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

Kalidas Shetty

Dr. Kalidas Shetty

Professor of Plant Science,

Founding Director of GIFSIA (Global Institute of Food Security & International Agriculture),

North Dakota State University,

Fargo, ND 58108

USA

Email: Kalidas.Shetty@ndsu.edu

Emerging Global Food Security Challenges

Sufficient food for 12 billion people

Food surplus for 3-5 billion

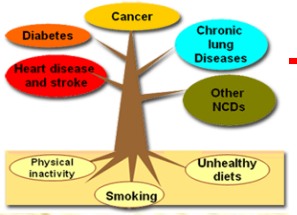
9 billion 2050

Current 7 billion

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

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**

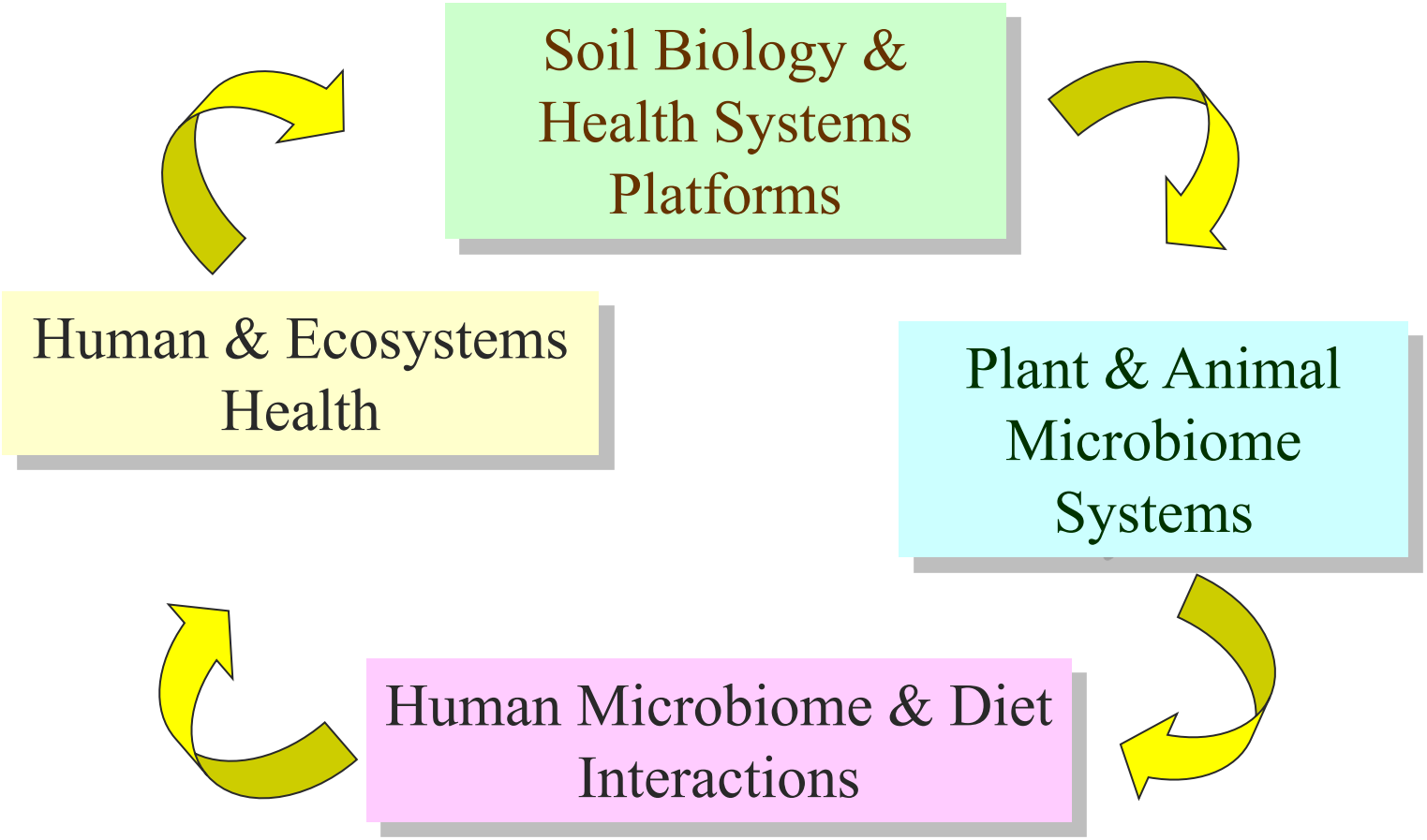
- **Vision: Seed/Soil/Crops/Animals to Food/Nutritional Security**

With Implications & Solutions for Global Public Health Challenges

- **Integrated (Systems) Approach using Fermentation Biology & Microbiome Knowledge

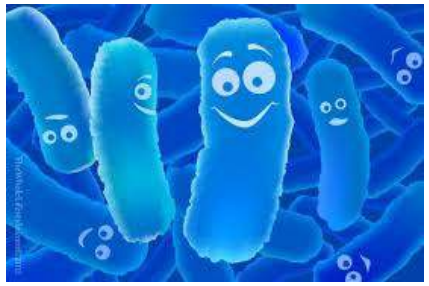
Systems Biology Technology Platforms
Systems & Metabolic Innovations

based on Critical Control Points -- CCP

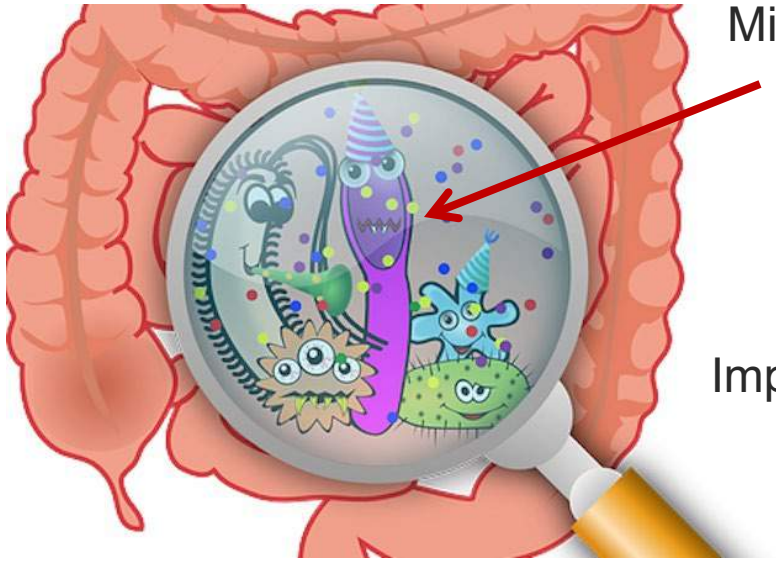


Diet-Linked Improvement of Gut Microbiome and Overall Health

Bioactive
Enriched
Healthy
Diet



Probiotic



Improved Gut Health

Overall Metabolism

Immunity

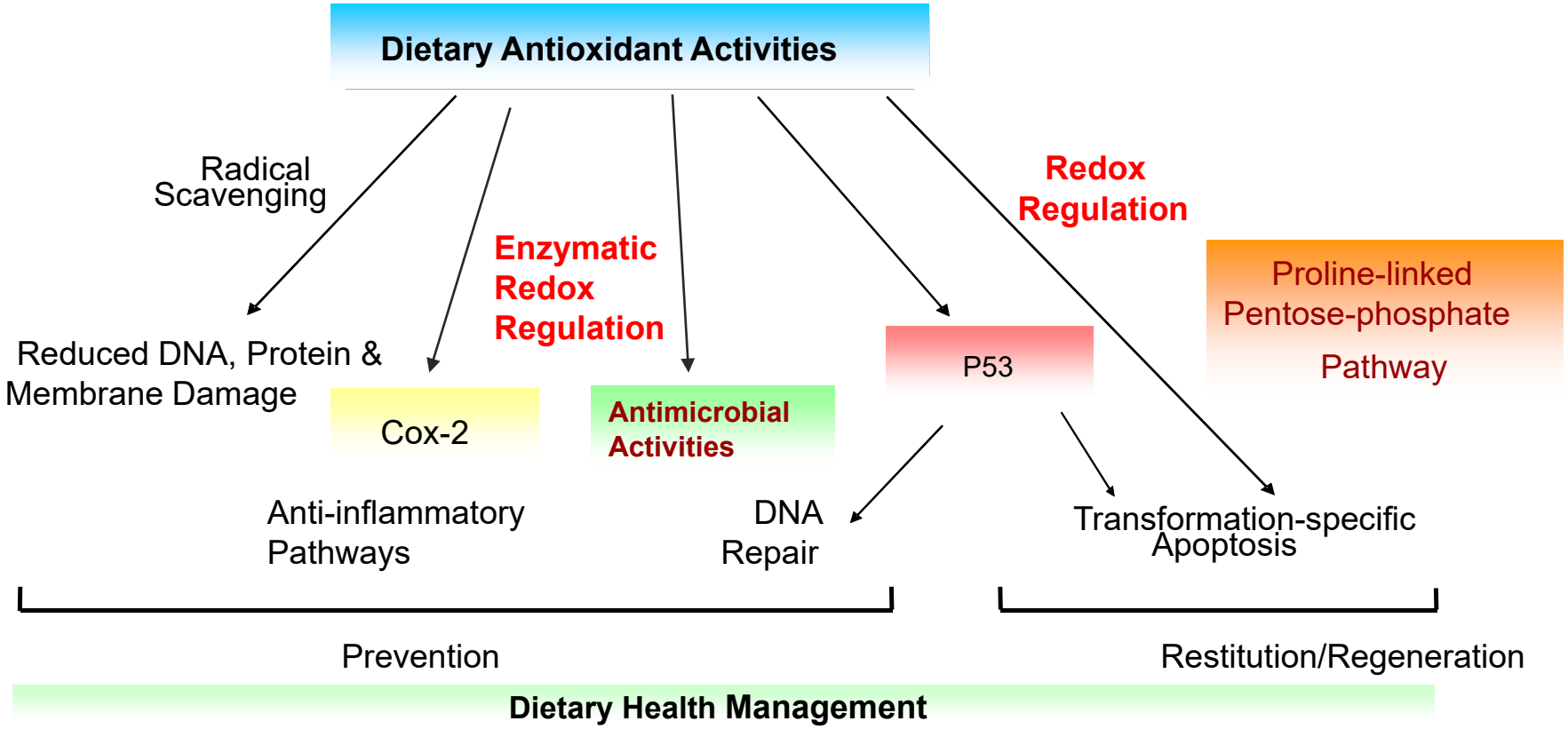
Chronic Disease Management

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.**

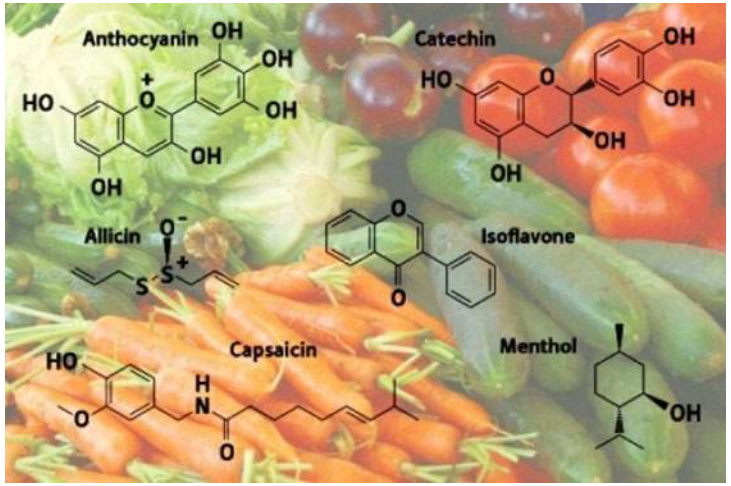
In particular role of inexpensive refined sugars & obesity

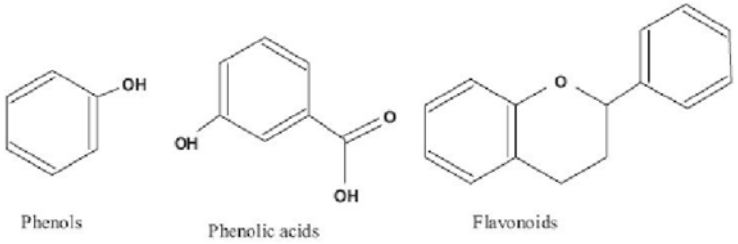
-Cardiovascular disease
-Diabetes
-Cancer
-Arthritis
-Cognition
Are all oxidation linked diseases.

Obesity enhance oxidation linked diseases

Aging also involves oxidation processes

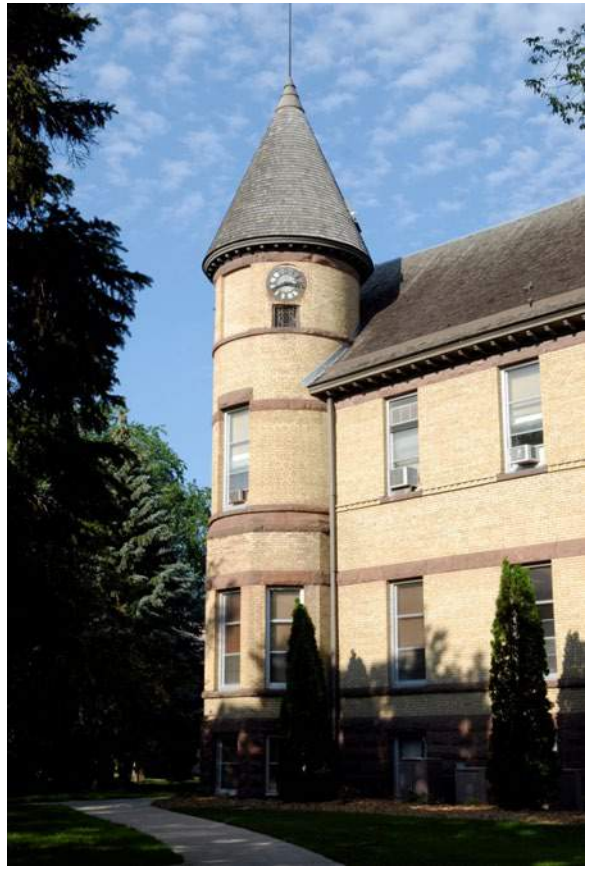
Role of Phenolic (Combinatorial Biochemistry) Profiles in Plant Growth and Development (Secondary Metabolites) Linked to Redox Balance





- 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)

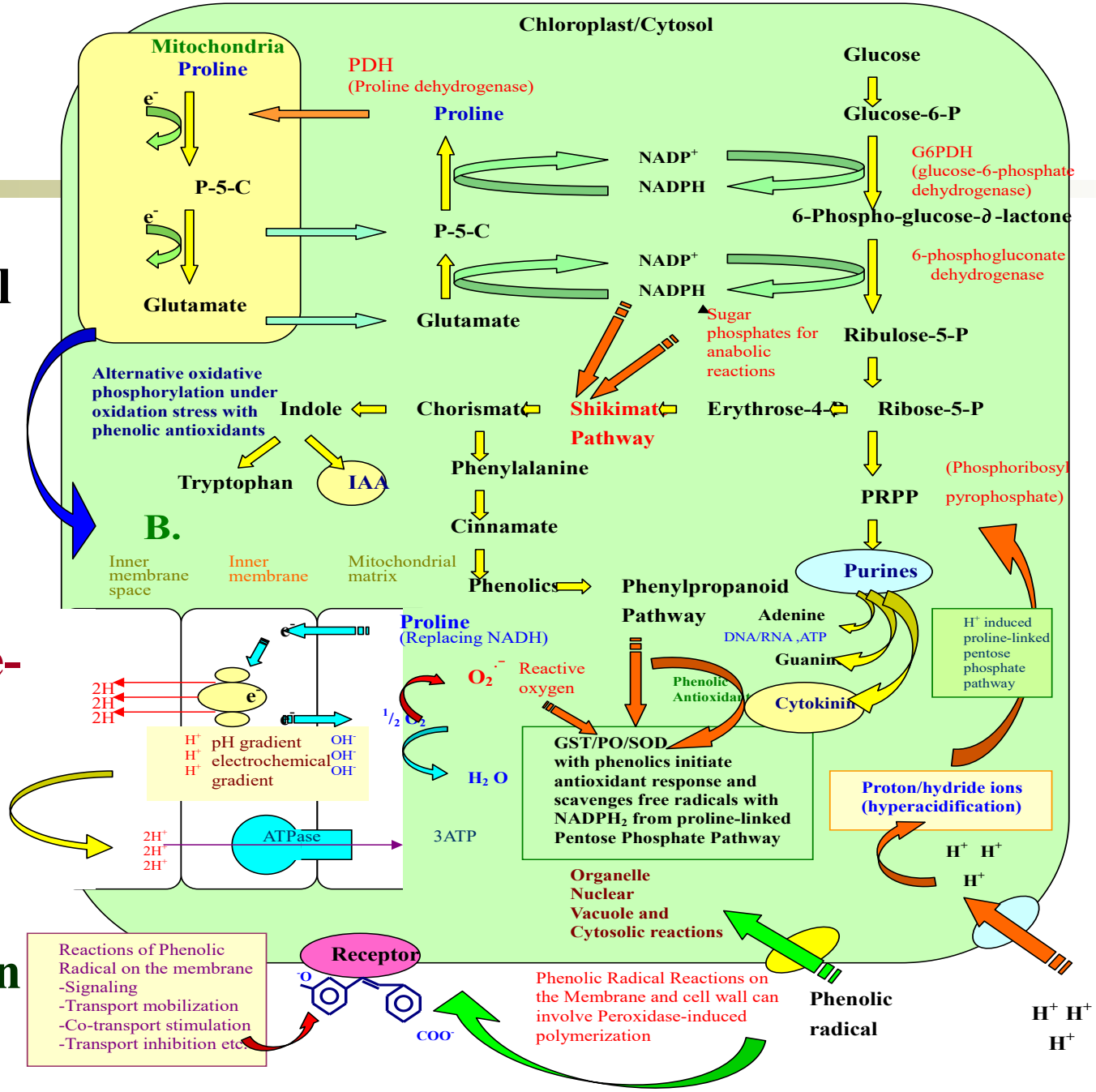
4) Flavonoids – Oregano, pea, mungbean (***Helicobacter pylori*** control; alpha-Glucosidase Inhibitor; Antioxidant Response)

5) Coumarins and Quinones – Fava bean; Fenugreek (***H.pylori*** and food borne pathogens)

Plant Cell

Plant Whole Foods

Structure-Function Plus PLPPP Redox Protection



Rationale

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

- Therefore finding solutions requires a strong dietary and whole food strategies coupled to changes in lifestyle such 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)

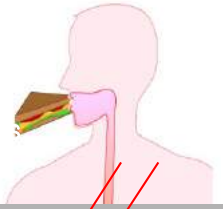
Glucosidase Inhibitor : Understanding how it works & Targeting Soluble Phenolics Crop Foods/Plants

#1 Inhibition of amylase

Starch

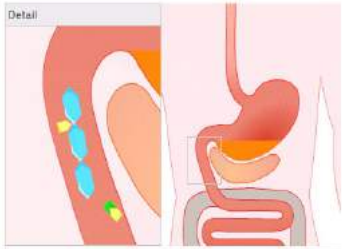
Sucrose

Pancreatic α-Amylase



Brush–border α-Glucosidases

#2 Inhibition of glucosidase



Effect of acarbose

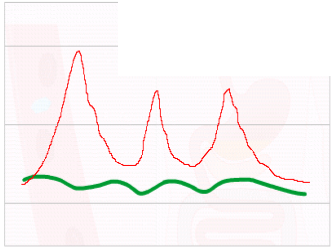
Acarbose arrives into the duodenum with the pre-digested pulp. Acarbose binds to the glucosidase, temporarily inhibiting its enzymatic process.

Glucose

Glucose + Fructose

Absorption

Glucose



significantly reduces postprandial glucose peaks.

Digestion of carbohydrates

Food is made up of complex carbohydrate chains that are split up into shorter chains by the enzyme glucosidase in the duodenum.

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

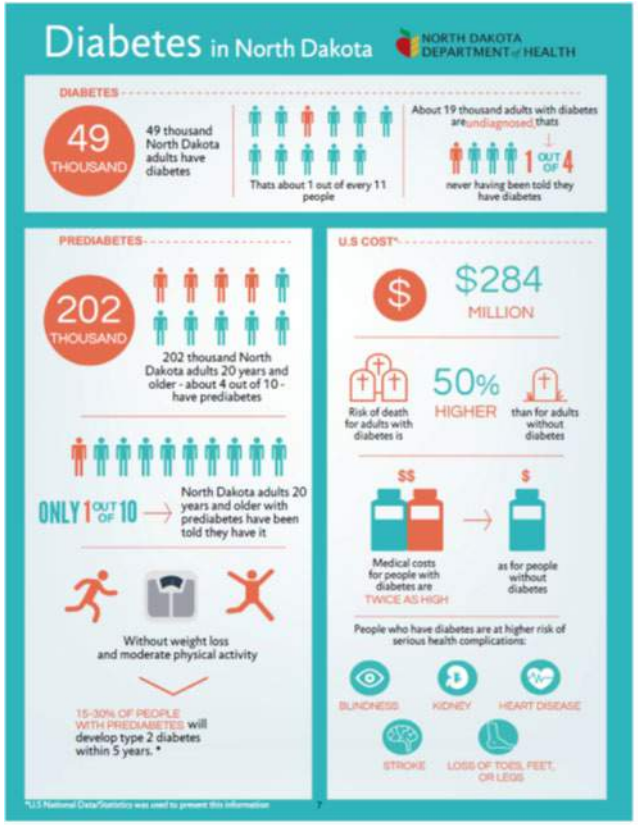
Role of inexpensive refined calories?

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.*

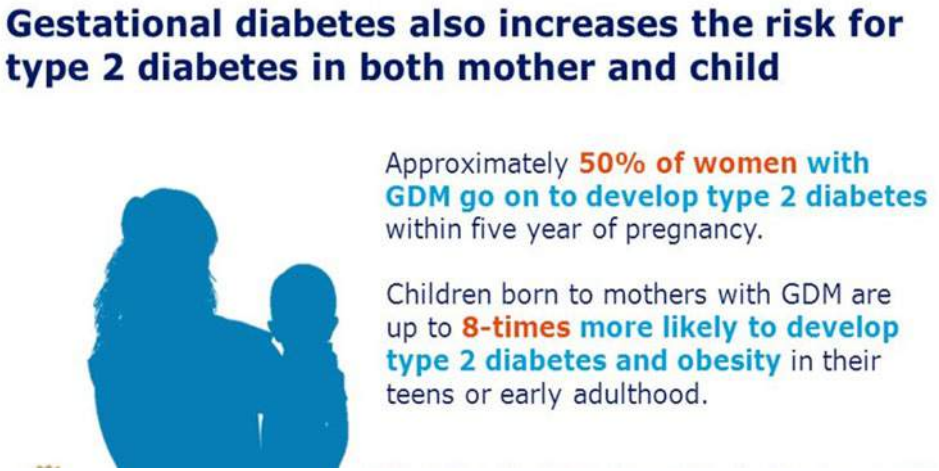
Diabetes in North Dakota: American Indians Health Perspectives

- 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.

Indigenous Food Systems & Health Benefits

Previous and Current Research

JOURNAL OF MEDICINAL FOOD
J Med Food 10 (2) 2007, 266–275

DOI: 10.1089/jmf.2006.234

Health Benefits of Traditional Corn, Beans, and Pumpkin: *In Vitro* Studies for Hyperglycemia and Hypertension Management

Y.-I. Kwon,[1] E. Apostolidis,[1] Y.-C. Kim,[2] and K. Shetty[1]

Departments of [1]Food Science and [2]Nutrition, University of Massachusetts, Amherst, Massachusetts

Previous and Current Research

JOURNAL OF MEDICINAL FOOD
J Med Food 12 (4) 2009, 704–713

DOI: 10.1089/jmf.2008.0122

Full Communication

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

Lena Galvez Ranilla,[1] Emmanouil Apostolidis,[2] Maria Ines Genovese,[1]
Franco Maria Lajolo,[1] and Kalidas Shetty[2]

TABLE 3. PHENOLIC COMPOUNDS DETECTED BY HPLC IN ANDEAN GRAINS

		Phenolic compound (μg/g of sample weight)		
Code	*Common name*	*Quercetin derivatives*[a]	*Protocatechuic acid*	p-*Coumaric acid*
1	Kañiwa	943 ± 35	ND	ND
2	Quinoa	1,131 ± 56	ND	ND
4	Corn 1	ND	287 ± 15	ND
6	Corn 3	ND	ND	22 ± 1
7	Corn 4	ND	ND	34 ± 5

Data are mean ± SD values. ND, not detected.
[a]Expressed as quercetin aglycone.

Anti-diabetic Potential of Selected Traditional Crop Foods

Crops	Total Phenolic Content (mg/g)	Total Antioxidant Activity (% inhibition)	Alpha-amylase Inhibition (%)	Alpha-glucosidase Inhibition (%)
Purple Corn	8.0	77%	0%	51%
Quinoa	2.3	86%	0%	30%
Andean Legume	4.0	40%	0%	20%
Round orange pumpkin	0.17	33%	60%	50%
Jack Bean	1.2	22%	50%	20%
Dark red corn	0.5	38%	32%	35%

Previous and Current Research

J Ethn Foods 4 (2017) 163–171

Contents lists available at ScienceDirect

Journal of Ethnic Foods

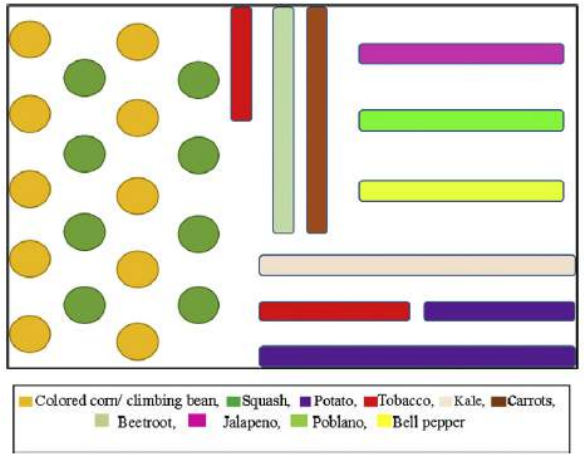
journal homepage: http://journalofethnicfoods.net

Original article

Bioactive vegetables integrated into ethnic "Three Sisters Crops" garden targeting foods for type 2 diabetes-associated health disparities of American Indian communities

Lokesh K. Mishra [a, b], Jacob Walker-Swaney [a], Dipayan Sarkar [a], Kalidas Shetty [a, *]

[a] Department of Plant Sciences, North Dakota State University, Fargo, USA
[b] College of Home Science, Central Agricultural University, Tura, Meghalaya, India



Previous and Current Research

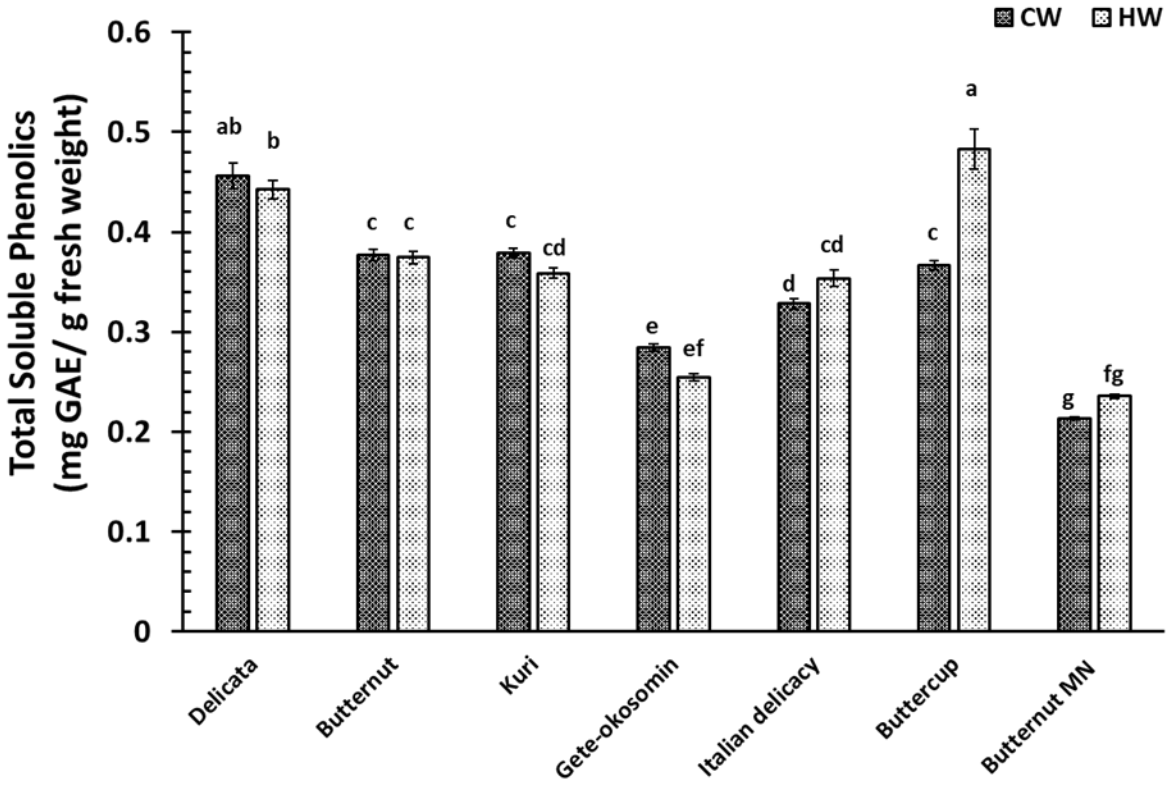
Phenolic Composition and Evaluation of the Antimicrobial Activity of Free and Bound Phenolic Fractions from a Peruvian Purple Corn (*Zea mays* L.) Accession

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

- Journal of Food Science 2017. 82(12):2968-2976.

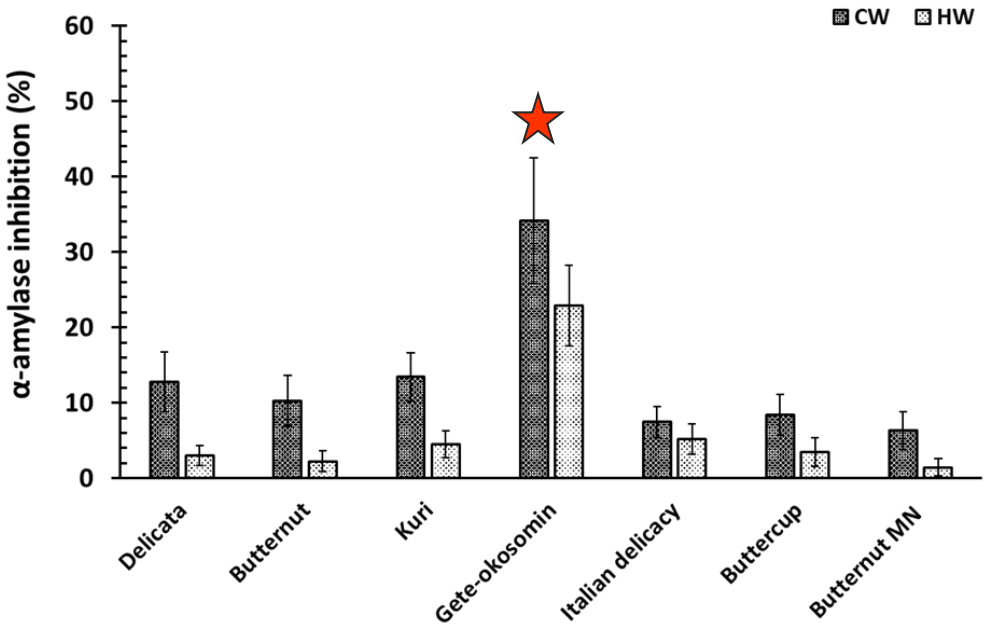
Previous and Current Research

- Screening of different squash cultivars for phenolic bioactive-linked T2D health benefits



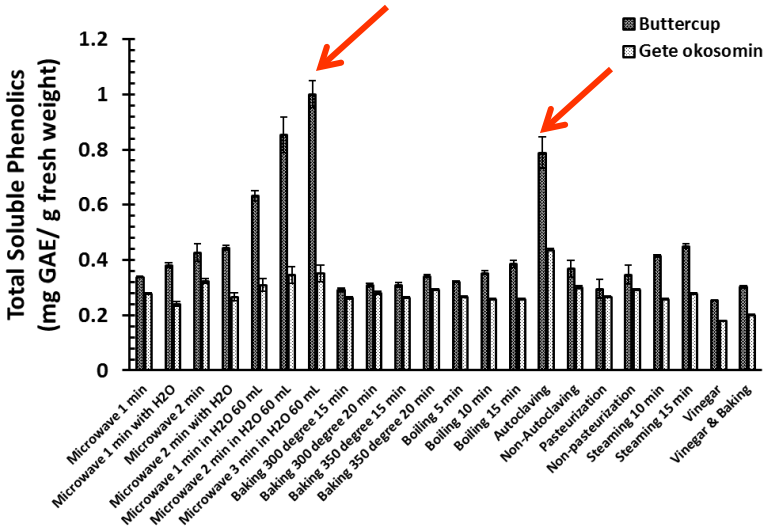
Previous and Current Research

- Screening of different squash cultivars for phenolic bioactive-linked T2D health benefits

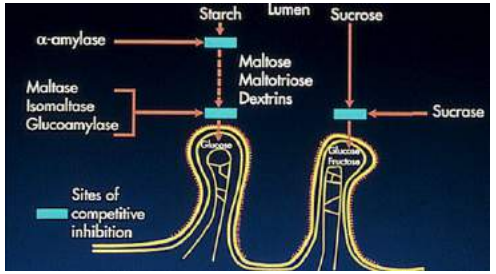


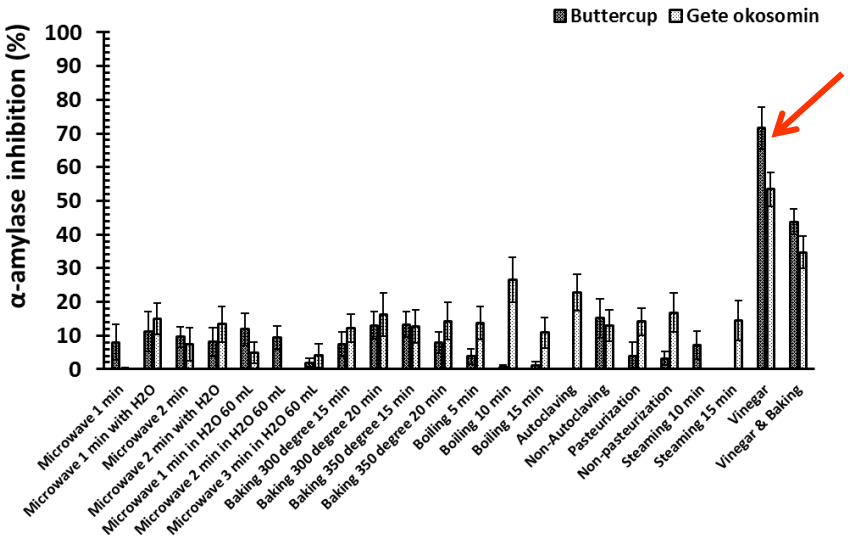
Previous and Current Research

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



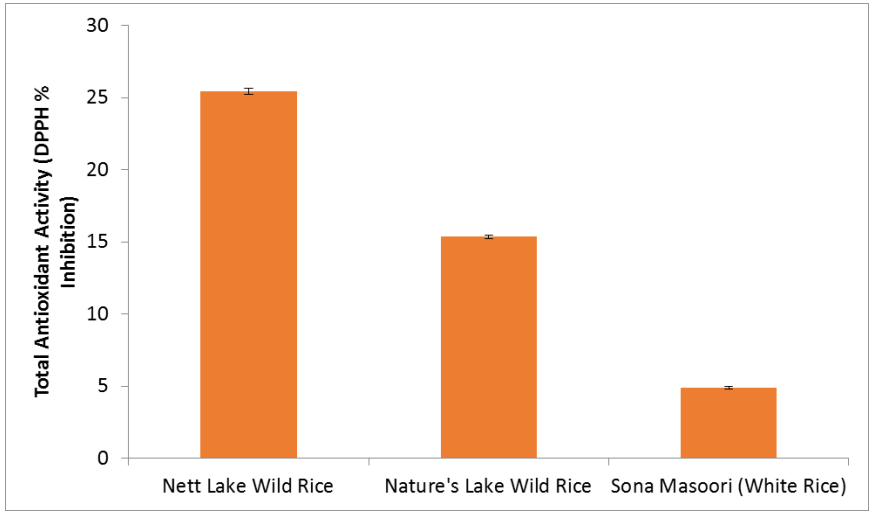
Microwaving & Autoclaving improved total phenolic content, while adding vinegar and baking improved α-amylase enzyme inhibitory activity.

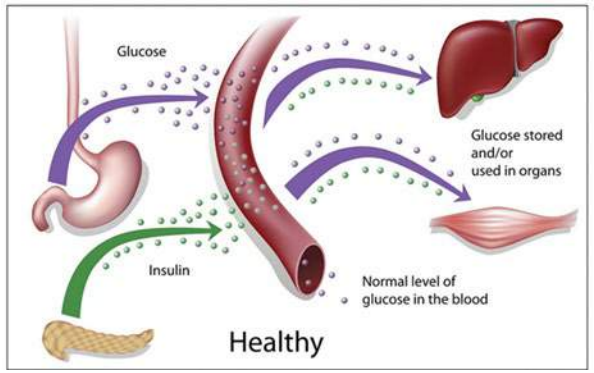


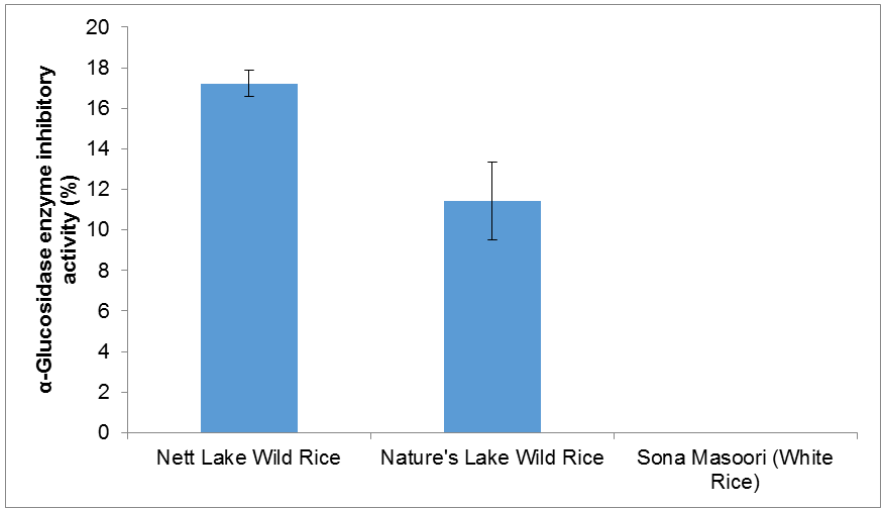


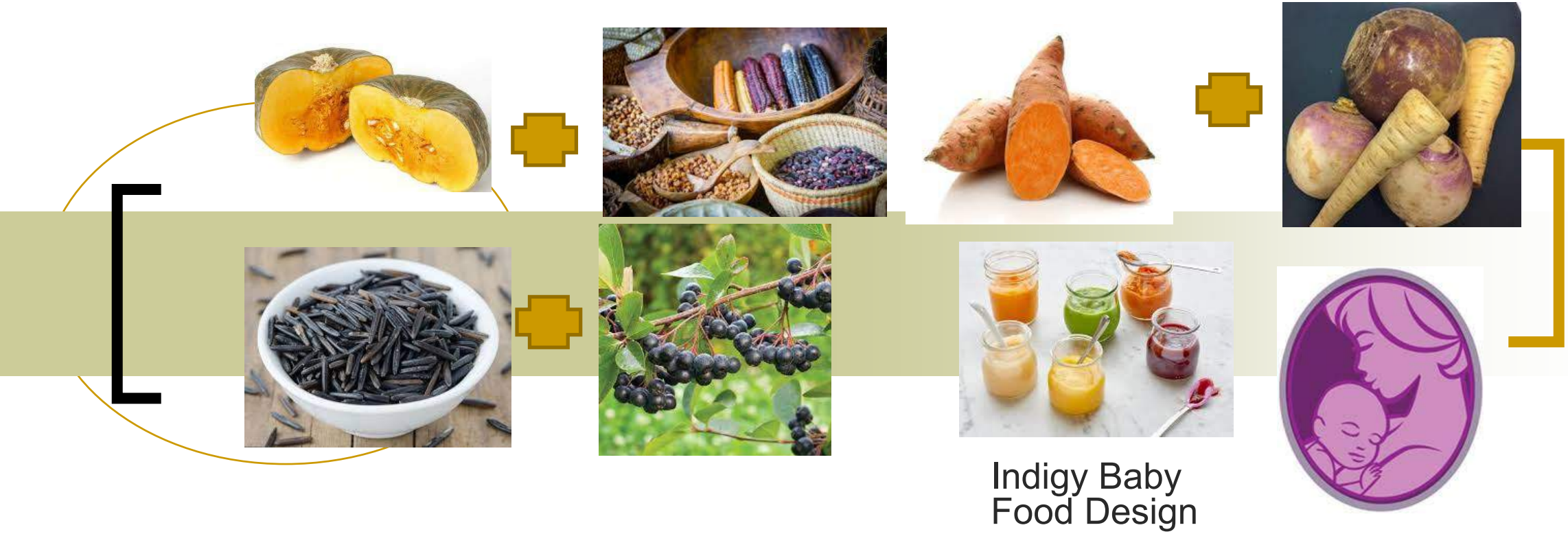
Previous and Current Research

Wild rice study (Cooked before extraction)





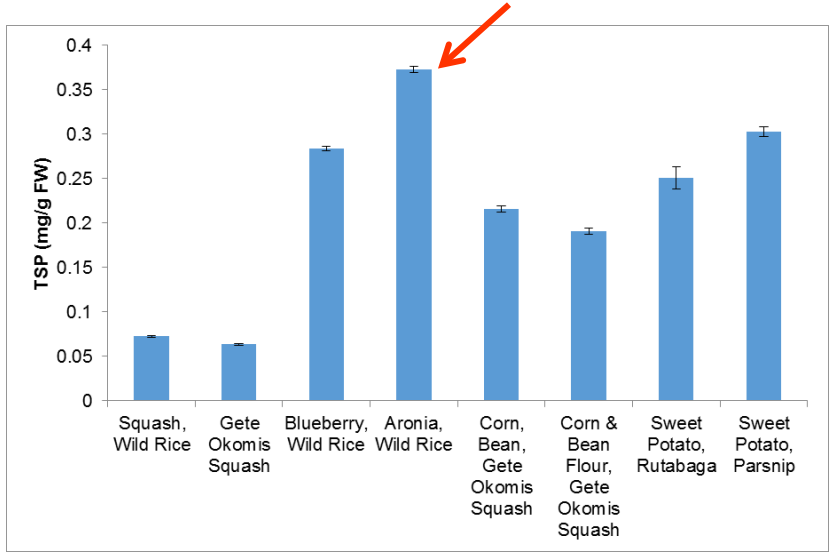


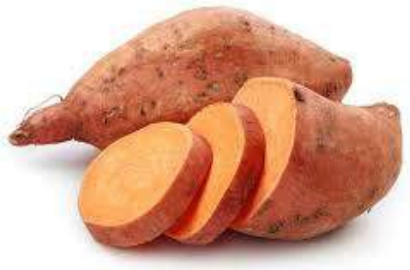


1. Selection of Suitable Cultivars with Health Benefits
2. Optimization of Food Processing Strategy
3. Integrations & Synergies of different Traditional Native American food Crops to Improve Health Benefits
4. Evaluation of Nutritional Qualities & Health Benefits of Indigenous Food Systems

Previous and Current Research

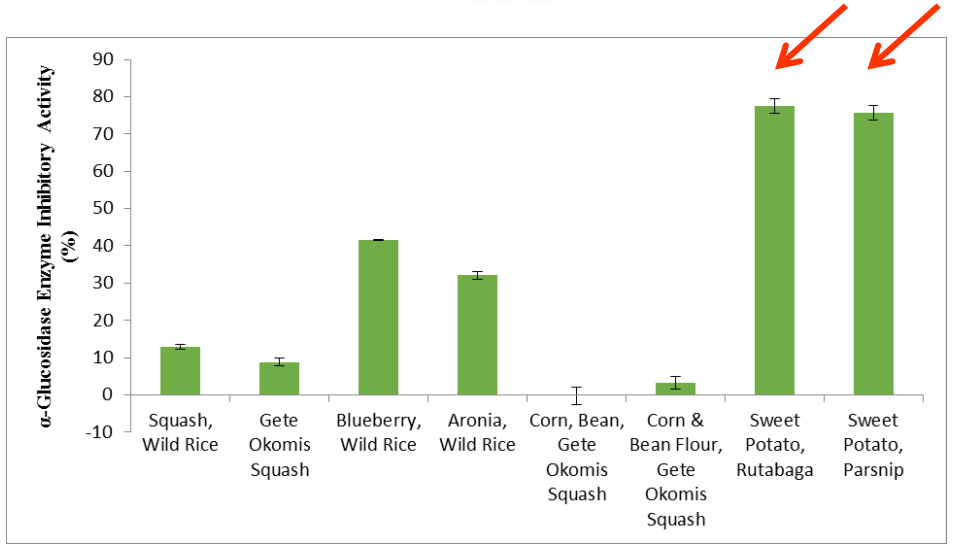
- Baby Food (Squash, sweet potato, wild rice, berries, corn, bean) Design Study.





Wild Rice

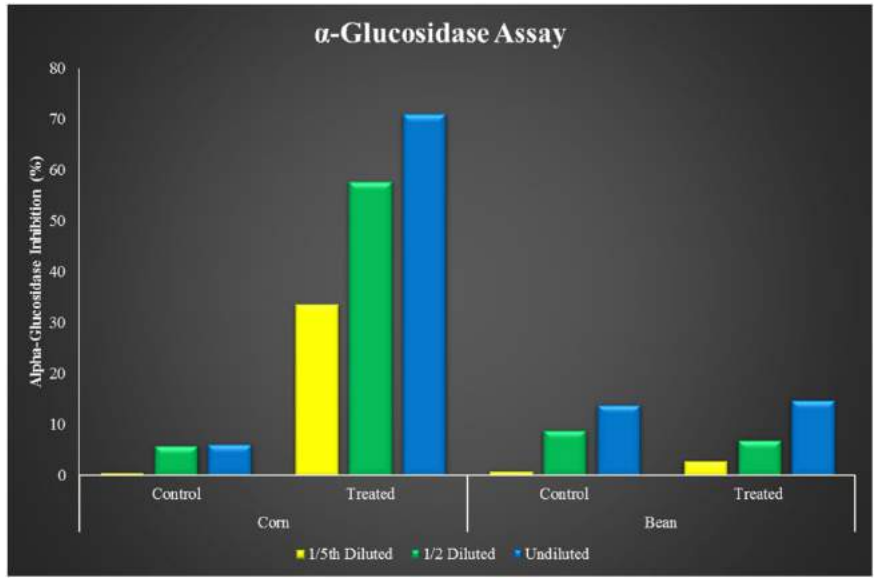
Aronia



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

Wild Rice

Aronia

Synergies and Integration of Different Traditional Foods to Improve Health Benefits

Traditional Food Recipes

Community Based Food Enterprise

Maternal and Child Health

Nutritional Security and Public Health

Future Direction

Strategies to Build Future Research Initiatives

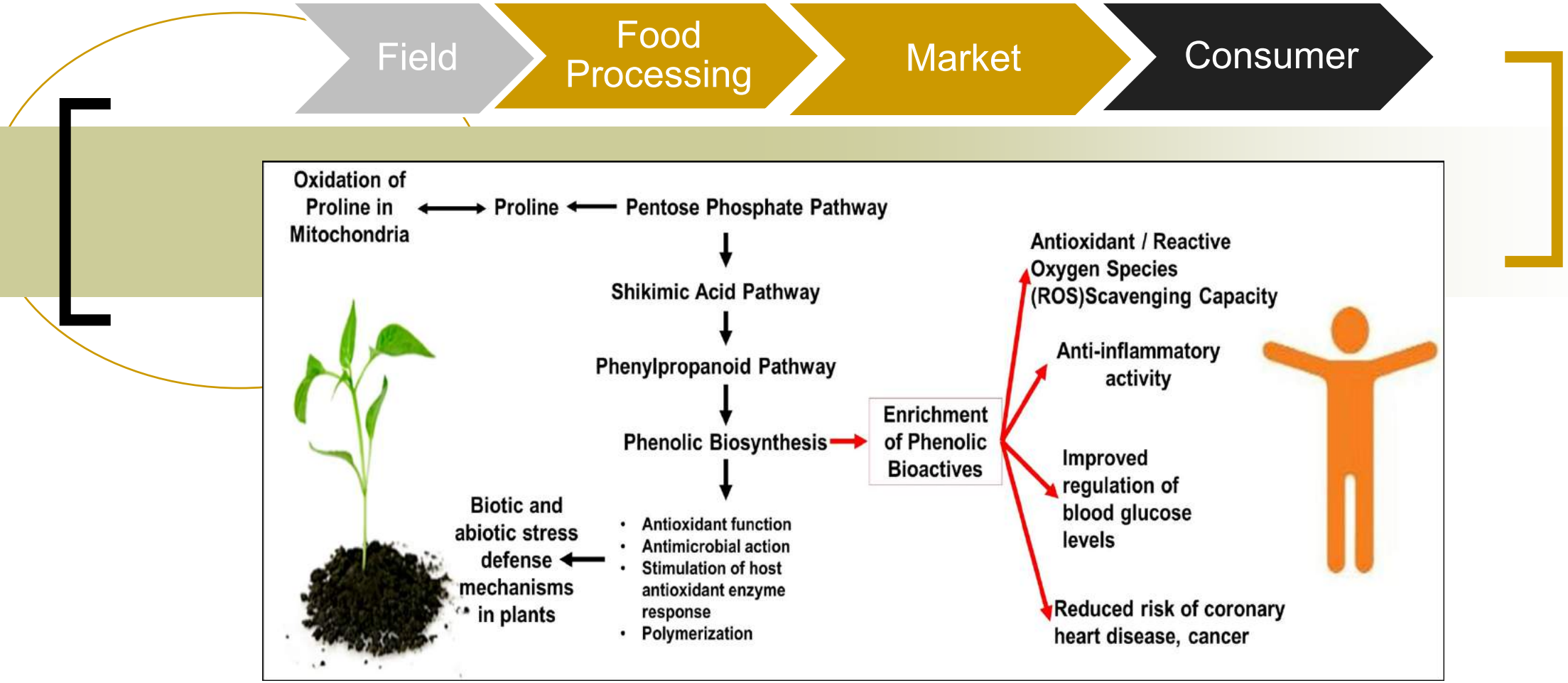
Agricultural Production and Marketing Initiatives

- 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

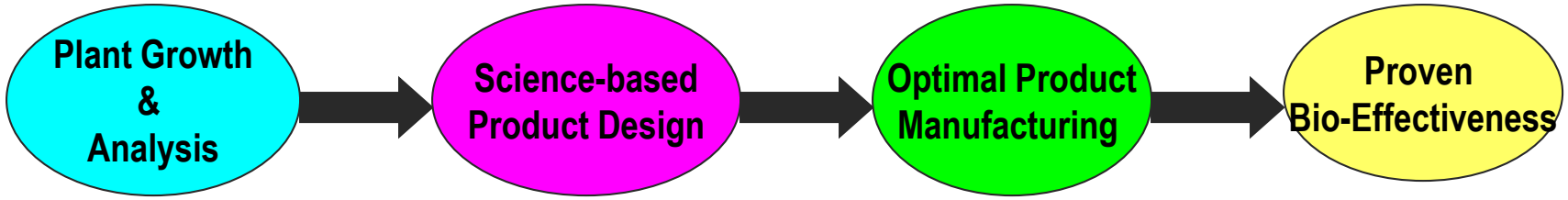
- Designing Courses on "Traditional Food and Health Benefits"
- Building Institute focusing research on Traditional Food and Indigenous Health
- Integration of Leading Global Research and Educational Institutes

Microbiome for Climate Resilience and Human Health



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