


**Delivering Benefits from the Bioactives in Plant-Based Foods:
Learnings from the North Carolina (NC) State University
Plants for Human Health Institute
and the NC Food Innovation Lab**
September 16, 2021

Presenter:
Mary Ann Lila, PhD
Director, Plants for Human Health Institute
David H. Murdock Distinguished Professor,
Food, Bioprocessing and Nutrition Sciences
North Carolina State University

Moderator:
Barbara J. Ivers, 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.





Webinar logistics

- A Handout of the slides presented today is available at: <https://michiganbean.com/hp-webinar-lila-presn/>
- The Continuing Education Credit certificate is available to download after the webinar: <https://michiganbean.com/hp-webinar-lila-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.



Today's Faculty

Mary Ann Lila, Ph.D.

- Director, Plants for Human Health Institute
- David H. Murdock Distinguished Professor, Food, Bioprocessing and Nutrition Sciences North Carolina 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 broader benefits associated with non-nutritive plant bioactive compounds
- Explain the connection between plant genetics, agriculture and food processing and their role in enhancing content of nutrients and bioactives in plant foods
- Discuss the type of ingredient and processing technologies being leveraged to make the next generation of plant based foods
- Describe how North Carolina State University serves as a critical partner to drive this innovation



Delivering Benefits from Bioactives in Plant-based Foods


INSIGHTS from the NC State University's Plants for Human Health Institute & the NC Food Innovation Lab

Mary Ann Lila, Director, Plants for Human Health Institute North Carolina State University



Available online at www.sciencedirect.com
ScienceDirect
 Journal of Sport and Health Sciences 9 (2020) 283–301
 www.elsevier.com/locate/jshs

Review
Coronavirus disease-2019: A tocsin to our aging, unfit, corpulent, and immunodeficient society
 David C. Nieman
 Department of Biology, College of Arts and Sciences, Appalachian State University, North Carolina Research Campus, Kannapolis, NC 28081, USA
 Received 23 April 2020; revised 27 April 2020; accepted 29 April 2020
 Available online 4 May 2020

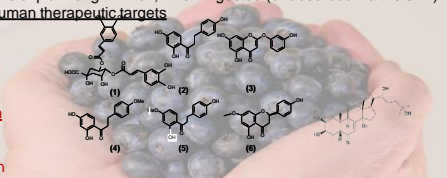
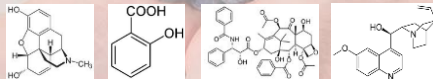
**Diet/
 Nutrients
 & phytoactives**

**Exercise/
 movement**

Plant Bioactives & Immune Health

Bioactive compounds (phytoactives): not essential nutrients, but biologically-active chemicals of plant origin which, when ingested (or absorbed via the skin) interact with human therapeutic targets

.....and/or,
 interact first with the human gut microbiome
 (more likely than not)

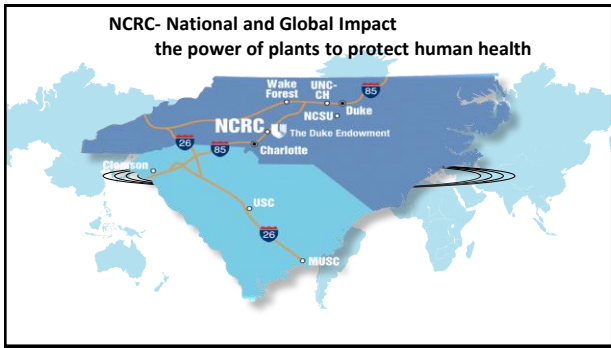



Leading the discovery and delivery of innovative plant-based solutions to advance human health



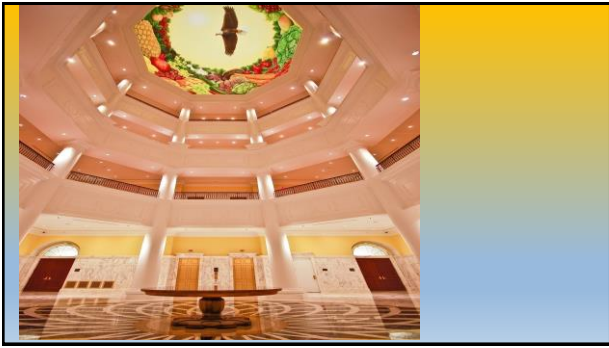
PLANTS FOR HUMAN HEALTH INSTITUTE





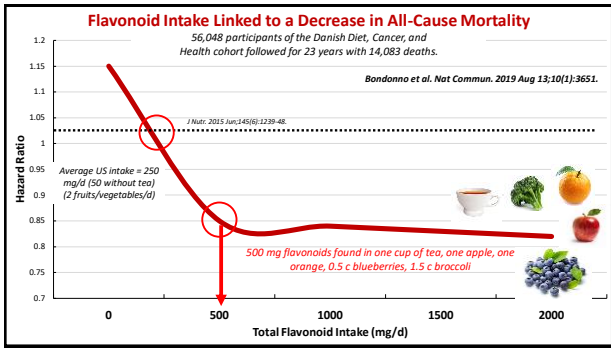


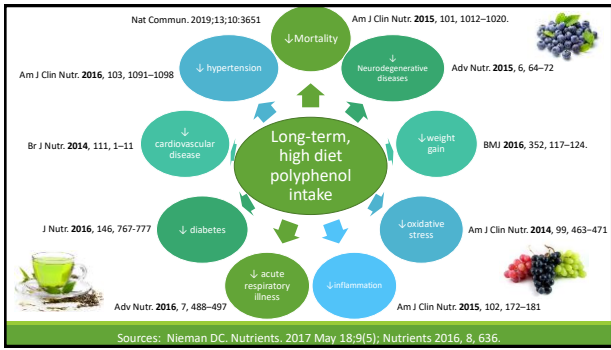




1. What are the BENEFITS of phytoactives?
(bioactive secondary compounds from plants – not necessarily nutrients)

Food Crops – What are we looking for?



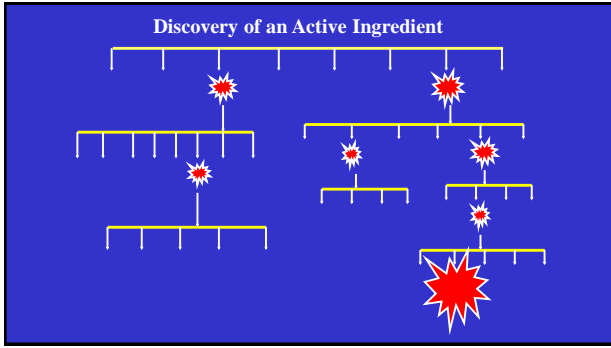


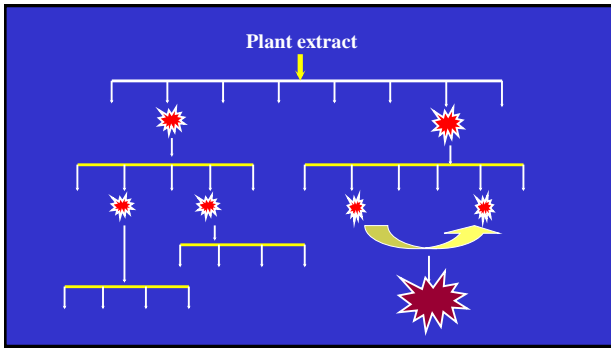
- single active ingredient
- high throughput screens
- defined dose and clearance

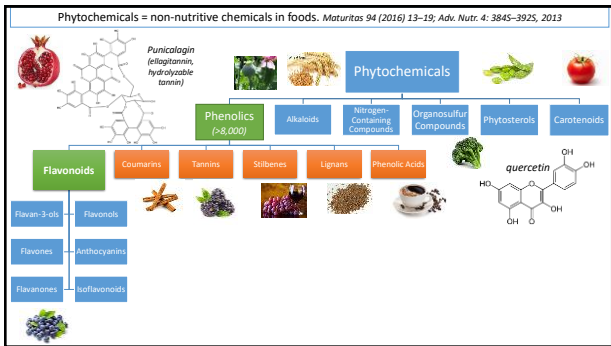
MULTIPLE Phytoactive Components

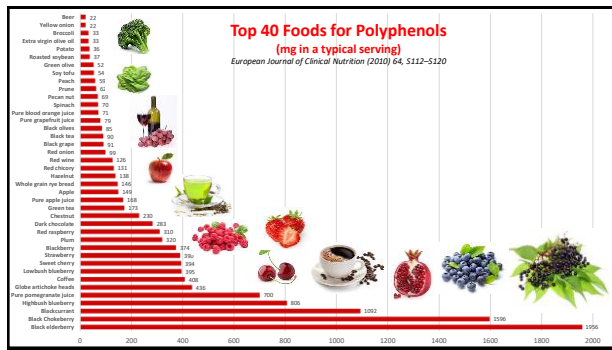
INTERACTIONS (synergies)

Undefined METABOLITES & targets







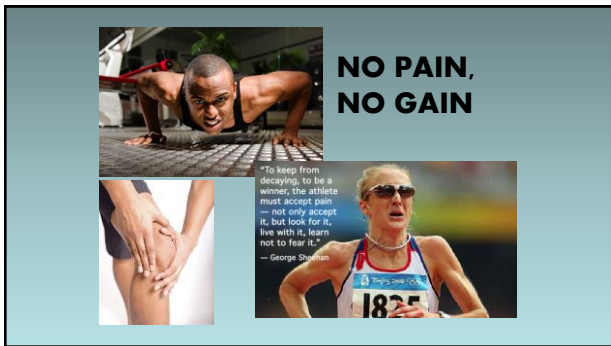




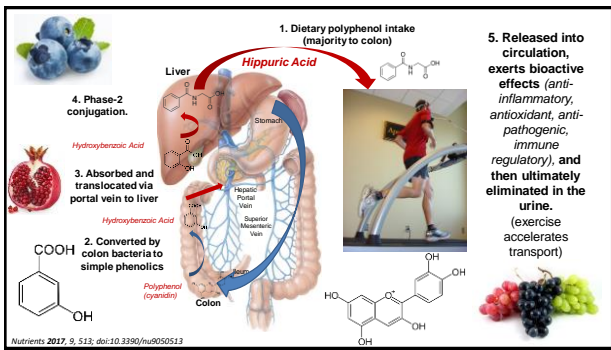












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Plants for Human Health
INSTITUTE

The "hidden" fruit & vegetable quality attributes:
Biopotency & Bioavailability

Biopotency

The **STRENGTH** of a phytoactive chemical compound

The **POWER** of the compound to improve human health

The **CONTENT**
The **CONCENTRATION**

& Bioavailability

What amount of phytoactive chemicals in the fruit/vegetable actually get **ABSORBED** and enter human **CIRCULATION**?

Plants for Human Health Institute, 2021 - Lisa Lab

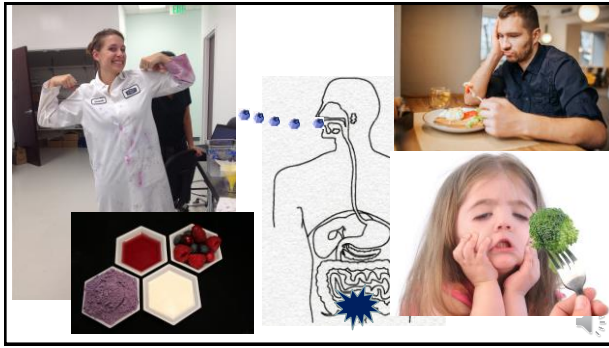
Is the phytoactive content BIOAVAILABLE?
(is it **DELIVERED** to human targets?)

BIOAVAILABILITY: the proportion of the phytoactive chemicals in the fruit/vegetable that actually will be **ABSORBED** and enter human **CIRCULATION**

Digestion
Absorption
Metabolism

Plants for Human Health Institute, 2021 - Lisa Lab

2. What are the CONNECTIONS b/t plant genetics, agriculture & food processing to enhance nutrients & bioactives? [content & bioavailability]



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RESEARCH AWARD
 FOUNDATION FOR FOOD & AGRICULTURAL RESEARCH

\$2M Title: Closing the gap in delivery of fruit and vegetable benefits
 Partners: NCSU PHH; Dole; GMI; Sensory Spectrum

Problem: Only 13% of population consumes the 4.5 Servings recommended by 2015 DGA

Goal: Develop strategies that close the gap in delivery of fruit and vegetable health benefits through improvement of nutritional quality and effectiveness of consumer products.

Approach: Expansion of breeding strategies to identify genetic factors that **control content, concentration & bioavailability** of micronutrients/bioactives can be leveraged with emerging technologies to develop processed products that can **improve delivery** of fruit and vegetable benefits to consumers.

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Integrated program combining functional phenotyping, food technology and nutrition science to enhance fruit/vegetable impact

Fruit/Vegetable Targets

- Blueberry**
 - Well-recognized health protective fruit
 - US is largest producer and processor
 - Diverse public germplasm available
 - NCSU Team experience with blueberry
- Banana**
 - 2nd most consumed fresh fruit in US diet
 - High potential as platform for delivery
 - Value to consumers and US industry
 - Access to Dole germplasm collection
- Spinach**
 - Recognized nutrient dense leafy green
 - Strong consumption of fresh and processed form
 - Diverse germplasm available (UC Davis)

Leverage Diverse Blueberry, Banana and Spinach Public and Private Germplasm Collections

Aim 1

Phenotyping and genetic mapping of nutrient/phytochemical content and bioaccessibility to select and breed for improved produce

- High-throughput nutrient and phytochemical phenotyping
- Apply physiologically relevant in-vitro model of bioavailability
- Establish QTLs for nutrient density and bioaccessibility

Aim 2

Ingredient technologies for expanded consumer relevant fruit and vegetable product formats

- Apply Protein Particle Complexation to capture and deliver fruit and vegetable nutrition in relevant consumer products
- Assess nutrient delivery and consumer acceptability of new product forms

Aim 3

Metabolomics to establish nutritional equivalency of novel produce & products

- Practical prioritization of selected fruits and vegetables (Aim 1) and novel products (Aim 2)
- 48h clinical bioavailability and metabolic signature of select products to establish equivalency factors of delivery to the body

A high-throughput phenotyping method for the evaluation of anthocyanin content in blueberry

HPLC analysis (for Total ANC) takes an average of 77 min/sample (NOT including running of standards, integration of chromatogram, and processing of raw data)

New tools for rapid fruit quality analysis in blueberry

P. Perkins¹, G. Ma¹, M. Pottorff¹, M.A. Lila² and M. Iorizzo¹

Blueberry fruit quality, defined here as size, firmness, color, and chemical composition, attracts consumer purchases while a positive sensory experience encourages repeat purchases. Phenotyping using traditional methods is expensive and time consuming. A system was developed to screen about 3000 samples each from Florida and Oregon breeding programs for fruit puree soluble solids content (SSC), pH and titratable acidity (Tacid) using ball mill homogenization and refractometers. **Near Infrared spectrometry of freeze dried powders was done to determine individual and total soluble sugars. R² of the NIR 0.86 to 0.90 for fructose and glucose, respectively.**

LAB vs. NIR

Y-axis: Predicted Anthocyanin

X-axis: Observed Anthocyanin

$R^2 = 86.8\%$

1.5 minutes/sample

frontiers
in Plant Science

Diversity in Metabolites and Fruit Quality Traits in Blueberry: Ploidy and Species Differentiation Establishes a Strategy for Genetic Studies

Molla F. Mergel¹, Mary H. Grace¹, Jia Xiong¹, Colin D. Kyr¹, Nellie Elm Kim Hummer¹, Mario G. Ferruz², Mary Ann Lila^{1*} and Massimo Iorizzo¹

Component 1 (28.1%)

Component 2 (14.7%)

● Diploid ● Tetraploid ● Hexaploid

FIGURE 6 | PLS-DA model of metabolite and fruit quality data from 128 blueberry accessions in three ploidy levels (diploid, tetraploid, and hexaploid). The figure representing the first two components of the PLS-DA model.


Mergel et al. *Horticulture Research*
https://doi.org/10.1038/s41438-021-00605-z

Horticulture Research
www.nature.com/hortres

ARTICLE Open Access

High-density linkage map construction and identification of loci regulating fruit quality traits in blueberry

Molla F. Mergel¹, Ahmed Sultan¹, Elizabeth Young¹, Kristine M. Mario G. Ferruz², Hamid Anzali¹, Mary Ann Lila^{1*} and Massimo Iorizzo¹



Crop → Bioactives → Health

Blueberry health research Cranberry health research

VacCAPx \$13M award from USDA SCRI

What is VacCAP?
 The *Vaccinium Coordinated Agricultural Project (VacCAP)* is a nationwide coordinated transdisciplinary project focused on addressing major bottlenecks limiting the growth of the U.S. *Vaccinium* industry by developing and implementing marker assisted selection (MAS) capacity in breeding programs.

The project objectives are to: 1) Establish **genomic resources** to enable effective association mapping studies in blueberry and cranberry; 2) Discover **DNA markers and FCs** that maximize industry profitability and match consumer preferences in blueberry and cranberry; 3) Deliver **molecular and genetic resources** to improve blueberry and cranberry fruit quality traits that maximize industry profitability and match consumer preferences; 4) Assess the potential socio-economic impact of blueberry and cranberry fruit quality improvements on market demand; and 5) Engage U.S. *Vaccinium* stakeholder groups by transferring **advanced phenomic and genomic tools to build a more efficient cultivar development system.**

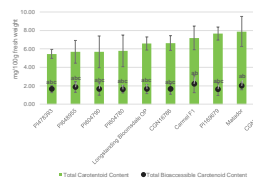
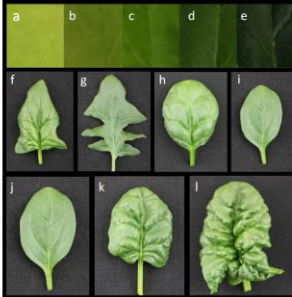
40

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

pubs.acs.org/JAFC

In Vitro Bioaccessibility of Carotenoids and Chloro Collection of Spinach Accessions and Commercial Varieties
 Micaela Hayes, Marti Pottorff, Colin Kay, Allen Van Deyne, Juliana Olor Massimo Iorizzo[†], and Mario G. Ferruzzi[†]

12.200

41

Food & Function

ROYAL SOCIETY OF CHEMISTRY

PAPER

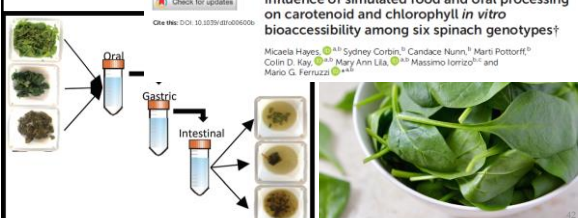
View Article Online
[www.rsc.org](#)

Check for updates

Cite this: DOI: 10.1039/C5FO00500G

Influence of simulated food and oral processing on carotenoid and chlorophyll *in vitro* bioaccessibility among six spinach genotypes?

Micaela Hayes,[†] Sydney Corbin,[†] Candace Nunzi,[†] Marti Pottorff,[†] Colin D. Kay,[†] Mary Ann Lila,[†] Massimo Iorizzo[†] and Mario G. Ferruzzi[†]



42

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Health impacts from fruits/vegetables are dependent on consumption of products with high nutrient/bioactive density and bioavailability

Our approach: Help consumers achieve DGA recommendations within current consumption patterns by enhancing nutritional density and bioavailability of nutrients/bioactives from common fruits, vegetables and diversify F&V consumer-products.

Blue Sky Thinking

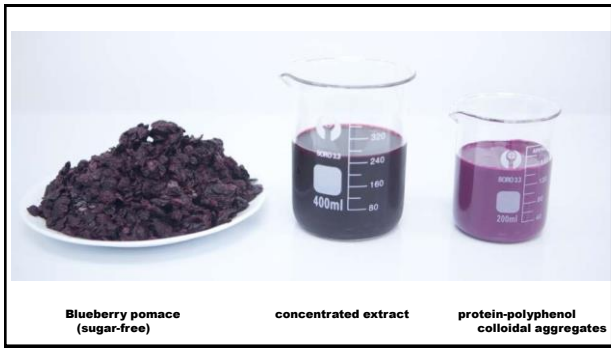
Breeding Better Fruits & Vegetables
 Can advanced phenotyping and genetic techniques be leveraged to breed fruits and vegetables with higher nutritive content and bioavailability to improve delivery of F&V benefits at present consumption levels?

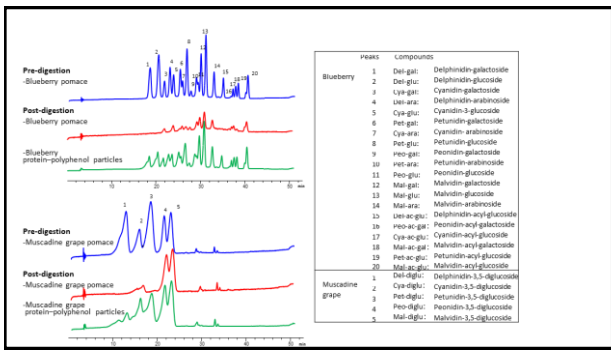
Diversifying Consumer Fruit & Vegetable Product Options
 Can emerging ingredient/processing technologies be applied to generate a diversified range of consumer relevant and acceptable products delivering F&V nutrition and benefits?

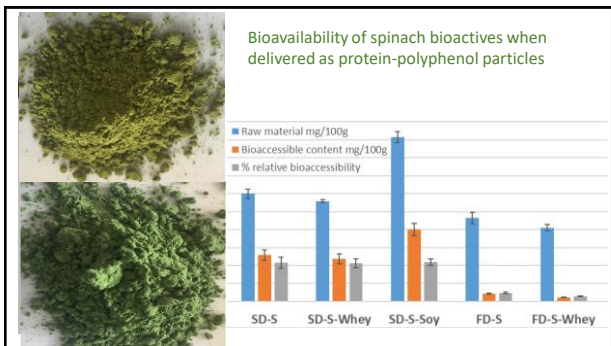
Defining Nutritional Equivalencies of Fruit & Vegetable Forms
 Can advanced metabolomic techniques help us redefine "servings" of F&V and associated products to what they deliver to the body rather than what they contain on the plate?

3. What INGREDIENT & PROCESSING TECHNOLOGIES can help craft the next generation of plant based foods?

Boosting the bioavailability of dietary polyphenols by delivery as colloidal aggregate protein-polyphenol particles







Food Industry Undergoing Change



Food Industry Shifting

Large F&B players changing, private label growing, niche growing, consumers seeking local, convenience



Health & Wellness

Natural flavors, probiotics, proteins, food to prevent disease, food targeted at specific conditions...



Green

Clean label, bio-based, renewable, natural and sustainable products



4. Describe how NC State University serves as a crucial partner to drive innovation

Growth of Plant-Based Foods



The Plant Science Challenge

Innovative use of technology in plant sciences, human health sciences and food technologies is vital to successful food production. Often working independently, significant time, talent and resources are spent in each of these areas of expertise to overcome complex food challenges.

Until now.



NC FOOD INNOVATION LAB



Discover NCFIL

America's Plant-based Food Processing Partner

NCFIL is a state-of-the-art product development and pilot plant facility that has the latest in food processing equipment, expert food scientists and partners from across the state to help food companies and entrepreneurs get their products to market quickly and effectively.

- Only facility with Good Manufacturing Practices (cGMP) capabilities dedicated to plant-based foods.
- Newest facility in USA and Canada
- Only facility that exclusively focuses on plant-based product development capabilities


Product Research & Development


Pilot Plant Production


Training and Workshops

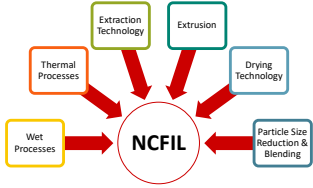

Food Industry Consulting



NCFIL

NC FOOD INNOVATION LAB

Pilot Plant Core Technologies



ALL with a focus on preserving phytoactive CONTENT and enhancing phytoactive BIOAVAILABILITY

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NC FOOD INNOVATION LAB




NCFIL



Questions?



Mary Ann Lila, PhD
 Director, Plants for Human Health Institute
 David H. Murdock Distinguished Professor
 Food, Bioprocessing and Nutrition Sciences
 North Carolina State University
mlla@ncsu.edu




MBC Bean Academy Summary

Delivering Benefits from the Bioactives in Plant-Based Foods


This webinar covered:

- Broader benefits associated with non-nutritive plant bioactive compounds
- The connection between plant genetics, agriculture and food processing and their role in enhancing content of nutrients and bioactives in plant foods
- Ingredient and processing technologies being leveraged to make the next generation of plant based foods
- How North Carolina State University serves as a critical partner to drive this innovation



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-lla-ceu/>
- A recording of today's webinar will be available to download at: <https://michiganbean.com/health-professional-resources>
- For questions: MBC.BeanAcademy@gmail.com



Next **MBC Bean Academy** Webinar

Reasons for the Disconnect between Dietary Recommendations and Legume Consumption Patterns in U.S. Adults

Gerd Bobe, PhD
Oregon State University

Date: **November 4, 2021**
2-3 pm EDT/1-2 pm CDT/noon MDT
Approved for 1 CPE (Level 2) by the Commission on Dietetic Registration



How are we doing?

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

Delivering Benefits from the Bioactives in Plant-Based Foods: Learnings from the NC State University's Plants for Human Health Institute and the NC Food Innovation Lab

Thank you!

