Innovation, Knowledge and Technology Transfer: CIFAR as a University-Industry Model of Global Collaboration for Development of Food and Feed

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Davis sunflowers showing appreciation for the year Professor Jovanka Levic spent as a visiting scholar at the UC Davis (2000-2001)

Presentation Flow

Brief Introduction to UC Davis and California

The CIFAR global model for collaboration

Examples
- Whole Vine Products
- Food Forsight
- Grain based products
- The Winery
- Anaerobic Digestion
- Cellulose bioconversion
- Rethinking processing
- Big data

Future
University of California

UC Davis is ranked #1 in the world in agriculture and environmental sciences.

- 10 UC Campuses
- 3 National Labs
California Agriculture

at-a-glance

8th largest global agricultural economy

~81,000 farms and ranches

26.3 Million acres ag land (10.6 Million hectare)

>400 commodities

$37.5B at farm gate,
$75B total value of Final Products

10% of California’s economy
California’s unique climate makes it a prime location for seed production.

- Large range of latitude and altitude.
- Coastal and inland valleys.
- Mediterranean rainfall pattern.
- Sufficiently low temperatures for chilling.
- Wide diversity of climates.

AND….

California produces half of the vegetables for the US and for export.
80 seed industry members within 3 hours from UC Davis, including 8 of the 10 largest global seed groups.
Our food supply is a fragile interdependent global system...

That requires transparency of food systems, traceability of ingredients, and response to trends and needs. Ingredients are being sourced from all parts of the world.
In Order to Feed the Growing Population We Need...
High yielding, affordable, high quality food, feed, fuel, fiber, sustainably
produced with adequate global infrastructure, storage and transparency

Greatest Grand Challenge of our time!
Population 9 billion by 2050!
70-100% More Food Required?

The Nexus of Food – Health – Energy – Natural Resources

Challenges: Changing climate, diminishing resources (degraded land, less water, less fuel, less fertilizer, less pesticides), fewer farmers (migration of people from countryside to cities), assurance of safety, educated base

Solutions: Sustainable Intensification using an integrated systems approach of various types with appropriate oversight (conventional, organic, biotech; food and fuel
Problem solving has changed

From simple, reductionist approaches to one of natural complexity; e.g. fiber, carbohydrates, lipids.

We now collect, store and manipulate large amounts of data and ‘mine’ this data to understand complex systems. Situations are more dynamic.

It now takes team science to solve important problems. Solutions require educated base, critical thinking skills, new technologies, appropriate policies, teamwork & trust.

Collaborations are an integral part to solving problems.
CIFAR is a California-centered, global network and innovation hub, for industry and research professionals, focused on emerging agri-food systems, technologies and solutions.

Mission:
To create opportunities for collaboration, multidisciplinary research and technology exchange between the university and the food and agricultural industries.
CIFAR’s Network of Global Affiliates

grouped according to areas of interest

Production

Agrian
Earthbound Farm
Marrone
Bio Innovations

Product Development

CA League of Food Processors
Clean World
Creative Research Management
Draco Natural Products
JM Equipment Company
LiveLeaf Bioscience
Lyons Magnus
Mattson
Jiangnan University, SKLF

Processing/Packaging

California Center
Cloud Farm
Prune Bargaining Association
WildBee Fine Wine

Distribution/Retail

International Food Information Council,
Nuffer, Smith, Tucker,
The Understanding and Insight Group®

Consumer

CIFARs Agri-Food Chain Clusters
Where we have been...

CIFAR's Timeline since 1991

Initiated and participated in activity in international exchanges 1992-present

1991
Transferred California food preservation lab to UCD

1992
Established UCD Biomass conversion research hub

1992-2002
Organized and led CA Water Management Project

1994-2004
Established NSF UCD site of Center for Aseptic Advanced Processing & Packaging Studies (CAPPS)

1994-
2004
Established NSF UCD site of Center for Aseptic Advanced Processing & Packaging Studies (CAPPS)

1999, '01, '02
Compiled 1st UCD Food for Health Directories

1999-2005
Established UCD Phaff Yeast Culture Collection

2007
Initiated Italian Connection and 1st Olive Oil Conference

2008- present
Partner in UCD Global HealthShare

2012
Established Water-Energy Nexus, CIFAR-China CIFAR-Canada

2013
Established Global Action Platform
Macro-View of CIFAR’s Network Interactions

http://www.codejobs.biz
CIFAR...from ideas to impact

1. PLANT THE SEED (idea)

2. WATER AND NURTURE (proof of concept and relationship building)

3. SEED GERMINATES TO PRODUCE A PLANT WITH STEMS AND ROOTS (expanding project and relationship)

4. BE PREPARED TO LET THE SEED MOVE TO A NEW PLACE (new sponsors and people)

5. CONTINUE TO SUPPORT (may generate 2nd gen seeds)
Example of the Power of CIFAR Collaboration

"The real voyage of discovery consists not in seeking new landscapes, but in having new eyes."

Marcel Proust

SonomaCeuticals is the only company using the whole produce of the vine, not just the grapes or juice. It is adding substantial value to vineyard operations and delivering natural purity, flavor & nutrition to food producers and their customers all while greatly reducing environmental impacts.
SonomaCeuticals Vision:
Create Value from Everything in the Grape Plant
WHOLE VINE FLOUR
derived from
Grapeseed and Grape Skin

varietal specific, high in fiber, gluten-free
adds flavor, texture and nutrition
varietal specific, cold-pressed, unrefined nature's soft scent of freshness. flavor, and heart healthy nutrition
Some Research Results

Plasma Lipoprotein Cholesterol

Liver of ChrSd and CabSd significantly lower compared to Control

The “Whole Vine” Story, 2007 to present

Outputs:
- Positive effects on health, adds flavor
- Media impact: 5 newspaper articles
- 5 articles in peer reviewed journals
- Listed as one of the major agricultural achievements in 2013
- Clinical study at the Mayo Clinic with Chardonnay grape oil (on its way)

Breads, cookies, Crackers
Oils, Flours

Future: Biochar as Soil amendment
Key Priority Areas in 2014

Resource Scarcity
Water, Water, Water

Biomass and ‘Food Waste’

Policy, Regulation
Conventional, Organic, Biotech
Production-Process Systems Integration
Big Data
Automation
Social Media

Food Safety

Food, Health and Well-being
Benefits of Whole Grains

• Antioxidant activity (phytochemicals)
• Carbohydrates are in complex form, not sugars
• High levels of B vitamins
  (thiamin, niacin, riboflavin, pantothenic acid)
• High levels of minerals (calcium, magnesium, potassium, sodium, iron)
• Elevated levels of basic amino acids (arginine and lysine)
• Elevated levels of tocols in lipids

“Milk the Grain and Not the Cow! -- CIFAR facilitates exchange of technologies” Dr. Cheryl Mitchell, President, Creative Research Management (CRM)

Whole grains shall consist of the intact, ground, cracked or flaked caryopsis, whose principal anatomical components — the starchy endosperm, germ and bran — are present in the same relative proportions as they exist in the intact caryopsis.

www.wholegrainscouncil.org
Comparing the Ingredients of CRM Whole Grain drink with other beverages

**Odwalla’s Wholly Grain!**
- Pasteurized orange juice
- Banana puree
- Whole grain rice
- Natural flavors

**Rice Dream-Enriched rice drink**
- Filtered water
- Brown rice (partially milled), expeller pressed high oleic safflower oil
- Tricalcium phosphate
- Natural flavors
- Sea salt
- Vitamins (Vitamin A palmitate, Vitamin B12 and Vitamin D2)

**Quaker’s Breakfast Shake (vanilla)**
- Water
- Milk protein isolate
- Sugar
- Dextrose
- Whole oat flour
- Polydextrose
- Canola oil
- Natural and artificial flavor
- Dipotassium phosphate
- Cellulose gel
- Maltodextrin
- Mono & diglycerides
- Gellan gum
- Carrageenan
- Cellulose gum
- Tocopherols
- Sucralose
- Enzymes

**Ryza Whole Grain Brown Rice Drink**
- Filtered water
- Organic whole brown rice
- Calcium phosphate
- Sea salt
- Carrageenan
- Vitamins and Minerals (zinc gluconate, riboflavin, Vitamin A, D2 and B12)
- Note: no sugar, sweeteners, or oils or lecithin
<table>
<thead>
<tr>
<th>Ingredients: Complex Natural vs. Simple Refined</th>
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<tbody>
<tr>
<td><strong>Rice Dream</strong> - Enriched Rice Drink</td>
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<tr>
<td><strong>Odwalla’s Wholly Grain!</strong></td>
</tr>
<tr>
<td><strong>Quaker Breakfast Drink</strong></td>
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<tr>
<td><strong>Ryza’s Whole Grain Brown Rice Drink</strong></td>
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Resource Scarcity - Water

Water is Vital to the Future of Food Processing

Delivering Membrane Technology through

“A loose representation of almost equals’
Jackson Sustainable Winery Building systems provides

- Self-Sustainable, On-Site, Non-Carbon Energy
- Self-Sustainable, On-Site Rainwater Capture
- Multiple Uses of Water and Cleaning Chemistry
- Green Cleaning Chemistry
- CO₂ Capture and Sequestration
- Solar Hot water (50C), cold water (5 C)
- Data system for performance measurement, research
Inside the UC Davis’ Teaching and Research Winery
Food Recovery Hierarchy

- Source Reduction
- Feed Hungry People
- Feed Animals
- Industrial Uses
- Composting
- Incineration or Landfill

www.epa.gov/foodrecoverychallenge
Potential FEEDSTOCKS for new applications:
Example of what we have in California

E.g. CA grape pomace, ~300,000 T/year

Composition of Pomace
1.66% H₂O
10.96% Protein
7.03% Fat
10.04% Ash
70.30% Carbohydrates
(56.57% TDF - cellulose, hemicellulose--mostly cellulose)

- Red pomace: ferment with pulp, freshly squeezed, sometimes up to 20% residual alcohol.
- White pomace, more water (~60%) and less carbohydrate and alcohol.
- Freshly squeezed wine pomace assumed to be 15% moisture.
Tomato Processing Pomace
Agricultural Value Chain

- Food
- Feed
- Bio-energy & materials
Bioenergy: Opportunities for Anaerobic Digestion

- In California alone, **25 percent** – more than **6 million tons** per year -- of ALL landfill waste is **food and agricultural waste’** that could be used to make enough renewable biogas to power **500,000 homes**.

- Annually, the United States produces **225 million tons** of municipal solid waste, of which **100 million tons** is organic and agricultural waste. The direct cost to landfill these materials exceeds **$4 billion per year**.

- Landfilled organic waste produces greenhouse gas emissions (GHG) that are **23 times more harmful** than emissions from automobiles.

**Key to commercialization - Coproducts**

Targeting the digestate as a soil amendment or fertilizer.
Technology Transfer of UC DAVIS Renewable Energy Anaerobic Digester

- Designed and built by CleanWorld, using innovative, high rate anaerobic digestion (AD) technology invented by Dr. Ruihong Zhang at the University of California, Davis (UCD). CIFAR is a partnering organization with Clean World and Dr. Zhang.
- Represents a unique public-private partnership, enabling the university and its surrounding region to be a direct recipient of many economic and environmental benefits.
- Generates 5.6 GWh of renewable electricity and diverts 20,000 tons of organic waste from local landfills annually.
  - CleanWorld Organics specializes in creating valuable soil and fertilizer products from digester effluent.
  - BioPreferred-100% USDA Certified Biobased Products
  - A typical BioDigester will produce enough liquid and solid fertilizer product to provide nitrogen for 290 acres of California farmland, every day.

Commissioned in January 2014
Ribbon Cutting Ceremony, April 22, 2014
Targeting cellulosic biomass to reduce its recalcitrance is a major goal of U.S. Department of Energy with “Big Science” Funding. The outcomes of coordinated research at 3 Centers of Excellence in USA is far reaching and will impact the future of food and feed.

Joint Bioenergy Institute (JBEI), UC Berkeley
Bio-Energy Science Center (BESC), Oak Ridge Nat. Lab
Great Lakes Bioenergy Research Center, U. Wisconsin

For example, at BESC, over 200 researchers at 20 institutions do coordinated research to better understand underlying science and engineering, such as plant cell wall biosynthesis and biodegradation.

Annual BESC Scientific Retreat (July 2014).
S. Shoemaker advises.
Biofeedstocks

Switchgrass

Populus

Complexity of the Problem

Lignocellulosic Biomass

Primary Wall
- Pectin
- Hemicellulose
- Cellulose
- Lignin

Secondary Wall
down
- Pectin
- Hemicellulose
- Cellulose
- Lignin

(proteins)
Discoveries from “Big Science” funded bioconversion centers applied to Food and Feed

The Future of Biorefineries Requires Biocatalyst Development

• Discovery of novel enzymes and activities
  – Classical screening
  – Extensive exploitation of biodiversity
    • Metagenomics
    • Post genomic time — exploitation of the genomic data
    • Prediction of protein properties from the primary sequences

• Protein engineering to improve protein properties
  – Random and rational approaches
  – Engineering substrate specificities

• HT techniques in screening, protein engineering, and expression

J. Buchert, VTT
Example: Pacific Ethanol (Madera, CA)
Dry Mill Corn Processing
Typical Ethanol Plant Inputs and Outputs

• Plant Inputs (40 MGY)
  – 15 million bushels corn
  – 30,000 MWh electricity
  – 1,000,000 mmbtu nat gas
  – 980 ac-ft of water

• Plant Outputs (40 MGY)
  – 335,000 tons WDGS (65% moisture, 170 ac-ft)
  – 40 million gal ethanol
  – 90,000 tons of CO₂
"Cell Factories" for Production of Bioproducts

Energy crops
- Agro Excesses
- Forest residues

Municipal waste
- Fruit and Vegetable Excesses

Lignocellulosics

Metabolic engineering of microbes and plants

Chemicals
- Butyric acid
- Lactic acid
- 1,3-propanediol
- Succinate, fumarete, malate (TCA)
- Other organic acids

Sugars

Lipids

Aromatics

Biofuels
- Bioethanol
- Biobutanol
- Biodiesel

Higher value products
- Xylitol
- Pharma precursors
- Amino acids
- Food ingredients
- Flavor components
- Polymers (fibres, food)
CIFAR’s Global Collaborations
with China since 1985

**Academic Exchange**

Multiple Universities: Jiangnan, Zhejiang, Fuzhou, China Agricultural University

**Industry Exchange**

Agriculture, food, enzyme, and biotechnology

**Government Exchange**

Sister City established in 2001 between Davis, CA USA – Wuxi (Huishan), Jiangsu, China

Confucius Institute-established in 2013
Educational Exchange between UC Davis and Jiangnan University

- **8** International Food Science conferences, since 1991
- **17** faculty from UCD visited JU
- **6** faculty from JU visited UCD
- **5** students from JU completed PhD at UCD
- **14** graduate students from JU studied at UCD
- **8** PhD JU exchange students studied at UCD
- **36** Undergraduate JU exchange students have come to UCD
- **30** senior administrators from JU attended conference at UCD
A State Key Laboratory in Enzymes

Harnessing the power of biotechnology

R&D

➢ The first in the world to launch a phytase of *E. coli* origin in 2003. This innovation brought an annual profit of over 3 billion/year for Chinese feed industry and reduced phosphorus release by more than 100 million tons/year.


➢ Launched a series of enzyme products for maltose processing (enzyme for maltooligosaccharide production, isomaltose synthetase, thermotolerant isoamylase, α-transglucosidase, pullulanase, thermotolerant β-amylase, high-efficiency α-amylase) in 2010-2012.
RANGE OF PRODUCTS

Feed enzyme products (With production permit)
Phytase / Xylanase / Mannanase / Glucanase / Amylase / Cellulase / Lipase / Protease (Keratinase) / Enzyme cocktails

Food enzyme products (Coming to market)
Food enzymes / Flavor enzymes
Enzymes for maltose processing (enzymes for maltooligosaccharide production, Isomaltose synthetase, thermotolerant isoamylase, α-transglucosidase, pullulanase, thermotolerant β-amylase, high-efficiency α-amylase)

Other specialized industrial enzymes (Coming to market)
Textile enzymes / Enzymes for papermaking industry / Nitrilases (Fine chemicals) / Enzymes for leather industry / Superoxide dismutase (SOD) / Deacetylases (Biopharma) / Enzymes for preparation of functional peptides / Enzymes for functional oligosaccharide production
Food Safety

Should we routinely monitor the microbiota of all food and beverage production facilities?
Microbial surveillance: Next Generation Sequencing

Extract DNA

Quantify ALL fungal and bacterial populations in ALL samples simultaneously

Sequence: Illumina Platform

Ref: David Mills 2014
Next generation sequencing illustrates microbial diversity and ability to survey microbiota in a winery setting.
Looking Forward…

**Develop knowledge centers**
Educate & train with ethical principles

**Foster innovation and trust**
Guiding principles, shared values, incentives (prizes)

**Convene, align and mobilize global entities to connect the dots between**
Food, Health & Prosperity
Energy sources & efficient use
Balancing needs of people for water, air, land
1. The **Global Action Platform** convenes, aligns and mobilizes global corporations, universities, government agencies, and NGOs to create abundance through innovation

   Member of Steering committee

2. **EXPO 2015: Feeding the Planet – Energy for Life**

   **Claudio PERI**, Founder
   Food Science Department, University of Milan, Italy
   Advisor, CIFAR

   CIFAR to meet at Ipack-Ima International Fair of Food Technologies: “Technological Innovation for a Sustainable Development of Agrofood Chains”
Thank you for your attention!