Can We Breed Staple Food Crops To Improve Human Health: An Emerging Facet in Contemporary Crop Improvement

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**Goal:** Reduce morbidity and mortality from chronic disease through the improvement of staple crops and the dissemination of those crops within the world marketplace

**Focus = Discovery**
- Discover traits that will decrease the morbidity and mortality associated with chronic disease?
- Breed crops with improved health beneficial properties
I will focus my presentation on Pulse Crops. What are they?
In Fact:

FAO and the United Nations has declared 2016

“The International Year of the Pulses”
The Plant Breeders Conundrum! Who do we target for breeding healthier crop varieties?
Problem: Chronic Disease Prevalence is Increasing in the USA

- Obesity
- Heart Disease
- Cancer
- T2D
Objectives

1. Review the health beneficial properties of pulse crops.

2. Illustrate how we can use new tools to develop healthier food crops to reduce the economic burden and mortality of chronic disease.
Some Long Term Health Benefits of Pulse Crops in the Human Diet

Studies have shown beans in the human diet can reduce the risks for:

- Cancer (colon and mammary)
- Type 2 Diabetes
- Obesity
- Heart disease
Pathogenesis of all the Major Chronic Diseases Has the Same Underlying Principles

- Underlying Pathogenesis
  - Signaling Pathways
  - Lipid metabolism
  - Cell Proliferation
  - Cell Death
  - Vascularity


- Obesity
- Diabetes: Type-2
- Heart Disease
- Cancer
We Need Agriculture to Become an Instrument of Public Health to Save Lives Through Diet Intervention
Can dry bean in the diet reduce the Incidence of Mammary Cancer?

Research Approach:
Pre-Clinical Model for Breast Cancer

Carcinogenesis (not cancer)
- A process
- Multiple obligatory steps
Bean in the diet can also mediate Obesity in Preclinical Studies

**Fig. 1.** Growth curves of mice fed either high-fat control (HF CTRL, ⋄) or high-fat 60% (w/w) small red dry bean (HF 60% SR, ⋄) for 12 d. Values are means, with their standard errors for each point represented by vertical bars (n = 20). *The growth curves were statistically different (P < 0.05; repeated-measures ANOVA). **From 5 d post experimental diet until the end of the experiment, significant differences between HF CTRL and HF 60% SR were observed (P < 0.05).
Pulse Crops are High in Dietary Fiber

• Recommended adult DF daily intake:
  – Ranges from 21 – 40 g/day

• Actual consumption ranges from 14 to 29 g/day
Dietary Fiber

Dietary Fiber Intake and Mortality in the NIH-AARP Diet and Health Study

Yikyung Park, ScD; Amy F. Subar, PhD; Albert Hollenbeck, PhD; Arthur Schatzkin, MD†

Background: Dietary fiber has been hypothesized to lower the risk of coronary heart disease, diabetes, and some cancers. However, little is known of the effect of dietary fiber intake on total death and cause-specific deaths.

Methods: We examined dietary fiber intake in relation to total mortality and death from specific causes in the NIH (National Institutes of Health)-AARP Diet and Health Study, a prospective cohort study. Diet was assessed using a food-frequency questionnaire at baseline. Cause of death was identified using the National Death Index Plus. Cox proportional hazard models were used to estimate relative risks and 2-sided 95% confidence intervals (CIs).

Results: During an average of 9 years of follow-up, we identified 20,126 deaths in men and 11,330 deaths in women. Dietary fiber intake was associated with a significantly lowered risk of total death in both men and women (multivariate relative risk comparing the highest with the lowest quintile, 0.78 [95% CI, 0.73-0.82; P for trend, <.001] in men and 0.78 [95% CI, 0.73-0.85; P for trend, <.001] in women). Dietary fiber intake also lowered the risk of death from cardiovascular, infectious, and respiratory diseases by 24% to 56% in men and by 34% to 59% in women. Inverse association between dietary fiber intake and cancer death was observed in men but not in women. Dietary fiber from grains, but not from other sources, was significantly inversely related to total and cause-specific death in both men and women.

Conclusions: Dietary fiber may reduce the risk of death from cardiovascular, infectious, and respiratory diseases. Making fiber-rich food choices more often may provide significant health benefits.

Arch Intern Med.
Published online February 14, 2011.
doi:10.1001/archinternmed.2011.18
What is Dietary Fiber?

- Dietary fiber is composed of carbohydrate polymers which are not digested and absorbed in the small intestine of humans.

- Total Dietary (TDF) includes three components: Soluble (SDF) and Insoluble dietary fiber (IDF), and oligosaccharides. (AOAC 2011.25)
Dietary Fiber

Dietary fiber is the part of food that is not affected by the digestive process in the body. Only a small amount of fiber is metabolized in the stomach and intestine, the rest is passed through the gastrointestinal tract and makes up a part of the stool.
## Dietary fiber content in cooked cereals and pulses (g/100 g dry matter)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fructans</th>
<th>Arabinoxylan</th>
<th>Cellulose</th>
<th>β-Glucan</th>
<th>Resistant starch</th>
<th>Dietary fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>2.9</td>
<td>5.9</td>
<td>2.5</td>
<td>0.6</td>
<td>1.3</td>
<td>12.9</td>
</tr>
<tr>
<td>Corn, sweet</td>
<td>1.1</td>
<td>1.4</td>
<td>1.9</td>
<td>n.d.</td>
<td>3.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Rice, whole meal</td>
<td>2.2</td>
<td>0.5</td>
<td>1.6</td>
<td>0.4</td>
<td>0.5</td>
<td>7.0</td>
</tr>
<tr>
<td>Bean, common</td>
<td>1.4</td>
<td>2.2</td>
<td>6.0</td>
<td>n.d.</td>
<td>4.8</td>
<td>18.2</td>
</tr>
<tr>
<td>Lentils</td>
<td>1.5</td>
<td>1.0</td>
<td>5.4</td>
<td>n.d.</td>
<td>2.1</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Adapted from Dodevska et al, 2013.

n.d., not detectable. Dietary fiber by AOAC 985.29.
Can we improve Dietary Fiber in Dry Edible Bean?

- Can we?
  - Increased total fiber content
  - Increased insoluble fiber content
  - Lower oligosaccharide content

- What does success look like?
  - A bean balanced in fiber (soluble/insoluble), fewer available calories, and reduced oligosaccharides
The USDA Common Bean Coordinated Agricultural Project

BeanCAP

1. Sequenced the complete bean genome.

2. Genome wide association mapping using genotype by sequencing and GWAS (Genome Wide Association Studies).

3. Genomic marker development and application to improving the health benefits of dry edible beans.
## Dietary Fiber Varies Among Bean Cultivars

<table>
<thead>
<tr>
<th>Entry</th>
<th>% IDF</th>
<th>% SDF</th>
<th>% TDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (%)</td>
<td>11.4 - 16.9</td>
<td>5.1 - 10.3</td>
<td>22.8 - 30.2</td>
</tr>
<tr>
<td><strong>Highest</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR0443-151</td>
<td>16.9</td>
<td>8.2</td>
<td>30.2</td>
</tr>
<tr>
<td>IP08-2</td>
<td>15.7</td>
<td>9.5</td>
<td>30.1</td>
</tr>
<tr>
<td>ND021717</td>
<td>16.2</td>
<td>7.6</td>
<td>29.8</td>
</tr>
<tr>
<td>AC Resolute</td>
<td>15.9</td>
<td>8.3</td>
<td>29.4</td>
</tr>
<tr>
<td>Max</td>
<td>16.1</td>
<td>8.0</td>
<td>28.6</td>
</tr>
<tr>
<td><strong>Lowest</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T9905</td>
<td>12.6</td>
<td>7.5</td>
<td>23.6</td>
</tr>
<tr>
<td>Norstar</td>
<td>12.7</td>
<td>6.4</td>
<td>23.4</td>
</tr>
<tr>
<td>BelMiNeb-RMR-7</td>
<td>11.8</td>
<td>7.1</td>
<td>23.4</td>
</tr>
<tr>
<td>Topaz</td>
<td>12.5</td>
<td>6.7</td>
<td>23.2</td>
</tr>
<tr>
<td>AC Pintoba</td>
<td>11.4</td>
<td>7.0</td>
<td>22.8</td>
</tr>
</tbody>
</table>
We identified a region in the bean genome that was highly associated with dietary fiber.

Some regions were exclusively associated with specific types of dietary fiber.

We identified candidate genes associated with specific types of dietary fiber in dry edible beans.
Biofortification of Staple Crops

Golden Rice
Deficiency in dietary Vitamin A is estimated to kill 670,000 children under 5 each year.
Biofortification of Iron and Zinc in Bean

In some parts of Africa, an estimated 71% of children under 5 and 53% of women are iron deficient.
Summary

1. Dry bean have been shown to reduce cancer in preclinical models, and evidence suggests they reduce mortality in humans.

2. New tools and genomics have allowed us to better understand how genes are inherited and expressed.

3. Genomics will enhance breeding for more nutritious crops.
Final thoughts: Are We Ready?

- It will take a significant investment in research to alter staple food crops for better nutrition and health.

- Who will be the drivers of this change:
  - Land Grant Universities?
  - Private Industry?
  - Partnerships?
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