Michigan BEAN COMMISSION

Anatomy of the Bean: Dry Bean Breeding and Production for Consumer Acceptance

June 17, 2021

Presenter:

Karen Cichy, PhD
Research Plant Geneticist USDA,
Agriculture Research Service and Adjunct Associate Professor
Michigan State University

Moderator:
Barbara J. Ivens, MS, RDN, FADA, FAND

Approved for 1 CPE (Level 2) by the Commission on Dietetic Registration

Bean Academy webinars

The Michigan Bean Commission (MBC) is pleased to offer a series of free accredited webinars, many with a plant-forward eating focus, that cover a broad range of contemporary nutrition and food topics.

Webinars are a blend of research, science and practice to help nutrition professionals stay informed on recent developments on relevant topics.

Webinars are funded as part of a 2020-2021 USDA grant to the Michigan Bean Commission.

Michigan BEAN COMMISSION

Webinar logistics

- A Handout of the slides presented today is available at: https://michiganbean.com/hp-webinar-cichy-presn/
- The Continuing Education Credit certificate is available to download after the webinar: https://michiganbean.com/hp-webinar-cichy-ceu/
- The presenter will answer questions at the end of this webinar. Please submit questions by using the ‘Q&A’ feature on your computer screen.

Michigan BEAN COMMISSION

Today's Faculty

- **Karen Cichy, Ph.D.**
  - Research Plant Geneticist USDA Agriculture Research Service
  - Adjunct Associate Professor, Michigan State University

- Moderator:

Barbara J. Ivens, MS, RDN, FADA, FAND – Consultant, Michigan Bean Commission

Learning Objectives

Upon completion of this webinar participants will be able to:

- Describe the genetic diversity of beans
- Explain methods used in bean breeding
- Discuss approaches used in breeding beans for nutritional and culinary quality
- Outline contributions of bean breeding research to consumer acceptance

Anatomy of the Bean: Dry Bean Breeding and Production for Consumer Acceptance

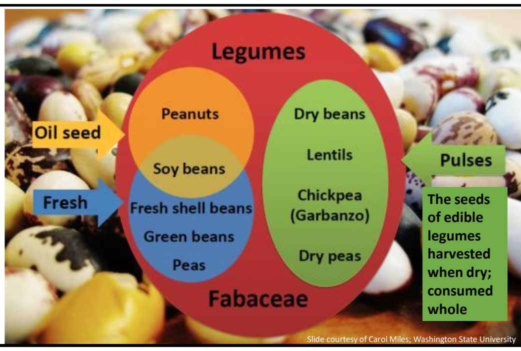
Karen Cichy, USDA-ARS

June 17, 2021

USDA-ARS Food Legume Genetics

Program Goal:
To increase market demand for beans and pulses and increase consumption by improving end-use quality traits through plant breeding

Focus
- Cooking time & canning quality
- Nutrition
- Flavor
- Use as a flour



Worldwide production of legumes (FAO 2019 data)

Crop	Total production (metric tons)
Soybean	348,712,311
Groundnuts	45,950,901
Beans, dry	30,434,280
Chickpeas	17,192,188
Peas, dry	13,534,166
Cowpeas, dry	7,233,408
Lentils	6,333,352
Pigeon Peas	5,960,575
Fava Beans	4,923,090
Lupins	1,188,213
Bambara beans	195,151

From: Acosta Gallegos, et al. 2020. Phaseolus Beans Crop Vulnerability Statement. (accessed August 18, 2020)

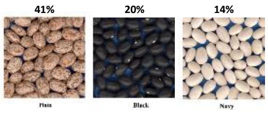
Photo Credit: https://akm-img-a-in.tosshub.com/indiatoday/images/story/201512/modi-pulse---2_647_120615102747.jpg

Dry Bean Production in the United States

U.S. is in the top 10 of dry beans in the world: 3,296 million pounds in 2020

10 major market classes grown in United States

<u>Top 3</u>:

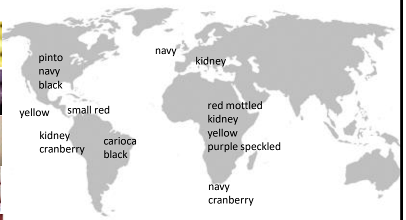


USDA-NASS Crop Production 2020 Summary. January 2021

Large diversity for dry bean seed color, shapes, and sizes

Major Dry Bean Market Classes- in the U.S

Globally 62 different market classes recognized
Strong regional preferences for specific market classes



Food and Agriculture Organization of the United Nations (FAO). (2002). Production Yearbook 2002 (vol. 56). Roma: FAO.

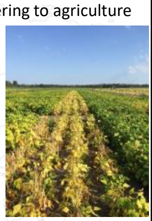
Origin and Domestication of Beans

Domestication: Process done by humans starting about 10,000 years ago in specific and multiple locations in the world to move from hunter-gathering to agriculture

Traits of importance during domestication:

1) Plant growth habit
2) Pod dehiscence
3) Seed Dormancy
4) Photoperiod sensitivity
5) Seed Weight
6) Seed Color

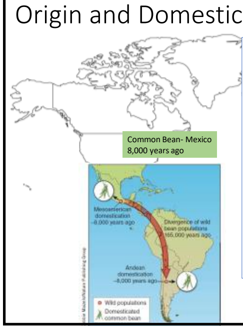
a wild relative of the lima bean growing in Costa Rica
DANIEL DEBOUCK/CIAT



Common bean growing in Michigan
KAREN CICHY

Reviewed in Parker, T.A. and Gepts, P., 2021. Population Genomics of Phaseolus spp.: A Domestication Hotspot

Origin and Domestication of Beans

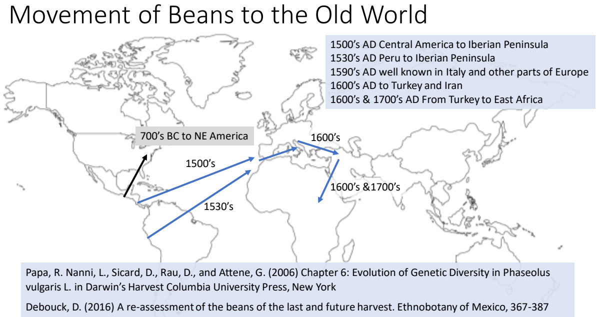


Bitocchi, Elena, et al. PNAS (2012): 201108973.
Schmutz, J. et al. Nat. Genet. 46, 707–713 (2014).
Gaut, Brandon S. Nat. Genet 46.7 (2014): 663.

Domestication of Beans

Movement of Beans to the Old World

- 1500's AD Central America to Iberian Peninsula
- 1530's AD Peru to Iberian Peninsula
- 1590's AD well known in Italy and other parts of Europe
- 1600's AD to Turkey and Iran
- 1600's & 1700's AD From Turkey to East Africa



Papa, R. Nanni, L., Sicard, D., Rau, D., and Attene, G. (2006) Chapter 6: Evolution of Genetic Diversity in Phaseolus vulgaris L. in Darwin's Harvest Columbia University Press, New York

Debouck, D. (2016) A re-assessment of the beans of the last and future harvest. Ethnobotany of Mexico, 367-387

Agricultural Production Niches of *Phaseolus* Beans

Climbing bean production, Rwanda
Photo Credit: Phil Miklas, USDA-ARS

Altitudes: sea-level to 3000m

Plant growth habits: determinate, indeterminate and climbing

Production: 1) Monoculture 2) Intercropped 3) various rotations

Plant Uses: leaves, green pods, fresh beans, dry beans

Maize and Bean Intercrop, Rwanda
Photo Credit: Phil Miklas, USDA-ARS

De Ron et al., (2016) History of the Common Bean Crop: Its Evolution Beyond its Area of Origin and Domestication ARBOR Vol. 192-779, mayo-junio 2016, a317. ISSN-L: 0210-1963

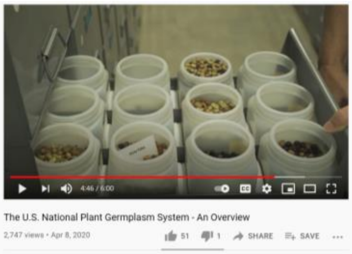
Germplasm Banks: Sources of Genetic Diversity

~1750 worldwide

~7.4 million accessions

Only ~2% have been used in breeding

Varshney et al., (2020) 5Gs for Crop Improvement. Current Opinion In Plant Biology 56:190-196



https://www.youtube.com/watch?v=uHOclGNELuw

Phaseolus Germplasm Collections

Photo of bean germplasm greenhouse seed increase at the Western Regional Plant Introduction Station, Pullman, WA

	US Collection, Pullman, WA	CIAT Collection (International Center, Colombia)
Geographic Origin	Number (percent of collection)	
Northern America	2,287 (17%)	1,929 (5%)
Central America	3,681 (27%)	11,461 (30%)
South America	1,654 (12%)	12,174 (32%)
Caribbean	136 (1%)	340 (1%)
Europe	2,334 (17%)	3,995 (11%)
Asia	2,707 (20%)	3,154 (8%)
Africa	639 (4.7%)	3,896 (10%)
Oceania	20 (0.2%)	51 (0.1%)
Uncategorized	241 (1.8%)	938 (2%)
Total	**13,699**	**37,938**

US Numbers From: Acosta Gallegos, et al. 2020. Phaseolus Beans Crop Vulnerability Statement. CIAT numbers courtesy of Dr. Peter Wenzl, CIAT Genetic Resources Program Head and Luis Guillermo Santos Meléndez, Seed Conservation and Viability Lab Coordinator, June 16, 2021

A need to characterize and utilize genetic diversity

Origin	**Number of Lines**
Africa	282
Asia	6
Caribbean	30
Cen. America	7
Europe	12
North America	117
South America	32
Unknown	13
Cultivation status	**Number of Lines**
Landrace	202
Breeding Line	66
Variety	132
Unknown	102

Currently 500+ genotypes collected in the ADP

Cichy et al, (2015) *Crop Sci*

Germplasm Sources for Public Plant Breeding for Cultivar Development (All Crops)

49.4% from other public breeding programs

24.7% USDA Germplasm Collections

5.6% private industry

95% of public breeders regularly share their germplasm with other public sector breeders and they use an MTA 61% of the time.

Dawson, J. et al., 2018 Establishing Best Practices for Germplasm Exchange, Intellectual Property Rights, and Revenue Return to Sustain Public Cultivar Development. Crop Sci. 58:469-471

Shelton, A.C. and Tracy, W.F. 2017 Cultivar Development in the US Public Sector. Crop Sci. 57: 1823-1835

Bean Breeding Nursery, Saginaw Valley Research Farm and Extension Center, Richville, Michigan July 2020

Dry Bean Variety Development in the US

Major Selection Factors:

1. Dry Seed Characteristics (shape, size, color)
2. Seed Yield
3. Plant growth habit (for ease of production/harvest)
4. Plant Disease Resistance
5. Canning Quality

Photo Credit: J. Kelly

Bean Breeding- Process Overview

1. Determine breeding objective (i.e- increased seed yield)
2. Identify sources of genetic variability for the trait(s) of interest
3. Combine/hybridize and make selections
4. Multi-year and location testing
5. Seed Increase-Disease free
6. Release improved varieties

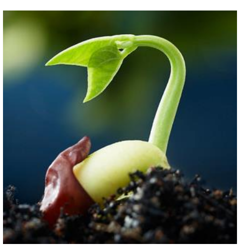
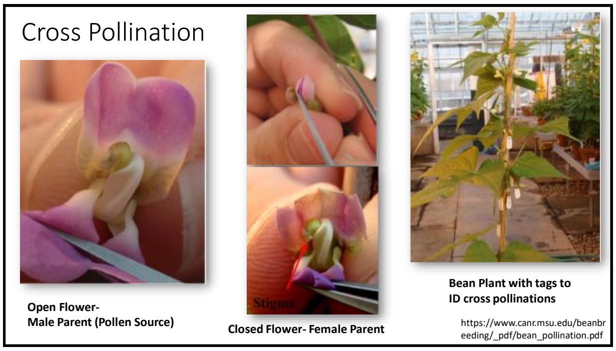
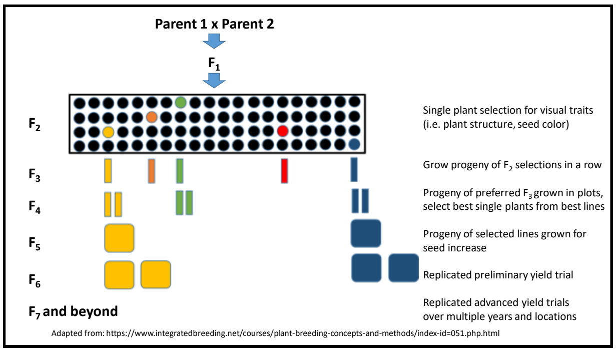


Photo Credit: USDA


Cross Pollination
Stigma
Open Flower-
Male Parent (Pollen Source)
Closed Flower- Female Parent
Bean Plant with tags to
ID cross pollinations
https://www.canr.msu.edu/beanbreeding/_pdf/bean_pollination.pdf


Parent 1 x Parent 2
F_1
F_2
F_3
F_4
F_5
F_6
F_7 and beyond
Single plant selection for visual traits (i.e. plant structure, seed color)
Grow progeny of F_2 selections in a row
Progeny of preferred F_3 grown in plots, select best single plants from best lines
Progeny of selected lines grown for seed increase
Replicated preliminary yield trial
Replicated advanced yield trials over multiple years and locations
Adapted from: https://www.integratedbreeding.net/courses/plant-breeding-concepts-and-methods/index-id=051.php.html


Dry beans breeding for consumer quality characteristics: Rationale
Largely consumed as a whole food
Minimally processed
Agricultural Product
Clean label
Therefore, genetic variability first option to achieve acceptable quality

Consumer Quality Improvement: Opportunity to Increase Consumption

Consumption low in the US ~7 lbs per capita

Why?

- Lack of familiarity with eating and cooking pulses
- Long cooking times
- Preference for other foods
- Unpleasant taste
- Cause digestive problems

Perera, T., et al.,. (2020). Legume consumption patterns in US adults: National Health and Nutrition Examination Survey (NHANES) 2011–2014 and Beans, Lentils, Peas (BLP) 2017 survey. *Nutrients, 12*(5), 1237.

Niva, M et al. (2017). Barriers to increasing plant protein consumption in Western populations.

Phillips, Tet al. (2015) Canadian Journal of Dietetic Practice and Research, 76(1), 3-8.

Genetic improvement of beans for quality characteristics relevant to consumers

1. Canning Quality
2. Cooking Time
3. Nutritional Composition

Canning quality: how well beans withstand the canning process

This measurement helps:

Breeding-Selection of superior varieties

Identify agronomic and seed handling practices influencing quality

Canning Quality: Major End Use factor since 1930's

via small scale evaluation method

Important characteristics

- Water uptake during soaking
- Seed coats withstand breakage
- Beans stay intact
- Firm end product texture

1. Manual seed cleaning.

2. Moisture content measurement.

3. Individual subsample preparation.

4. Soaking and/or Blanching.

5. Seeds transferred to cans.

6. Hot brine added to cans.

7. Cans sealed with an automatic sealing system.

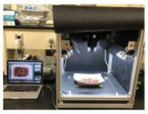
8. Cans cooked in retort.

Wang, W., Wright, E., Uebersax, M., and Cichy, K.A. A Pilot-scale Dry Bean Canning and Evaluation Protocol. Under Review: Journal of Food Processing and Preservation

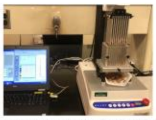
1. Cans are matched with labeled paper trays.

2. Sensory evaluation for appearance by a trained panel in person or through recorded video.

3. Samples weighted for drained weight.



4. High quality images are taken with a machine vision system.



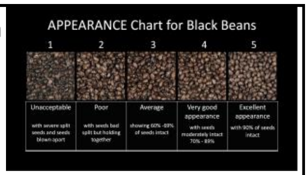
5. Texture is measured as the maximum force (kg) to cut through a subsample.

6. Color is measured as CIE L*, a*, and b* values.

Wang, W., Wright, E., Uebersax, M., and Cichy, K.A. A Pilot-scale Dry Bean Canning and Evaluation Protocol. Under Review: Journal of Food Processing and Preservation

Canning Quality Evaluation

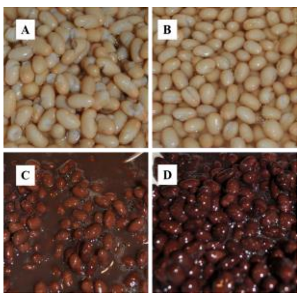
Trained panelists rate beans for appearance and color



Mendoza, F.A., Kelly, J.D., and Cichy, K.A. (2017) Automated prediction of sensory scores for color and appearance in canned black beans (Phaseolus vulgaris L.) using a color imaging technique. International Journal of Food Properties 20:83-99

Canned beans with differences in processing quality.

A) Navy beans with many splits and poor processing quality.
B) Navy bean with acceptable processing quality.
C) Black bean which appears brown following processing.
D) Black bean which maintains black color following processing.

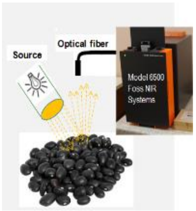


Kelly, J.D., Cichy, K.A 2013. Dry bean breeding and production technologies. Dry beans and pulses: Production, processing, and nutrition. Wiley-Blackwell, Chichester, UK, pp.23-54.

Genetic Variability for Color Retention in Black Beans

Al Dossary, O. (2016) "COLOR RETENTION AND ANTHOCYANIN CONCENTRATION IN CANNED BLACK BEANS" M.S.. Thesis, Michigan State University

Non-destructive Imaging as a Breeding Tool to Assess Canning Quality of Dry Bean



Data Sets (Grown at the MSU Saginaw Valley Res. & Ext. Center)	Accuracy (%)	
	Appearance	Color
3 varieties: Eclipse, Zorro, Zenith from 2013 – 2014 (190 samples)	74.3	96.5
92 varieties from the major U.S. bean breeding programs grown in 2014 (184 samples)	69.1	77.1
Combination of both Sets (374 samples)	75.1	88.2

Mendoza, F.A, Cichy, K.A., Lu, R. and Kelly, J.D. (2014) Evaluation of canning quality traits in black beans (Phaseolus vulgaris L.) by visible/near-infrared spectroscopy. Food and Bioprocess Technology 8:1-13

Canning Quality Summary

Canned beans: major form of delivery of beans to US consumers

Goal: improve consumer acceptability

http://the99centchef.blogspot.com/2011/04/cuban-black-beans.html

http://shewearsmanyhats.com/mexican-black-bean-pizza/

Cooking Dry Beans

2 cups dry beans = 4 to 5 cups cooked beans

Soaking beans prior to cooking will reduce cooking time and gas causing sugars.

- traditional soak: overnight in cold water
- hot soak: in boiling water (let stand for 4 hrs.)
- quick soak: boil and let stand for one hour

Hard water for soaking and cooking will increase cooking times

As dry beans age, their cooking time will increase. Cooking time will also increase by storing beans in high temperature, high humidity.

Adapted from: Garden-Robinson, J. and McNeal, K. (2013) All About Beans, NDSU extension.




Cooking time: globally important

In Sub-Saharan Africa **76%** of the population uses wood or charcoal as primary fuel for cooking.

1kg of wood for 1kg maize flour vs **7 – 11** kg of wood to cook 1 kg of beans.

11 hours spent gathering firewood per household per week.

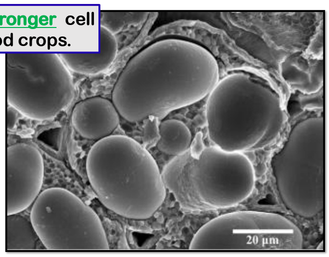
WHO – Exposure to cooking emissions leads to **1.6 million** premature deaths world wide.

Felix M, Gheewala SH (2011) Energy Procedia 9:338-343
Adkins et al (2012) Energy for sustainable development 16.3
WHO. (2007) Global Health Atlas

Why do beans have long cooking times?

✧ **Beans have thicker and stronger cell walls compared to other food crops.**

Chemistry of Cooking Time:
1. **Denature Proteins**
2. **Gelatinization of Starch**
3. **Solubilization of Cotyledon Cell Walls**



Bean (Phaseolus vulgaris) cotyledon cell (raw), imaged by scanning electron microscopy. *Photo by Amber Bassett*

Breeding beans for faster cooking times

Step 1: Evaluate genetic diversity for cooking time

Origin	Number of Lines
Africa	282
Asia	6
Caribbean	30
Cen. America	7
Europe	12
North America	117
South America	32
Unknown	13

Cultivation status	Number of Lines
Landrace	202
Breeding Line	66
Variety	132
Unknown	102

Cichy et al, (2015) *Crop Sci*

Currently 500+ genotypes collected in the ADP

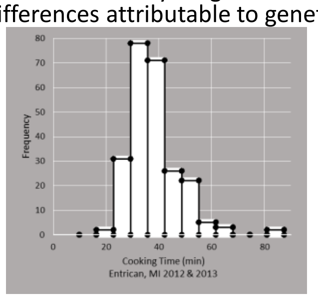
Bean germplasm grown at a single field location

- 200+ genotypes
- Two years (2012, 2013)
- 2 replications
- Randomized complete block design
- Two 4.5 m rows per plot
- Agronomic, symbiotic nitrogen fixation, cooking time and nutritional composition

Cooking time measurement

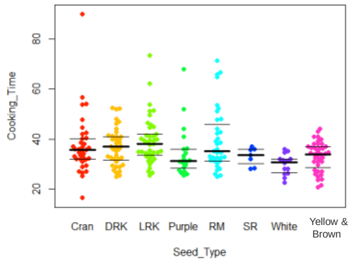
- Seeds soaked in distilled water for 12 hrs.
- Cook time measured with a Mattson (pin drop) cooker in boiling water.
- Determined on a 25 seed sample as time when 80% of pins drop.

Cooking Times in the study ranged from 16 to 90 min Differences attributable to genetics

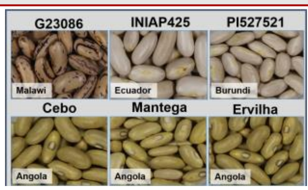


Cichy, K. A. et al. (2015) *Theoretical and Applied Genetics*

Cooking times also varied within different varieties of the same market class



Fastest Cooking Beans Identified in the Study



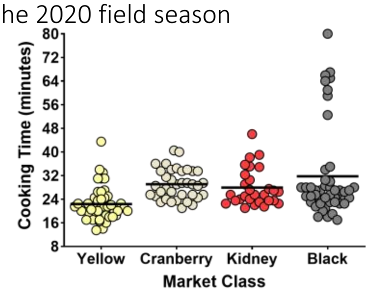
Cooking Time <20 minutes

Cooking Time <25 minutes

Mostly landraces from Africa- we use these to breed fast cooking beans adapted to the US growing conditions

Cichy et al. (2015) *Theor. Appl. Genet.* **128**(8): 1555-1567; **Wiesinger et al. (2019)** *Nutrients* **11**: 1768

Current breeding progress for cooking times: Data from the 2020 field season



At-Home Bean Sensory Kits:
A tool for educating consumers

Welcome to at-home sensory evaluation experiments!

Please make sure your kit contains the following

- 2 bags of dry kidney beans
- 1 bag of kelp Strip
- 1 water testing strip
- 1 can of kidney beans
- 1 instruction booklet (this one you are reading now)
- Pulses cookbook and magnet as a thank you gift for your participation

Table of contents of this booklet

Anna Akariza, MSU 2021

Photo Credit: Chelsea Didinger

Cooking Time Summary

Findings

1. Genetic variability for cooking time in beans- even within market classes
2. Cooking time has moderate to high heritability
3. Yellow beans especially fast cooking

Mayacoba yellow bean

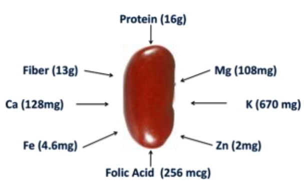
Outcomes

4. Identified unique fast cooking bean germplasm
5. Introgressed fast cooking trait into U.S adapted germplasm
6. Germplasm/variety release pending

Biofortification

optimize nutritional composition through genetic improvement or fertilization

Bean Biofortification Efforts:
What: Increase seed iron concentration
How: plant breeding with natural variation
Focus Regions: Africa and Latin America
Who: CIAT and others
In US? Not yet, but opportunities



Biofortification Definition: HarvestPlus and World Health Organization (WHO)

"Biofortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology."

"Biofortification differs from conventional fortification in that biofortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops."

"Biofortification may therefore present a way to reach populations where supplementation and conventional fortification activities may be difficult to implement and/or limited."

https://www.who.int/elena/titles/biofortification/en/

Need for Biofortification: Micronutrient Malnutrition

Affects over 2 billion people worldwide

Iron Deficiency

- >50% of women and pre-school children are anemic
- Impairs physical and mental development in children
- One of the major causes of death among women during childbirth

Zinc Deficiency

- One of the leading causes of child and infant stunting among the world's population
- Impairs immunity, vitamin A use, and vitamin D function, and leads to higher mortality

Breeding for increased seed iron and zinc

Step 1: Evaluate genetic diversity for seed iron & zinc

Major breeding strategy for bean iron biofortification is via phenotypic selection for **raw seed concentrations**.

Iron Concentration

Range: 34 to 91 mg kg^{-1}

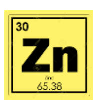
Average: 55 mg kg^{-1}

Photo credit: Scott Bauer, USDA

Zinc Concentration

Range: 20 to 59 mg kg^{-1}

Average: 34 mg kg^{-1}



Islam, F. M. A., et al. Genetic Resources and Crop Evolution 49.3 (2002): 285-293.

Evidence that high iron beans improve human iron status

Human Efficacy Study
Location: Rwanda
Participants: 195 women (aged 18–27 y) with serum ferritin <20 µg/L
Test diet : carioca biofortified (86 ppm Fe) versus non-biofortified beans (50 ppm FE)
Length of study: 128 days
Outcome: women consuming biofortified beans consumed more iron and had improvement in iron status as measured through increased hemoglobin, and body iron.

Haas JD, Luna SV, Lung'aho MG, Wenger MJ, Murray-Kolb LE, Beebe S, et al. Consuming Iron Biofortified Beans Increases Iron Status in Rwandan Women after 128 Days in a Randomized Controlled Feeding Trial. The Journal of Nutrition. 2016;146(8):1586-92

Additional considerations to optimize bean breeding biofortification strategies

1. Raw Seed Nutrient Density

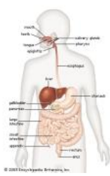
2. Genetic Markers

→

Thermal Hydrolysis

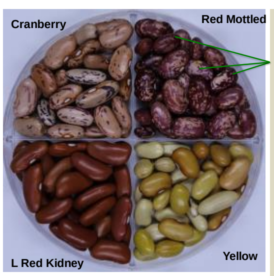
3. Nutrient changes after cooking

→



4. Nutrient Bioavailability

How much iron and zinc is retained after cooking?



12 Entries

4 Market classes

3 Different cooking classes

Representing: East and South Africa, Caribbean, North America

Measured post-harvest & after 1 year in storage

Encompasses broad cooking time spectrum (18 – 90 min)

Iron and Zinc Retention Values of Cooked Seed

Market Class	Entry	Cooking Class	Retention after cooking (%)[z] Iron	Zinc
Yellow	Cebo Cela	Fast	84^{ab}	80^{abc}
	Uyole 98	Moderate	71^{ef}	69^{de}
	Canario	Slow	77^{cde}	76^{cd}
Cranberry	G23086	Fast	81^{bc}	81^{ab}
	OPS-RS4	Moderate	74^{def}	73^{cde}
	Kat. Kibala	Slow	67^{f}	69^{de}
Red Mottled	JB178	Fast	86^{ab}	80^{ab}
	Vazon-7	Moderate	72^{ef}	66^{e}
	PR0737-1	Slow	79^{bcd}	73^{cde}
L R Kidney	AC ELK	Fast	90^{a}	84^{a}
	Clouseau	Moderate	82^{bc}	78^{bc}
	Pink Panther	Slow	79^{bcd}	70^{de}
			67 - 90	66 - 84

[z]Retention values calculated by comparing content differences between 100 lyophilized raw and cooked whole seed.
Wiesinger, J.A., et al., (2016) Demonstrating a nutritional advantage to the fast-cooking dry bean (Phaseolus vulgaris L.). Journal of Agricultural and Food Chemistry 64:8592-8603

Iron and Zinc Retention Values of Cooked Seed

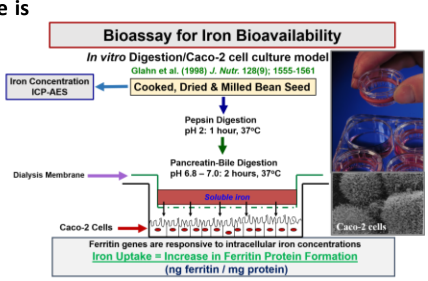
Genetic variability for nutrient retention after cooking. Fast cooking genotypes retain more Fe and Zn.

Market Class	Entry	Cooking Class	Retention after cooking (%)[z] Iron	Zinc
Yello			84^{ab}	80^{abc}
			71^{ef}	69^{de}
			77^{cde}	76^{cd}
Cran			81^{bc}	81^{ab}
			74^{def}	73^{cde}
			67^{f}	69^{de}
Red			86^{ab}	80^{ab}
			72^{ef}	66^{e}
			79^{bcd}	73^{cde}
L R K			90^{a}	84^{a}
	Clouseau	Moderate	82^{bc}	78^{bc}
	Pink Panther	Slow	79^{bcd}	70^{de}
			67 - 90	66 - 84

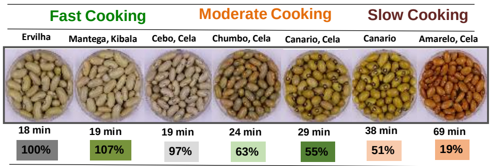
[z]Retention values calculated by comparing content differences between 100 lyophilized raw and cooked whole seed.
Wiesinger, J.A., et al., (2016) Demonstrating a nutritional advantage to the fast-cooking dry bean (Phaseolus vulgaris L.). Journal of Agricultural and Food Chemistry 64:8592-8603

How bioavailable is the iron?

- Proportion of a consumed nutrient that can be digested, absorbed, and utilized by an organism for body functioning and health
- Influenced by
  - Food composition (matrix)
  - Nutrient status of the consumer



Iron bioavailability linked to seed coat color and cooking time



In vitro **Digestion/Caco-2 Cell Iron Bioavailability Assay**
ng ferritin/mg protein (% of navy bean control)

Wiesinger, J. A., Cichy, K. A., Tako, E., & Glahn, R. P. (2018). The fast cooking and enhanced iron bioavailability properties of the Manteca yellow bean (Phaseolus vulgaris L.). Nutrients, 10(11), 1609.

Biofortification Summary and US Opportunities

- Currently, over 60 high iron bean varieties have been released in Latin America and Africa, in both regions beans are a dietary staple
- High iron content is not valued as a trait in the U.S.; thus far, as many Americans have diverse diets and beans are only a minor component
- With an increase in the number vegetarians and vegans in the U.S. the prevalence of iron deficiency is expected to increase
- Export of beans to Latin American countries with a greater prevalence of iron deficiencies, also makes a good case for improving the iron and zinc content and iron bioavailability of U.S. produced beans.

Thank you

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Joe Cramer, Michigan Bean Commission
Scott Bales, Michigan State University
Donna Winham, Iowa State University

Pulse Crop Health Initiative

Questions?

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MBC Bean Academy Summary

Anatomy of the Bean: Dry Bean Breeding and Production for Consumer Acceptance

This webinar covered:

- The genetic diversity of beans
- Methods used in bean breeding
- Approaches used in breeding beans for nutritional and culinary quality
- Contributions of bean breeding research to consumer acceptance

MBC Bean Academy webinar details

- Continuing Education Credit certificate and the handouts are available at the Michigan Bean Commission website: https://michiganbean.com/health-professional-resources
- CEU: https://michiganbean.com/hp-webinar-cichy-ceu/
- A recording of today's webinar will be available to download at: https://michiganbean.com/hp-webinar-cichy-presn/
- For questions: MBC.BeanAcademy@gmail.com

Next **MBC Bean Academy** Webinar

Delivering Benefits from the Bioactives in Plant-Based Foods:

Learnings from the NC State Plants for Human Health Institute and the NC Food Innovation Lab

Mario Ferruzzi, PhD
Mary Ann Lila, PhD
William Aimutis, PhD
Plants for Human Health Institute, North Carolina State University

Date: **September 16, 2021**
2-3 pm EDT/1-2 pm CDT/noon MDT
Applied for 1 CPE (Level 2) by the Commission on Dietetic Registration

How are we doing?

- Stay on the line for a brief survey about this **MBC Bean Academy** webinar:

Anatomy of the Bean: Dry Bean Breeding and Production for Consumer Acceptance

Thank you!