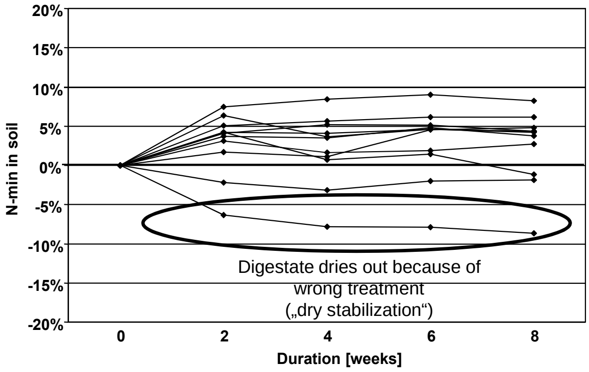
Consequences of inadequate storage or treatment of solid digestate

High danger that ammonia is lost as gas.
soil after application of digestate



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Consequences of inadequate storage or treatment of solid digestate

- **High danger that ammonia is lost as gas.**
  - If treated wrong, solid digestate can block nitrogen in the soil.
- **If treated or stored wrong, greenhouse gases can be emitted in elevated amounts (CH_4, N_2O, …).**
- **If treated or stored wrong, the biological quality may be reduced (e.g. phytotoxicity).**

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Preliminary experiments on solutions

- **Questions:** - Can a high-value product be produced from solid digestate?
  - How can nitrogen losses be minimized ?
- **Approaches:**
  - Post-fermentation composting of solid digestate
  - Optimization of aeration and humidity, to assure sufficient oxygen supply and minimal ammonia losses.
  - Addition of additives to improve composting and minimize ammonia losses.

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Preliminary experiments on solutions

- Experiment 1:

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Preliminary experiments on solutions

- Experiment 1:
  - **Treatments:**
    - 1A: 70% digestate + 30% sieve remains
    - 1B: 30% digestate + 10% sieve remains + 60% green manure
    - 1C: 30% digestate + 10% sieve remains + 60% young compost
  - **Young compost used:** no optimal quality (technical problems in the composting process)
  - **Composting system:** small piles turned daily
  - **Trial period:** 6 weeks (28.06.2005 – 09.08.2005)

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Preliminary experiments on solutions

- **Experiment 1:** 1A: 70% digestate + 30% sieve remains
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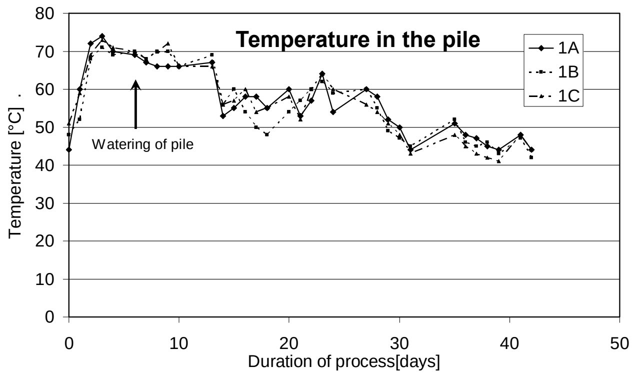

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Preliminary experiments on solutions

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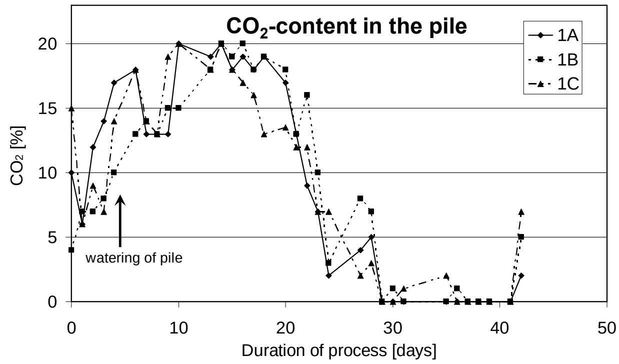

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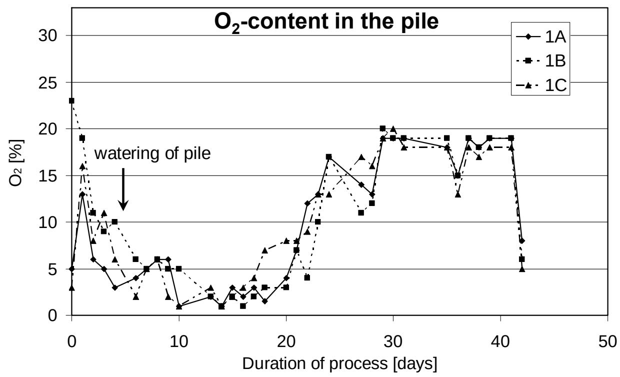

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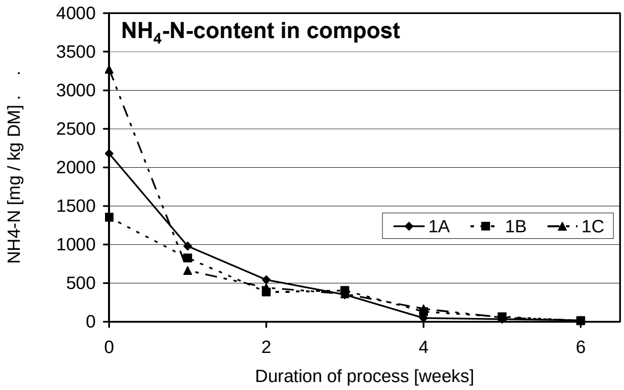

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Preliminary experiments on solutions

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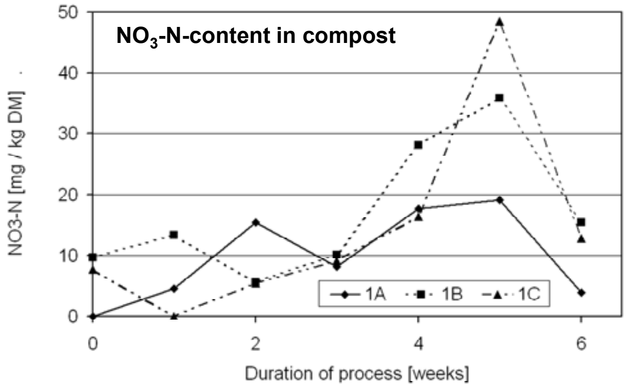

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Preliminary experiments on solutions

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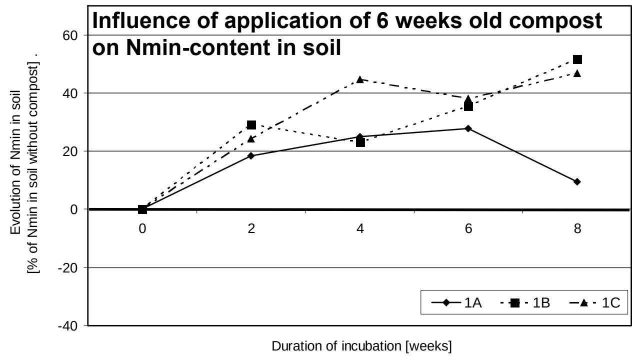

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Preliminary experiments on solutions

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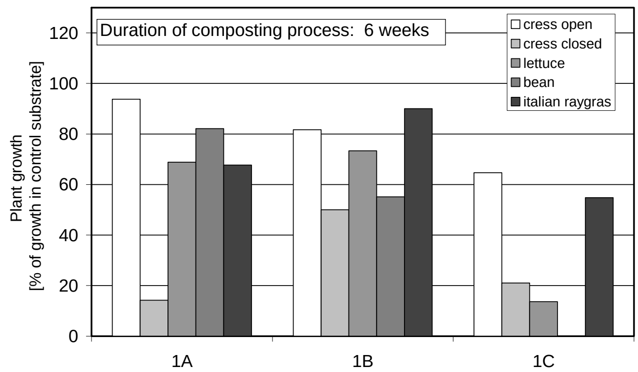
Phytotoxicity tests



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Preliminary experiments on solutions

- **Experiment 1:**
  - Active composting process in all mixtures
  - Similar development in all composting parameters (Temp, O_2- und CO_2) and all treatments
  - Great reduction in NH_4 in the first 4 weeks in all treatments
  - After ca. 3 weeks elevated NO_3 in mixtures with 30% digestate, as compared with 70% digestate
  - No Nmin blocking in soil. Elevated release of Nmin in mixtures with 30% digestate, as compared with 70% digestate
  - After 6 weeks of composting: low phytotoxicity. Treatment with 60% young compost: less good (problems with the quality of the young compost?)

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Preliminary experiments on solutions

- **Experiment 2:**

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Preliminary experiments on solutions

- **Experiment 2:**
  - **Treatment:** -2A: 100% digestate
    -2B: 70% digestate + 30% sieve remains
    -2C: 30% digestate + 10% sieve remains + 60% young compost
  - **Young compost used:** no optimal quality (technical problems in the composting process, high acetate content: lack of oxygen)
  - **Composting system:** small piles turned daily
  - **Trial period :** 8 weeks (04.10.2005 – 29.11.2005)

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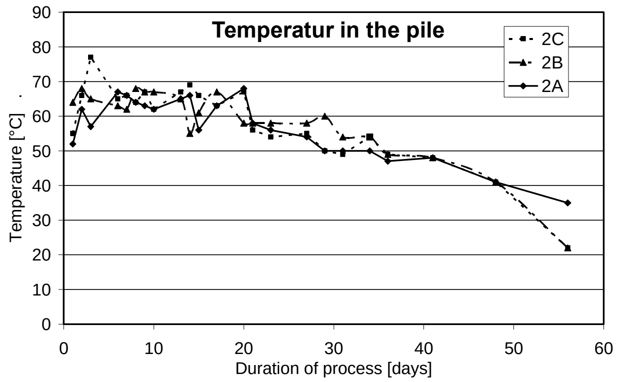
Preliminary experiments on solutions

- **Experiment 2:** 2A: 100% digestate
  2B: 70% digestate + 30% sieve remains
  2C: 30% digestate + 10% sieve remains + 60% young compost



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Preliminary experiments on solutions

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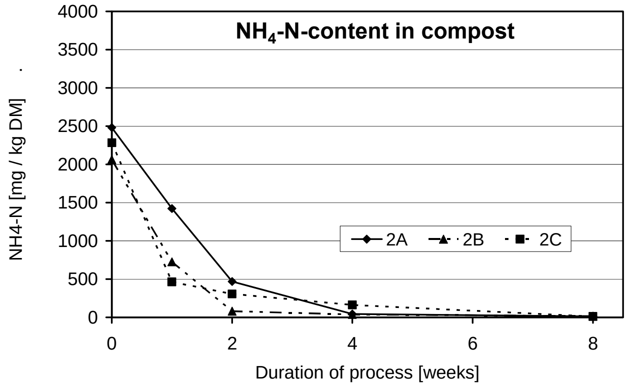

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Preliminary experiments on solutions

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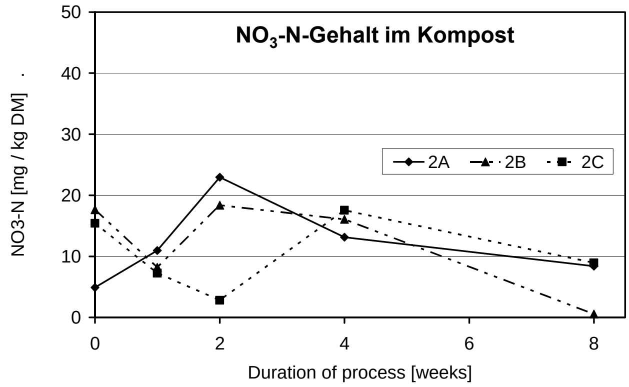

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Preliminary experiments on solutions

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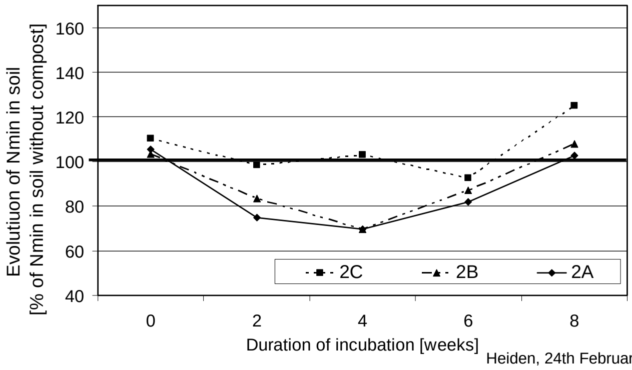
  2B: 70% digestate + 30% sieve remains
  2C: 30% digestate + 10% sieve remains + 60% young compost

Influence of application of 8 weeks old compost on Nmin-content in soil



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Preliminary experiments on solutions

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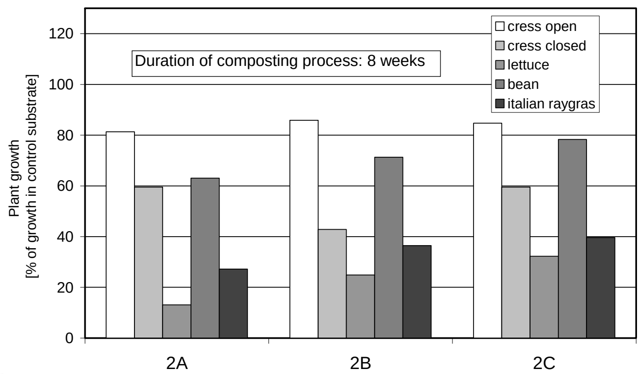
Phytotoxicity tests



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Preliminary experiments on solutions

- **Experiment 2:**
  - Composting process started quickly. With 100 % digestate slightly delayed.
  - Similar development of parameters (Temp, O_2- und CO_2) in all treatments
  - Strong reduction in NH_4 during the first 4 weeks in all treatments. With 100% digestate, less pronounced during the first 2 weeks
  - Low content of NO_3-Gehalte in all treatments during the whole experiment
  - After 8 weeks of composting : Nmin blockage in the soil in the treatments with 100 and 70% digestate. NH_4 losses ? Admixture of fresh compost reduced the problem.
  - After 8 weeks of composting: intermediate phytotoxicity in all treatments.

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Preliminary experiments on solutions

- **Experiment 3:**

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Preliminary experiments on solutions

- **Experiment 3:**
  - **Treatments:**
    - A: Mixtures digestate/green material (100/0; 50/50, 25/75, 0/100)
    - B: Mixtures digestate/young compost (100/0; 75/25, 50/50, 25/75, 0/100)
    - C: Mixtures digestate/mature compost (100/0; 75/25, 50/50, 25/75, 0/100)
  - **Standard mixture of the composting plant**
  - **Green material:** 20% branches, 30% green manure, 25% lawn cuttings, 10% sieve remains, 15% soil rich in clay
  - **Young compost:** 6 weeks old, from: 15% branches, 25% green manure, 25% lawn cutting, 15% sieve remains, 5% paper lime, 15% soil rich in clay
  - **Mature compost:** 10 months old, from: 20% branches, 30% green manure, 20% lawn cutting, 10% sieve remains, 5% paper lime, 15% soil rich in clay
  - **Composting system:** small piles turned 2x weekly
  - **Trial period:** 10 weeks (04.10.2005 – 29.11.2005)

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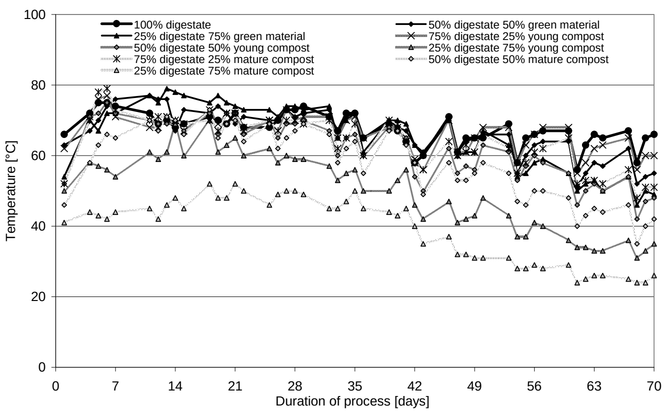
Preliminary experiments on solutions

- **Experiment 3**

Temperature in the pile



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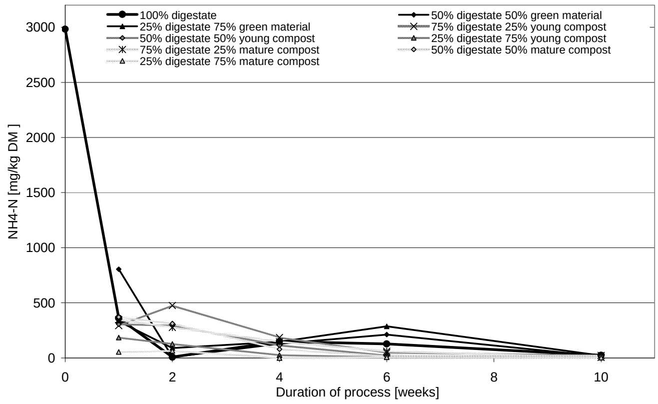
Preliminary experiments on solutions

- Experiment 3

NH_4-N-content in compost



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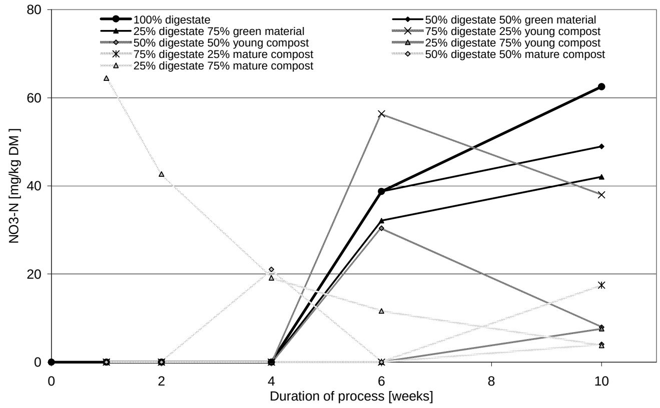
Preliminary experiments on solutions

- Experiment 3

NO_3-N-content in compost



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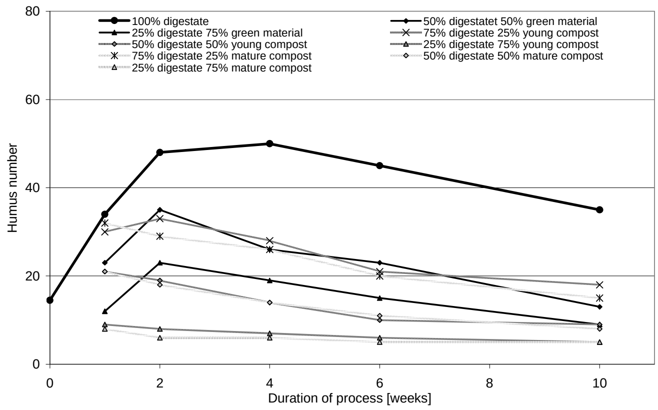
Preliminary experiments on solutions

- Experiment 3

Humuszahl



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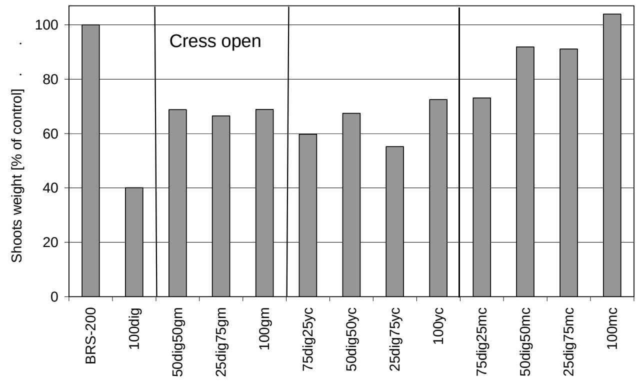
Preliminary experiments on solutions

- **Experiment 3**

Pflanzenverträglichkeit nach 6 Wochen



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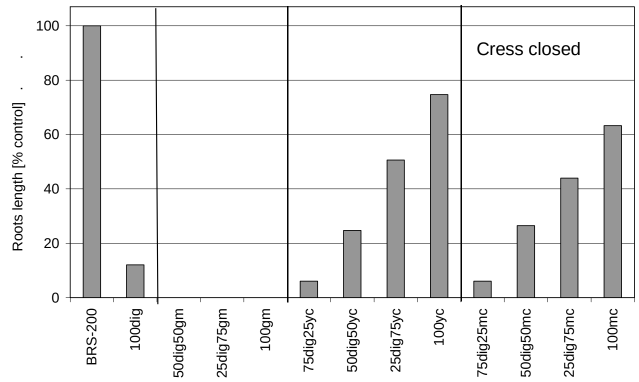
Preliminary experiments on solutions

- **Versuch 3**

Pflanzenverträglichkeit nach 6 Wochen



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Preliminary experiments on solutions

- **Experiment 3 (small piles):**
  - Very active process by all treatments with more than 25% digestate.
  - Strong reduction in NH_4 during the first week by digestate.
  - NO_3-contents elevated by almost all treatments after ca. 4 weeks. However, these contents stay modest. Nitrate content in the mixture with mature compost sink during the process. It will be probably integrate in the microbiological biomass.
  - It is in this experiment not possible to determined how much NH_4-N is lost and how much is bind in the biomass.
  - After 8 weeks composting process: moderate phytotoxicity by all treatments.
  - Addition of compost (young or mature) improved the stability of the organic matter.
  - In opposite to green material, addition of mature compost reduced the phytotoxicity of the compost already after 6 weeks composting process

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Preliminary experiments on solutions

- **Experiment 4:**

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- **Experiment 4:**
  - **Treatments:** - A: 90% young compost, 10% sieve remains
    - B: 25% digestate, 65% young compost, 10% sieve remains
    - C: 50% digestate, 40% young compost, 10% sieve remains
    - D: 75% digestate, 15% young compost, 10% sieve remains
  - **Kompostiersystem:** high piles, turne with wheel loader
  - **Turn intensity:** first month: each 10 days
    from second month: each 15 days
  - **Trial period:** 12 weeks (22.06.2009 – 14.09.2009)

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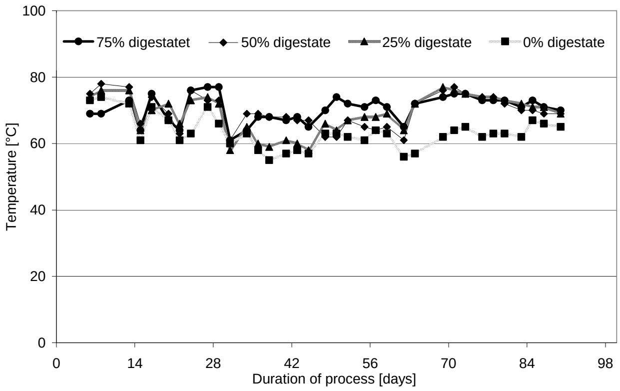
Preliminary experiments on solutions

- **Experiment 4**

Temperature in the pile



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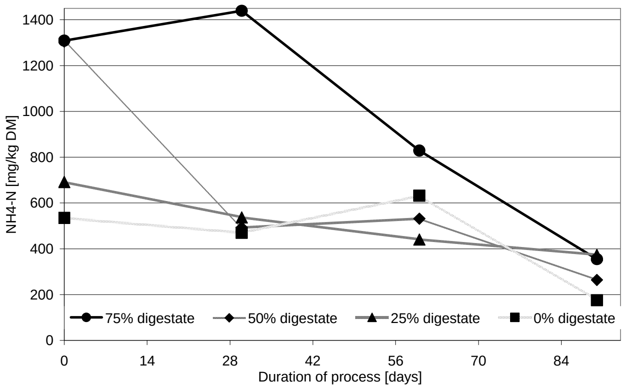
Preliminary experiments on solutions

- Experiment 4

NH4-N-content in compost



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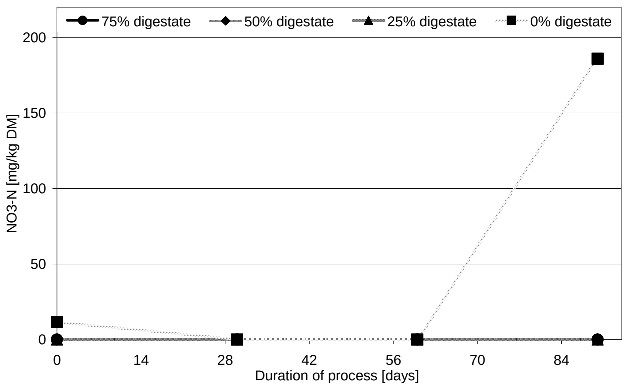
Preliminary experiments on solutions

- Experiment 4

NO3-N-content in compost



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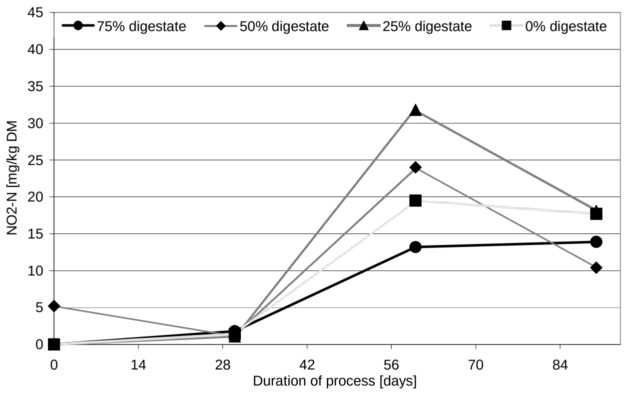
Preliminary experiments on solutions

- Experiment 4

NO2-N-content in compost



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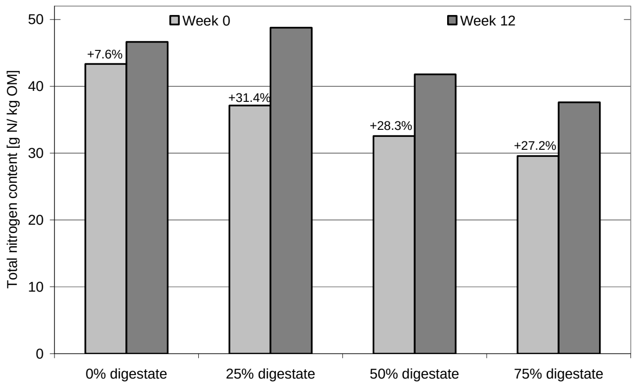
Preliminary experiments on solutions

› **Experiment 4**

Total nitrogen in relation to OM



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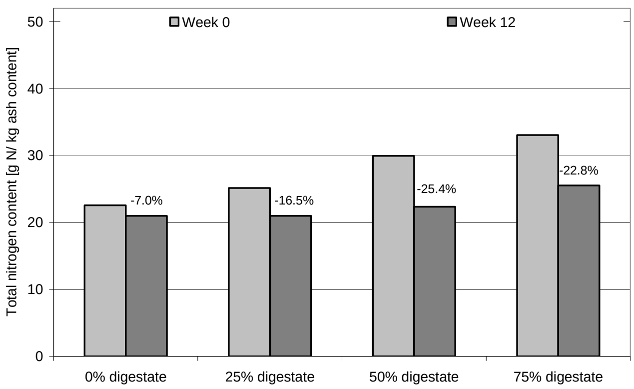
› **Versuch 4**

Total nitrogen in relation to ash content



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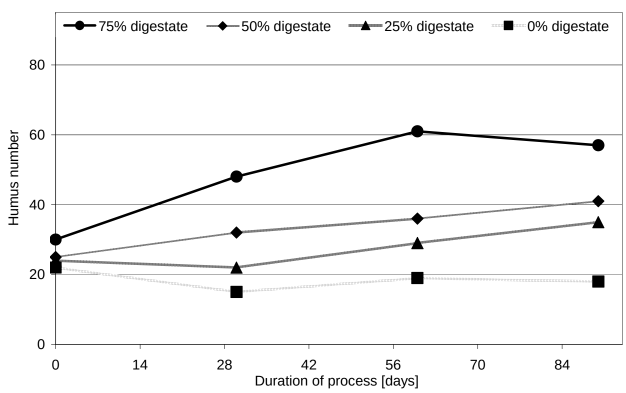
› **Experiment 4**

Humus number



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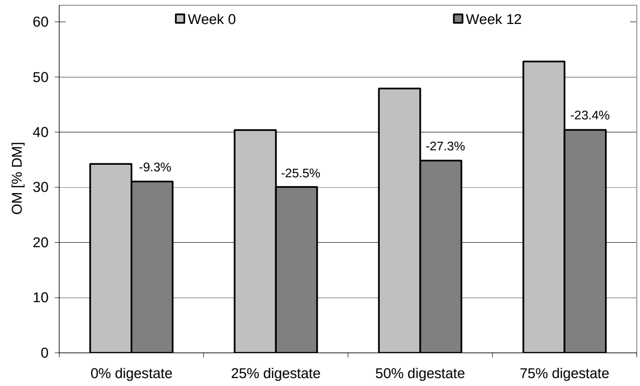
- **Experiment 4**

Organic matter



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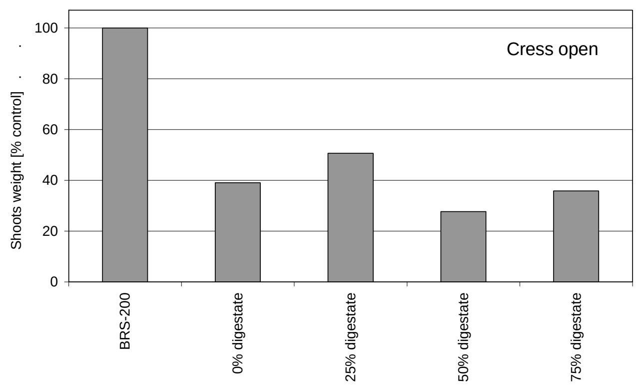
- **Experiment 4**

Phytotoxicity



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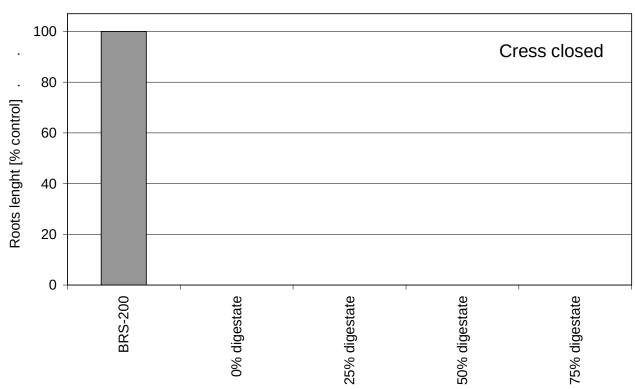
- **Experiment 4**

Phytotoxicity



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Preliminary experiments on solutions

- **Experiment 4 (high piles):**
  - High temperatures were observed during the all experiment by all treatments with digestate (70°C after 12 weeks process)
  - Relatively regular reduction of NH_4 during the all process
  - Almost no development of NO_3 during the first 12 weeks of process. Possible reasons: not enough oxygen and/or too high temperatures.
  - Ca. 20% lost of nitrogen in all treatments with digestate. The addition of young compost has these loses hardly reduced.
  - Humus number: In high piles we could observed almost no stabilization of the organic matter.
  - A decomposition of the organic matter from digestate could be observed, but no development of crumbly structure. The product stay very fibrous.
  - By all the treatments was an important phytotoxicity to observed also after 12 weeks of process. Probably is the insufficiently supply of oxygen in the pile the reason for the poor biological quality of the compost produced.

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Conclusions of preliminary experiments

- **Process development**
  - Digestate contains enough energy for post-treatment
  - Improved aeration in small heaps favors rotting of organic substance
  - Addition of rotted green material can optimize the rotting process.
- **NH_4 losses**
  - Danger of NH_4 losses is higher in small heaps with intensive rotting.
  - Addition of rotted green material or compost can reduce NH4 losses and N blocking.
- **Biological quality of compost**
  - Post-treatment can greatly reduce phytotoxicity
  - Addition of rotted green material can reduce phytotoxicity, if the quality is good. Otherwise, it can have negative consequences.
  - In large heaps with low movement, the biological quality remains unsatisfactory, because there is not enough oxygen for an optimal rotting process.

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First experiences in practice

- **Post-composting of solid digestate from dry digestion (>20% in the digester) at thermophilic temperature**

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First experiences in practice

- **1: First step of post composting:**
  - **in a hall, with forced aeration (3 - 4 weeks)**
  - **Addition of paper lime, soil und sieve remains**
  - **Pile turning with a turn machine Grizzli**

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First experiences in practice

- **2: Eventually interim storage**
  - **Storage boxes with aeration**

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First experiences in practice

- **3: Second step of post composting (maturation)**
  - **High piles with turn machine Grizzli**
  - **Digestate alone or with green manure**

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First experiences in practice

› 4: Sieving and production of different products

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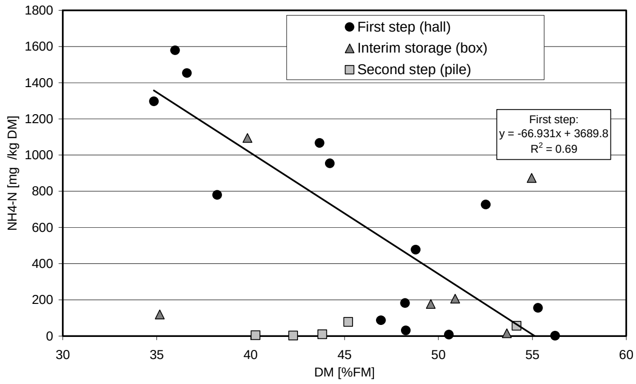
First experiences in practice

› Water content and NH_4 losses



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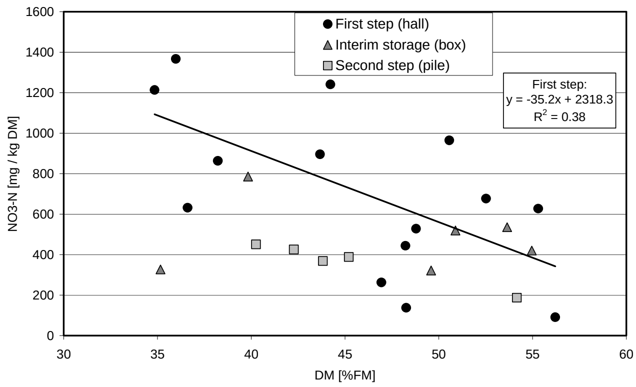
First experiences in practice

› Influence of water content on NO_3 content



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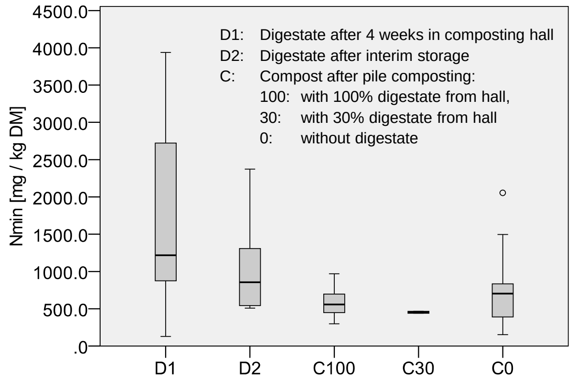
First experiences in practice

- **Evolution of Nmin content**



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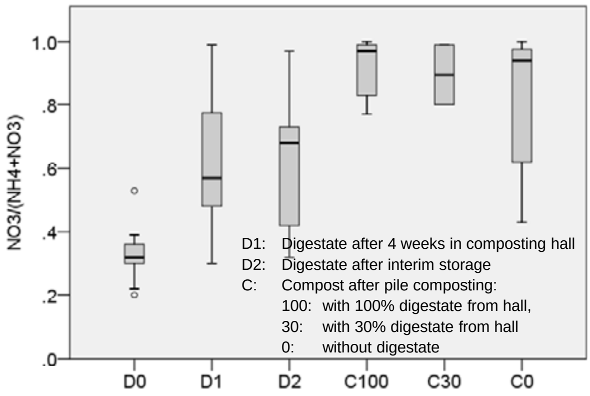
First experiences in practice

- **Evolution of maturity process**



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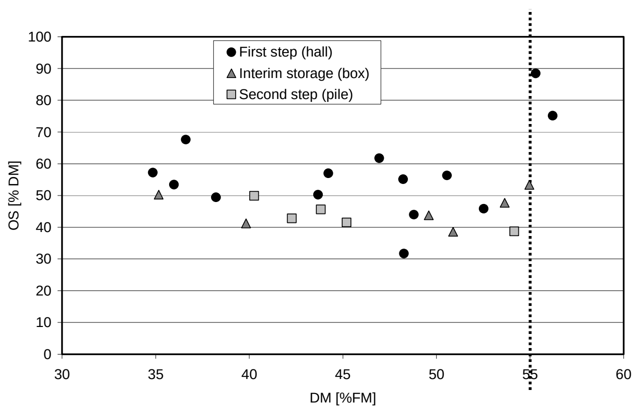
First experiences in practice

- **Influence of water content on decomposition process**
  - Up to 55% DM: almost no degradation of organic matter



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First experiences in practice

- Influence of compost addition on the rotting process

Digestate after step 1

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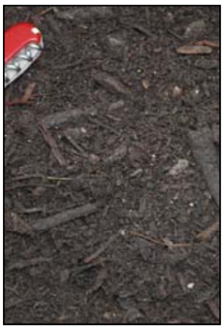
First experiences in practice

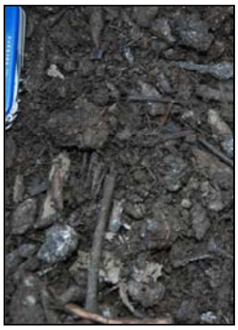
- Influence of compost addition on the rotting process

Digestate after step 2



Digestate + compost after step 2

Compost after step 2



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First experiences in practice

- Optimized rotting allows the production of high value composts
- To reduce NH_4 losses, the material should be kept moist
- If the dry matter content is too high, there is no breakdown
- If there is enough humidity, good nitrification is observed.
- Addition of green material improves breakdown and soil structure

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Aspects for additional research and development

- **Minimization of NH_4-N losses**
  - Optimization of humidity management
  - Optimization of the quantity and quality of added green material
  - Optimization of airation management
  - Addition of rotted green material / young compost
- **Optimization of the build-up phase (particle structure)**
- **Compromise between biological needs, technical feasibility and economical aspects.**
- **Post-fermentation rotting must be tailored to the quality requirements and the intended use of the end product.**

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Conclusions

- **Improvement of solid digestate with post-fermentation rotting is possible, but requires time and efforts.**
- **Post-fermentation rotting can stabilize the production and lead to high value, stable products.**
- **Post-fermentation rotting can broaden the spectrum of applications of solid digestate.**
- **To be successful, post-fermentation rotting must be carefully planned and carried out.**

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Acknowledgements

The authors thank

> **the Swiss Federal Office for the Environment FOEN,**
> **the Swiss Federal Office of Energy SFOE,**
> **the Federal Office for Agriculture FOAG,**
> **Axpo Kompogas AG**
> **Leureko AG**

for financial and/or technical support.

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