Biological Utilization of Geothermal Gas.

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Background

- **2004**: Project starts at Prokaria ehf.:
- Cultivation of bacteria on H\(_2\) & H\(_2\)S on geothermal gas for the production of industrial enzymes.

Energy and carbon from the gas utilized for growth

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\begin{align*}
\text{H}_2 + \text{O}_2 & \rightarrow \text{H}_2\text{O} \\
\text{H}_2\text{S} + \text{O}_2 & \rightarrow \text{S}_0 \rightarrow \text{SO}_4 \\
\text{CO}_2 + \text{H}_2\text{O} & \rightarrow (\text{CHO})_n \\
\text{biomass}
\end{align*}
\]
The sulfur cycle
**H$_2$S** oxidation

\[
egin{align*}
\text{HS}^- & \rightarrow \text{S} \rightarrow \text{SO}_3^{2-} \rightarrow \text{SO}_4^{2-} \\
\text{S}_2\text{SO}_3^{2-} & \rightarrow \text{APS}
\end{align*}
\]

Sulfur deposits in a microbial mat

**Sulfur sheath**
Energy biotechnology: Single-cell-protein (protein meal) from $H_2$ & $H_2S$ and $CO_2$ for animal feed.
Laboratory at Nesjavellir

- **2007**: Cooperation with OR
- Laboratory established at Nesjavellir.
- Microbes cultivated on geothermal gasses directly from the power plant
- Aim: remove $\text{H}_2\text{S}$, and produce protein & sulfur
The laboratory at Nesjavellir

Cultivation of microbes on gasses directly from a geothermal powerplant
Isolation of microbial strains

Enrichment experiments

16S rRNA analysis:
Thiobacillus sp.
Thiomonas sp.
Reactions:

Step 1: \( \text{H}_2\text{S} + \text{O}_2 \rightarrow \text{S}^0 \)

(Step 2: \( \text{S}^0 + \text{O}_2 \rightarrow \text{SO}_4 \))

Suklfur as product metabolism
“Proof-of-principle”


Main results from Nesjavellir:

- Good microbial growth on geothermal gasses
- The microbes utilize all the H$_2$S from the gas as an energy source
- Approx. 99% pure elemental sulfur precipitates from the cultures
- The biomass formed contains >80% protein

Main problems: Sensors and control equipment
Pilot scale

- **2009**: Design and construction of a pilot plant.

If all the gas is utilized:

- 450 tons of $\text{H}_2$
- 2,500 tons of protein
- Binds 4,500 tons of $\text{CO}_2$ (of a total of 25,000 tons)
- Removes ca 7,000 tons of $\text{H}_2\text{S}$
Pilot factory at the Power plant in Hellisheiði

- **2010**: 2000 L pilot plant will be ready in the end of June 2010 at Hellisheiði.
- The plant will be run for 12 months
- Will “clean” 1% of the gas and produce protein and sulfur in tons scale
- Experiments started:
  - Protein: fish feed
  - Sulfur: fertilizer (“organic” sulfur)
Example: Bio-protein protein-meal has been produced from microbes

Known source
Known production method
Lab products have been tested
Content known

Similar factory (Norway)
Methane utilizing
Large scale production
Permitted in EU
Markets in place & growing
Experiments using the sulfur in fertilizer

- Experiments using sulfur in fertilizer started in the greenhouse of Landgræðslan í Gunnarsholti started this spring
- Experiments outside will start with increasing production (when the pilot plant is up and running)
Feed experiments

- Microbial protein in feed, experiments will also start when larger quantities can be produced.
- Tilapia
- Cooperation with Matís and the company Arctic Tilapia, in Keldnaholt & in cooperation with the Norwegian feed company Mowi (Salmon)
Tilraunastöðin á Hellisheiði
Cooperation

- **Prokatín**: Dr. Arnþór Ævarsson, Dr Jakob K. Kristjánsson, Guðný Inga Ófeigsdóttir, MS nemi við HÍ
- **Háskóli Íslands: & Matís**: Dr. Guðmundur Óli Hreggviðsson
- **Matís & Arctic Tilapia ehf**: Dr. Ragnar Jóhannsson (líka)
- **Mannvit**: Ásgeir Ívarsson efnaverkfræðingur ofl.
- **Háskólinn á Akureyri**: Dr. Jóhann Örlygsson og stúdentar
- **Háskóli Íslands**: Dr. Andri Stefánsson jarðefnafræðingur
- **Nýsköpunarmiðstöð Íslands**: Hermann Þórðarson, efnafræðingur
- **Landgræðslan**: Dr. Guðmundur Halldórsson, rannsóknastjóri
Gott samstarf og mikil tækifæri