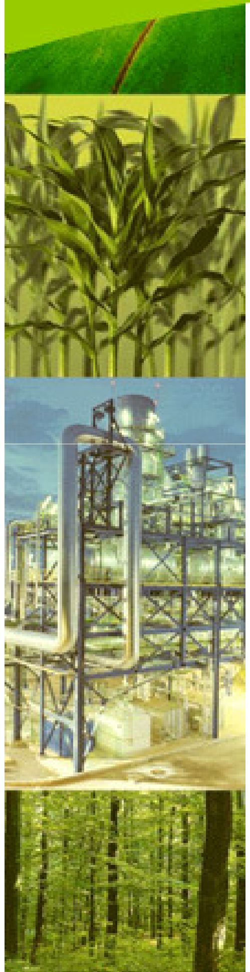

Sweet Sorghum biogas plant in temperate region. Demonstration plant for biogas and high value biofertilizer production

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SUMMARY

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  - crushed juice
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General introduction

1. Due to its high photosynthetic efficiency (3-4%) S. Sorghum hybrids have an impressive biomass yield per hectare at all latitudes (up till 95 tons of fresh biomass per ha per cycle)

2. Mostly well known for ethanol production (up till 6-7 m^3 per hectare)

3. Even if the climate is not suitable for two cycle cultivation, it has been estimated that a specific sweet sorghum hybrid could still have a biomass yield of about 70-85 fresh tons per hectare.

4. The idea is to cultivate sweet sorghum hybrid in a 25 ha land placed on the limit between Belgium and France

5. Sweet Sorghum stalks will be processed in anaerobic digestion reactors in order to have three main marketable products:

6. Grains for animal food, Energy from biogas production, Enviromental sustainable Bio-Fertilizer

Sorghum cultivation: optimal soil and climate conditions

- Sorghum is mainly grown on low potential, shallow soils with high clay content, which usually are not suitable for the production of maize. S.S. usually grows poorly on sandy soils, except where a heavy textured sub-soil is present.

- Sorghum is more tolerant of alkaline salts than other grain crops and can therefore be successfully cultivated on soils with a pH (KCl) between 5.5 and 8.5.

- Optimal clay percentage in soil: 10 % - 30 %

- Temperature for germination is 7 - 10 ºC. (At 15 ºC: 80 % of seed germinate). The best time to plant is when there is sufficient water in the soil and the soil temperature is 15 ℃

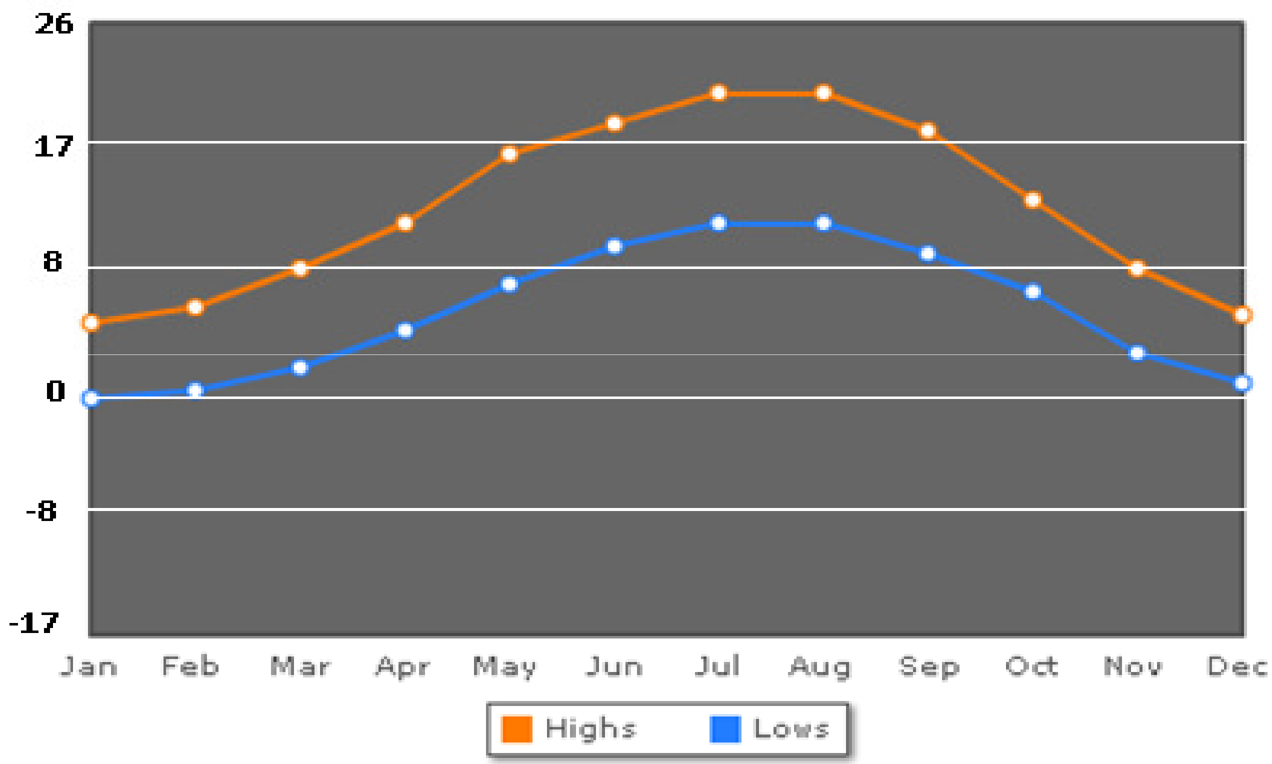
- Sowing temperature: 14℃. Optimum growth: 25 - 27 ℃.

- The temperature can, however be as low as 20 ℃, without a dramatic effect on growth and yield

Sorghum cultivation: optimal soil and climate conditions

Suitable period for Sweet Sorghum Cultivation in belgium:

- **Sowing: May**
- **Harvesting:September / October (50 days using specific different varieties of s.s.)**
- **Days: 150**
- **Expected yield: 70 fresh tons /ha**



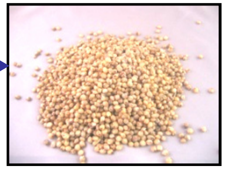
Possible evaluation of crop rotation. (Crambe, Sun hemp, are demonstrated to be able to grow even in very low temperature).

Sorghum cultivation: expected yield and products

Total fresh matter produced:	**70 t/ha**
Total dry matter produced (50%):	35 t/ha

Stalks	**51,1 t/ha**
Leaves	**11,5 t/ha**
Pannicles	**2,31 t/ha**
Grains	**5,46 t/ha**

As result of many agronomic experiments, the total harvested biomass gives the followed products:



1. **Grains: 5,4 tons/ha**
2. **Stalks: 51 tons/ha**
3. **Leaves and pannicles 13,8 t/ha**

Sugar Juice:

30 tons / ha

Dry biomass:

17,4 dry tons /ha

(50% moisture)

Stalks milling process produces about 30 tons of sugar and 21 tons of fresh bagasse.

Anaerobic digestion:
crushed juice and solid bagasse

Simple crushed sugar juice: 30 tons

- **DM = 16 % Total fresh**
- **Sugars (digestible)= 84%DM**
- **Ashes= 2.8%DM**
- **SV= 97,2%ST**

Biogas yield of carbohydrates fibre:	790 l/kgSV
Methane related yield:	50 %

Sugar Juice:	30,15 fresh tons
Solid Biomass:	4,82 tons
Organic Biomass:	4,69 tons
Biogas yield:	483 m3 Biogas/t SV
Toal biogas per ha:	2264,68 m3/ha

Bagasse + leaves & pannicles: 34,8 tons

- **DM= 50% total fresh**
- **Ashes = 9% DM**
- **SV =91%ST**
- **To be diluited with water**

Cubic meters of Biogas	550 m3 biogas/tSV
Methane related yield	60%

Raw Biomass:	34,601 tons fresh
Solid Biomass:	17,3005 tons ST
Organic Biomass:	15,743455 tons SV
Biogas Yield	550 m3 Biogas/t SV
Biogas production:	8658,90 m3 /ha

Anaerobic digestion:
crushed juice

Harvesting of Sweet sorghum without chopping on fields. (Utilization of new concept sweet sorghum harvester).

Cutting 30 cm lenght stalks. Separation of leaves. Trasportation to the reactor.

↓

Separation of liquid (ST 16%) from solids (50%) before digestion stage. Total fresh sugar juice recovered: 861 fresh tons

Mixed substrate with 483 m^3 biogas/t SV, with a 10% of total solid content ←

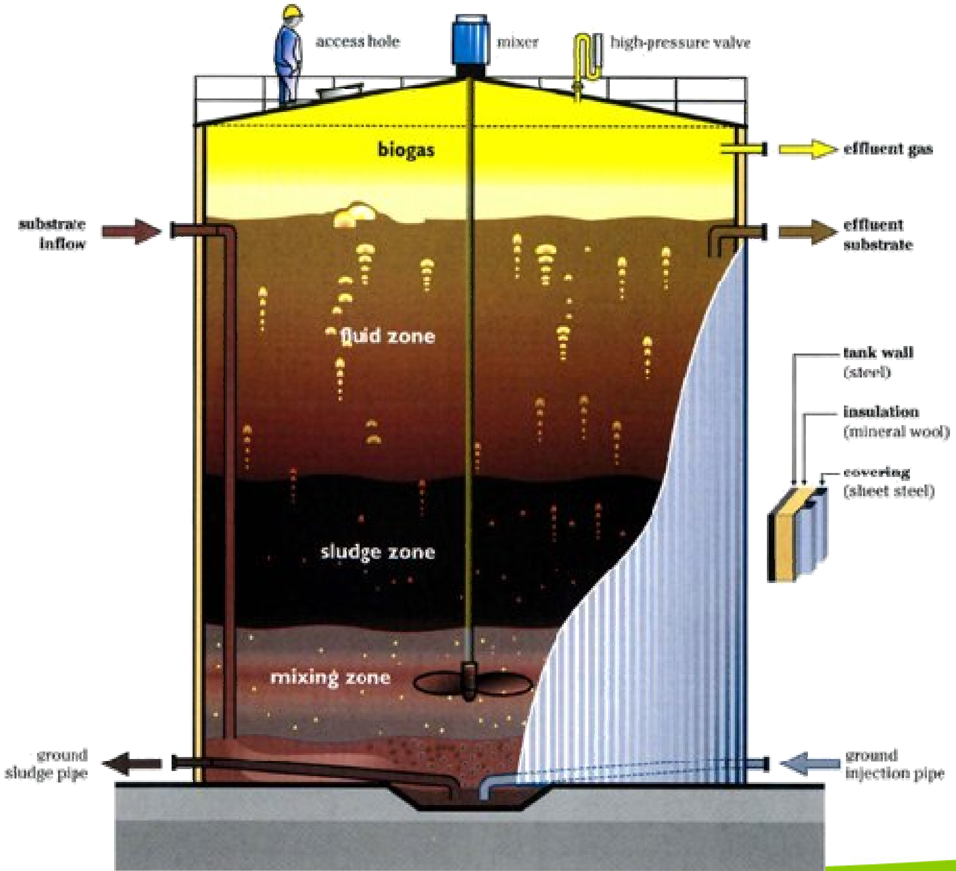
Water: 344 tons (40% of fresh sugar)
+
Slurry: 172 tons (20% of fresh sugar)

Total fresh biomass is 1378 m^3 of substrate with a solid content of about 10%.

Sugar Juice will be thus digested in termophilic reactor (one stage). Substrate will be recirculated to a second hydroliser in order to reduce time of retention.

Anaerobic digestion:
crushed juice

Sugar juice is digested in a liquid-one-stage reactor with pumps/propellers for circulating substrate.
The termophilic conditions (55°C) allow to complete the digestion in ~10 days



Total biogas production:
65,097 m^3/year

Total estimated Methane production:
32,548 m^3/year

Estimated theoretical energy production:
310,175 kWh

Estimated digester dimension:
Harvesting in 50 days.

280 m^3

Anaerobic digestion:
Solid bagasse (45% moisture)

Bagasse and solid biomass residues will be digested in two separated stages semi solid, thermophilic reactor (55%). The substrate will be prepared using the following materials to reduce solids and enhance digestion:

Total solid residues: 988,6 fresh tons/ha (45% DM)

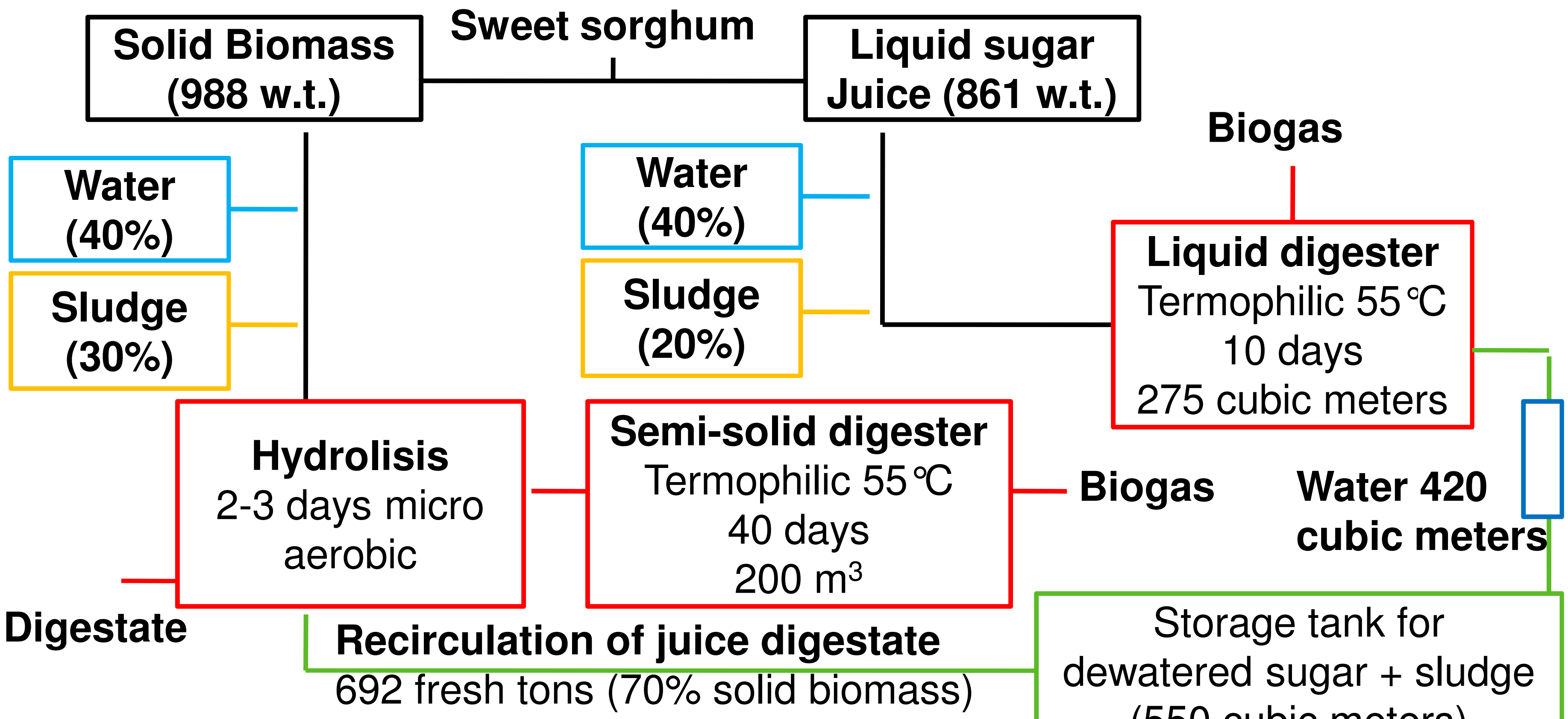
Total sludge: 296,5 (30% bagasse) fresh tons (0,04 % DM)

Total water: 395,5 (40% bagasse) cubic meter (tons)

Total digested Sugar Juice: 692 (70% bagasse) fresh tons (0,05% DM)

Fresh substrate is 2,371 fresh tons, with a total solid content of 20% and biogas potential of 550 m^3 biogas/t SV.

Anaerobic digestion:
Plant scheme



Possible solution evaluated to maximise efficiency and reduce sugar losses.
Reducing solid biomass retention time and increasing storage efficiency.

Anaerobic digestion:

Summary on anaerobic digetsion process

- The solid separated & pretreated bagasse, adjusted to 20 % dry biomass, pass through an aerobic upstream stage (2-3 days) where organics are partially hydrolyzed and ca. 2 % lost through respiration.
- After a two-day retention time, the pre-digested wastes are pumped through methanogenic reactors. The digestion lasts 35-40 days at 55 °C and 20 % TS. Biogas with 60% methane is produced.
- In parallel. Sugar juice digestion takes place in 10 days at 55°C producing biogas with 50% methane content.
- Two digesters, one hydrolysis tank and two post digestion tank (and one for slurry) must be provided.
- Biogas yield from bagasse is estimated to be around: 233,070 m^3/year
- Biogas yield from sugar juice is estimated to be around: 65,097 m^3/year
- Total Biogas estimation: 298,167 m^3/year

Energy production:
Power engines and digester dimension

Cost of Engine:

2000€/kWe

Total estimation:

350,000 €

Energy production estimation	Biogas (m3)	Methane (m3)	Hours operation	Electricity (kWhe)	Heat (kWht)	Engine Power (kWe)
Juice	65,097	32,548.5	1,200	101,031	183,118	88
Solid biomass	233,070	139,842	5,500	434,070	786,751	80

	Hydrolyser	Digester	Storage tank
Juice	/	280	460
Solid Biomass	270	270	300

Cost of digester:

200 €/m3

Total estimated:

400,000 €

Biofertilizer Production

Need of intensive dedicated mono-colture plantations

Need of high biomass yield & fast growing rate

Need of adequate flow of nutrients from the soil

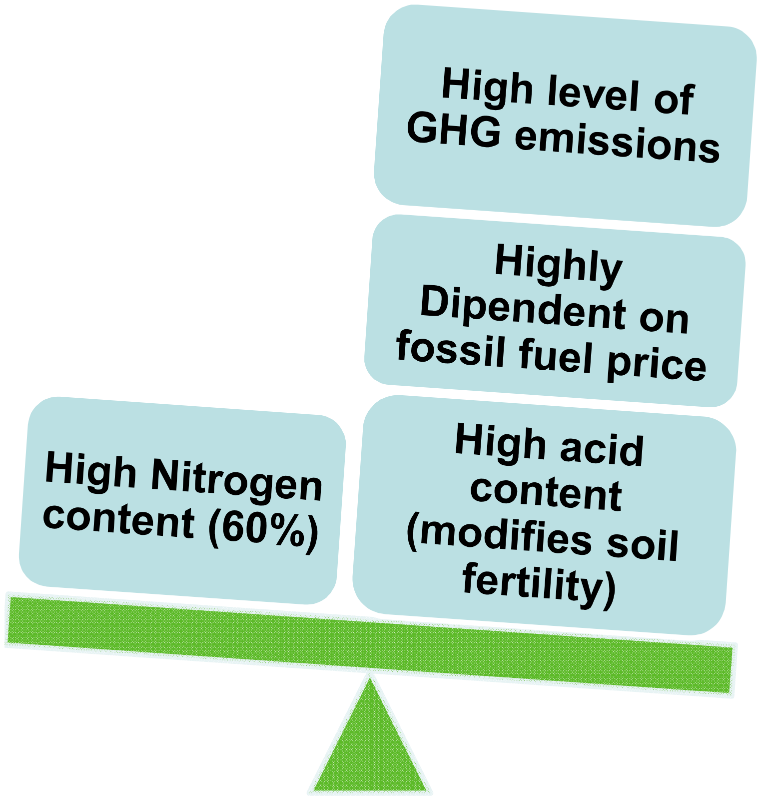
Economic and environmental sustainability of a biorefinery as well as of every agricultural activity, highly depend on FERTILIZERS!

SYNTHETIC FERTILIZERS: (Anydrhous Ammonia, Ammonium Nitrate , Urea)

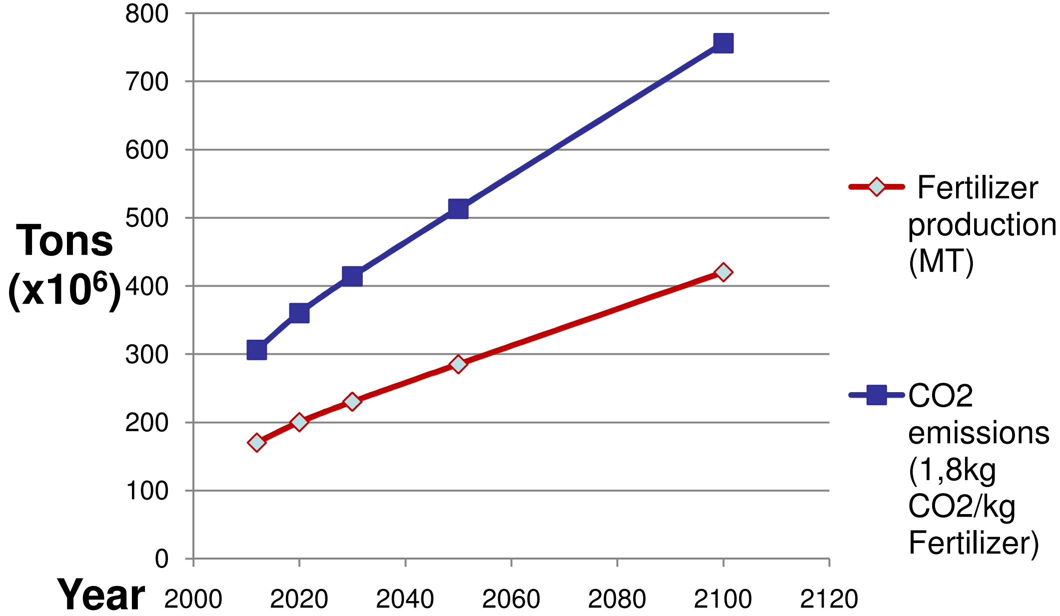
1. **Currently the most employed in the world due to their high amount of Nitrogen.**
2. **Long term forecast anticipate an increase from present value of 500 $/t to 1500$/t.**

Synthetic fertilizer. General overview

1. Currently the most employed in the world due to their high amount of Nitrogen.
2. Long term forecast anticipate an increase from present value of 500 $/t to 1500$/t.



Expected increase of CO_2 emission due to fertilizer production growth 2012-2050.



Total amount of CO_2 in 2012 : About 300 Million tons/year

Biofertilizer Potential

Biofertilizers can become a new valuable bioproduct to replace the Nitrogen sources made with fossils.

New systems based on bacteria and fungi inoculation highly increase biofertilizers nitrogen content.

The sustainability of biofertilizer derives mostly from the Phosphorus content. The production of fertilizer fom digestate include the recirculation of Phosphorus, which is one of the most importan nutrinet in nature.

It is thus very important to concentrate the attention on the increase of Nitrogen content iof substrate.

The technology identified is the following:

Integration of anaerobic digestion technology improving digestate nutrient content with inoculation of cellulolytic fungi (T. *harzianum*)and Azotobacter (*or Azospirillium*) for highest value biofertilizer production.

Biofertilizer Production

Substrate will be dried separating liquids with a screw conveyor in order to obtain a most suitable substrate of about 22% solid content.

The separated liquid part, with a remaining solid content of about 2% is evaporated recovering the nitrogen.

The inoculation of specific funghi and bacteria for 7 days is provided to increase fertilizer properties (next slide)

	Sugar Juice (m3)	Solid biomass (m3)
Total Fresh matter (without water)	947,3	1877,7
Total dry matter	37,892(0,04)	187,77(0,1)
tons N / fresh tons	1%	4%
Total N content	9,473	75,108
Total avaliable N in substrate	84,581	

Ammonia content is increased by anaerobic digestion and it is about 60-80% of total N

Biofertilizer Production

Total amount of potential Nitrogen available

Inoculation of bacteria will allow to increase the fertilizer content up till 5-6% Nitrogen. 84,581 kg of Nitrogen are estimated to be available just after digestion. The estimated potential Nitrogen content after treatment is of 108,000 kg/year.

Incoulation data source: Bayani M. Espiritu

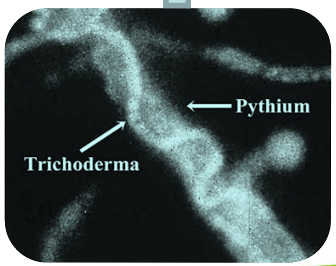
Inoculation of Azotobacter at 0.5 %, v/w

Solid liquid separation

~ 7 days retention

Biofertilizer

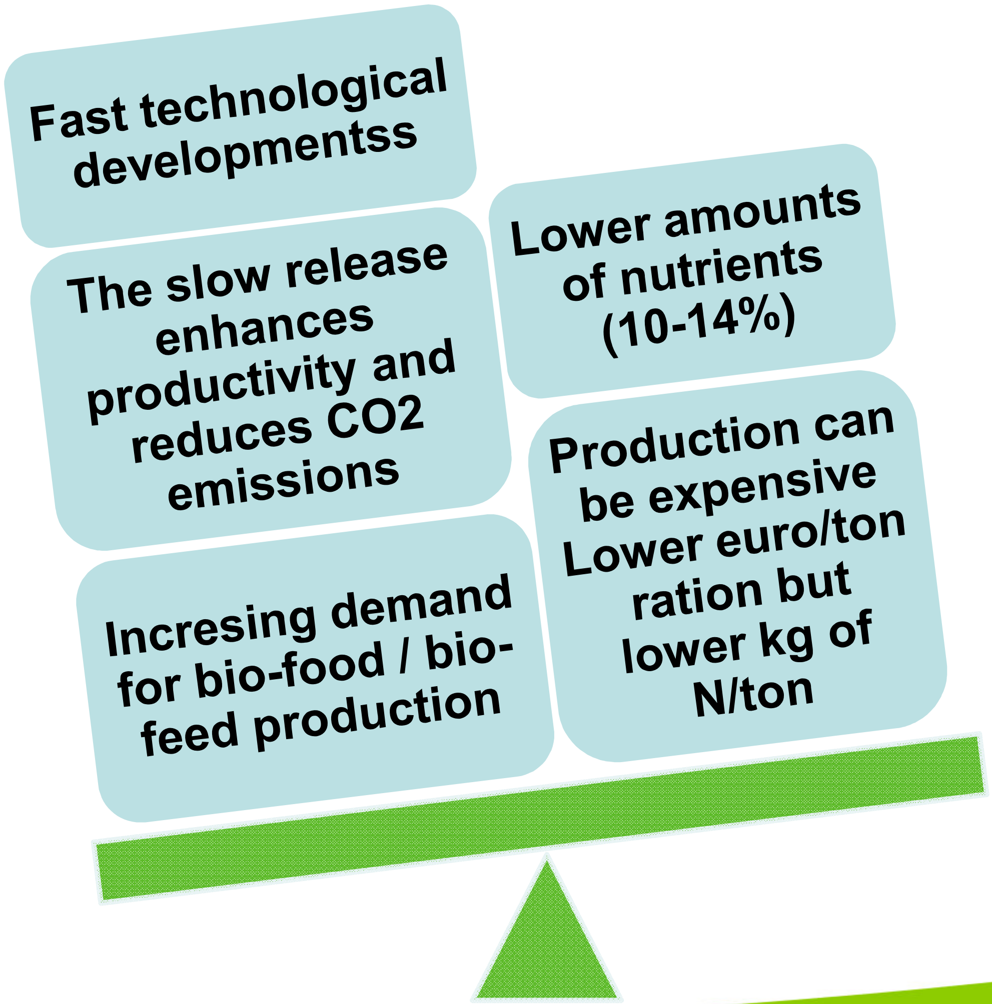
Inoculation of Trichoderma harzianum at 0.5%, v/w



Digestate:
NH_4 -N: 60-80% of total
PH: 8,2%
N content: -4%

Biofertilizer Production

Advantages and disadvantages



Biofertilizer Production

Solutions for the stabilization and trading of biofertilizer

❑A new pelletization machineries has been created by a consortium of industries and investors which is able to pelletize biomass with very high moisture content (trials with peat have been made)

❑This machine operates at about 80°C, this process avoids ammonia losses

Results:

❑Sweet sorghum requires about 150 kg of Nitrogen per year per hectare of cultivation.. Means about 3,750 kg per year re-used on fields.

❑The rest of nitrogen will be dried and sold as high value biofertilizer to the market. Challenges represented by governments directives.

❑EUBIA is working together with policy makers to change regulation concerning digestate utilization as biofertilizer in Europe

Thank you for your attention!

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