

# The Cutting Edge of Industry: Applications of Genetic Engineering

By: **Mahdi Morshedi Yekta** and **Fatemeh Faryadras**

# INTRODUCTION

# What is Genetic Engineering?

- Genetic engineering, also known as **recombinant DNA technology**, manipulates the genetic makeup of an organism.
- Scientists can insert, remove, or change specific genes to create organisms with desired traits.
- This has numerous applications in medicine, agriculture, and industry.



# Tools and Techniques in Genetic Engineering

- **CRISPR-Cas9 Technology:** The revolutionary CRISPR-Cas9 system enables precise gene editing, allowing scientists to **modify DNA** sequences with unprecedented **accuracy** and **efficiency**.
- **Gene Insertion and Silencing:** Techniques such as gene insertion and gene silencing play a pivotal role in altering the expression of specific traits, providing opportunities for tailored genetic modifications.
- **Genetic Modification in Microorganisms:** Genetic engineering is extensively utilized in microorganisms to enhance their capabilities for industrial processes, including the production of **biofuels** and **biodegradable** products.

# Engineered Products for Human Health

# Pharmaceutical Industry

Genetic engineering has been used to **mass-produce various drugs**, including insulin, human growth hormones, follistim (for treating infertility), human albumin, monoclonal antibodies, antihemophilic factors, vaccines, and many other drugs.



# Cell factories for insulin production

Review | [Open access](#) | Published: 02 October 2014

Volume 13, article number 141, (2014) [Cite this article](#)



The rapid increase in the number of diabetic patients globally and exploration of alternate insulin delivery methods such as inhalation or oral route that rely on higher doses, is bound to escalate the demand for recombinant insulin in near future. **Current manufacturing technologies would be unable to meet the growing demand of affordable insulin due to limitation in production capacity and high production cost.**

Manufacturing of therapeutic recombinant proteins require an appropriate host organism with efficient machinery for posttranslational modifications and protein refolding. Recombinant human insulin has been produced predominantly using ***E. coli* and *Saccharomyces cerevisiae*** for therapeutic use in human. We would focus in this review, on various approaches that can be exploited to increase the production of a biologically active insulin and its analogues in *E. coli* and yeast. **Transgenic plants** are also very attractive expression system, which can be exploited to produce insulin in **large quantities** for therapeutic use in human. Plant-based expression system hold tremendous potential for **high-capacity production** of insulin in **very cost-effective** manner. Very high level of expression of biologically active proinsulin in **seeds or leaves with long-term stability, offers a low-cost** technology for both injectable as well as oral delivery of proinsulin.

# FOLLISTIM

Generic Name: follitropin beta

Brand Name: Follistim AQ

Drug Class: [Ovulation Stimulators](#), [Gonadotropins](#)

Medical Editor: John P. Cunha, DO, FACOEP Last updated on RxList: 7/5/2022

[Related Drugs](#)



[Follistim AQ User Reviews](#)

## Drug Summary

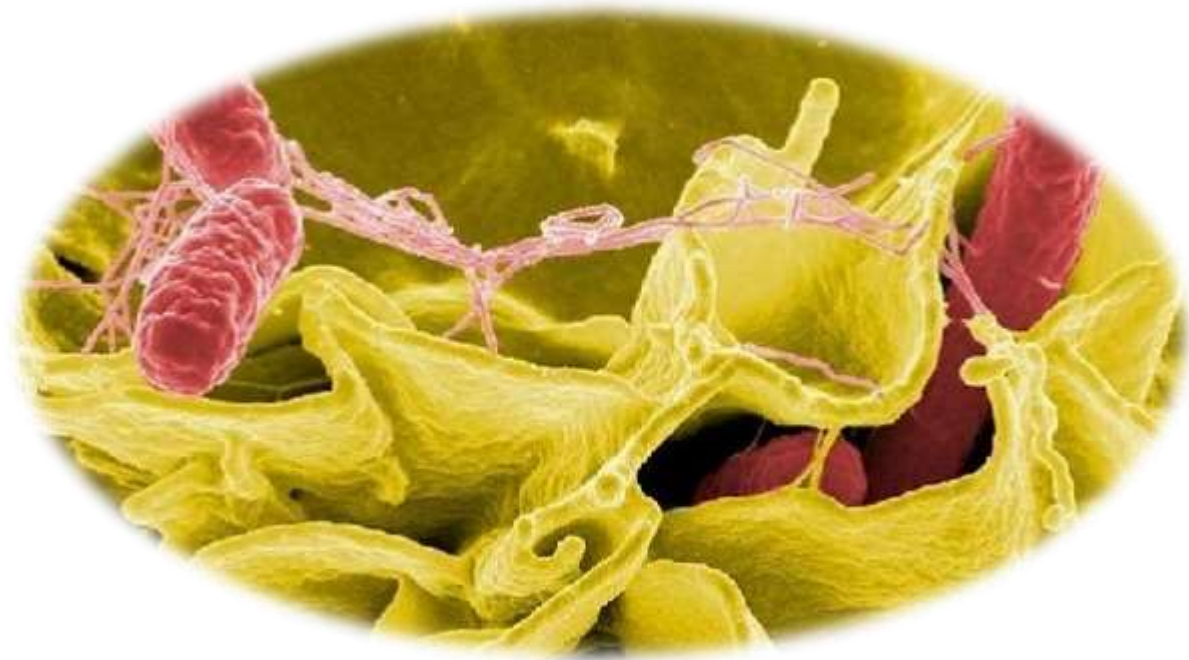
### What Is Follistim?

Follistim AQ (follitropin beta injection) contains follicle stimulating hormone (FSH), a naturally occurring hormone and is used to stimulate a follicle (egg) to develop and mature. Follistim AQ is used when a woman desires pregnancy and her ovaries can produce a follicle but hormonal stimulation is not sufficient to make the follicle mature. Follistim AQ is also used to stimulate the development of multiple eggs for [in vitro fertilization](#), and can be used by men to increase the production of [sperm](#).

# Impact on Healthcare Industry

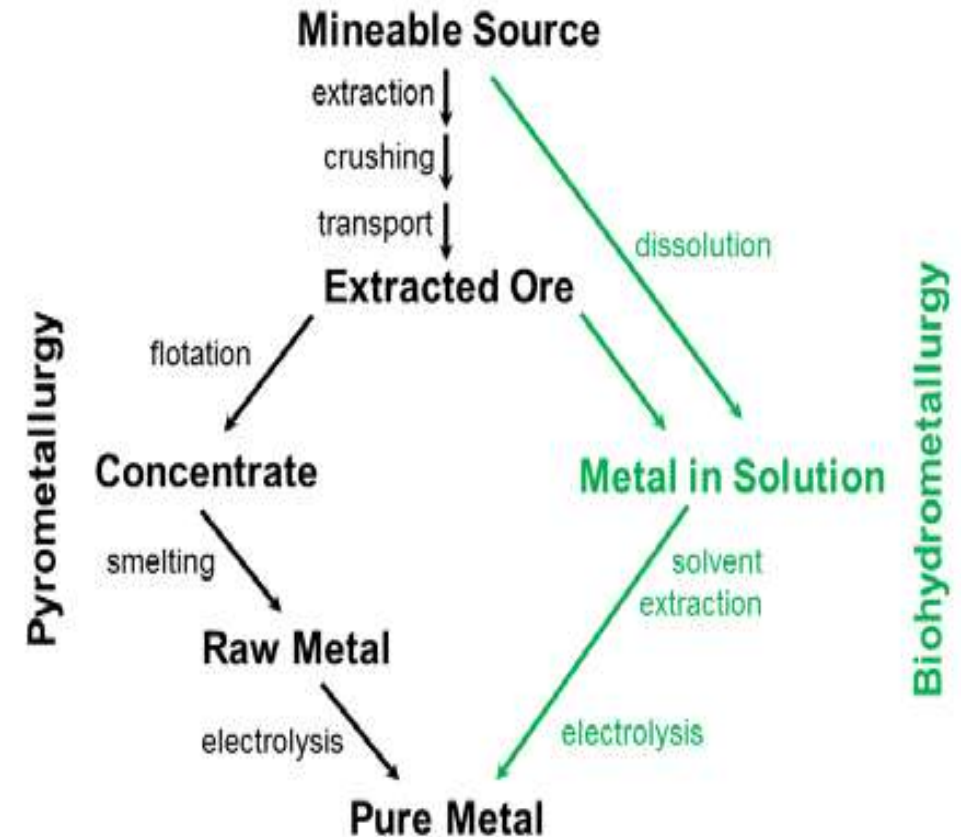
- **Advancements in Medical Science:** Genetic engineering has led to significant advancements in medical science, offering new approaches to treating diseases, improving patient outcomes, and shaping the future of healthcare.
- **Potential for Personalized Medicine:** The use of genetically **engineered products** opens the door to personalized medicine, with tailored treatments based on **individual genetic profiles**, revolutionizing healthcare practices.

# Bio-Hydrometallurgy: Harnessing Microbes for Metal Magic



# What is Bio-Hydrometallurgy?

- Bio-hydrometallurgy leverages microbial activity to dissolve metals from their ores.
- Microbes like Fungi and bacteria(**archaea**) play a crucial role in this process.
- They break down minerals, releasing the target metals into a solution.



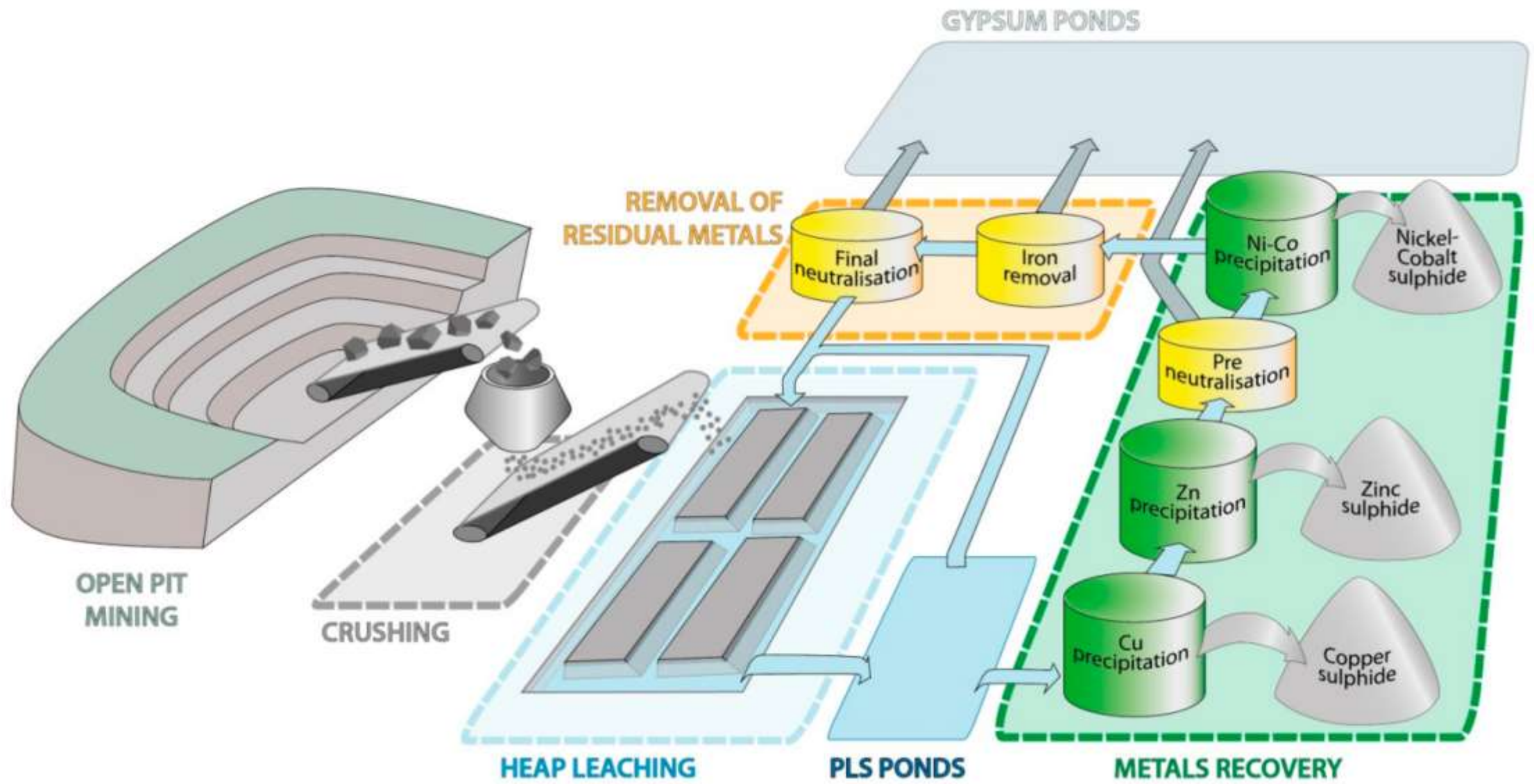
# Applications in Metal Mining

**Bio-heap leaching:** Crushed ore is piled onto heaps and inoculated with microbes.

Microbes gradually dissolve target metals like copper and gold from the ore.

The metal-laden solution is then collected for further processing.

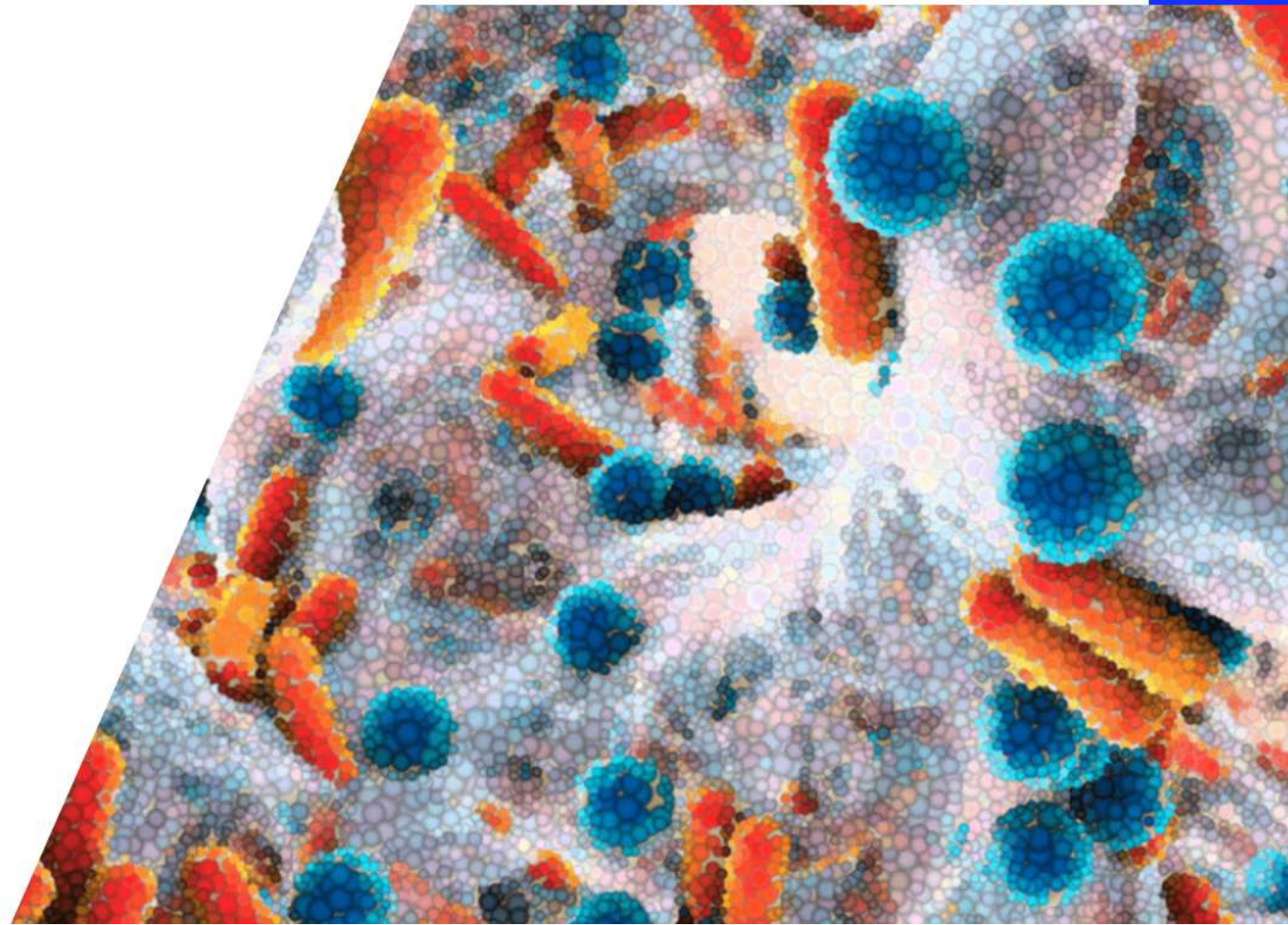




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# Biohydrometallurgy. The recycling of the future

Eco-innovation



# Bio-Hydrometallurgy for E-Waste Recycling

- E-waste contains valuable metals like gold, silver, and palladium.
- Bio-hydrometallurgy offers a cleaner alternative for e-waste recycling.
- It breaks down e-waste components, allowing for metal recovery.



Bioresource Technology Reports

Volume 11, September 2020, 100526

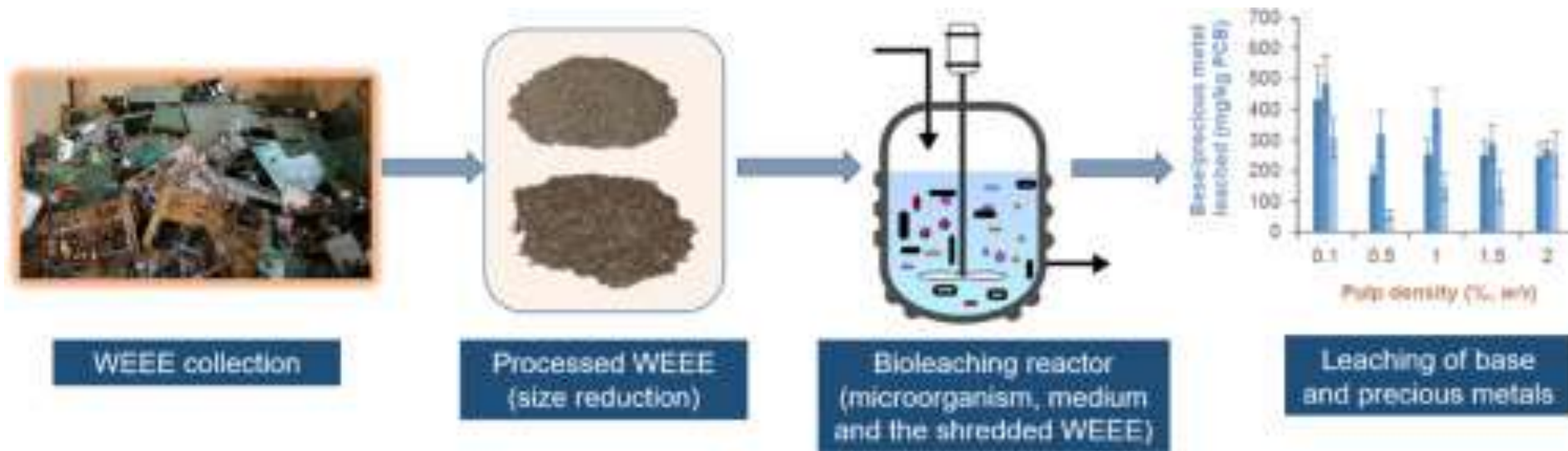


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**Biohydrometallurgical processes for the recovery of precious and base metals from waste electrical and electronic equipments: Current trends and perspectives**

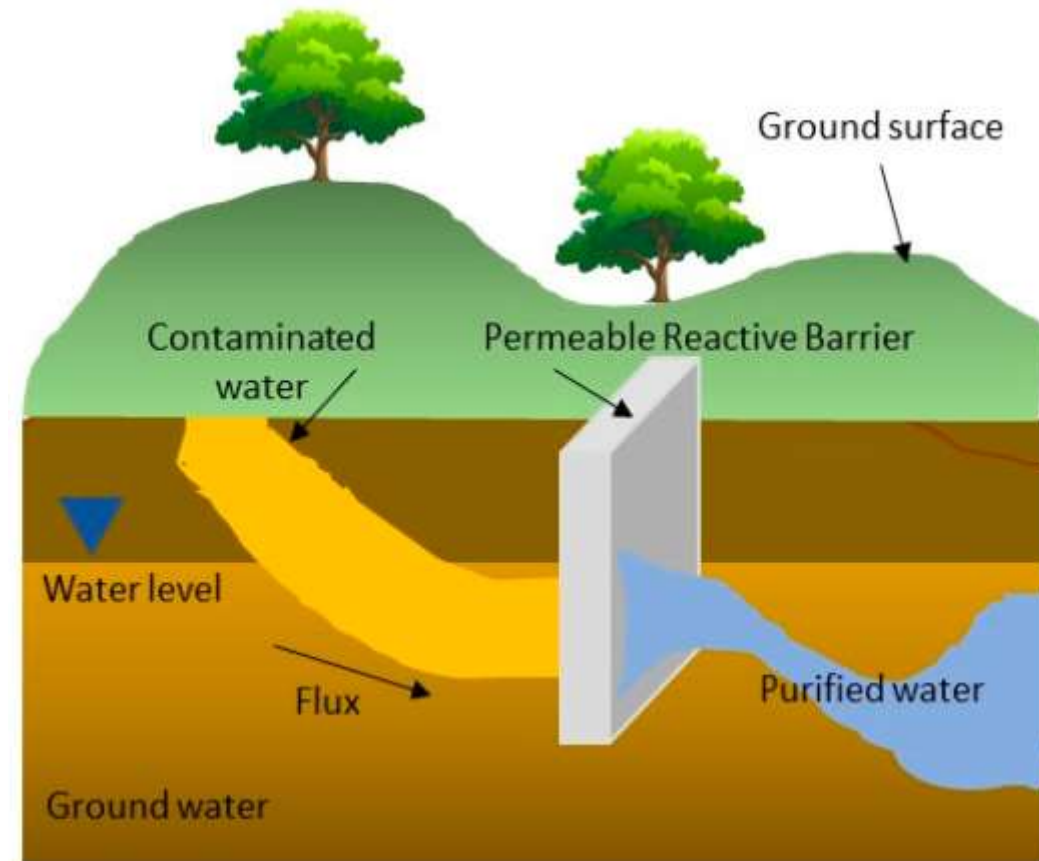
## Autotrophic microbial bioleaching

Autotrophic prokaryotes involved in acidolysis and redoxolysis mechanisms include **acidophilic chemolithoautotrophic microbes** (*Acidithiobacillus ferrooxidans*, *Leptospirillum ferrooxidans*, *Acidithiobacillus thiooxidans* and *Sulfobacillus thermosulfidooxidans*). In this context, the term prokaryote is used since bacteria as well as archaea were found to make up microbial communities with the ability for metal solubilisation. These prokaryotes use inorganic carbon as a carbon source and electrons...



# Bioremediation: Cleaning Up with Microbes

- bio-hydrometallurgy can be used for bioremediation of metal-contaminated sites.
- Microbes help to detoxify the soil by immobilizing or transforming the metals.
- Contaminated soil and water often pose a significant threat due to the presence of **heavy metals**.
- This reduces the risk of metal leaching into the environment.



# Bioremediation of environmental wastes: the role of microorganisms

Modupe S. Ayilara<sup>1,2,3</sup>Olubukola O. Babalola<sup>1\*</sup>

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<i>Phanerochaete chrysosporium</i>	N-heterocyclic explosives, benzene, xylene, ethylbenzene, toluene and organochlorines
<i>Phanerochaete chrysosporium</i>	4,4 dibromodiphenyl ether
<i>Saccharomyces cerevisiae</i>	Arsenic
<i>Aspergillus</i> sp.	Arsenic
<i>Coprinus comatus</i>	4-Hydroxy-3,5- dichlorobiphenyl
<i>Aspergillus</i> sp. and <i>Penicillium</i> sp.	Aliphatic hydrocarbons, polycyclic aromatic hydrocarbons and chlorophenols
<i>Aspergillus</i> sp.	N-hexadecane
<i>Phomopsis liquidambari</i>	Phenanthrene
<i>Ganoderma lucidum</i>	Pyrene
<i>Trichoderma</i> sp., <i>Penicillium</i> sp. and <i>Aspergillus</i> sp.	Cobalt and copper

<i>C. reinhardtii</i> , <i>Ulothrix tenuissima</i> and <i>Spirulina</i> sp.	Chromium
<i>Ralstonia</i> sp., <i>Microbacterium</i> sp., <i>Pseudomonas</i> sp. and <i>Acinetobacter</i> sp.,	Aromatic hydrocarbons
<i>Aerococcus</i> sp., and <i>Rhodopseudomonas palustris</i>	Cadmium, lead and chromium
<i>P. aeruginosa</i> , <i>Corynebacterium propinquum</i> , <i>Alcaligenes odorans</i> and <i>B. subtilis</i>	Phenol
<i>K. oxytoca</i> , <i>B. firmus</i> , <i>B. macerans</i> , and <i>Staphylococcus aureus</i>	Vat dyes
<i>Chlorella</i> sp. and <i>Spirulina</i> sp.	Lead, nickel and dichromate
<i>Saccharomyces cerevisiae</i> and <i>Cunninghamella elegans</i>	Heavy metals and mercury
<i>Bacillus licheniformis</i>	Dyes
<i>Bacillus subtilis</i> and <i>Pseudomonas fluorescense</i>	Iron and zinc
<i>Pseudomonas</i> sp., <i>Bacillus</i> sp., <i>Escherichia</i> sp., <i>Shewanella</i> sp., <i>Enterobacter</i> sp. and <i>Thermus</i> sp.	Chromium

# Advantages of Bio-Hydrometallurgy

- **Environmentally friendly:** Uses microbes instead of harsh chemicals.
- **Energy efficient:** Operates at lower temperatures compared to traditional methods.
- **Cost-effective:** Can be viable for processing low-grade ores.
- **Applicable to various metals:** Can recover a wide range of metals from different sources.

# Biodegradable Plastics: A Sustainable Solution for Industry



# What are Biodegradable Plastics?

- Made from renewable resources like **corn starch**, **cellulose**, or bacteria.
- Degrade by Bacteria and fungi into harmless components like water, CO<sub>2</sub>, and biomass.
- Offer a solution to traditional plastic pollution issues.

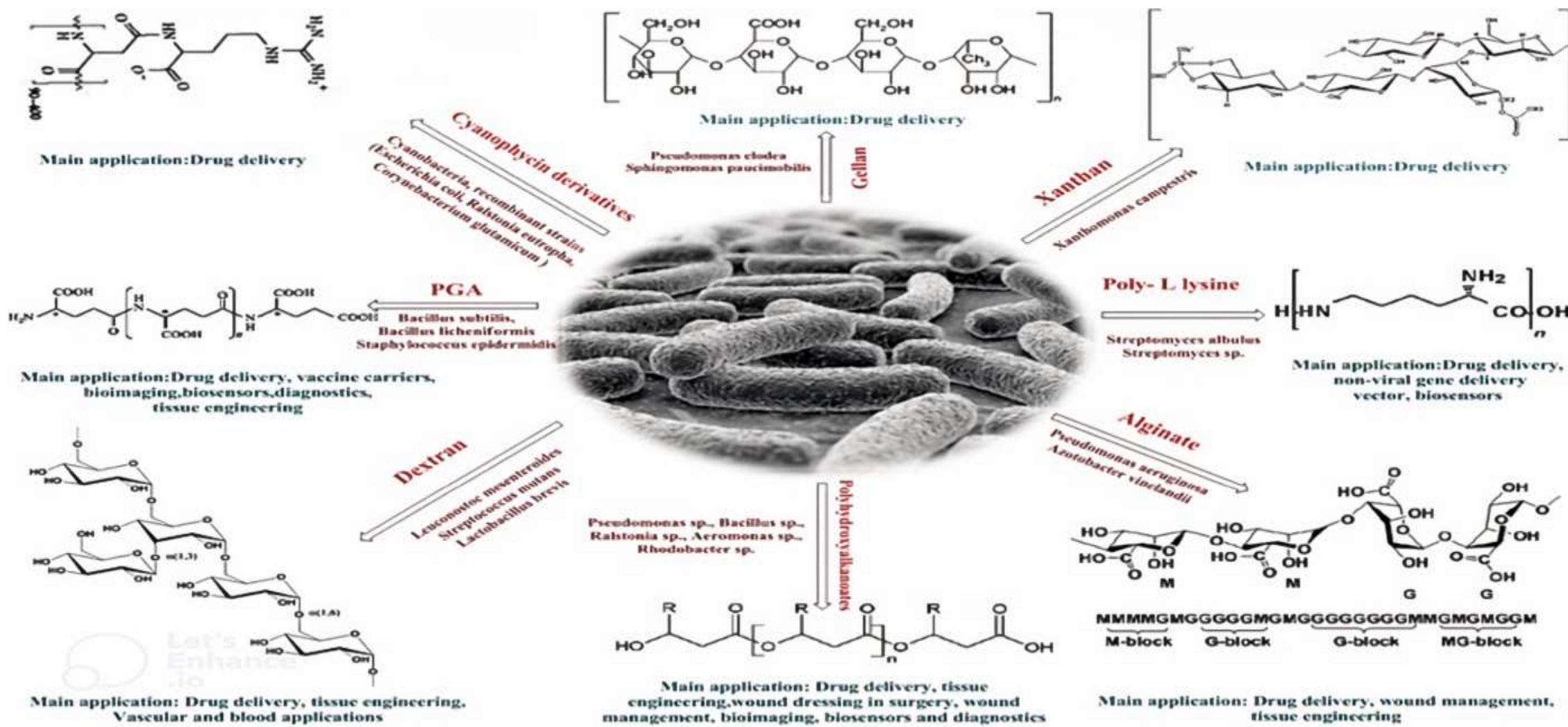


## Bacteria for Bioplastics: Progress, Applications, and Challenges

Felipe Martins de Souza<sup>†</sup> and Ram K. Gupta<sup>‡\*††</sup>

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Ref: <https://doi.org/10.1021%2Facsomega.3c07372>



# Applications

- **Applications in Packaging**
- **Food packaging:** Trays, bags, wraps for fruits, vegetables, and baked goods.
- **Beverage containers:** Bottles for water, juices, and other drinks.
- **Carrier bags:** Shopping bags and takeaway containers for restaurants.
- **Applications in Agriculture & Horticulture**
- **Seedling pots:** Biodegradable pots for nurseries and greenhouses.
- **Crop covers:** Protect crops from frost, insects, and harsh weather.
- **Fashion industry:** Clothes made from biodegradable fabrics like PLA.
- **Medical field:** Sutures, surgical tools, and disposable medical equipment.
- **Electronics industry:** Biodegradable casings for electronic devices.

# **The Oil Industry: Powering Modern Industry**

# The Three Streams of Oil & Gas

1. **Upstream:** Finding and extracting oil & gas
2. **Midstream:** Transporting oil & gas
3. **Downstream:** Refining oil & gas into products



# Upstream: Locating the Black Gold

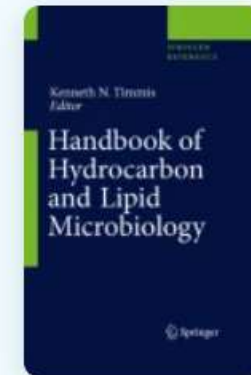
- Exploration: Seismic surveys & geological studies
- Drilling: Different drilling techniques for various conditions

[Home](#) > [Handbook of Hydrocarbon and Lipid Microbiology](#) > Reference work entry

## Using Microorganisms as Prospecting Agents in Oil and Gas Exploration

Reference work entry

pp 2711–2725 | [Cite this reference work entry](#)



**Handbook of Hydrocarbon and Lipid  
Microbiology**

# Abstract:

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Migration of hydrocarbons from subsurface petroleum reservoirs to surface environments has led to the use of hydrocarbon seep detection as an exploration tool in the oil and gas industry. Here we discuss microbiological features of hydrocarbon seeps and propose ways to take advantage of seep-associated microorganisms as useful pathfinders to aid petroleum exploration strategies. Environments where hydrocarbons seep to the surface are colonized by aerobic and anaerobic hydrocarbon-utilizing microorganisms. Detecting increasing densities of these organisms can indicate the presence of seeps and hence subsurface hydrocarbon reservoirs. Anaerobic microorganisms native to petroleum reservoir habitats may be transported upwards with seeping hydrocarbon fluids to surface environments. These “hitchhiker cells” may represent alternative and conspicuous targets for use in hydrocarbon seep prospecting. The development of either approach depends on a thorough understanding of the microbiology of surface hydrocarbon seeps and deep petroleum reservoirs. Both strategies also require quantitative detection assays that are well-constrained for carefully chosen indicator organisms. Integrating microbiological data with other prospecting approaches will offer additional and independent information to strengthen oil and gas exploration strategies.

## Ref:

[https://link.springer.com/reference/workentry/10.1007/978-3-540-77587-4\\_201](https://link.springer.com/reference/workentry/10.1007/978-3-540-77587-4_201)

# Downstream: The Refinery Hub

- Crude oil refining: Separation into various products
- Fractional distillation: The core separation process

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## Bioengineered

[Bioengineered](#). 2013 Sep 1; 4(5): 292–304.

Published online 2012 Dec 6. doi: [10.4161/bioe.23114](https://doi.org/10.4161/bioe.23114)

PMCID: PMC3813529

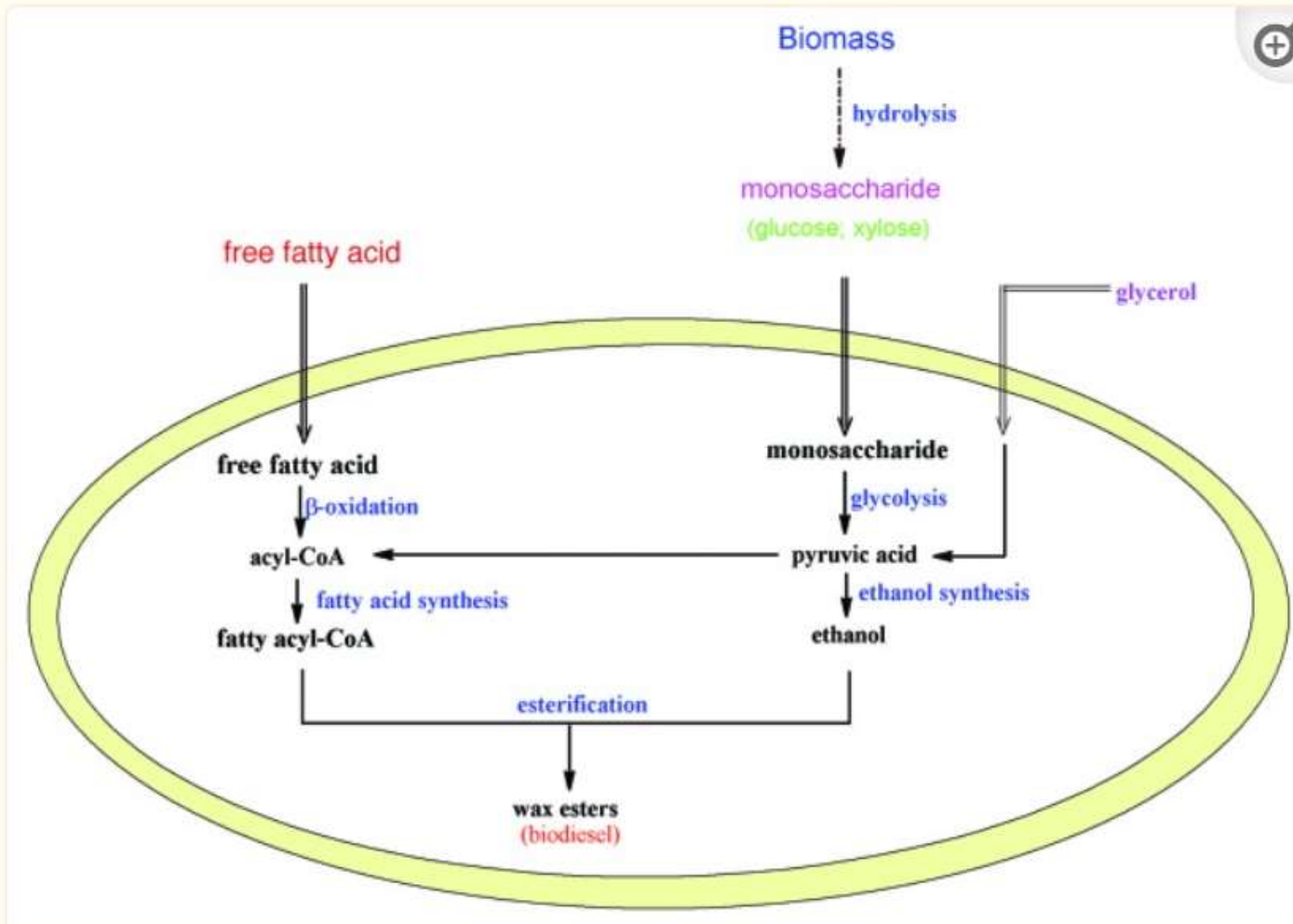
PMID: [23222170](https://pubmed.ncbi.nlm.nih.gov/23222170/)

Genetic engineering of microorganisms for biodiesel production

[Hui Lin](#),<sup>1</sup> [Qun Wang](#),<sup>1</sup> [Qi Shen](#),<sup>2</sup> [Jumei Zhan](#),<sup>2</sup> and [Yuhua Zhao](#)<sup>1,\*</sup>

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Biodiesel, as one type of renewable energy, is an ideal substitute for petroleum-based diesel fuel and is usually made from triacylglycerides by transesterification with alcohols. Biodiesel production based on microbial fermentation aiming to establish more efficient, less-cost and sustainable biodiesel production strategies is under current investigation by various start-up biotechnology companies and research centers. Genetic engineering plays a key role in the transformation of microbes into the desired cell factories with high efficiency of biodiesel production. Here, we present an overview of principal microorganisms used in the microbial biodiesel production and recent advances in metabolic engineering for the modification required. Overexpression or deletion of the related enzymes for de novo synthesis of biodiesel is highlighted with relevant examples.



**Figure 1.** Representative pathways in microorganisms could be engineered for de novo biosynthetic process of biodiesel (e.g., fatty acid ethyl esters).

## $\beta$ -Glucosidase (BGL)

BGL1	<i>Saccharomycopsis fibuligera</i>	<i>S.cerevisiae</i> <sup>149</sup>
BGL1	<i>Aspergillus aculeatus</i>	<i>S. cerevisiae</i> , <sup>148</sup> <i>K. marxianus</i> , <sup>147</sup> <i>T. reesei</i> , <sup>159</sup> <i>Issatchenkia orientalis</i> <sup>160</sup>
BGL1	<i>A. oryzae</i>	<i>S.cerevisiae</i> <sup>125</sup>
BGL	<i>Penicillium brasilianum</i>	<i>A. oryzae</i> <sup>161</sup>

## endoglucanase (EG)

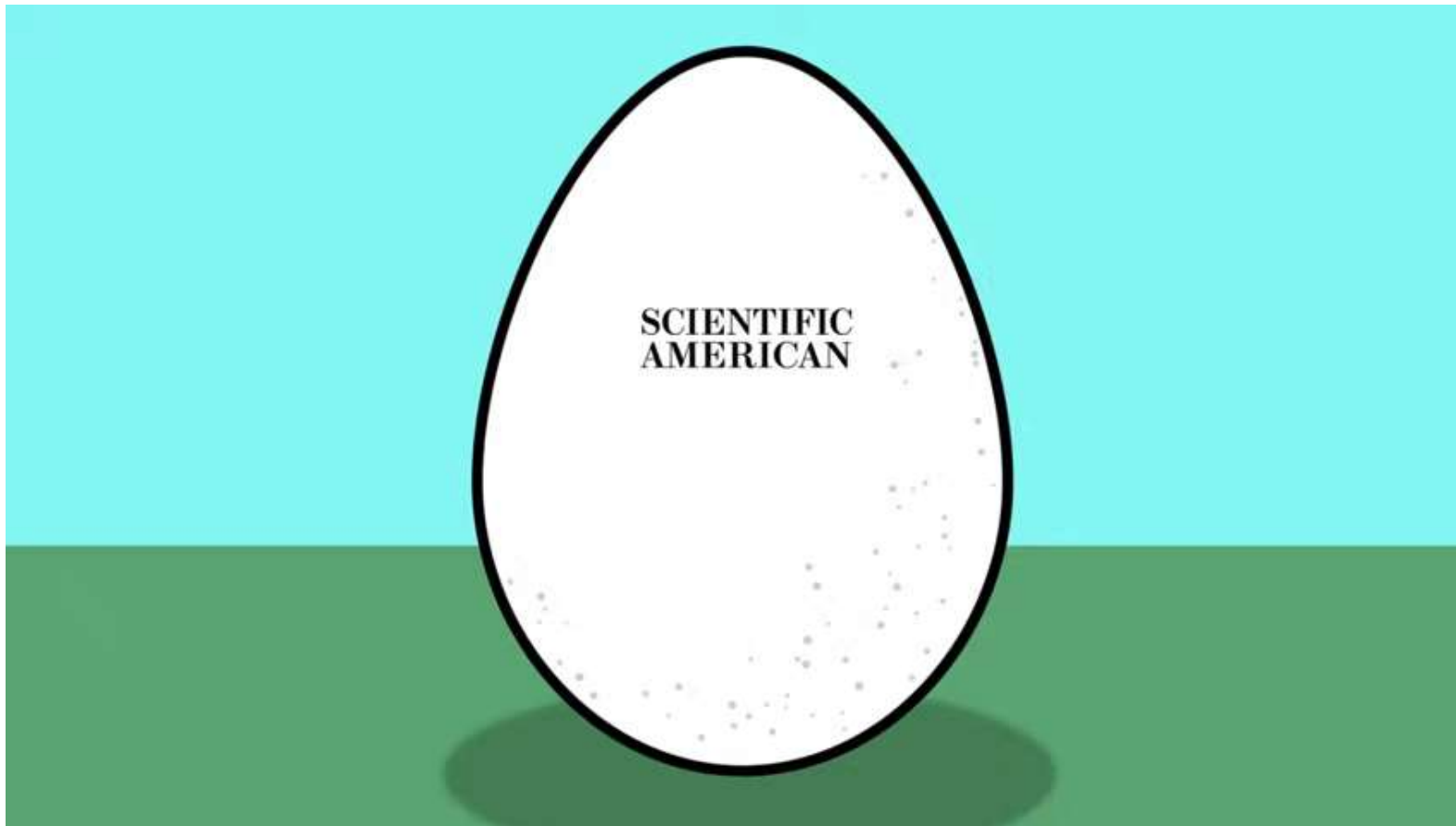
EGI	<i>Trichoderma reesei</i>	<i>Saccharomyces cerevisiae</i> , <sup>143</sup> <i>Yarrowia lipolytica</i> , <sup>144</sup> <i>Ashbya gossypii</i> <sup>145</sup>
EGII	<i>T. reesei</i>	<i>S. cerevisiae</i> , <sup>124</sup> <i>Y. lipolytica</i> , <sup>146</sup> <i>Pichia pastoris</i> , <sup>147</sup> <i>Kluyveromyces marxianus</i> <sup>148</sup>
EG(CelE)	<i>Clostridium thermocellum</i>	<i>S. cerevisiae</i> , <sup>149</sup> <i>Escherichia coli</i> <sup>150</sup>
EG (CelA)	<i>C. thermocellum</i>	<i>Bacillus subtilis</i> , <sup>151</sup> <i>Lactobacillus gasseri</i> , <sup>152</sup> <i>Lactobacillus johnsoni</i> <sup>152</sup>
EG (Cel9A)	<i>Thermobifida fusca</i>	<i>S. cerevisiae</i> <sup>153</sup>
EGIII	<i>Trichoderma harzianum</i>	<i>P. pastoris</i> <sup>154</sup>

# Biotechnology in the Oil Industry

- Bioremediation: Cleaning up oil spills
- Enhanced oil recovery: Using microbes to extract more oil

**Ref:**

[https://www.youtube.com/watch?v=a\\_HWIFzgQiM&ab\\_channel=ScientificAmerican](https://www.youtube.com/watch?v=a_HWIFzgQiM&ab_channel=ScientificAmerican)



**Ref:**

<https://www.nature.com/articles/news.2011.191>

# Protein & Enzyme Engineering

# Protein Engineering for Industrial Enzyme

- **Enhancing Enzyme Activity:** Protein engineering has enabled the **enhancement of industrial enzymes** by making them more stable and active, through the introduction of **disulfide bonds for stability** and **modification of active sites for increased biocatalytic ability**.
- **Application in Various Industries:** Genetically engineered enzymes find applications in the food industry, animal feed industry, textile manufacture, and detergent production, offering benefits such as reduced use of chemicals and environmental impact.

# Advantages of Genetically Engineered Enzymes

- **Pure Enzyme Production:** Genetically engineered enzymes offer the advantage of producing pure enzymes, reducing the use of chemicals in the production process, and minimizing environmental impact.
- **Reduced Energy Consumption:** The use of genetically engineered enzymes in various industries, such as baking, starch manufacture, fruit juices, and detergents, leads to reduced energy consumption and waste, contributing to sustainable practices.
- **Specificity and Bulk Production:** Genetically engineered enzymes are highly specific for their target, can be produced in bulk, and have the ability to increase the shelf life of final products, thus reducing food loss.

# Environmental and Economic Impact

- **Reduction of Phosphorus Release:** Genetically engineered enzymes contribute to the reduction of phosphorus release in the environment, particularly in the animal feed industry, promoting sustainable practices.
- **Economic Benefits:** The use of genetically engineered enzymes provides economic benefits through reduced energy consumption, waste reduction, and improved product quality in various industries.

# Examples of Genetically Engineered Enzymes

- **Chymosin for Cheese Production:** Genetically engineered chymosin used in cheese production offers predictability, purity, and is preferred by vegetarians and certain religious organizations.

## **Development of Biotechnological Techniques for the Processing and Use of Bovine Chymosin on an Industrial Scale.**

<sup>1</sup>Paulina Gonçalves, <sup>2</sup>Paz García, <sup>3</sup>Gloria Fernandez-Lorente, <sup>4</sup>Miguel Ladero and <sup>3,5</sup>Benevides Pessela

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<sup>2</sup>Universidad Autónoma de Madrid (UAM). Espanha.

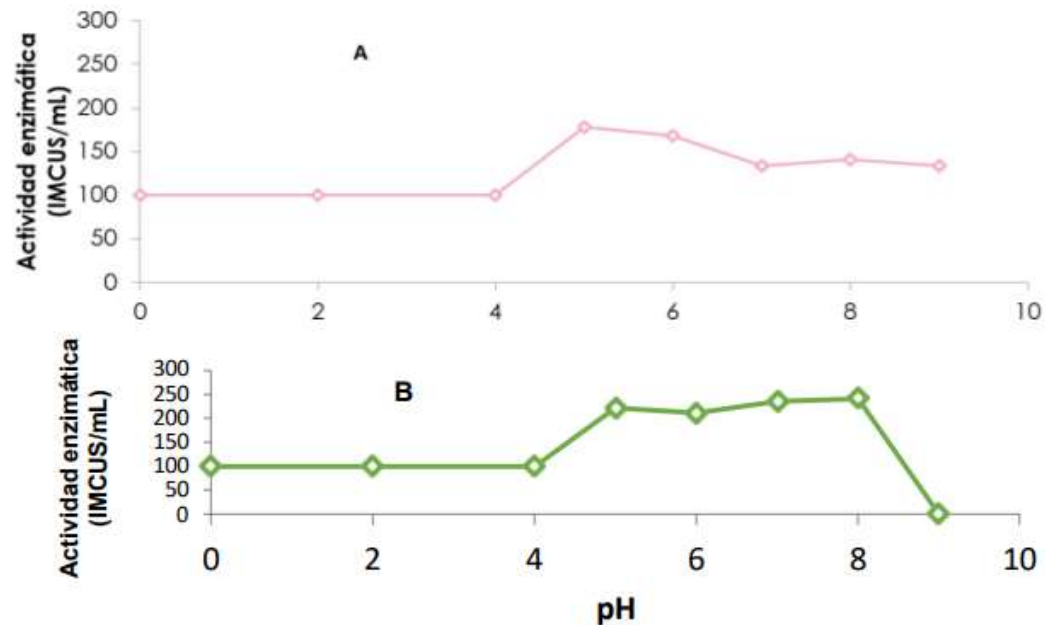
<sup>3</sup>Departamento de Biotecnologia e Microbiologia de Alimentos (CIAL) C/ Nicolás Cabrera 9, 28049, Cantoblanco, Campus UAM. Madrid Espanha.

<sup>4</sup>Departamento de Engenharia Química, Faculdade de Ciências Complutense Av. Séneca, 2, 28040 Madrid, Espanha.

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# Abstract

Chymosin is an enzyme, traditionally obtained from the fourth stomach of young ruminants, used in the coagulation of milk to make cheese. In the present work we will address other aspects that are difficult to resolve during the processing of this protein, its activation, purification process and alternatively, its immobilization in various chromatographic matrices that allow its manipulation under more technically industrial and economically beneficial industrial conditions. **The process consisted of cloning the coding gene for this enzyme, using optimized codons for its overexpression in Escherichia coli, with the pBAD/HIS vector under the control of the pBAD promoter inducible by L-arabinose, as it is a more economically profitable process.** Overexpression of the gene generates inclusion bodies that can be denaturalized by washing with NaOH, for subsequent opening of the protein by dilution and adjustment of the pH with glycine, in a more easily manipulated way. Once unfolded, prochymosin is activated by a drastic change in pH, first at pH 2 and then rising to pH5 to increase its activation process. After this process, a highly active protein was obtained, tested under its natural substrate, milk. Due to the complexity of the activation-reativation- purification process that takes place at very acidic pHs, its control becomes difficult, which is why new



# Production of Maral (*Cervus elaphus sibiricus* Severtzov) Recombinant Chymosin in the Prokaryotic Expression System and the Study of the Aggregate of Its Biochemical Properties Relevant for the Cheese-Making Industry

Published: 01 December 2020

Volume 56, pages 647–656, (2020) [Cite this article](#)

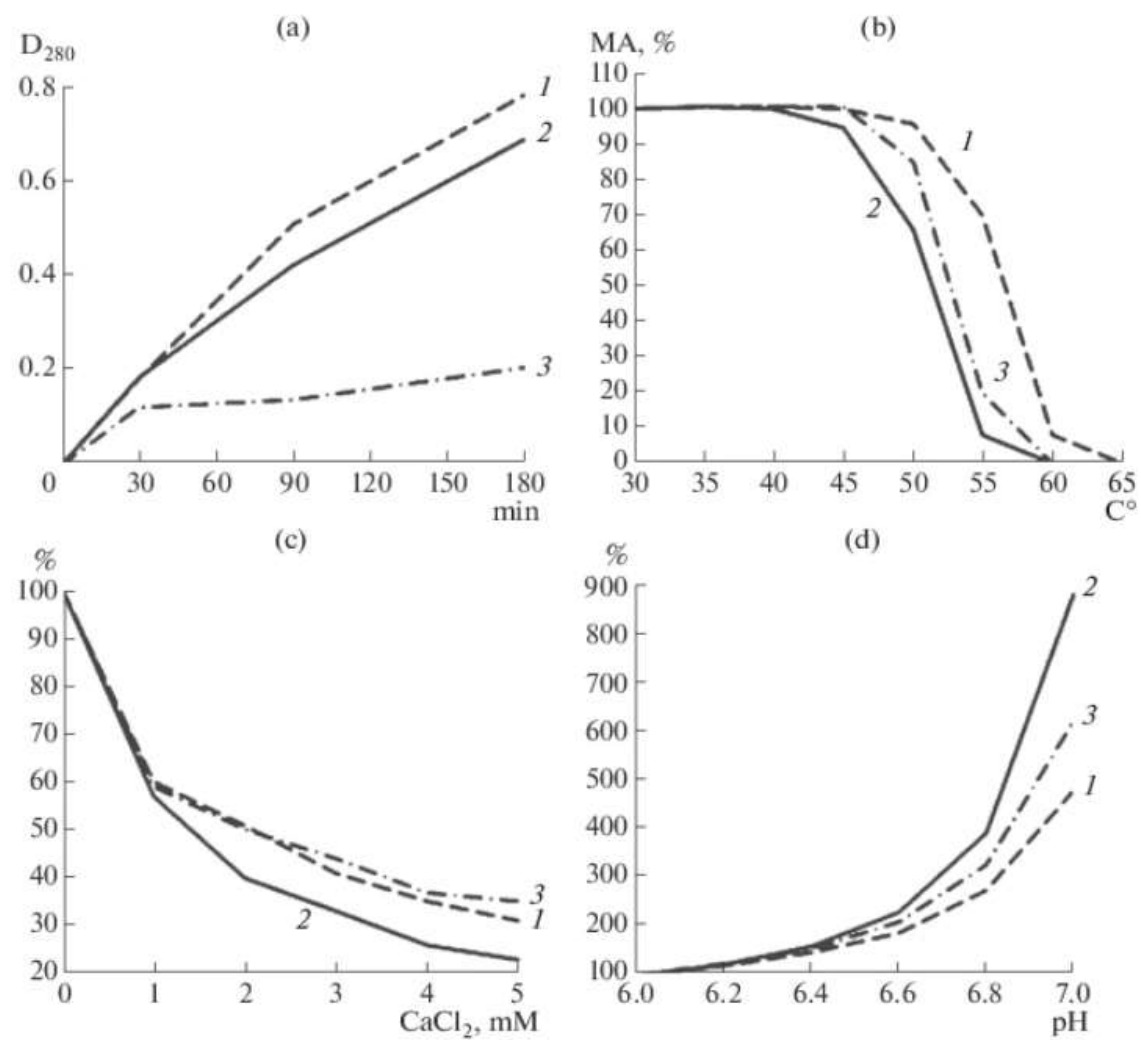


**Applied Biochemistry and Microbiology**

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## Abstract

The paper reports on the production of the maral recombinant chymosin in the *Escherichia coli* expression system (SHaffle express strain) and the study of its biochemical properties relevant for the cheese-making industry. The highest maral recombinant prochymosin content in inclusion bodies was observed when producer cells were cultured at 25°C for 6 h after the introduction of an inducer, 10 mM isopropyl-β-D-1-thiogalactopyranoside. The biochemical properties of the obtained enzyme were compared with those of bovine and dromedarian recombinant chymosins. It is shown that total proteolytic activity of the maral recombinant chymosin was comparable with that of the bovine enzyme and that it exceeded the activity of the dromedarian enzyme by **about 3.8 times**. The thermal stability of the recombinant chymosin from maral was found to **be 5–10°C higher** than that of the chymosins from the cow and dromedary. The patterns of dependence of milk-clotting activity on the pH level and calcium chloride concentration in cow's milk on the enzyme from maral met the requirements set by the cheese industry. **Its high proteolytic activity and thermal stability limits the scope of application of maral recombinant chymosin to the production of cheeses with short ripening and short storage times.**



Results of a comparative study of the following dependency patterns: total proteolytic activity ( $D_{280}$ ) on the incubation time (a), residual milk-clotting activity (MA, %) on the heating temperature (b), and milk-substrate coagulation time (%) on the calcium chloride concentration (c) and pH (d); 1—maral rCn, 2—bovine rCn, and 3—dromedary rCn.

- **Bovine Somatotropin (BST) for Milk Production:** Genetically engineered BST enhances milk production in adult cows, offering benefits to milk producers and contributing to the dairy industry.



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## The Influence of Recombinant Bovine Somatotropin (rbST) on the Metabolic Profile and Milk Composition of Lactating Murrah Buffalo

by Marcelo Arne Feckinghaus <sup>1,\*</sup> , Mariana Guimarães de Oliveira Diogo <sup>2</sup>, Vanessa Martins Storillo <sup>2</sup> , Fabio Celidonio Pogliani <sup>1</sup>  , Bruno Moura Monteiro <sup>1</sup>  , Paulo Fantinato Neto <sup>2</sup> , Melina Marie Yasuoka <sup>2</sup>  , Daniela Becker Birgel <sup>3</sup>  and Eduardo Harry Birgel Junior <sup>3,\*</sup>  

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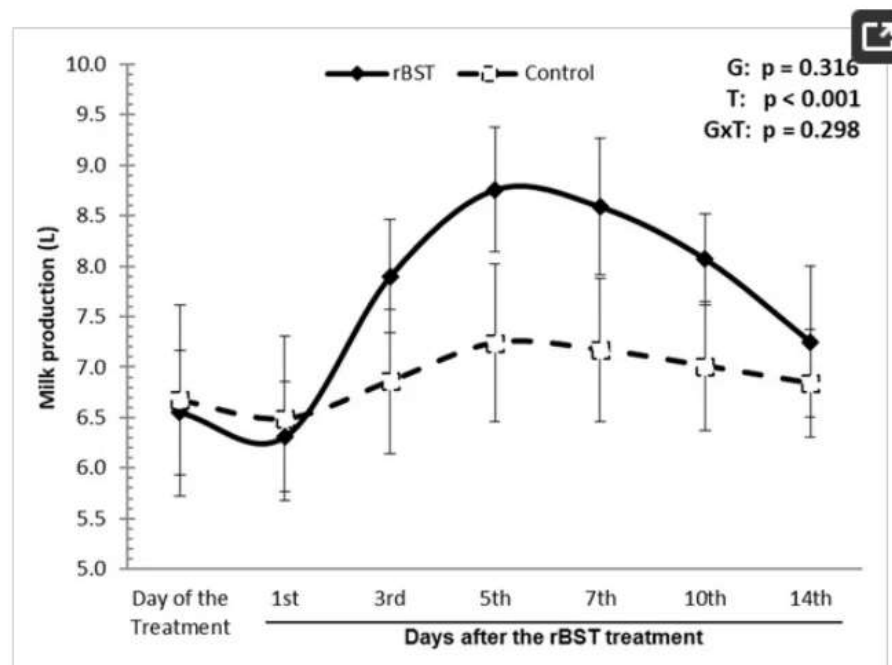
<sup>2</sup> Department of Surgery, School of Veterinary Medicine and Animal Sciences, University of São Paulo, 87 Professor Orlando Marques de Paiva Avenue, São Paulo 05508-010, SP, Brazil

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\* Authors to whom correspondence should be addressed.

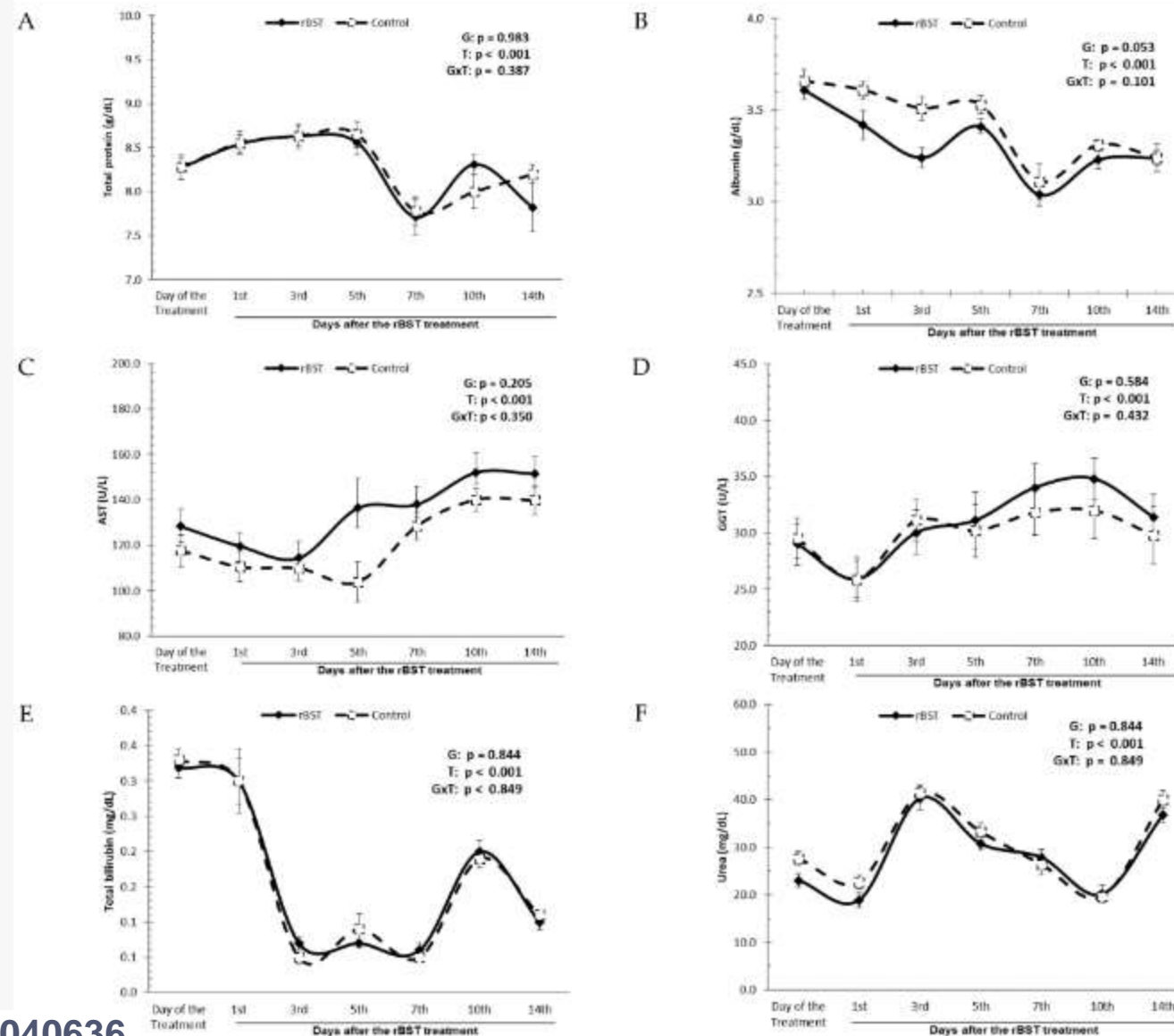
## Abstract

The use of recombinant bovine somatotropin (rbST) leads to an increase in variable amounts of milk production in buffalo, but there is a lack of information on the influence of rbST on their metabolism. This study looked at the effects of a single 500 mg dose of rbST on the lipid profile, liver and kidney function, and physical, chemical, and cellular constitution of milk in 14 buffalo over 14 days, from the 100th day of lactation, compared with 14 animals in a control group. From the first day after rbST, there was a rise in beta-hydroxybutyrate ( $\beta$ -HBO), possibly due to higher dry matter intake or the biotransformation of NEFA into  $\beta$ -HBO. The treatment did not influence blood glucose, non-

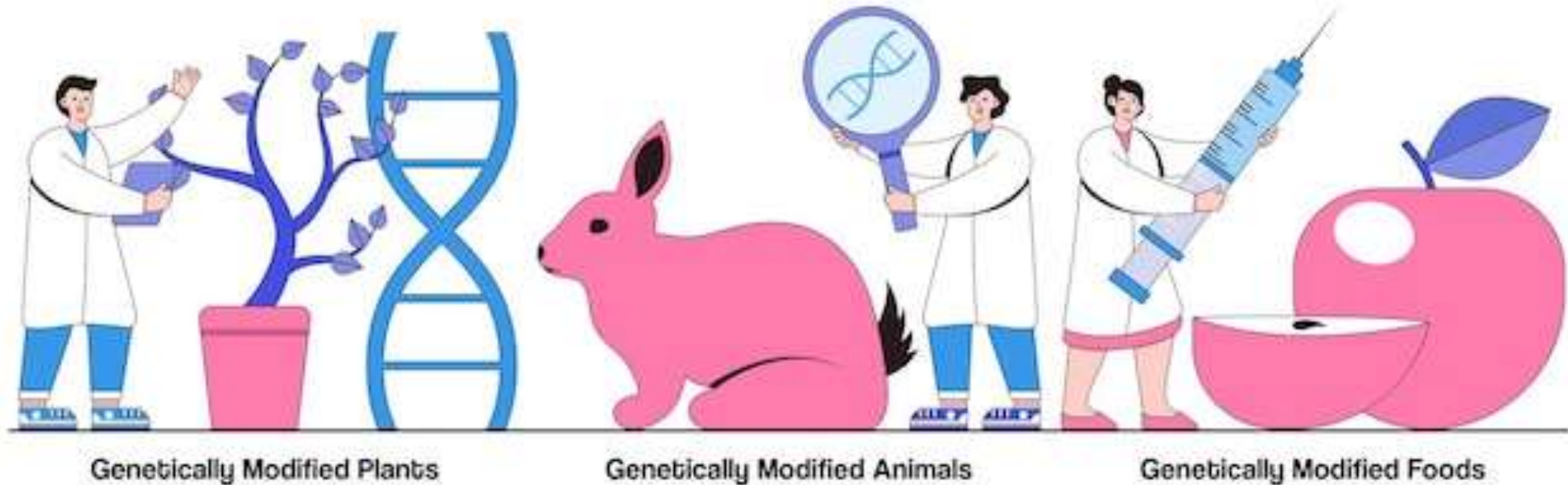


**Figure 1.** Influence of the use of recombinant bovine somatotropin (rbST) on the amount of milk (L) produced from Murrah buffaloes.

**Figure 4.** Influence of the use of recombinant bovine somatotropin (rbST) on the liver and renal function of Murrah buffaloes. **(A)** Total protein serum levels; **(B)** albumin serum levels; **(C)** AST serum levels; **(D)** GGT serum levels; **(E)** total bilirubin serum levels; **(F)** urea serum levels; **(G)** creatinine serum levels.



# Genetically Engineered Plants and Animals in Industry



# Engineering Plants for Industrial Applications

- **Insect Resistance:** Genetically engineered plants exhibit resistance to insects through the incorporation of genes such as *Bacillus thuringiensis* (Bt), offering sustainable solutions in agriculture and reducing the need for chemical pesticides.
- **Enhanced Nutritional Capabilities:** Genetic engineering has led to the enhancement of nutritional capabilities in crops, such as engineering vitamin A into rice and amino acids into legumes and cereals, addressing global food security challenges.

[nature](#) > [nature biotechnology](#) > [letters](#) > article

Letter | Published: 01 April 2005

## Improving the nutritional value of Golden Rice through increased pro-vitamin A content

[Jacqueline A Paine](#), [Catherine A Shipton](#), [Sunandha Chaggar](#), [Rhian M Howells](#), [Mike J Kennedy](#), [Gareth Vernon](#), [Susan Y Wright](#), [Edward Hinchliffe](#), [Jessica L Adams](#), [Aron L Silverstone](#) & [Rachel Drake](#) 

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## Abstract

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'Golden Rice' is a variety of rice engineered to produce  $\beta$ -carotene (pro-vitamin A) to help combat vitamin A deficiency<sup>1</sup>, and it has been predicted that its contribution to alleviating vitamin A deficiency would be substantially improved through even higher  $\beta$ -carotene content<sup>2</sup>. We hypothesized that the daffodil gene encoding phytoene synthase (*psy*), one of the two genes used to develop Golden Rice, was the limiting step in  $\beta$ -carotene accumulation. Through systematic testing of other plant *psys*, we identified a *psy* from maize that substantially increased carotenoid accumulation in a model plant system. We went on to develop 'Golden Rice 2' introducing this *psy* in combination with the *Erwinia uredovora* carotene desaturase (*crtI*) used to generate the original Golden Rice<sup>1</sup>. We observed an increase in total carotenoids of up to 23-fold (maximum 37  $\mu\text{g/g}$ ) compared to the original Golden Rice and a preferential accumulation of  $\beta$ -carotene.

# Transgenic Animals as Bioreactors

- **Pharming:** Transgenic animals serve as bioreactors for the production of pharmaceuticals, offering cost-effective and exclusive methods for drug production, contributing to the development of value-added agricultural products.
- **Advantages of Transgenic Bioreactors:** The use of transgenic animals as bioreactors provides advantages such as lower drug costs, faster manufacturing, and the production of drugs that may be unavailable through other methods.

# Transgenic Animals in Agriculture

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Protein Expressed	Species Where Expressed	Promoter	Reference
Lysozyme	goat	Bovine $\alpha$ 1-casein	(Maga <i>et al.</i> 2006)
Lysostaphin	cattle	Ovine $\beta$ -lactoglobulin	(Wall <i>et al.</i> 2005)
Bovine $\beta$ and $\kappa$ casein	cattle	Bovine $\beta$ -casein	(Brophy <i>et al.</i> 2003)
IGF-I	pig	Bovine $\alpha$ -lactalbumin	(Donovan <i>et al.</i> 2001)
$\alpha$ -lactalbumin	pig	Bovine $\alpha$ -lactalbumin	(Bleck <i>et al.</i> 1998)
IGF-I	rabbits	Bovine $\alpha$ 1-casein	(Wolf <i>et al.</i> 1997)
Lactoferrin	cattle	Bovine $\alpha$ 1-casein	(Krimpenfort <i>et al.</i> 1991)

**Table 2: Mammary expression of transgenic proteins.**

# Conclusion

- Genetic engineering is a powerful tool with the potential to revolutionize industries.
- As research continues, we can expect even more innovative applications that benefit society.
- Responsible development and ethical considerations are crucial for maximizing the positive impact of this technology.

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