US-India Consortium for Development of Sustainable Advanced Lignocellulosic Biofuel Systems

US-India Joint Clean Energy Research & Development Center

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Dr. Wilfred Vermerris
Department of Microbiology & Cell Science
University of Florida
Gainesville, FL, USA

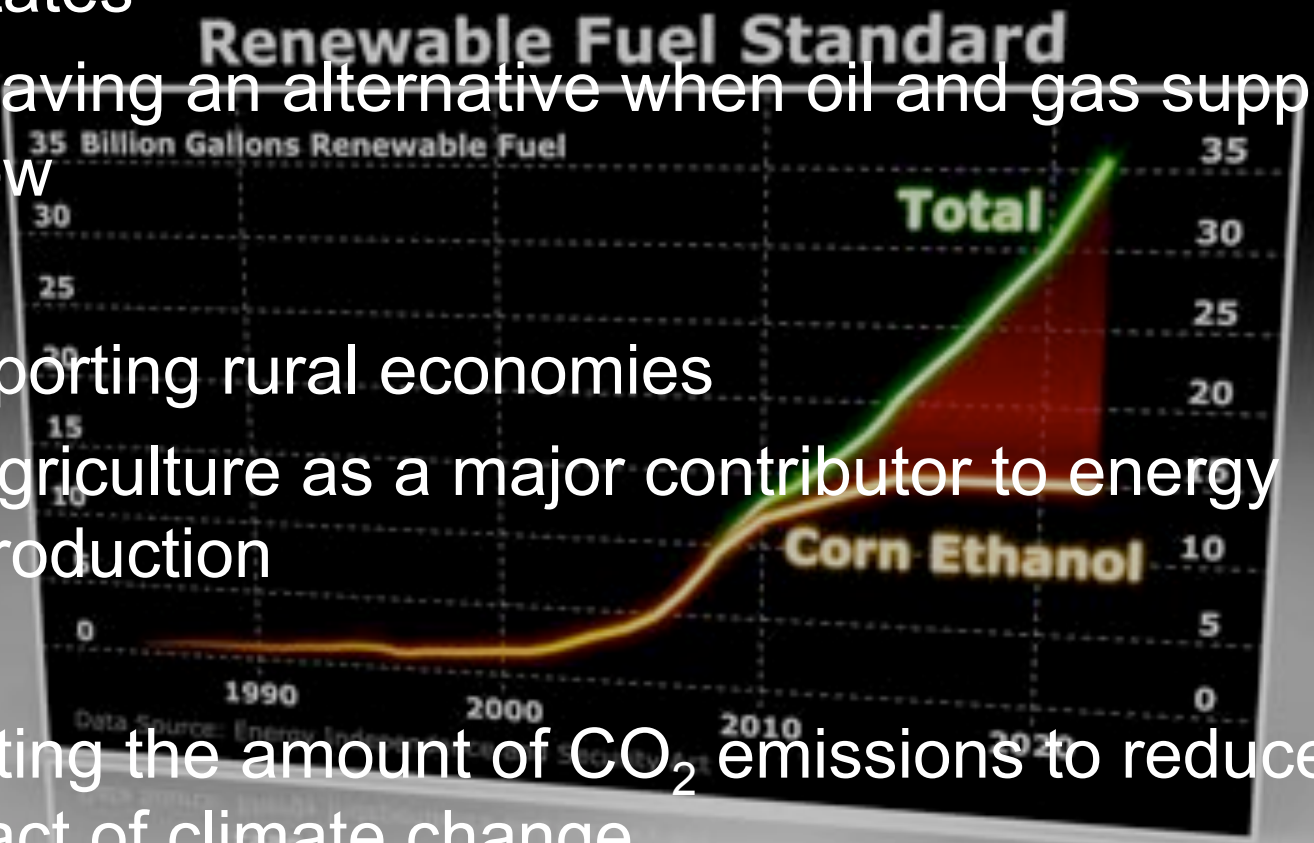
Dr. Ahmed Kamal
CSIR - Indian Institute of Chemical Technology
Hyderabad, India

Bioenergy – Capturing solar energy in chemical bonds via photosynthesis

- By using plants and algae as a source of energy, we are substantially reducing the net amount of carbon released in the atmosphere
- The overall reduction depends on:
  - The amount and source of 'inputs'
    - Fertilizer, transportation
  - Processing costs
  - Land use change

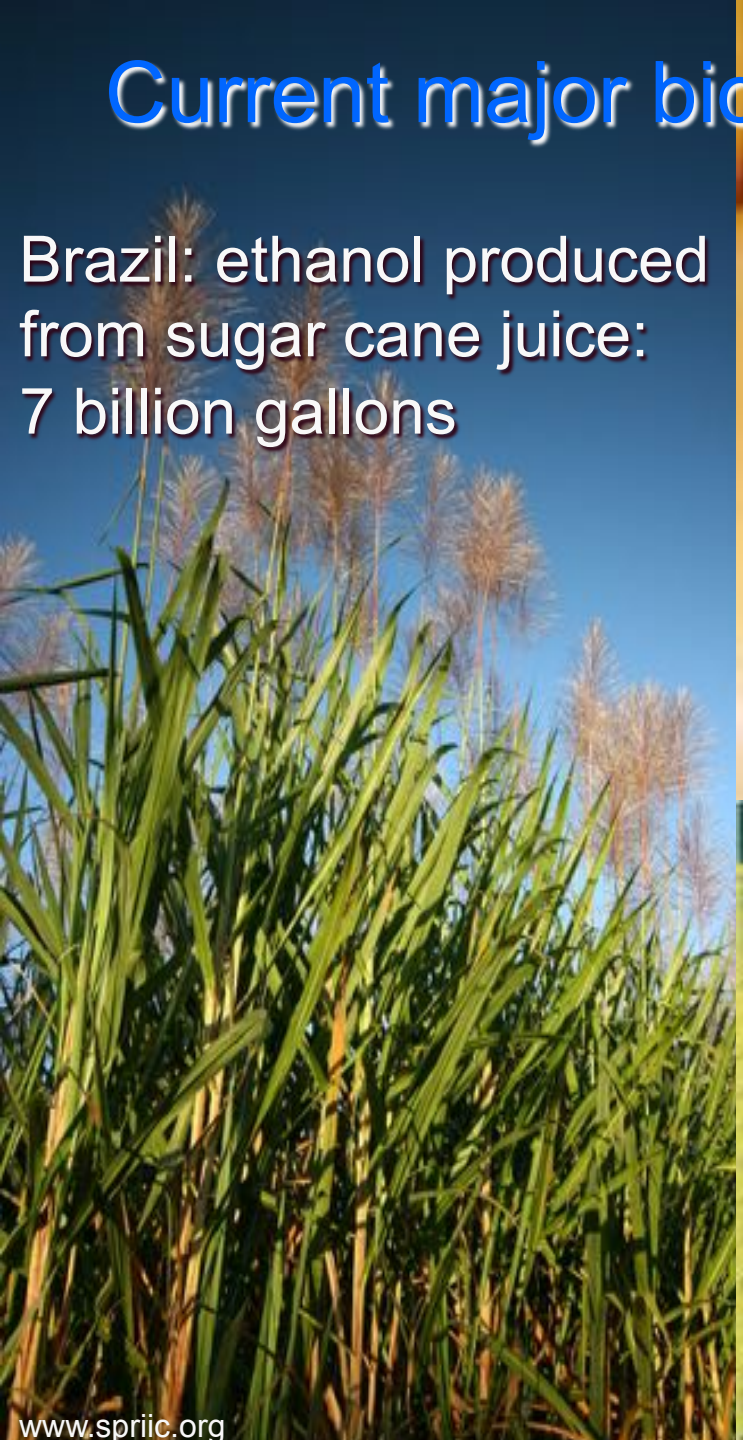
Drivers behind deployment of biofuels

- Energy security (EISA, 2007)
  - Reduced dependence on ‘unreliable’ oil-producing states
  - Having an alternative when oil and gas supplies get low
- Supporting rural economies
  - Agriculture as a major contributor to energy production
- Limiting the amount of CO_2 emissions to reduced the impact of climate change



Current major biofuel sources: First generation

Brazil: ethanol produced from sugar cane juice: 7 billion gallons



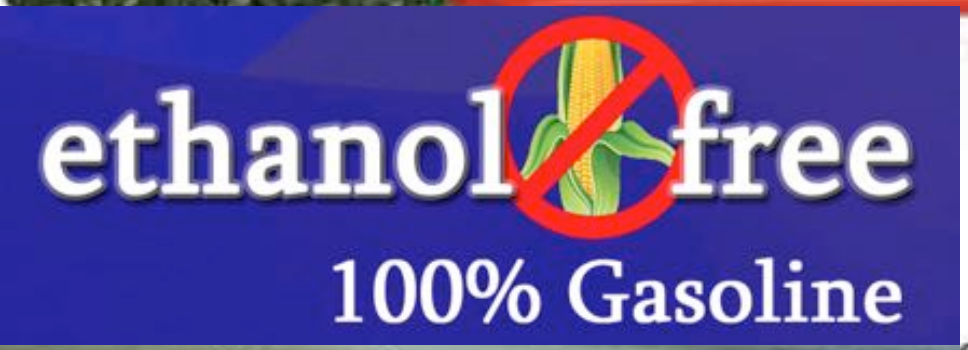
www.spriic.org

United States: ethanol produced from corn starch: 15 billion gallons

European Union: biodiesel produced from canola (oil seed rape), imported palm oil, waste oil: 2 billion gallons

www.nytimes.com


E-15
ETHANO!
SAY NO TO E-15 FUEL
GET THE FACTS.
SIGN THE PETITION ▸


ethanol free
100% Gasoline

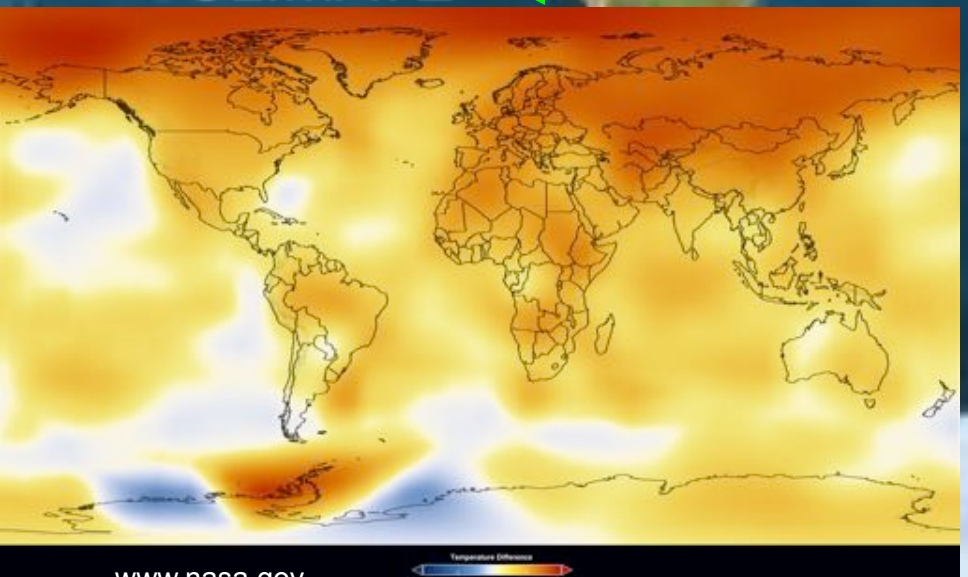

Ethanol
YOU'LL HAVE TO REDUCE YOUR CONSUMPTION

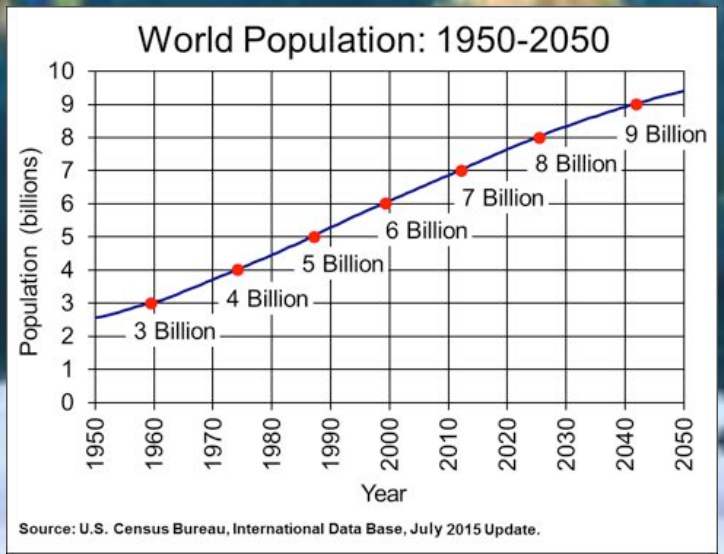
There are no more easy choices….

ENERGY

CLIMATE

POPULATION





Advanced lignocellulosic biofuels produced from biomass crops cultivated on low-productivity land

- Not ethanol, but butanol
- Not from sugar or starch
- Not from food crops
- Not on prime agricultural land

Sorghum: Common focus in US and India

- Annual, seed-propagated grass
- Originated in Africa
- Genetically diverse
- Robust: adaptable to many different conditions
  - Preferred in hot and dry environments
- Used for the production of grain, sugars and biomass

- *Disease tolerance*
- *Drought-tolerance*
- *Flooding tolerance*
- *Consistent yields*
- *Amenable to biomass processing*
  - *Modified cell wall composition*

Adapting sorghum to Florida

Crop production on flood-prone land (Missouri)

- Several million acres of agricultural land are prone to seasonal flooding
- This land would be ideal for bioenergy crops
- This requires flood-tolerant crops and risk-tolerant farmers

Enhancing sorghum's response to flooding

Formation of aerial roots from internodes above the water level

Formation of dense roots that 'float' on the water

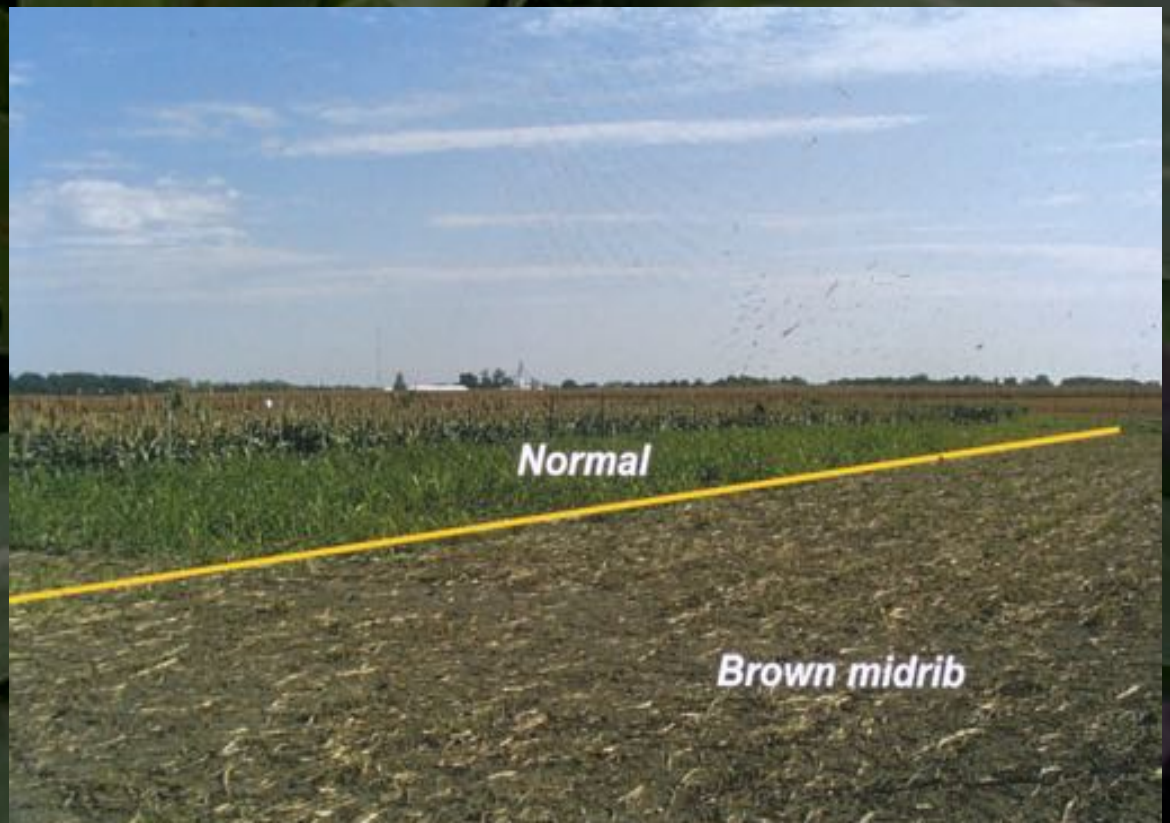
Alejandra Abril

Rhizotrons

- Observation of roots in the soil via a camera inserted in transparent tubes
- Observe differences between flooded vs. well-watered roots
- Match observations with gene expression studies conducted in parallel

Improving biomass conversion with *brown midrib* mutants

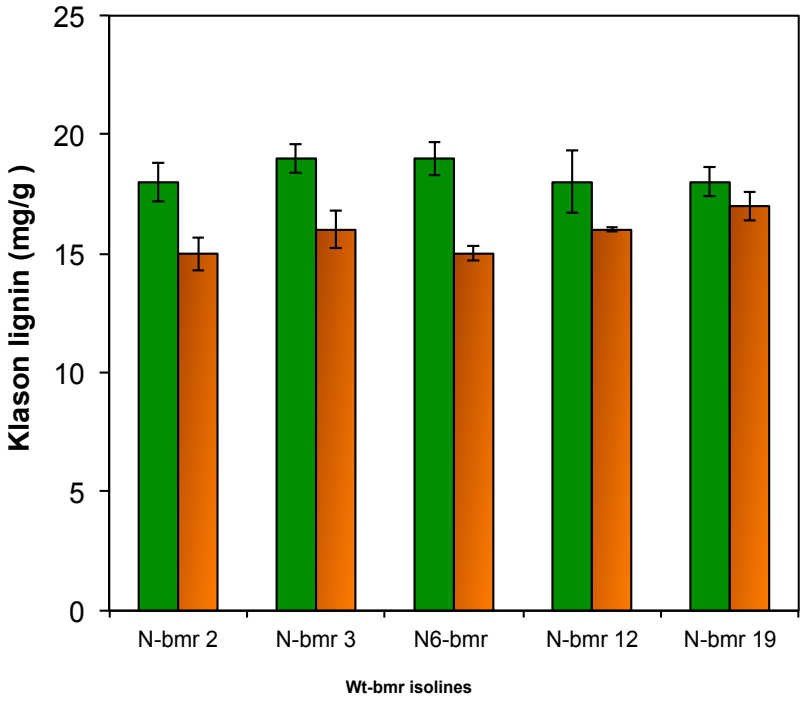
- Defective genes resulting from treating the seed with chemicals that modify DNA
- *brown midrib* mutants have altered cell wall composition
- Initially used as forage because of improved intake and palatability



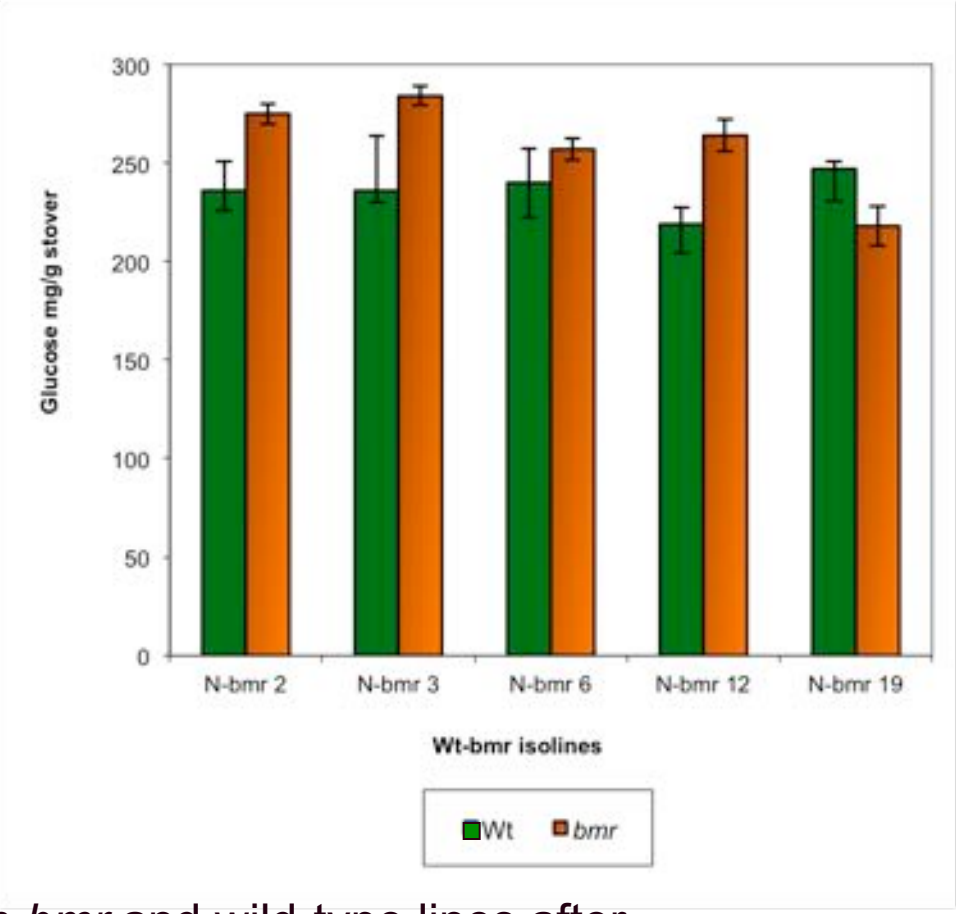
Glucose yield from *bmr* biomass increased by 20-30%

Lignin content

Aromatic cell wall polymer



Glucose yield

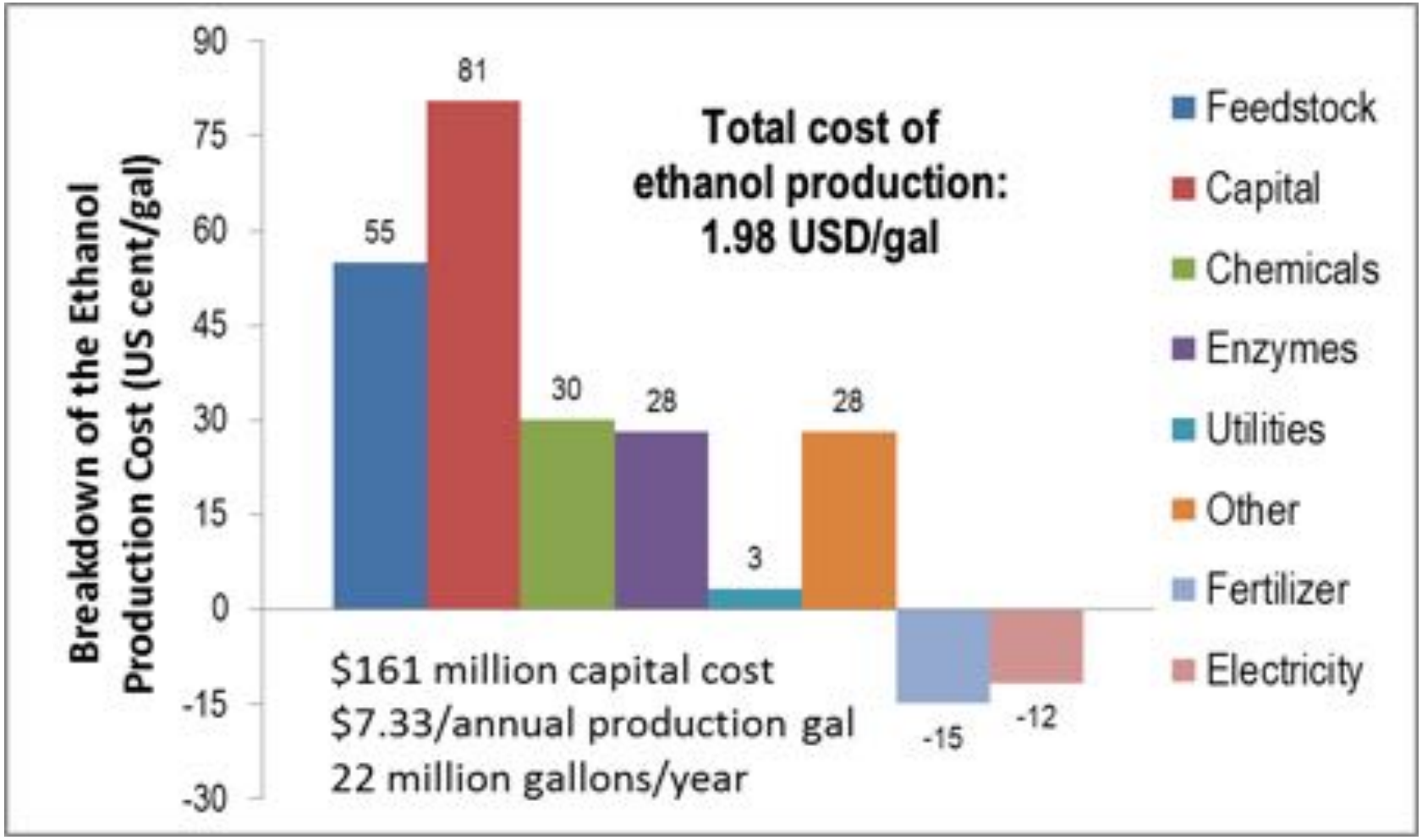


Glucose yields of sorghum stover from *bmr* and wild-type lines after pretreatment and 48 h of enzymatic saccharification (60 FPU/g cellulose)

University of Florida Stan Mayfield Biorefinery

- Fully equipped to process biomass at pilot scale
- 5 tons of biomass per day
- 3 x 10,000 gal fermentors

Techno-economic analysis: Ethanol from biomass



Assumptions:

2.5% enzyme, $1.00 kg enzyme, $40/ ton dry bagasse, 0.24 g EtOH/g DW

I. Nieves/ R. van Rijn

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Fermentation of sweet sorghum derived sugars to butyric acid at high titer and productivity by a moderate thermophile *Clostridium thermobutyricum* at 50 °C

BUTANOL !

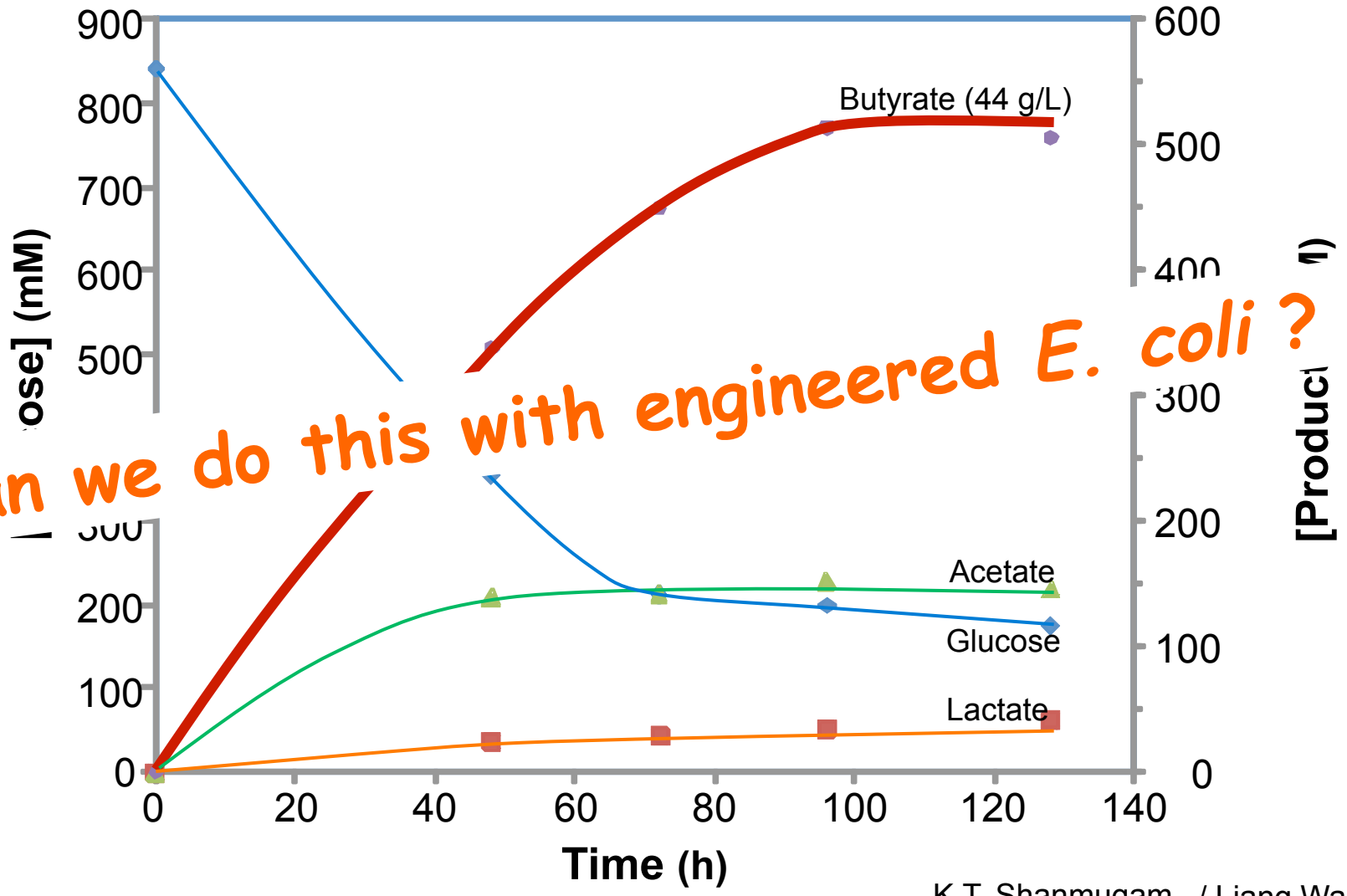
Liang Wang [a], Mark S. Ou [a], Ismael Nieves [a], John E. Erickson [b], Wilfred Vermerris [a], L.O. Ingram [a], K.T. Shanmugam [a,*]

Bioenerg. Res.
DOI 10.1007/s12155-015-9670-6

Sweet Sorghum Juice and Bagasse as Feedstocks for the Production of Optically Pure Lactic Acid by Native and Engineered *Bacillus coagulans* Strains

Mark S. Ou [1] · Deepika Awasthi [1] · Ismael Nieves [1] · Liang Wang [1] · John Erickson [2] · Wilfred Vermerris [1,3] · L. O. Ingram [1] · K. T. Shanmugam [1]

Fermentation of glucose by *C. thermobutyricum* at 50°C



K.T. Shanmugam / Liang Wang

LB medium + yeast extract (5 g/L) + glucose (150 g/L) + betaine (1 mM) + $CaCO_3$ (20 g/L); pH 7.0

Challenges for biorefineries in the US

- The prices of oil and natural gas are at record lows
  - Difficult for biofuels to compete
- There are major risks associated with the exploration and use of the yet untapped reserves of petroleum
  - Biofuels can play a role in the transition away from oil, and do so in a sustainable manner
- Major opportunities for the genetic improvement of bioenergy crops and industrial microbes

Florida Axes State Renewable Fuel Standard

This has had a major impact on the construction of new biorefineries

We need a level playing field (tax policies) and a mechanism to reward sustainably produced biofuels from home-grown crops

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Indian consortium

- IICT, Hyderabad
- ICRISAT, Hyderabad
- DSR, Hyderabad
- JNTU, Hyderabad
- CESS, Hyderabad
- IIT-Delhi
- IIT-Madras
- TNAU, Coimbatore
- RVSKVV, Gwalior
- Abellon Clean Energy Ltd., Ahmedabad*
- Hindustan Petroleum Corp. Ltd., Bangalore*

US consortium

- University of Florida, Gainesville, FL
- University of Missouri, Columbia, MO
- Virginia Tech, Blacksburg, VA
- Montclair State University, Montclair, NJ
- Texas A&M University, College Station, TX
- Green Technologies, LLC Gainesville, FL*
- Tiger Energy Solutions, LLC, Columbia, MO*

US funding: $12 million over 5 years

U.S. DEPARTMENT OF ENERGY

*Industry partners