“Food Diversity and Indigenous Food Systems to Combat Diet-Linked Chronic Diseases”

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Emerging Global Food Security Challenges

Challenges:
- Food distribution - 1 billion still hungry
- Excess Calorie for 1.5 billion
- Climate Adjustment & Resilience
- Wastage of food 1.3 billion tons

Solutions:
- Food security & Food quality
- Preventing Non-communicable chronic diseases
- Improvement of plant stress tolerance
- Food preservation & safety

Current 7 billion
9 billion 2050
Sufficient food for 12 billion people
Food surplus for 3-5 billion
Summary of Today’s Presentation

- Current Model of Nutrigenomics/Metabolomics & Critical Flaws in the Current Model & Approach & is Relevant for Food Crops for Health
  - Role of Oxygen-Linked Biology (Redox Biology)/Mitochondrial Function
  - Role of Whole Food Profiles (Protective Ingredients)
  - Role of Microbiome and Biotransformation in Gut & Fermentation Biology

- How are we addressing these Flaws?
  —Challenges and Concepts
    - Based on current global and local challenges (problem-solving approach)
    - Integrated (Systems) approach to Metabolic Biology based on Redox Biology
    - Climate Resilient Food Crops for Food Security and Health

- Rationale Food/Design Design based on Redox-Linked Metabolic Biology and Whole Food concepts

- Effective Human Host Response for Better Nutrition and Health based on Redox-Linked Metabolic Biology

- Vision: Seed/Soil/Crops/Animals to Food/Nutritional Security
  - With Implications & Solutions for Global Public Health Challenges
    - Integrated (Systems) Approach using Fermentation Biology & Microbiome Knowledge
Systems Biology Technology Platforms
Systems & Metabolic Innovations

Based on Critical Control Points -- CCP

- Soil Biology & Health Systems Platforms
- Plant & Animal Microbiome Systems
- Human Microbiome & Diet Interactions
- Human & Ecosystems Health
Diet-Linked Improvement of Gut Microbiome and Overall Health

- Bioactive Enriched Healthy Diet
- Probiotic
- Improved Gut Health
- Overall Metabolism
- Immunity
- Chronic Disease Management
Dietary Antioxidant Activities

Reduction DNA, Protein & Membrane Damage

Radical Scavenging

Enzymatic Redox Regulation

Cox-2

Antimicrobial Activities

DNA Repair

P53

Transformation-specific Apoptosis

Proline-linked Pentose-phosphate Pathway

Redox Regulation

Dietary Health Management

Underlying Core Concept (Paradox of Oxygen)

Chemopreventive activities of Antioxidants

(Mitochondria & Cytosolic PPP link)

(Medicinal Plants & Foods to Stimulate REDOX PROTECTIVE PATHWAYS)

(Adapted from Brash and Havre, PNAS 2002; 99,13969)
Food has Profiles that is more than Carbohydrates, Proteins, Lipids, Vitamins, Minerals and Water

**Are Phenolic Phytochemicals from Food Crops & Foods essential for Human Health for fine tuning Oxygen Biology at Mitochondria?**

- Are phytochemicals from 500 million years of land plant evolution and which are a critical part of modern diet key to countering oxidation-linked, stress related diseases that are part of 2~3 million years of human evolution?

- Disease sensitivity could be made worse with our contemporary calorie rich diet with reduced phytochemicals! (NOT all calories are equal—calorie in –calorie out model vs —inexpensive soluble “C” calories linked to hormonal breakdown?)

- Are phytochemical (Combinatorial) profiles from Food Crops & Medicinal Plants keys to modulating our own immune and defenses responses especially antioxidant response?
Why phenolic antioxidant from plants?

- We live in an **oxygen paradox**, where we need oxygen for key metabolic processes and yet some forms of superoxide oxygen and related free radicals along with **high calorie (refined sugars) diet** & **environmental pollutants** increase disease risk.

- Diet-Linked Phenolic Antioxidants to Protect MITOCHONDRIAL FUNCTION & Cytsolic PPP

- **Top diseases as society reaches calorie sufficiency.**

  In particular role of **inexpensive refined sugars & obesity**

    - Cardiovascular disease
    - Diabetes
    - Cancer
    - Arthritis
    - Cognition

  Are all oxidation linked diseases.

**Obesity enhance oxidation linked diseases**

Aging also involves oxidation processes.
Role of Phenolic (Combinatorial Biochemistry) Profiles in Plant Growth and Development (Secondary Metabolites) Linked to Redox Balance

- Antioxidant Response
- Signals for development
- Stress Response (salinity, drought, cold)
- Seed Vigor Response
- Disease Response/Antimicrobials
- Beneficial Interaction
- Pollutant Response
- Color
- Texture
- Flavor
Phenolic Metabolites - Focus on Food Crop Plants with Long History of Use in the Human Diet

Lamiaceae • Oregano, Thyme, Rosemary and Spearmint, Ocimum, Melissa, Perilla

Legumes • Soy, Fava bean, Mungbean, Peas, Fenugreek, Chickpea

Fruits • Cranberry, Blueberry, Raspberry, Strawberry

Cereals/Grains • Barley, Rye, Sorghum, Millets and Buckwheat

Medicinal • Hypericum, Gingko, Ginger, Turmeric, Capsicum, Rhodiola
Plant Phenolics-Human Health Applications

1) Rosmarinic Acid – Oregano, thyme, rosemary and spearmint (Antioxidant Response, alpha-Glucosidase Inhibitor, ACE-I and Anti-inflammatory)

2) L-DOPA – Fava bean (Parkinsons)

3) Isoflavonoids – Soy, chickpea (Estrogen physiology; alpha-Glucosidase Inhibitor)

4) Flavonoids – Oregano, pea, mungbean (*Helicobacter pylori* control; alpha-Glucosidase Inhibitor; Antioxidant Response)

5) Coumarins and Quinones – Fava bean; Fenugreek (*H.pylori* and food borne pathogens)
Alternative oxidative phosphorylation under oxidation stress with phenolic antioxidants.

Phenolic radical reactions on the membrane and cell wall can involve peroxidase-induced polymerization.

Reactions of phenolic radical - signaling - transport mobilization - co-transport stimulation - transport inhibition etc.

Phenolic Radical Reactions on the Membrane and Cell Wall can involve Peroxidase-induced polymerization.
Rationale

- Diabetes (Type 2-over 90% of the cases) is a diet and lifestyle influenced disease.

- Therefore finding solutions requires a strong dietary and whole food strategies coupled to changes in lifestyle such as enhanced physical activity and stress management.
Global Costs

- World Population affected by Diabetes
  - 2000-171 Million
  - 2010-220 million
  - 2030-400 Million (now projected 500 M plus)

- The World Health Organization (WHO) estimates that 4 to 5% of health budgets are spent on diabetes-related illnesses

- Affects 9% of US population-33 million (2011)
Glucosidase Inhibitor: Understanding how it works & Targeting Soluble Phenolics Crop Foods/Plants

1. Inhibition of amylase

Starch

Pancreatic α-Amylase

Sucrose

Brush-border α-Glucosidases

Glucose

Blood

Glucose + Fructose

Absorption

Glucose

Inhibition of glucosidase

#2

Inhibition of amylase

#1

Effect of amylase

Since enters into the distal small with the products of digestion.

Brush-border amylase, temporarily inhibiting the brush-border amylase.

Glucose

Inhibition of glucosidase

#2

Inhibition of amylase

#1

Targeting Soluble Phenolics Crop Foods/Plants
Prevention of Diabetes Complications

- Glucose control
- Beta cell function
- Oxidative Breakdown-Microvascular
- Blood pressure control-Macrovascular

Also important
- Control of blood lipids reducing possibility beta-oxidation linked complications
- Glucose vs Fructose Implications for Fatty Liver

Role of inexpensive refined calories?
Health Disparities: Epidemic of Diabetes in Indigenous Communities

• Nearly 400 million estimated indigenous population (5%) of the world face significant health disparities compared to their non-indigenous counterparts.

• More than 50% of indigenous adults over age group of 35 are suffering with type 2 diabetes (IDF, 2012).

• 2.2 times higher probability of American Indians and Alaska Natives to have diabetes compared to their non-Hispanic counterparts (American Diabetes Federation).

• Among Australian aboriginals diabetes prevalence rate is as high as 30% (WHO, 2007).

• Rapidly changing lifestyle and dietary pattern along with ecological degradation and socio-economic deterioration significantly contributed to the outbreak and prevalence of type 2 diabetes among indigenous communities.
Diabetes in North Dakota: American Indians Health Perspectives

- American Indians have a diabetes prevalence 2.3 times higher than non-Hispanic whites.
- American Indian youths aged 10-19 are 9 times more likely to be diagnosed with Type 2 diabetes compared to non-Hispanic whites.
- The rate of kidney failure due to Diabetes in American Indians compared with the general US population is 1.9 times higher.
- The mortality rate for Native Americans is 1.6 time higher than the rate for non-Native American in ND.
Gestational Diabetes and Child Nutrition

- Gestational diabetes mellitus (GDM), or the onset of diabetes during pregnancy, is a serious yet undertreated condition that affects 14% of women worldwide and 18 million live births per year.
- Balanced nutrition is critical to prevent and manage gestational diabetes.
- Increase in total intake of dietary fiber can reduce the risk of Gestational diabetes significantly.
- Maternal and child health solution is essential to address chronic disease-linked food security challenges.

Gestational diabetes also increases the risk for type 2 diabetes in both mother and child

Approximately 50% of women with GDM go on to develop type 2 diabetes within five years of pregnancy.

Children born to mothers with GDM are up to 8-times more likely to develop type 2 diabetes and obesity in their teens or early adulthood.
Health Benefits of Traditional Corn, Beans, and Pumpkin: In Vitro Studies for Hyperglycemia and Hypertension Management

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Evaluation of Indigenous Grains from the Peruvian Andean Region for Antidiabetes and Antihypertension Potential Using *In Vitro* Methods

Lena Galvez Ranilla, Emmanouil Apostolidis, Maria Ines Genovesi, Franco Maria Lajolo, and Kalidas Shetty

**Table 3. Phenolic Compounds Detected by HPLC in Andean Grains**

<table>
<thead>
<tr>
<th>Code</th>
<th>Common name</th>
<th>Phenolic compound (µg/g of sample weight)</th>
<th>Quercetin derivatives*</th>
<th>Protocatechuic acid</th>
<th>p-Coumaric acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kañawa</td>
<td>943 ± 35</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>Quinoa</td>
<td>1,131 ± 56</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>4</td>
<td>Corn 1</td>
<td>ND</td>
<td>287 ± 15</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>6</td>
<td>Corn 3</td>
<td>ND</td>
<td>ND</td>
<td>22 ± 1</td>
<td>ND</td>
</tr>
<tr>
<td>7</td>
<td>Corn 4</td>
<td>ND</td>
<td>ND</td>
<td>34 ± 5</td>
<td>ND</td>
</tr>
</tbody>
</table>

*Data are mean ± SD values. ND, not detected.

*Expressed as quercetin aglycone.*
# Anti-diabetic Potential of Selected Traditional Crop Foods

<table>
<thead>
<tr>
<th>Crops</th>
<th>Total Phenolic Content (mg/g)</th>
<th>Total Antioxidant Activity (% inhibition)</th>
<th>Alpha-amylase Inhibition (%)</th>
<th>Alpha-glucosidase Inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purple Corn</td>
<td>8.0</td>
<td>77%</td>
<td>0%</td>
<td>51%</td>
</tr>
<tr>
<td>Quinoa</td>
<td>2.3</td>
<td>86%</td>
<td>0%</td>
<td>30%</td>
</tr>
<tr>
<td>Andean Legume</td>
<td>4.0</td>
<td>40%</td>
<td>0%</td>
<td>20%</td>
</tr>
<tr>
<td>Round orange pumpkin</td>
<td>0.17</td>
<td>33%</td>
<td>60%</td>
<td>50%</td>
</tr>
<tr>
<td>Jack Bean</td>
<td>1.2</td>
<td>22%</td>
<td>50%</td>
<td>20%</td>
</tr>
<tr>
<td>Dark red corn</td>
<td>0.5</td>
<td>38%</td>
<td>32%</td>
<td>35%</td>
</tr>
</tbody>
</table>
Bioactive vegetables integrated into ethnic “Three Sisters Crops”
garden targeting foods for type 2 diabetes-associated health
disparities of American Indian communities

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b College of Home Science, Central Agricultural University, Fara, Mghulaya, India
Previous and Current Research

Phenolic Composition and Evaluation of the Antimicrobial Activity of Free and Bound Phenolic Fractions from a Peruvian Purple Corn (Zea mays L.) Accession

Lena Gálvez Ranilla, Ashish Christopher, Dipayan Sarkar, Kalidas Shetty, Rosana Chirinos, and David Campos

Previous and Current Research

- Screening of different squash cultivars for phenolic bioactive-linked T2D health benefits
Previous and Current Research

- Screening of different squash cultivars for phenolic bioactive-linked T2D health benefits
Previous and Current Research

- Optimization of different food processing strategies to improve phenolic bioactive-linked health benefits of squash

Microwaving & Autoclaving improved total phenolic content, while adding vinegar and baking improved α-amylase enzyme inhibitory activity.
Previous and Current Research

Wild rice study (Cooked before extraction)
1. Selection of Suitable Cultivars with Health Benefits
   2. Optimization of Food Processing Strategy
   3. Integrations & Synergies of different Traditional Native American food Crops to Improve Health Benefits
   4. Evaluation of Nutritional Qualities & Health Benefits of Indigenous Food Systems
Previous and Current Research

- Baby Food (Squash, sweet potato, wild rice, berries, corn, bean) Design Study.

Antidiabetic
Other Research Objectives

- Seed priming with human saliva to improve seed vigor and health relevant bioactives of colored corn and climbing beans.

- Bioactive profile and health benefits of wild edibles including winter hardy berries.

- Indigenous food preparation and its impact on nutritional qualities.
Three Sisters Crop Based Community Garden

Selection of cultivars with better nutritional profiles

Optimization of Sustainable Production Practices

Optimization of Food Processing & Preservation

Synergies and Integration of Different Traditional Foods to Improve Health Benefits

Traditional Food Recipes

Wild Rice

Aronia

Nutritional Security and Public Health

Community Based Food Enterprise

Maternal and Child Health
Future Direction

Strategies to Build Future Research Initiatives

Agricultural Production and Marketing Initiatives

- Sustainable Production of Traditional Food Crops in Field and in Greenhouse
- Co-operatives for Small Scale Traditional Food Crop Production
- Extension / Outreach Program for Traditional Food Crop Production and Marketing

Universities (like NDSU) and Educational Institutes Initiatives

- Designing Courses on “Traditional Food and Health Benefits”
- Building Institute focusing research on Traditional Food and Indigenous Health
- Integration of Leading Global Research and Educational Institutes
Microbiome for Climate Resilience and Human Health

Field → Food Processing → Market → Consumer

Oxidation of Proline in Mitochondria → Proline → Pentose Phosphate Pathway

Shikimic Acid Pathway → Phenylpropanoid Pathway → Phenolic Biosynthesis → Enrichment of Phenolic Bioactives

Biotic and abiotic stress defense mechanisms in plants

Antioxidant / Reactive Oxygen Species (ROS) Scavenging Capacity

Anti-inflammatory activity

Improved regulation of blood glucose levels

Reduced risk of coronary heart disease, cancer

Climate Resilience - Plant Health

Dual Function of Inducible Phenolics & Role of Microbiome

Bioactive Enrichment - Human Health
New Product “Discovery Engine” for meeting challenges and opportunities Globally from Seed to Health via Better Food & Nutrition (Microbiome & Redox Biology Platform)

The “Discovery Engine” for new product development based on Traditional Fermentations and Metabolic Biology is focused on condition-specific health issues and is based on protocols for: growing/fermentation, science-based formulation, community driven manufacturing, and proven effectiveness.
THANK YOU FOR YOUR KIND ATTENTION

Fermentation Ecology of Food Systems with Knowledge of Biochemistry and Metabolic Biology Applied to Challenges of Contemporary Nutrition and Food Science to Combat Diet-Linked Chronic Diseases

Need an Integrated (Systems) and Whole Food Approach to Nutrition With Sound Metabolic (Redox) Biology Rationale & Linked to Community Nutrition

Systems Biology Concepts allow for Problem & Solution-Oriented Approach Apply Systems Biology Platforms with Strong Ecological Foundations to meet the Global Challenges