Building Nutritious Food Baskets

Provitamin A Maize

A Biofortified Solution for Vitamin A Deficiency

Important!

- This module is designed to potentially serve a wide variety of audiences (nutritionists and agronomists, policymakers, extension workers, farmers)
- Not all of the material will be relevant to all audiences
- Please refer to the accompanying Facilitator's Guide for guidance on how to adapt these materials to your audience and facilitation best practices.

Legend

Icon	Description
Xm	Expected Duration, minutes
	Quick Review/Survey Questions
	Brainstorming Session
	Discussion Session
	Group Activity
	Animated Slide
	End of Animation

Unit 1

Introduction

Welcome

During this session, we will examine the potential of biofortified Provitamin A (PVA) Maize to help alleviate vitamin A deficiency in vulnerable populations.

Quick Survey

By show of hands:

- *How many of you are already familiar with Provitamin A Maize?*
- *How many of you are familiar with biofortification, but not PVA Maize, specifically?*
- *How many of you have only a vague idea or no idea of what "biofortification" is and hope to learn more?*

Objectives

By the end of this session, you should be able to:

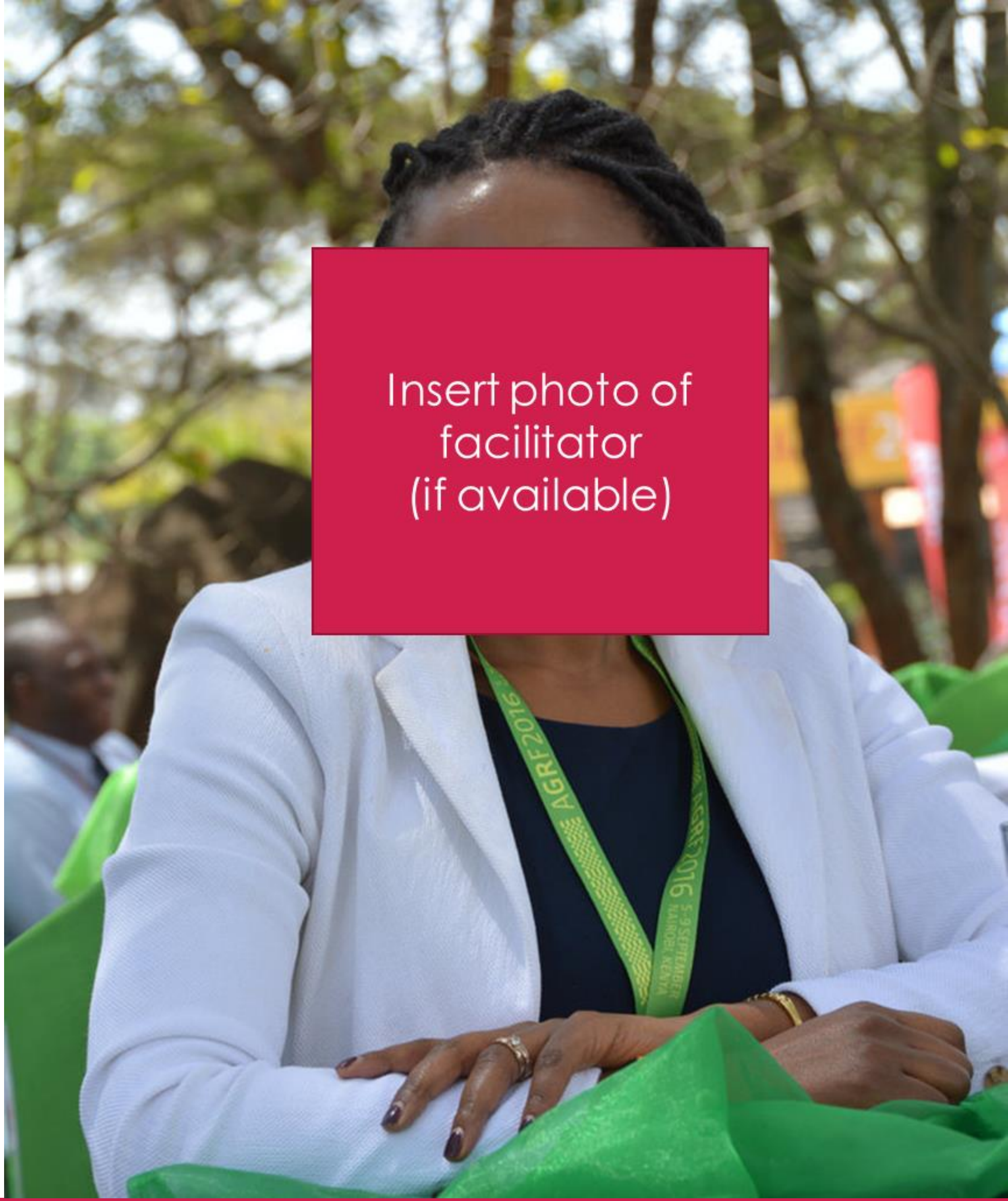
- Explain how biofortified provitamin A maize can address vitamin A deficiency among poor populations
- Describe the process used to develop new PVA Maize varieties
- Outline a strategy for promoting PVA maize to farmers, consumers and partner organizations
- Describe how PVA maize can be integrated into a healthy diet
- Summarize key studies demonstrating the effectiveness of PVA maize for addressing vitamin A deficiency

Agenda

- Standard “housekeeping” items for session (break times, end time, facilities, meals)

Meet the Facilitator

- Name
- Role, Organization
- Credential(s)
- Fun biographical detail



Ground Rules

- Mobile phones off
- In addition to lecturing, there will be opportunities for discussions and asking questions.
  - To keep things moving, we might have to cut some conversations short and move on to the next topic
  - Not everyone will get to answer every question, but everyone will get multiple chances to speak and be heard throughout the session
  - If one or two people are answering every question, we will politely ask them to give someone else a chance to speak.

Ground Rules

As participants in this learning experience, we need to:

- Share our ideas without fear of criticism, and listen to the ideas of others without criticizing
- Engage in discussions without arguing
- Help other participants and accept help from others
- Create a safe, supportive environment for everyone to learn
- Have fun

Activity (Groups)

Meet Your Fellow Participants

- Pair off with another participant (ideally someone you don’t already know)
- Talk to each other and find out:
  - Their name
  - One interesting fact about their professional background
  - Something they enjoy outside of work, such as:
    - Hobbies
    - Favorite foods
    - Favorite holiday destination
- Reconvene and have each pair introduce each other to the rest of the class

20 m

Unit 2

Micronutrients and Biofortification

Unit Objectives

By the end of this unit, you should be able to:

- List and describe the three types of malnutrition
- Define ‘hidden hunger’ and explain the importance of micronutrients for good health
- Identify natural sources of micronutrients
- List and describe common interventions for micronutrient deficiency
- Define ‘biofortification’
- Compare biofortification to other interventions and summarize its major advantages and challenges
- Differentiate between biofortified crops produced through selective breeding and GMOs

The Problem of “Hidden Hunger”

Brainstorming

Malnutrition

What do we typically think of when we hear the term “malnutrition”?

2 m

Key Terminology

Malnutrition

Lack of proper nutrition, caused by

- Not having enough to eat
- Not eating enough of the right things
- The body not being unable to use the nutrients from food that a person does eat

The Problem of Malnutrition

- Serious public health issue in many parts of the world
- Major impediment to equitable economic growth
- In countries with persistently high levels of malnutrition, costs can rise to **16.5 percent of the economy (GDP)**

Women and Children

- Disproportionately impacts women and children
- Factor in 45% of all child deaths and 20% of maternal deaths (WHO)
- Causes 110,000 deaths during childbirth each year (WFP)
- Malnourished children lag **four years** behind peers in educational achievement

Quick Survey

*What are some of the **visible** symptoms of malnutrition? (What does a malnourished person look like?)*

2 m

Types of Malnutrition

- Because of past famines, many people associate “malnutrition” with:
  - Calorie Deprivation
  - Protein Deficiency
- In extreme cases, these result in visible “wasting” of the body

Photo: DFID

Quick Survey

How have governments, NGOs and other groups addressed calorie deprivation?

2 m

Responses to Malnutrition

- Historically, interventions have focused on providing high-calorie **staple foods** foods to avoid starvation
  - Direct distribution of staple foods during emergencies
  - Helping farmers increase production of staple crops

Photo: VOA

Brainstorming

Staples

What are “staple” foods? Can you give some examples?

2 m

Key Terminology

Staple

A staple food, or simply a “staple”, is a food that

- Is eaten routinely in such quantities that it constitutes a dominant portion of a standard diet for a given people
- Supplies a large fraction of energy needs and generally forms a significant proportion of total nutrient intake.

Staples Around the World

- Popularity of different staples varies around the world
- Depends on availability, traditional preferences, etc.

Brainstorming

Staple Crops

Based on consumption, which crops would be considered the most important staples in:

- *Africa*
- *Latin America & The Caribbean*
- *Asia*

7 m

Calories by Staple Crop

Asia	Africa	Latin America and the Caribbean	World
Rice 55%	Wheat 33%	Maize 35%	Rice 47%
Wheat 35%	Maize 32%	Wheat 32%	Wheat 34%
Maize 5%	Rice 19%	Rice 23%	Maize 12%
Potato 4%	Cassava13%	Cassava 5%	Potato 4%
Cassava 1%	Potato 3%	Potato 4%	Cassava 3%

"Green Revolution"

- Improvements in farming have helped
- Increased production of **staple crops** has reduced incidence of famine
- Global rate of calorie deprivation decreased from 18.6% in 1992 to 10.9% in 2016 (FAO)
  - 1 in 4 people in Sub-Saharan Africa still calorie-deprived

Discussion

What types of nutrients do staples provide?

What types of nutrients do staples generally <u>not</u> provide?

5 m

Types of Nutrients

Macronutrients

- Carbohydrates, fats and protein
- Need to consume in large amounts to provide energy, build muscle and fat
- Staples contain large amounts carbohydrates, which can help keep people alive

Photo: Martin Karimi, WFP

Types of Nutrients

Micronutrients

- Vitamins and minerals
- Needed in small amounts for body to function properly.
- Most staple foods do not provide sufficient micronutrients for good health

Photo: Martin Karimi, WFP

Brainstorming

Micronutrients

Can you name some important vitamins and minerals? Can you describe how they are important for human health?

5 m

Micronutrients and Health

- **Vitamin A (beta-carotenoids)** - Eyesight and immune system
- **Vitamins B1, B2, B3, B6, B12** - Help turn food into energy, produce red blood cells, nervous system function
- **Vitamin C** – Immune system, brain
- **Vitamin D** – Bones, immune system
- **Vitamin E** – Prevents cell damage
- **Folate (Folic Acid)** – Heart health, prevents birth defects, produce new cells (esp. red blood cells)
- **Vitamin K –** Bones, blood clotting
- **Calcium** – Bones, muscle development, cell function
- **Chromium** – Regulates sugar
- **Copper** – Blood cells, bone health
- **Fluoride** – Bone health, dental health
- **Iodine** – Regulates hormones
- **Iron** - Carries oxygen through the body in red blood cells
- **Magnesium** – Muscles, nervous system, bones, heart health
- **Manganese** – Bone health, wound healing, process food
- **Molybdenum** – Processes protein
- **Phosphorus** - Cell function, bones
- **Potassium** – Nervous system, muscles, regulates water
- **Selenium** – Prevents cell damage
- **Zinc** – Immune system, reproductive health, nervous system

Three Types of Malnutrition

When we think of "malnutrition", we need to account for:

- Calorie Deprivation
- Protein Deficiency
- ***Micronutrient Deficiency***

Brainstorming

Symptoms of malnutrition

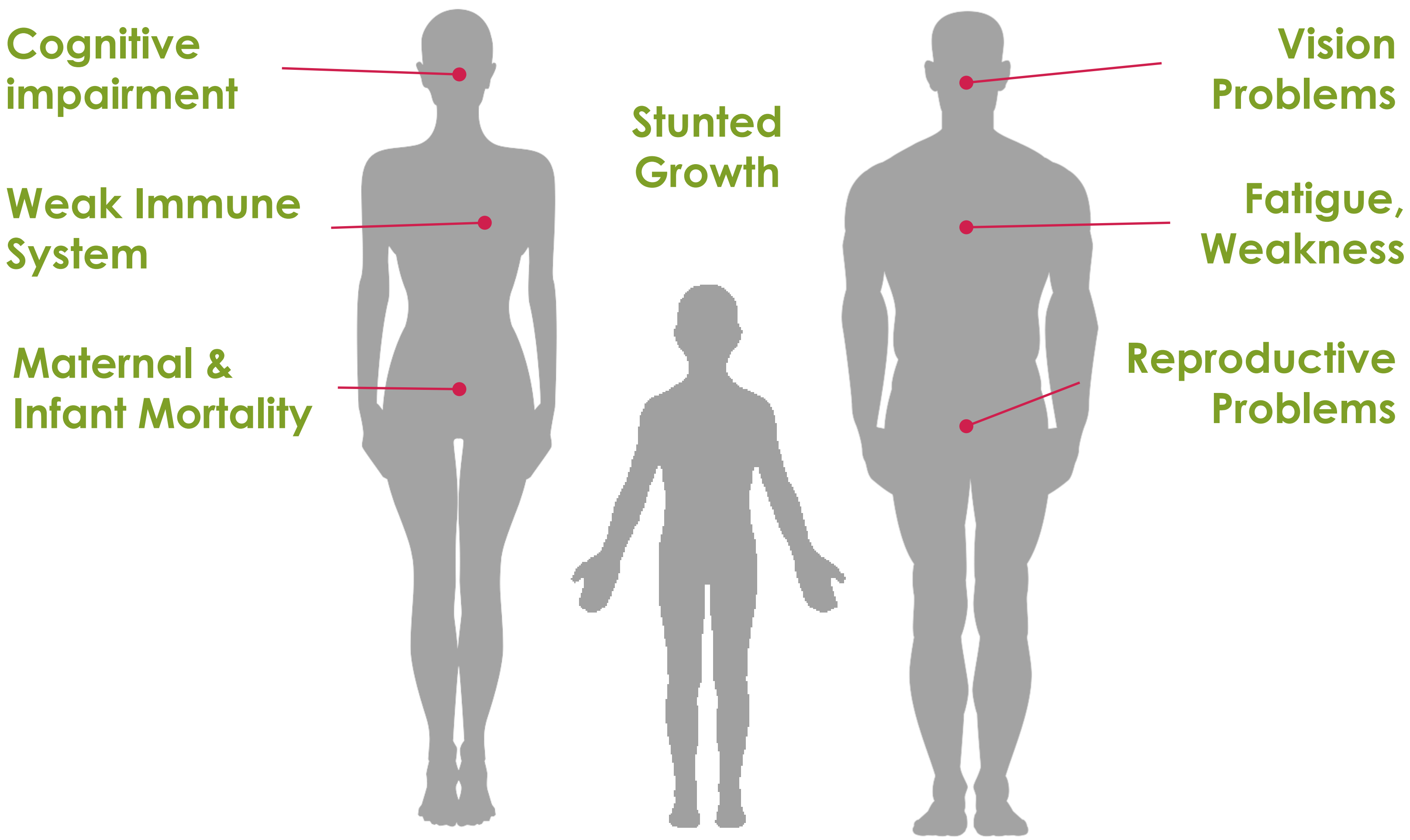
*What are the **visible** symptoms of micronutrient (vitamin/mineral) deficiency?*

3 m

“Hidden Hunger”

- Because micronutrient deficiency symptoms are less visible/obvious than macronutrient deficiency symptoms, micronutrient deficiency is called the **“Hidden Hunger”**
- Far more prevalent than calorie deprivation or protein
- Even mild deficiency, can have serious consequences:

Effects of Micronutrient Deficiency



Quick Survey

What percentage of the world's population are affected by micronutrient deficiencies?

2 m

Quick Survey

What percentage of the world's population are affected by micronutrient deficiencies?

Micronutrient deficiencies afflict more than **two billion individuals**, or **one in three people**, globally (FAO et al., 2015).

15m

Economic Impact

Annual losses from micronutrient malnutrition (World Bank)

Country	Losses in GDP
Bangladesh	$700M
DRC	$100M
India	$12B
Nigeria	$1.5B
Pakistan	$3B
Rwanda	$50M
Tanzania	$289M
Uganda	$145M
Zambia	$186M

Brainstorming

Vulnerable Groups

What groups of people are most vulnerable to micronutrient malnutrition?

3 m

Vulnerable Groups

- Micronutrient deficiency is a health issue for everyone, but disproportionately affects
  - Low-income populations
  - Women of reproductive age
  - Infants and young children

Vulnerable Groups

- Micronutrient deficiencies in the early years of life can stunt growth and cause irreversible damage
- Pregnant and lactating women have much higher micro-nutrient needs than non-pregnant, non-lactating women and men

Hidden Hunger Across the Life Cycle

Newborns
Low birth weight
Increased illness & mortality
Reduced physical & mental development

Children
Stunted growth
Increased illness & mortality
Lower resilience

Adolescents
Stunted growth
Increased illness
Reduced mental, physical performance

Adults
Lower productivity, income
Increased illness

Seniors
Chronic Illness
Lower Life Expectancy

Pregnant Women
High mortality
Perinatal complications

Quick Survey

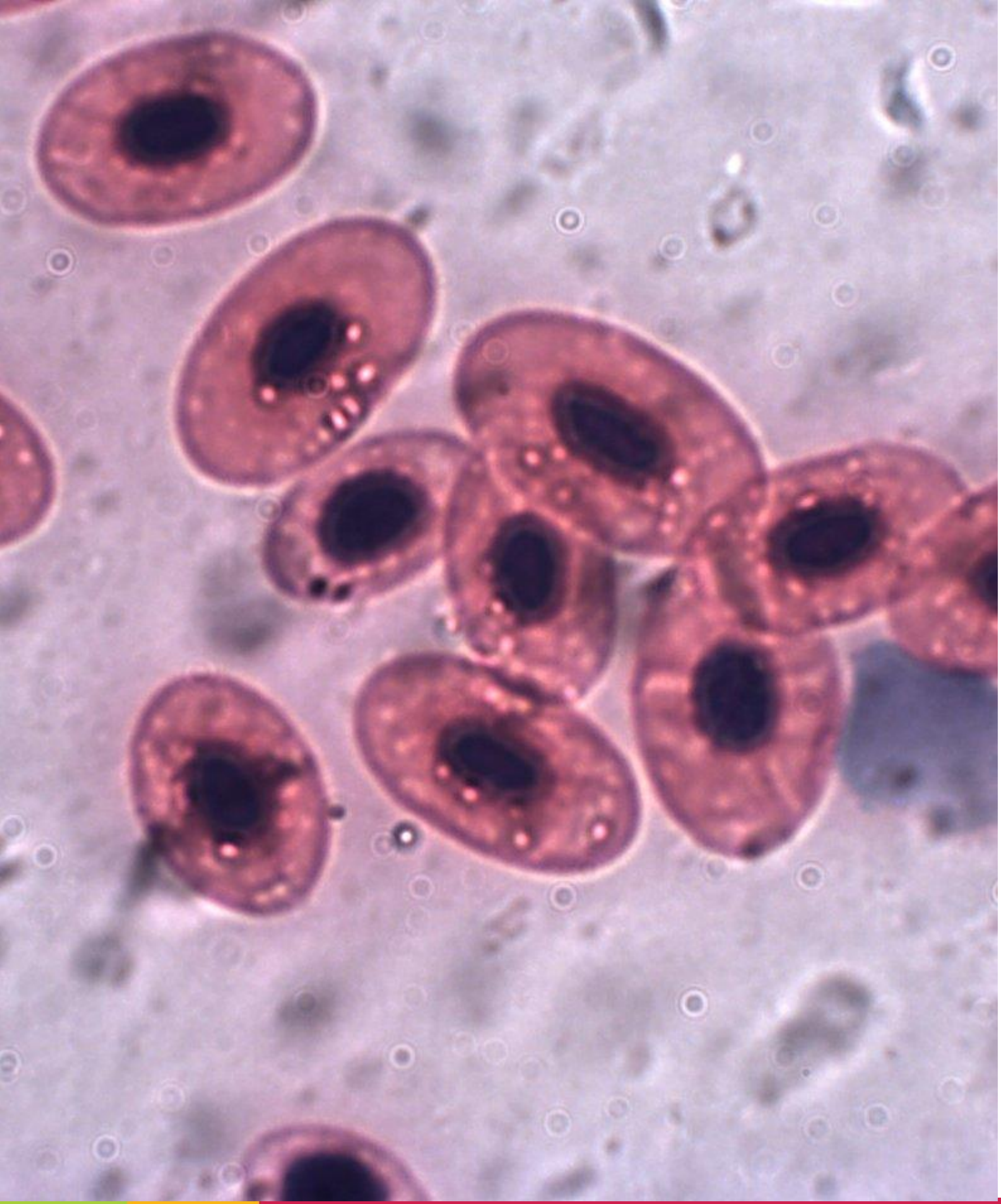
Which 4 micronutrients does the WHO consider to be of the highest public health importance?

2 m

Critical Micronutrients

The WHO considers four specific micronutrients as being of the highest public health importance:

- Iron
- Vitamin A
- Zinc
- Iodine



Iron

- Used throughout body, most critically in blood cells
- Without iron, blood cannot carry oxygen from lungs to other parts of the body
- Deficiency can result in fatigue and even death

Vitamin A

- Among other things, is used in various parts of the eye
- Without Vitamin A, eyes can become clouded, damanged
- Deficiency can result in poor night vision or even blindness

Zinc

- Used primarily by the body's immune and reproductive systems
- Deficiency results in stunted growth, hair loss, skin rashes, vulnerability to infections

Photo: Wikimedia / GNU

Iodine

- Used in body to regulate production of hormones
- Deficiency can result in enlarged thyroid gland (hyperthyroidism / goiter), cognitive impairment, birth defects

Micronutrients and Public Health

The WHO has defined thresholds for when micronutrient deficiency becomes a major problem in a population

Micronutrient	Benefits	Threshold
Vitamin A (beta-carotenoids)	Eyesight and immune system	15%
Iron	Carries oxygen through body in red blood cells	20%
Zinc	Immune system, reproductive health, nervous system	25%
Iodine	Regulates hormones	20-50%

Discussion

Are you aware of any specific micronutrient deficiencies that impact public health among the communities you work with?

7 m

Quick Review

“Micronutrient deficiency” refers to a lack of:

A. Calories

B. Vitamins and minerals

C. Protein

D. Beneficial microbes in the digestive system

1 m

Quick Review

Micronutrient malnutrition is often called
“hidden hunger” because…

A. Lack of micronutrients can cause people to lose their appetite
B. Many governments deny its existence
C. It is less prevalent, globally, than macronutrient malnutrition
D. Its symptoms are less obvious than those of macronutrient malnutrition

1 m

Quick Review

A healthy diet should include as many calories from ___________ as possible.

A. Whole-grain carbohydrates

B. Healthy fats and proteins

C. Vegetables

D. Sugar and honey

1 m

Quick Review

What are the four micronutrients that the WHO considers to be of the greatest public health importance?

A. Vitamin A, Iron, Zinc, Iodine
B. Vitamin A, Vitamin C, Iron, Zinc
C. Vitamin C, Zinc, Calcium, Iodine
D. Vitamin C, Calcium, Magnesium, Iodine

1 m

Quick Review

Alternate

- *What is the difference between "macronutrient" versus "micronutrient" malnutrition?*
- *Why is micronutrient malnutrition called "hidden hunger"?*
- *What micronutrients does the WHO consider most critical for human health?*
- *What are some of the consequences of hidden hunger?*

5 m

Biofortification: An Intervention for “Hidden Hunger”

Staples and Nutrition

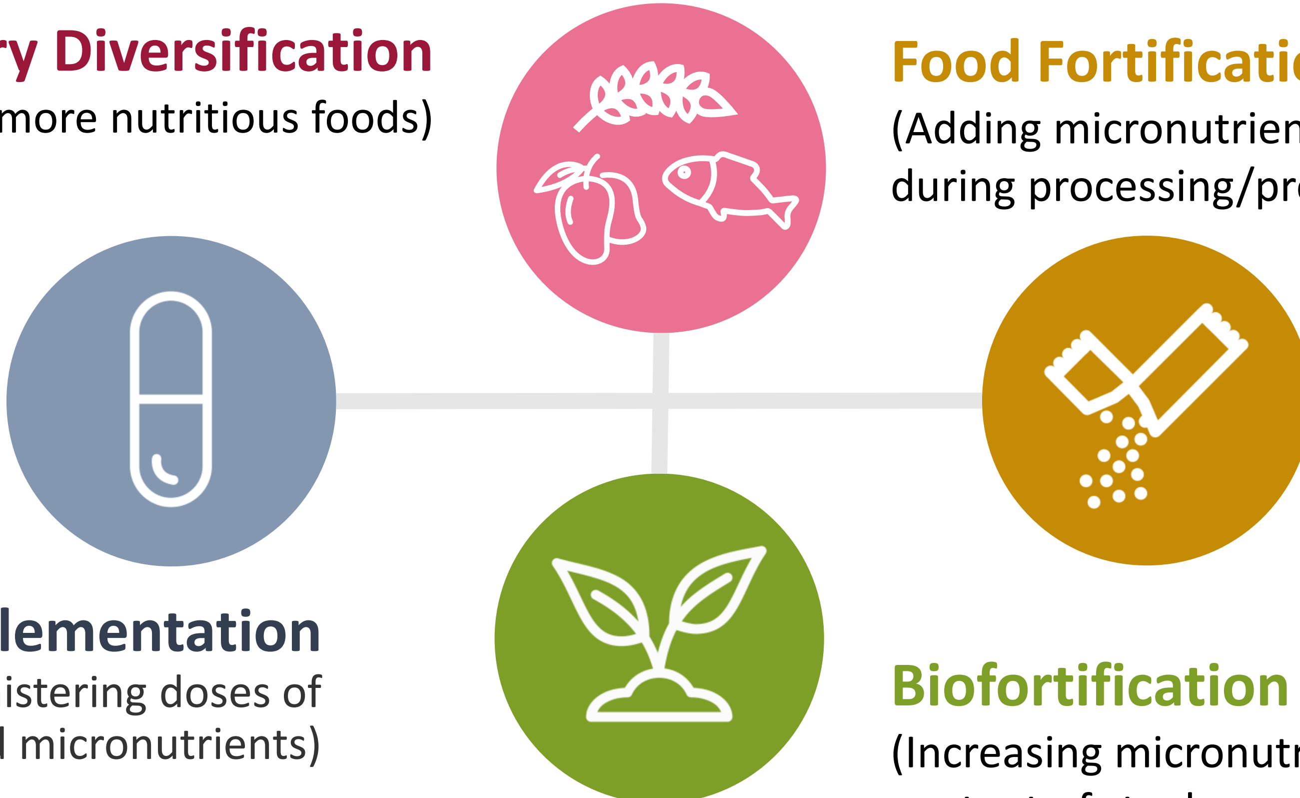
- Vulnerable populations get 60-70% of calories from staple crops
- Staples tend to be grains, high in carbohydrates / calories but lacking in important micronutrients

Discussion

What are some things that could be done to help vulnerable populations get more micronutrients?

5 m

Micronutrient Interventions



Dietary Diversification
(Eating more nutritious foods)

Food Fortification
(Adding micronutrient powder during processing/preparation)

Supplementation
(Administering doses of concentrated micronutrients)

Biofortification
(Increasing micronutrient content of staple crops)

These interventions are most effective when used <u>together</u>

Dietary Diversification

- Natural sources of micronutrients are always ideal
- In some areas, nutritious foods available seasonally
- Education can raise awareness, consumption

Brainstorming

Sources of Micronutrients

What are some natural sources of micronutrients?

3 m

Sources of Micronutrients

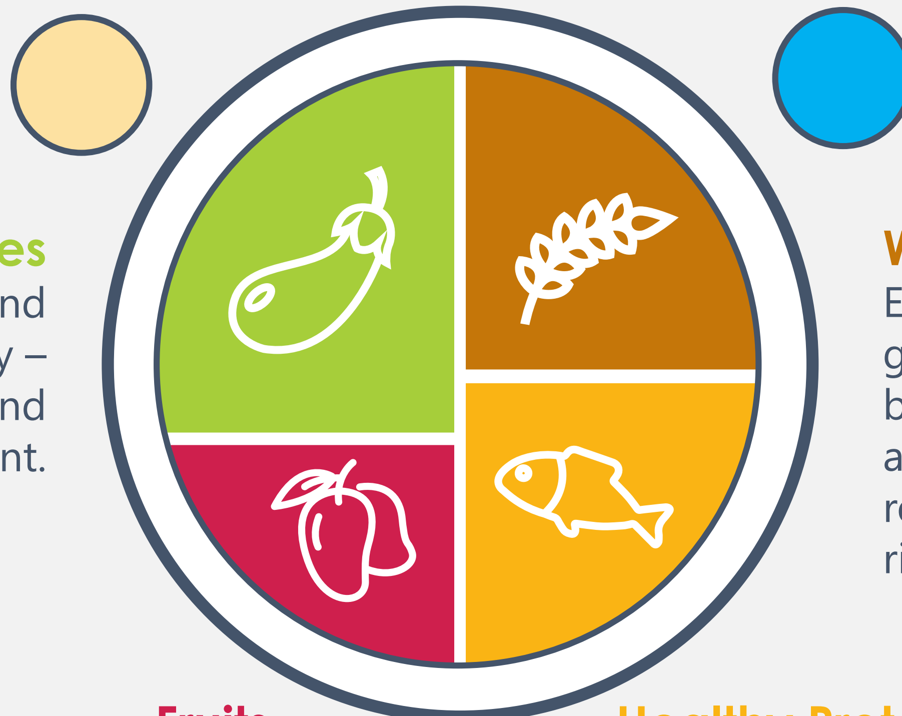
Major sources of micronutrients include:

- Animal products (meat, fish, dairy, eggs, liver and oil)
- Fruits & vegetables (esp. dark color)
- Nuts
- Legumes (beans, cowpea, pigeon pea, etc.)

What a Healthy Diet Looks Like

Use **HEALTHY OILS** (like olive and canola oil) for cooking, on salad, and at the table. Limit butter. Avoid trans fat.

Drink **WATER**, tea, or coffee (with little or no sugar). Limit milk/dairy (1-2z servings/day) and juice (1 small glass/day). Avoid sugary drinks.



Vegetables

The more veggies – and the greater the variety – the better. Potatoes and French fries don't count.

Whole Grains

Eat a variety of whole grains(like whole-wheat bread, whole-grain pasta, and brown rice). Limit refined grains (like white rice and white bread).

Fruits

Eat plenty of fruits of all colors.

Healthy Proteins

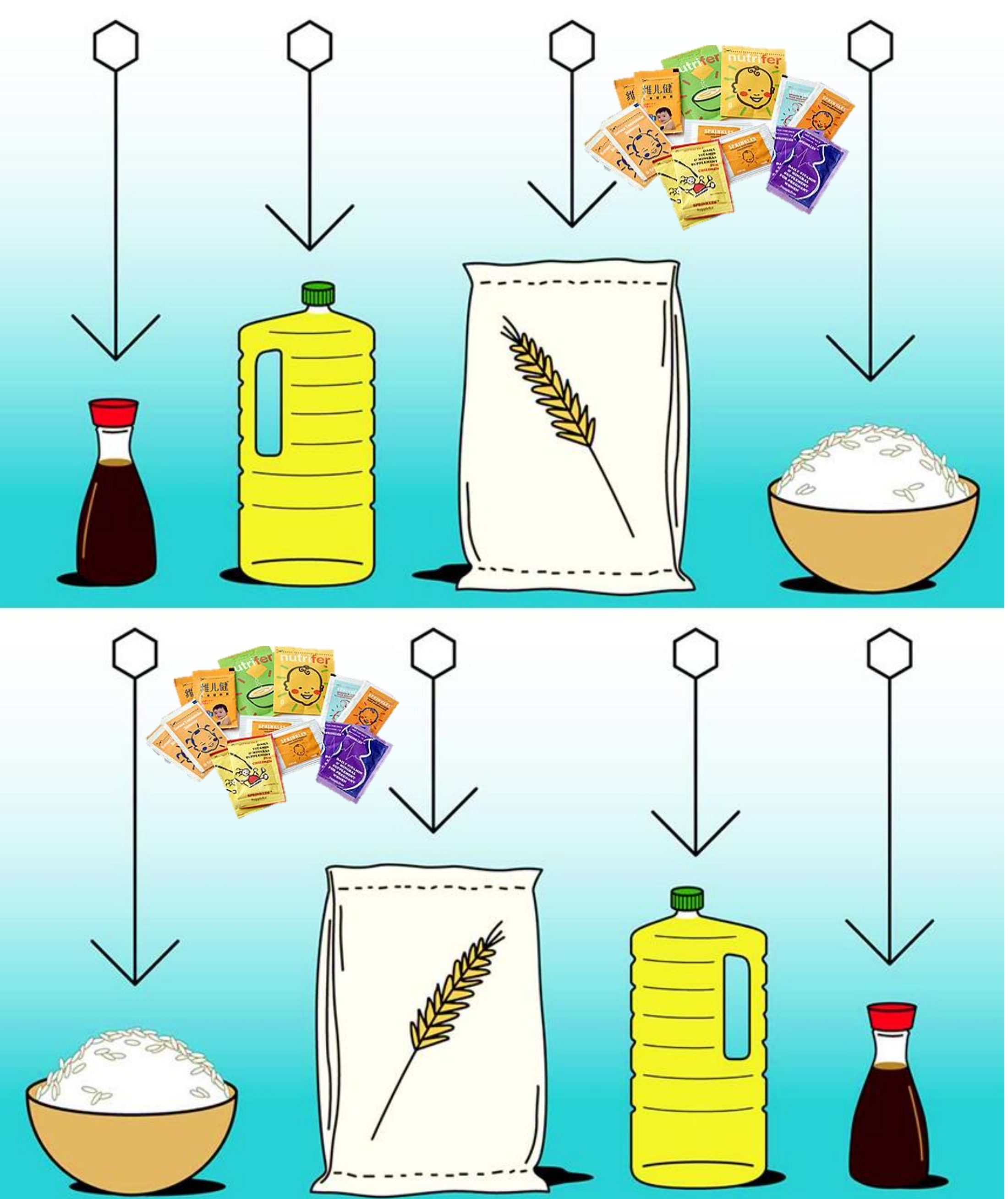
Eat fish, poultry, beans, and nuts; limit red meat and cheese; avoid bacon, cold cuts, and other processed meats.

Micronutrient Malnutrition

- Availability of nutritious non-staple foods (vegetables, pulses, meat, dairy) has not increased as much as staples
- Prices have increased significantly
- Availability often seasonal
- Rural, low-income populations often lack access

Supplementation

- Provide doses of highly concentrated vitamins and minerals
  - Capsules, tablets or injections
- Effective for young children esp. in first 2 years of life.
- Requires regular supply of supplements, which often cannot be sourced locally



Fortification

- Micronutrients added to food during processing (e.g., flour, rice, oils) or sprinkled on food before eating
- Micronutrient powders and oils sold at local markets, esp. in urban areas
- Vulnerable populations often lack access to processed foods, additives

The Challenge

- Staple crops are widely available, but deficient in micronutrients
- Supplements, additives, processed foods and nutritious non-staples are not available to many vulnerable populations

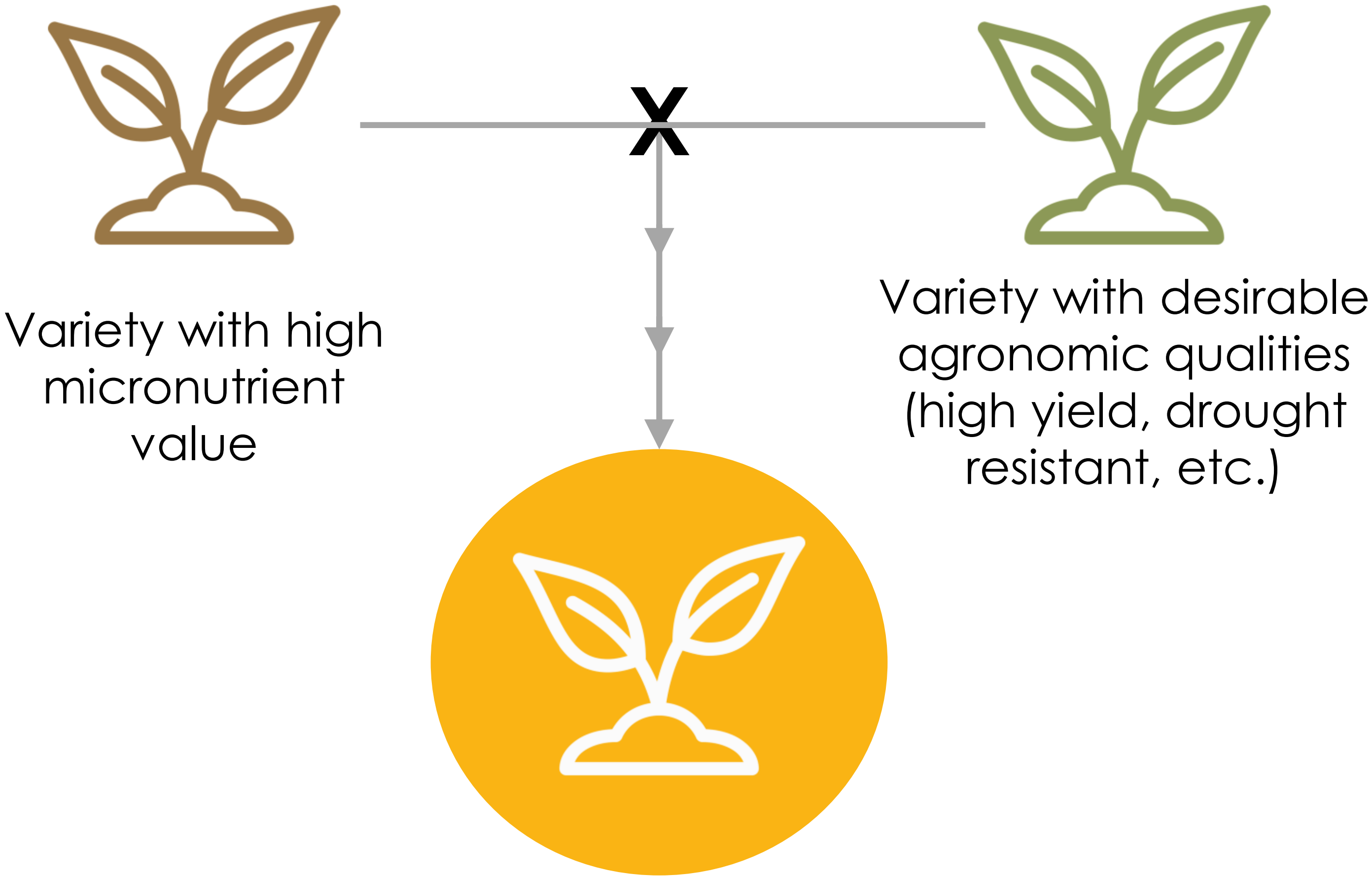
So…

- **Is it possible to make the staple crops that people *do* eat more nutritious?**

Biofortification

- **Biofortification involves breeding** new varieties of staple crops with higher micronutrient content
- Some traditional and wild varieties of certain staples have slightly higher micronutrient content
- **Selective breeding** can produce new varieties with **significantly** higher micronutrient content

Selective Breeding



Multiple generations of breeding produce new biofortified variety with best traits of parent varieties

Are Biofortified Crops GMOs?

Selective Breeding

- Plants allowed to reproduce naturally
- Traits are passed naturally from "parent" plants to offspring
- Breeders control which types of plants cross-breed with each other

GMO

- The DNA of a plant is modified artificially
- New traits are artificially added to plants, without any natural precedent

*All crops discussed in this course have been produced through **selective breeding** and are **not** GMOs.*

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Major Biofortified Crops

Zinc Rice
Up to 60% of daily zinc

Yellow Cassava
Up to 40% of daily vitamin A beta-carotenoids

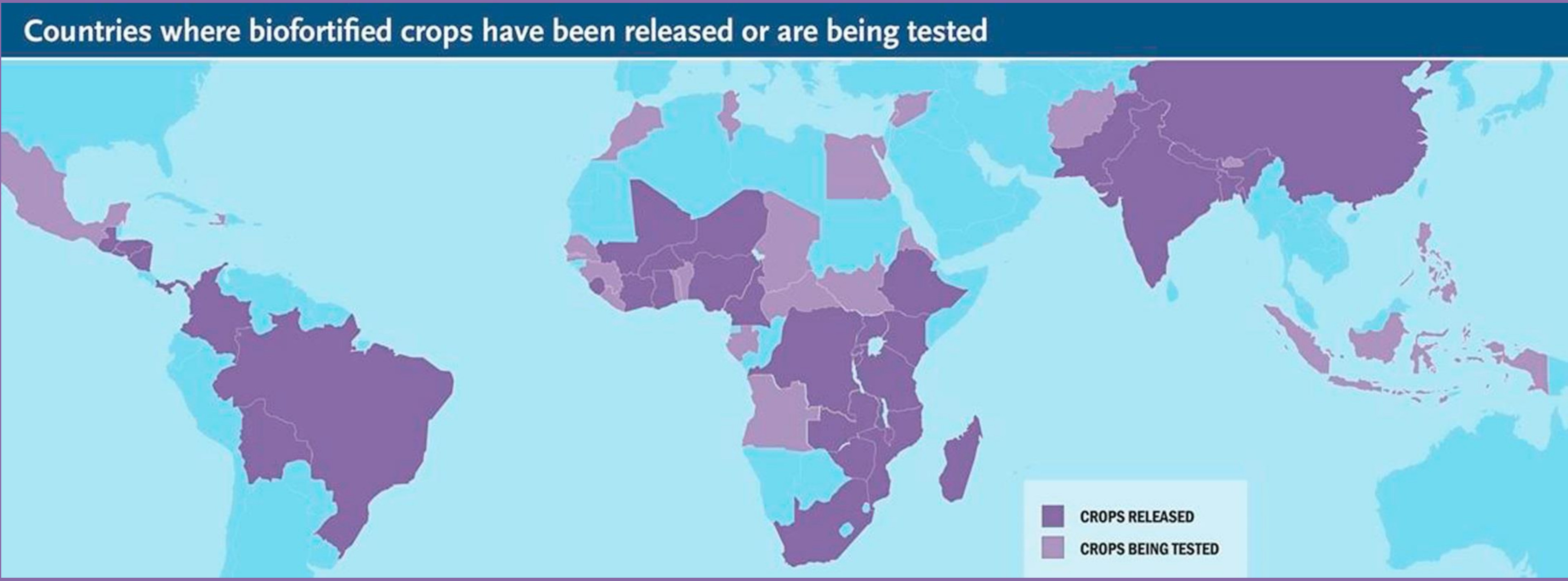
Iron Pearl Millet
Up to 80% of daily iron

High-Iron Beans
Up to 50% of daily iron

Orange-Fleshed Sweetpotato
Up to 100% of daily vitamin A (beta-carotenoids)

Zinc Wheat
Up to 50% of daily zinc

Pro-Vitamin A Maize
Up to 25% of daily vitamin A (beta-carotenoids)



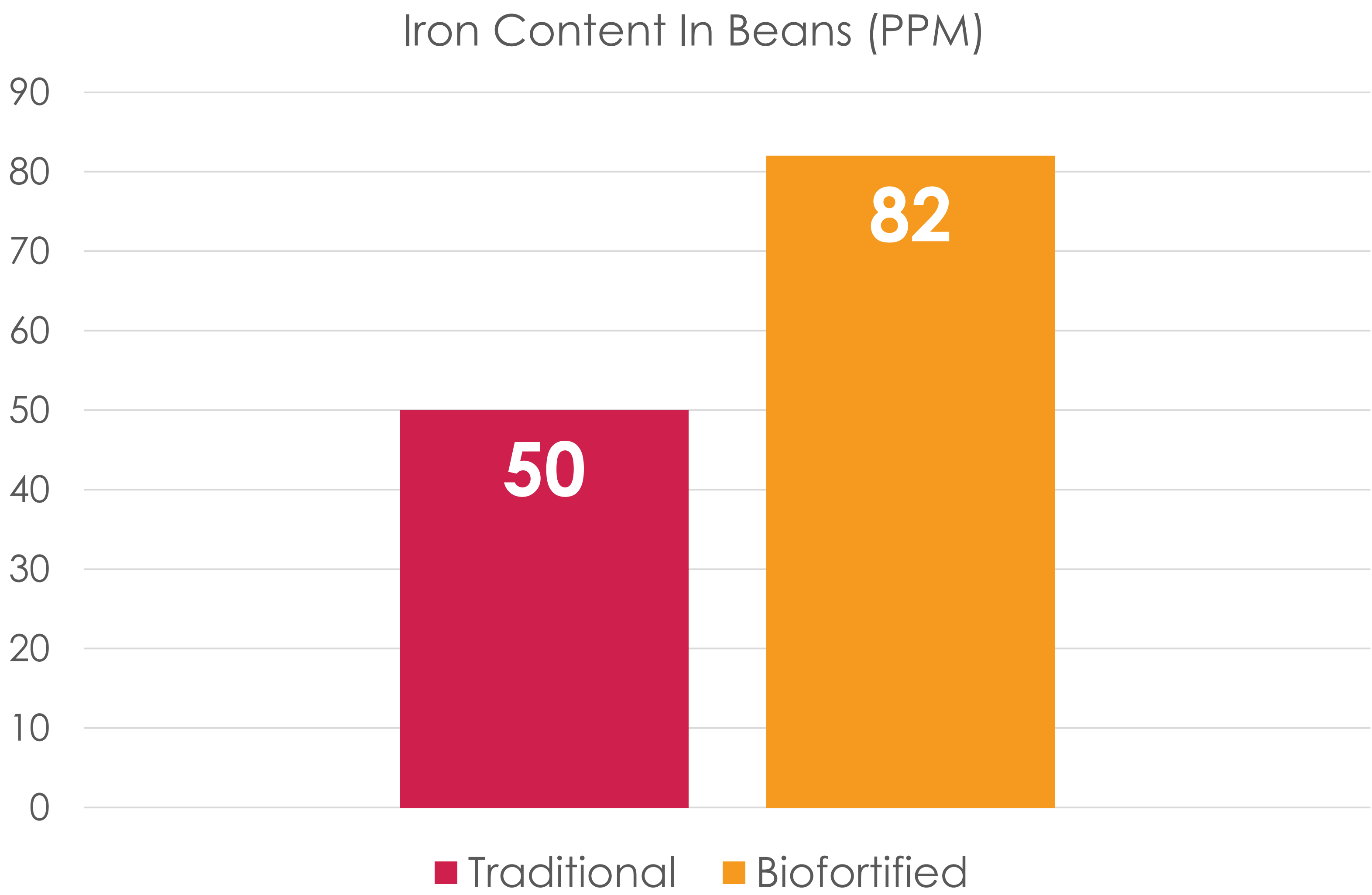
Biofortified Crop Distribution

Biofortified crops released in 30+ countries and currently being tested in 40+ countries

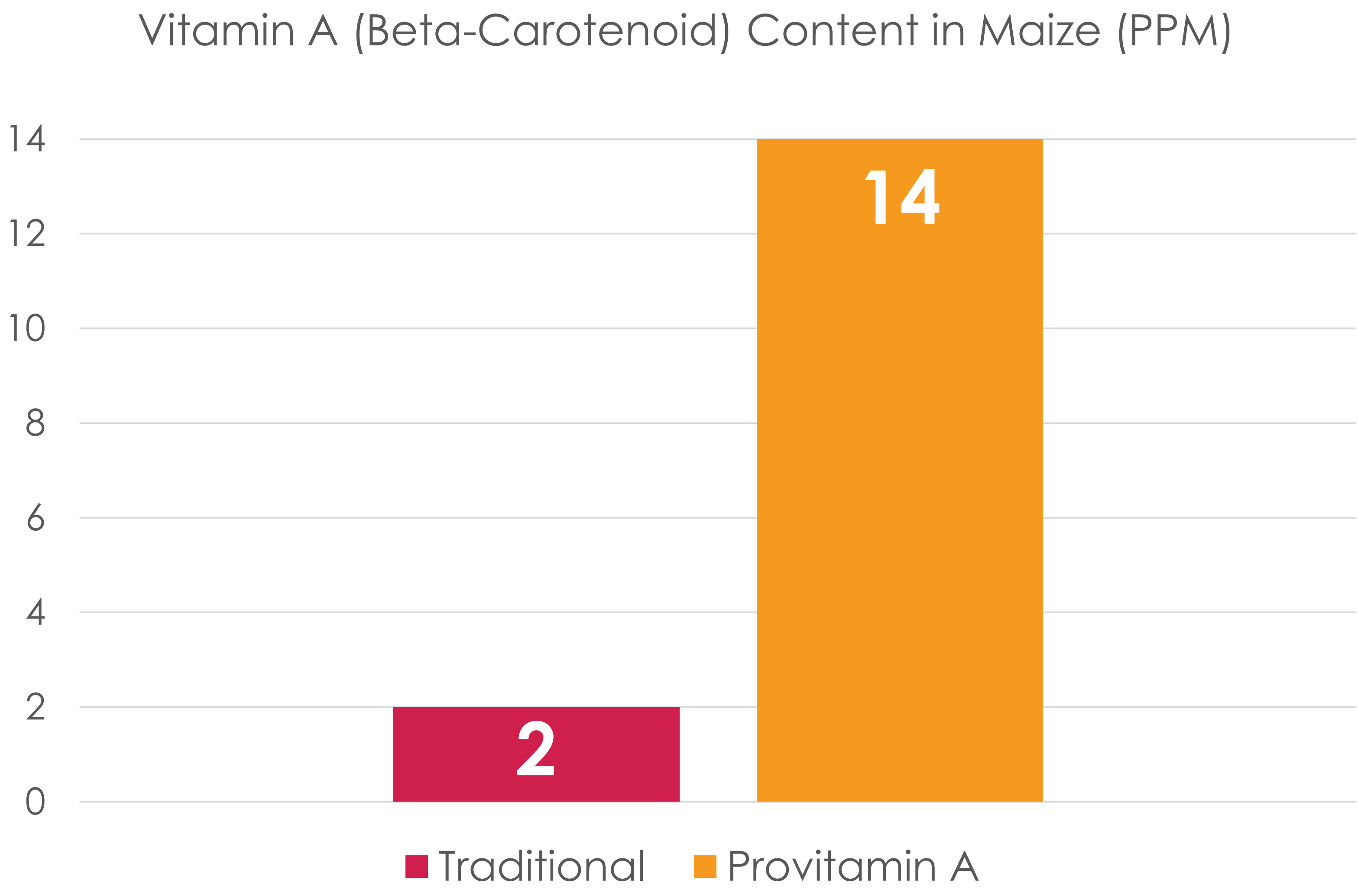
Biofortified Crop Distribution

	Hi-Iron Beans	Yellow Cassava	PVA Maize	Iron Millet	OFSP	Zinc Rice	Zinc Wheat
Bangladesh							
DRC							
India							
Latin America & Carribean							
Nigeria							
Pakistan							
Rwanda							
Tanzania							
Uganda							
Zambia							

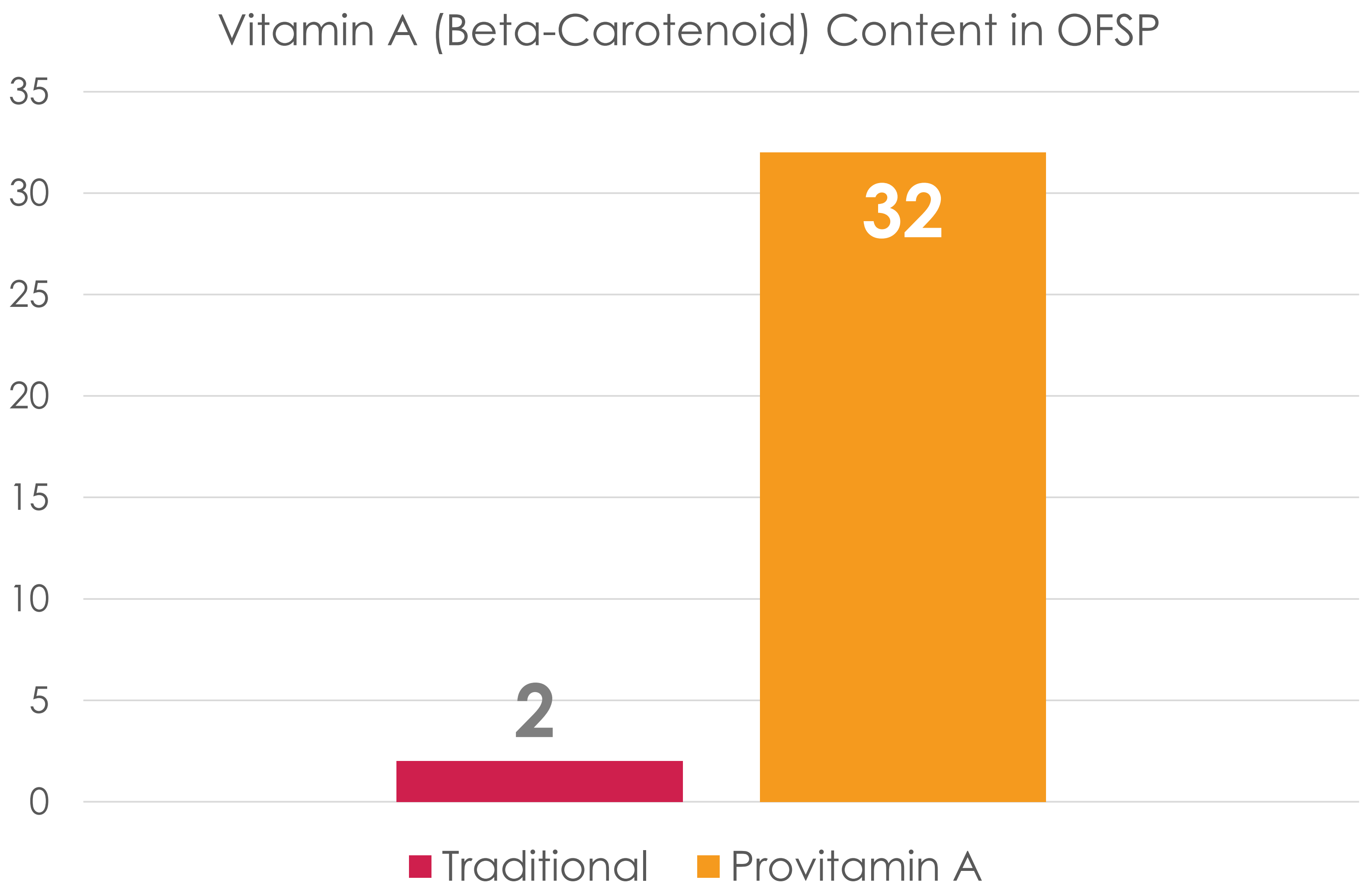
How much more nutrition?



How much more nutrition?

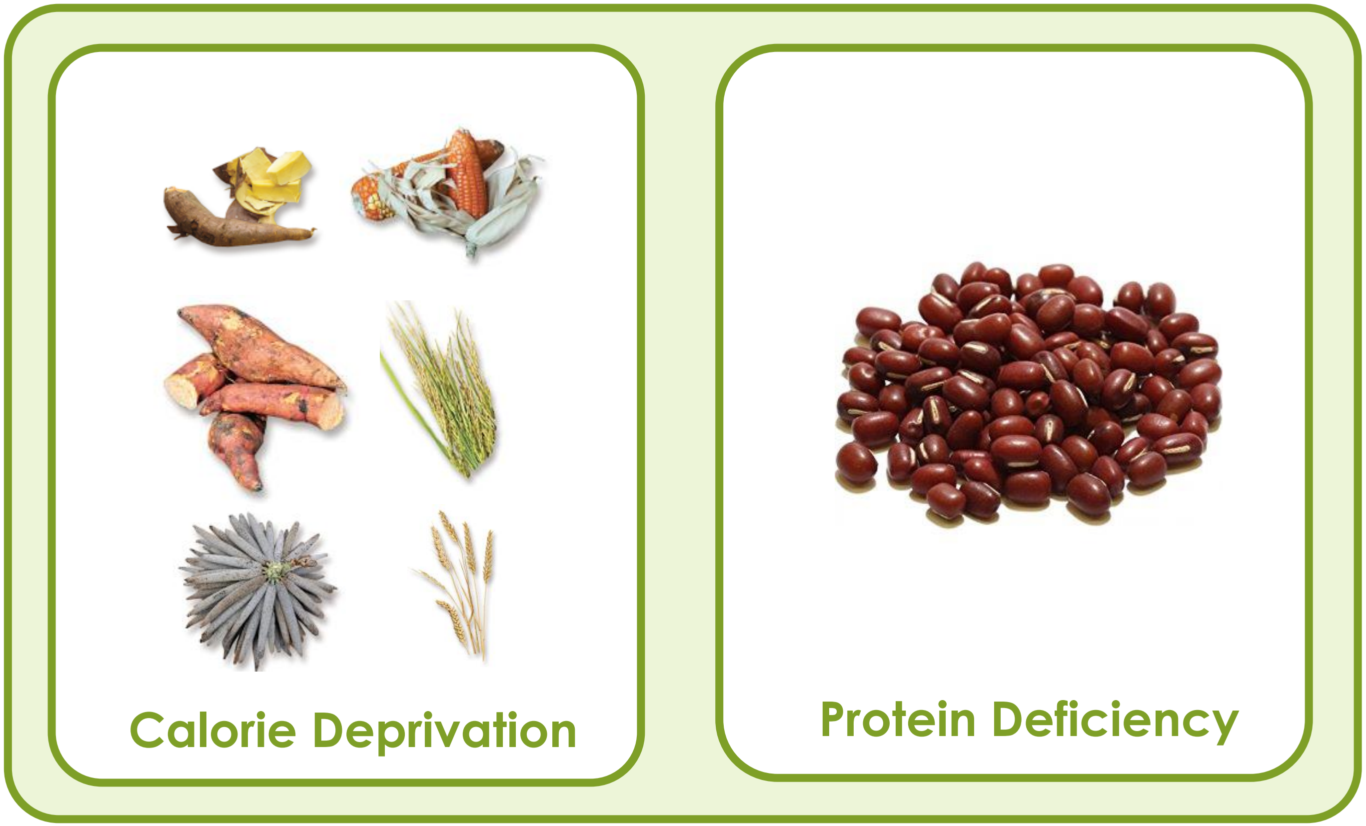


How much more nutrition?



“Food Basket” Approach

In combination, biofortified crops can address all dimensions of malnutrition.



Micronutrient Deficiency

Sustainability

- Once a biofortified staple is made available, farmers can cultivate it year over year at almost zero marginal cost.
- Goal is for biofortified crops to become fully integrated into food system and simply taken for granted
  - "Just crops"

Brainstorming

Comparing strategies

How is biofortification different from food fortification and supplementation?

How is biofortification different from dietary diversification?

What are some unique advantages of biofortification compared to other strategies?

7 m

Advantages of Biofortification

Biofortification's primary advantages include:

- Focus on **staple crops** that poor people already cultivate and consume
- **Sustainability** and cost

Case Studies

- **Orange-Fleshed Sweetpotato** - Randomized controlled trial of 24,000 households in **Uganda** and **Mozambique** from 2006 to 2009
  - In Uganda, introduction of biofortified OFSP over four growing seasons resulted in significantly increased vitamin A (serum retinol) for children with low vitamin A at the beginning of the study
  - In Mozambique, consumption of biofortified OFSP by children under five significantly reduced likelihood of diarrhea, the second leading cause of death in this age group, by 39% and duration of diarrhea episodes reduced by more than 10%

Case Studies

- Study of **Provitamin A Maize** conducted in **Zambia** with 5–7-year-old children
  - After three months of consumption, total body stores of vitamin A increased significantly compared with those in the control group
  - Consumption of orange maize has been demonstrated to improve total body vitamin A stores as effectively as supplementation
  - Significantly improved visual function in marginally vitamin A deficient children

Case Studies

- **Iron pearl millet** proved effective in six-month study of adolescent children in rural Maharashtra, **India**.
  - For secondary school children who consumed iron pearl millet flat bread twice daily, iron deficiency was significantly reduced and serum ferritin and total body iron were significantly improved after only four months.
  - Children who were iron deficient at beginning were 64% more likely to resolve their deficiency by six months.
  - Improved cognitive performance and levels of physical activity

Return on Investment

- Development and distribution of orange-fleshed sweet potato in Uganda cost **$15-$20 USD per Disability Adjusted Life Year (DALY)** saved
  - This is considered highly cost-effective by World Bank standards

Return on Investment

- For every dollar invested in biofortification, up to **$17 USD** of benefits may be gained (from increased productivity, reduced illness, etc.)

COPENHAGEN CONSENSUS CENTER

Recognition for Biofortification

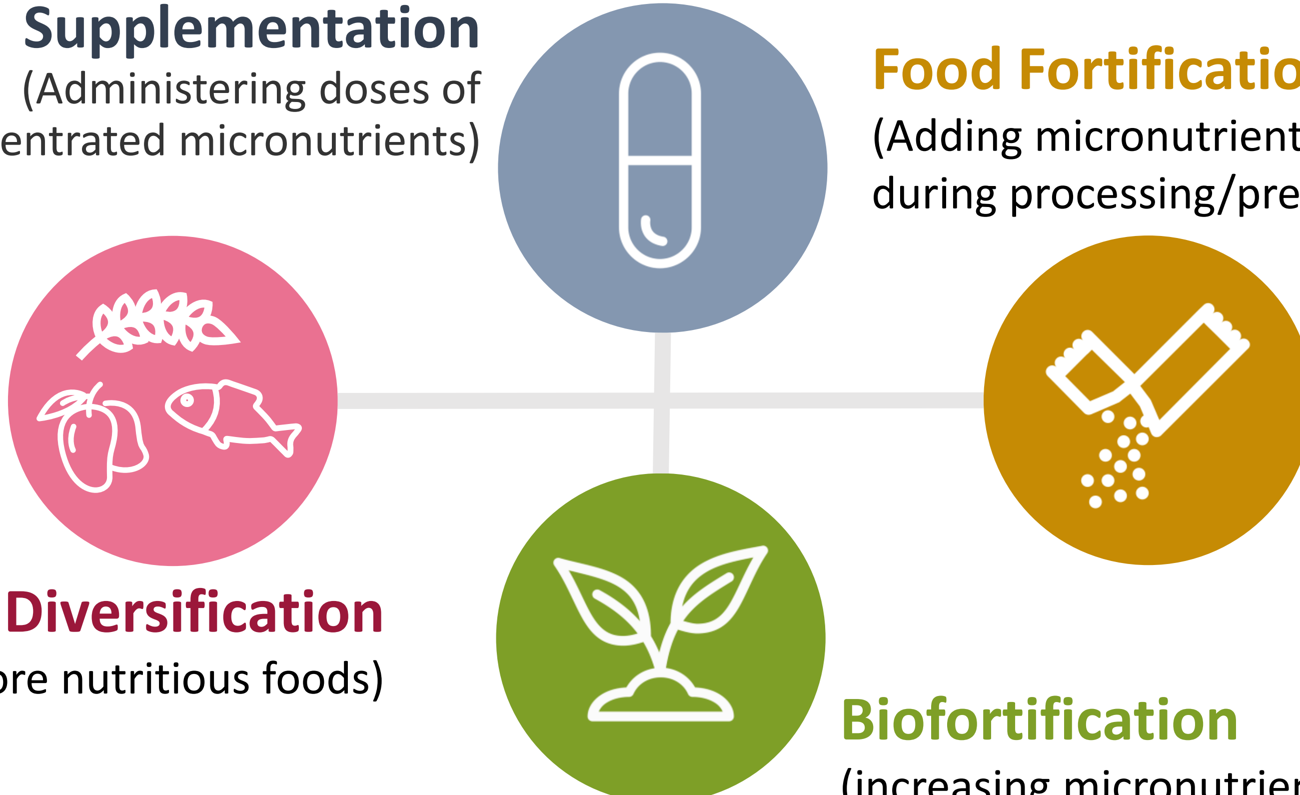
- Copenhagen Consensus, a panel of economists including multiple Nobel laureates, prioritized public health interventions
- For overall impact, biofortification ranked #5 out of 30 initiatives surveyed

Recognition for Biofortification

- 2016 World Food Prize awarded to developers of biofortified Orange-Fleshed Sweetpotato

- Howarth Bouls (IFPRI/HarvestPlus)
- Dr. Maria Andrade (CIP)
- Dr. Robert Mwanga (CIP)
- Dr. Jan Low (CIP)

Micronutrient Interventions



Supplementation
(Administering doses of concentrated micronutrients)

Food Fortification
(Adding micronutrient powder during processing/preparation)

Dietary Diversification
(eating more nutritious foods)

Biofortification
(increasing micronutrient content of staple crops)

These interventions are most effective when used <u>together</u>

Quick Review

Which of the following is NOT a common intervention for micronutrient malnutrition:

A. Supplementation
B. Food fortification
C. Nutrient substitution
D. Dietary diversification
E. Biofortification

1 m

Quick Review

Biofortification focuses on:

A. Eating a greater variety of nutritious foods, including animal products and non-staple crops
B. Giving concentrated doses of micronutrients in capsule or injection form
C. Adding micronutrient powders or liquids during processing/preparation
D. Breeding varieties of staple crops with higher micronutrient content
E. All of the above

1 m

Quick Review

The biofortified crops that we are studying in this course were produced by:

A. Genetic modification

B. Selective breeding

C. Adding special fertilizers to soil

D. All of the above

1 m

Quick Review

Which of these is **not** an actual biofortified crop?

A. Pro-vitamin A maize

B. Calcium wheat

C. High iron beans

D. Zinc rice

1 m

Quick Review

Alternate

- What are some common interventions for micronutrient malnutrition?
- What is biofortification?
- How is “biofortification” different from “food fortification”?
- Name some major crops for which biofortified varieties have been bred
- Are biofortified crops GMOs?

5 m

Discussion

We discussed the advantages… what challenges might we anticipate for popularizing biofortified crops as a solution for "hidden hunger" (micronutrient malnutrition)?

7 m

Major Questions

- Will a biofortified crop make an appreciable difference in a target population's health?
- Can we breed sufficiently micronutrient-rich varieties?
- Will local partners (governments, private companies) approve and support the crop?
- Will farmers grow the crop?
- Will consumers purchase and eat the crop?
- Can we achieve the necessary scale for a biofortified crop to become self-sustaining within local economies / food systems?
- How can we support biofortification through policy, business models, etc.?

Unit Objectives - Review

You should now be able to:

- List and describe the three types of malnutrition
- Define ‘hidden hunger’ and explain the importance of micronutrients for good health
- Identify natural sources of micronutrients
- List and describe common interventions for micronutrient deficiency
- Define ‘biofortification’
- Compare biofortification to other interventions and summarize its major advantages and challenges
- Differentiate between biofortified crops produced through selective breeding and GMOs

Unit 3

Vitamin A Deficiency and PVA Maize

Unit Objectives

By the end of this unit, you should be able to:

- Describe the effects of Vitamin A deficiency on human health
- Identify populations particularly vulnerable to Vitamin A deficiency
- Describe the nutritional characteristics of PVA Maize
- Describe the agronomic qualities of maize that make it a good crop for biofortification
- Define “Biofortification Priority Index”
- Explain key benefits of PVA Maize
- Summarise key challenges with PVA Maize adoption

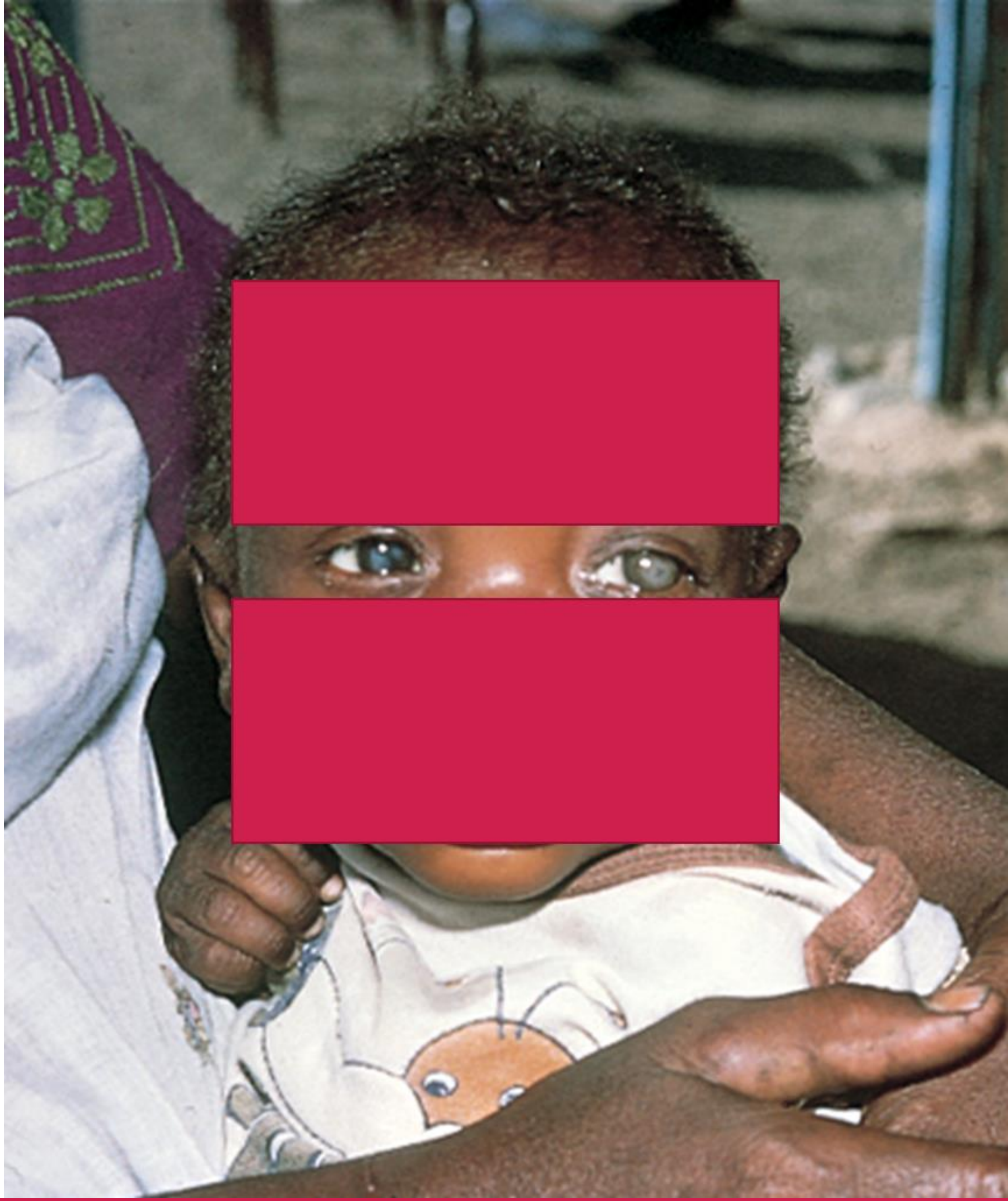
Vitamin A Deficiency

- **Vitamin A deficiency (VAD)** among most common micronutrient deficiencies
- According to a 2012 WHO report, VAD affects **250 million** preschool aged children
- Contributes to **2.7 million** preventable deaths each year

Vitamin A Deficiency

Effects include:

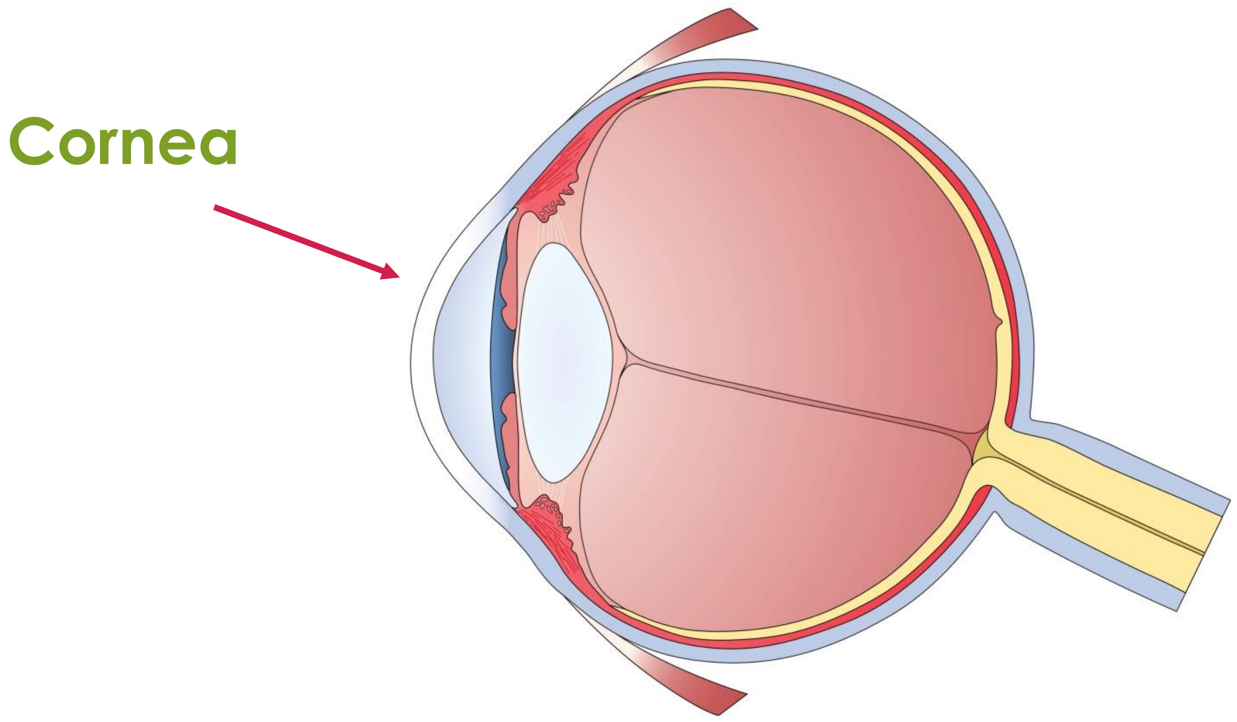
- Vision problems and blindness
- Reproductive issues
- Susceptibility to infection, disease
- Rough, scaly skin
- Low blood cell count



Vitamin A and Blindness

- VAD can cause
  - Irreversible **blindness**
  - Poor night vision

- Vitamin A deficiency **blinds up to 500,000 children** annually, esp. in Sub-Saharan Africa.



VAD and the Eye

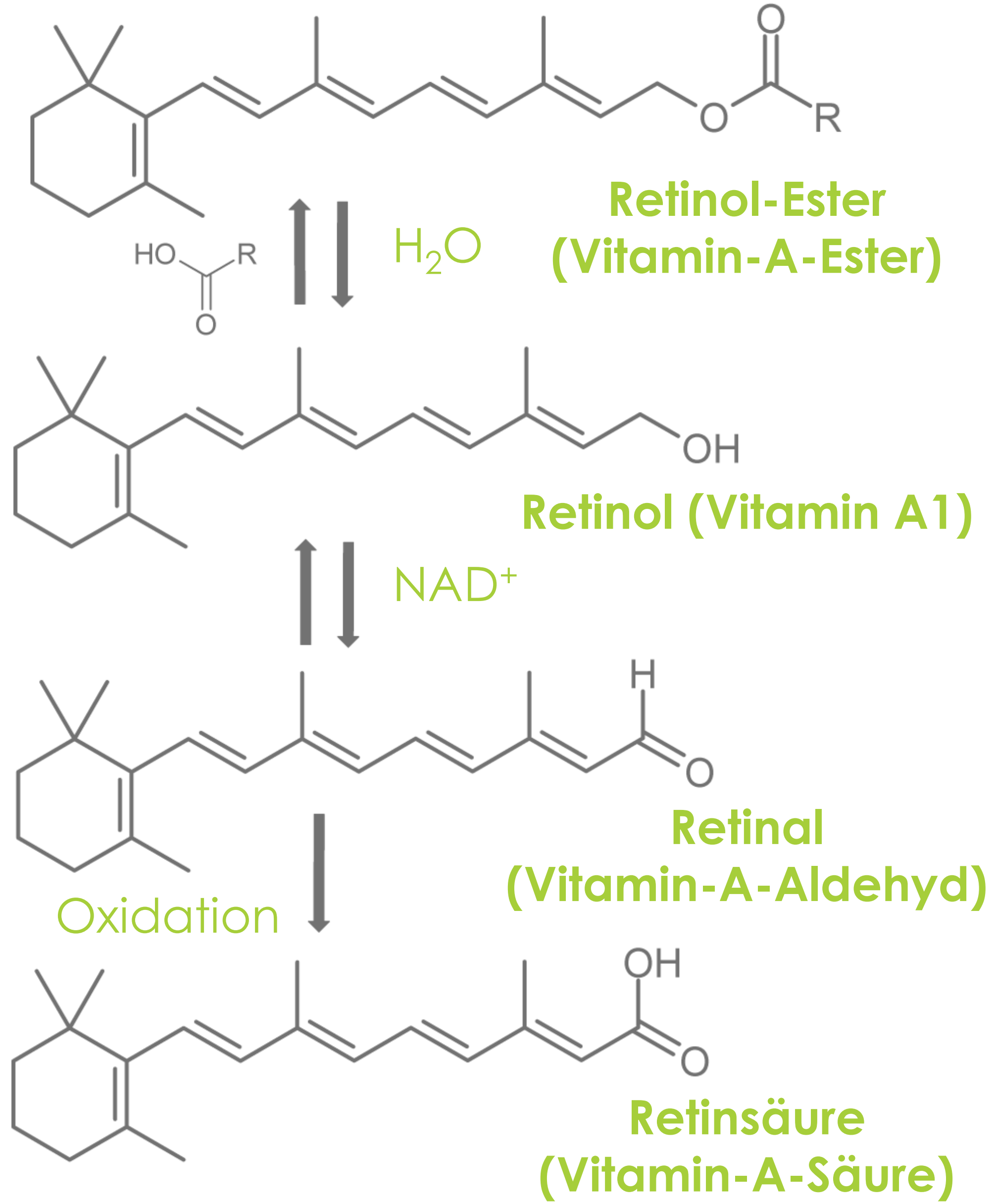
- Vitamin A keeps the cornea (outermost layer of eye) healthy
- VAD can make cornea:
  - Dried out
  - Clouded
  - Susceptible to infection

Night Blindness

- Vitamin A is also used by the structures in the eye (rods) responsible for night vision
- Ancient Egyptians recognized that night blindness can be treated by eating liver (rich source of Vitamin A)

What is Vitamin A?

- "Vitamin A" is **not a single chemical**
- Refers to a group of related chemicals that the body needs for certain critical functions



Forms of Vitamin A

There are two main types of vitamin A chemicals

- "Preformed" vitamin A (from animal sources)
- Provitamin A carotenoids (from plant sources)

Preformed Vitamin A vs. pVACs

Preformed Vitamin A

- Obtained from animal sources, including dairy products, fish, and meat (especially liver)
- Most readily absorbed and utilized by the human body
- Chemicals include
  - Retinol (an alcohol)
  - Retinal (an aldehyde)

Provitamin A Caretenoids

- Found in plants
- Body converts pVACs into vitamin A when reserves are low
- Chemicals include:
  - Beta-carotene
  - Alpha-carotene
  - Beta-cryptoxanthin

pVACs and Color

- Carotenoids are responsible for orange color of many plants/foods
- pVACs found in
  - Leafy green and yellow vegetables
  - Tomatoes
  - Certain other fruits

Discussion

Is vitamin A deficiency a problem among the communities you work with?

Do people in these communities have traditional approaches to diagnosing and/or treating vitamin A deficiency?

5 m

Quick Review

Vitamin A is important to human health because:

A. It keeps the eye cornea healthy
B. It enables red blood cells to carry oxygen from the lungs to other organs in the body
C. Human eyes consist primarily of vitamin A
D. The majority of a person's daily calories should come from vitamin A
E. A massive dose of vitamin A can immunize a person against blood-borne diseases such as HIV

1 m

Quick Review

Preformed vitamin A is found mostly in:

A. Leafy green and yellow vegetables
B. Animal sources, including dairy products, fish and meat
C. Nuts and honey
D. Alcohol
E. None of the above, it is chemically synthesised

1 m

Quick Review

Possible effects of vitamin A deficiency include:

A. Vision problems and blindness
B. Reproductive issues
C. Susceptibility to infection, disease
D. Rough, scaly skin
E. Low blood cell count
F. All of the above

1 m

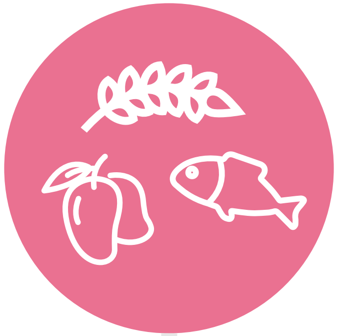
Quick Review

Alternate

- *Why is vitamin A so important for human health?*
- *Who is most affected by vitamin A deficiency?*
- *What are some common effects/symptoms of vitamin A deficiency?*

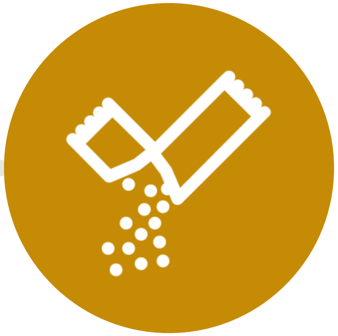
3 m

Micronutrient Interventions



Dietary Diversification
(Eating more nutritious foods)

Food Fortification
(Adding micronutrient powder during processing/preparation)



Supplementation
(Administering doses of concentrated micronutrients)

Biofortification
(Increasing micronutrient content of staple crops)

These interventions are most effective when used <u>together</u>

Dietary Diversification

Many vulnerable populations lack access to animal products and nutritious vegetables in sufficient quantities to meet Vitamin A requirements

- Cost
- Availability (often seasonal)

Photo: hoto by IFPRI/Milo Mitchell,

Supplementation & Fortification

- Many governments support vitamin A supplementation (capsules, injections) and sugar fortification programs
- WHO recommends for children 6-59 months of age
- Reduces risk of mortality by 24%

Photo: CDC

Supplementation & Fortification

- Unfortunately, supplements cannot be sourced locally
- Programs require continued investment / outside suppliers
- WHO recommends supplementation be supported with other, locally sustainable interventions

Photo: UNICEF

Biofortification

- **PVA Maize** is a biofortified crop bred for higher provitamin A carotenoid content than traditional maize varieties
- Cheap, readily available source of vitamin A
- PVA maize has a distinctive orange color due to pVAC content

Why Maize?

- #1 crop in the world (production tonnage)
  - 118M ha cultivated
  - 600M metric tons produced
- Consumed in large proportions in many areas where vitamin A deficiency is a health problem
- High yields make maize an important food source as population increases

Global Maize Production

- Most important cereal crop in sub-Saharan Africa and an important staple in Latin America, second only to rice in Southeast Asia
- Nigeria has highest area planted in Africa (5.8 M ha),
- Tanzania has the second largest (4.2 M ha)

Nutritional Characteristics

- Orange maize naturally contains more pVACs than yellow, white or red varieties, making it excellent for biofortification
- While orange maize has less pVACs per kg than carrots or spinach, poor people consume far more maize than vegetables

Agronomic Characteristics

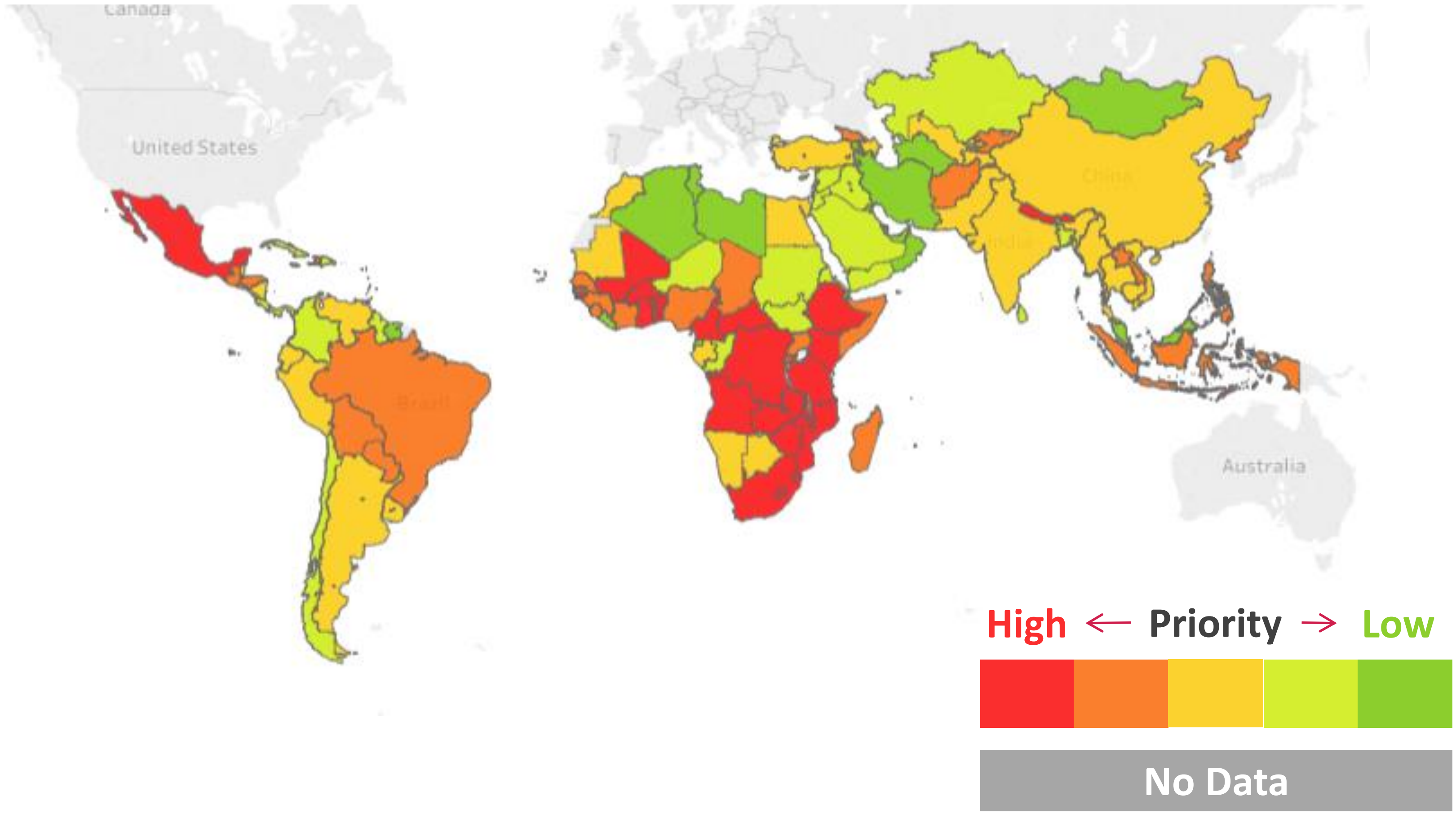
- Warm weather plant, grown under diverse climatic conditions
  - Grows anywhere in Africa except most arid regions
  - Grown year-round in many places
- High yielding
  - 5.9 tons/ha
- Less labor-intensive than millet, sorghum and rice

Maize Production

- PVA Maize bred to have superior agronomic qualities, but otherwise cultivation is no different than traditional maize varieties
- Visit CIMMYT website for information on agronomic best practices **www.cimmyt.org**

The Biofortification Priority Index (BPI)

Vitamin A (PVA) Maize



- Live link: http://www.harvestplus.org/knowledge-market/BPI

Distribution of PVA Maize

PVA Maize varieties have been released in:

- Africa
  - DRC
  - Ghana
  - Malawi
  - Mali
  - Nigeria
  - Rwanda
  - Tanzania
  - Zambia
  - Zimbabwe
- Latin America & Caribbean
  - Brazil
  - Panama

Return on Investment

- PVA Maize is a cost-effective intervention for vitamin A deficiency
- Study in Zambia found cost per disability-adjusted life year (DALY) saved is **$24**
  - Meets World Bank standard for cost effectiveness

Case Studies

- Study of 5-to-7 yo children in Zambia found that, after three months of eating PVA maize, vitamin A stores increased significantly
- Eating PVA maize improved visual function for marginally vitamin A deficient children

Discussion

Is maize a common food staple for the populations you work with?

Do you see any particular opportunities or challenges for addressing vitamin A deficiency and related public health issues with PVA maize?

5 m

Major Questions

- Can PVA Maize make an appreciable difference for populations affected by vitamin A deficiency?
- Can we breed maize with sufficient provitamin A carotenoid content?
- Will local partners (governments, private companies) approve and support PVA Maize?
- Will farmers grow PVA Maize?
- Will consumers purchase and eat PVA Maize?
- Can we achieve the necessary scale for PVA Maize to become self-sustaining within local economies / food systems?
- How can we support the adoption of PVA Maize through policy, business models, etc.?

Quick Review

An especially popular intervention for Vitamin A deficiency (apart from biofortification) is:

A. Supplementation

B. Dietary diversification

C. Fortification with powders

D. Cash subsidies

1 m

Quick Review

All of the following factors make PVA maize an excellent crop for biofortification, except:

A. High yield
B. Naturally high levels of pVAC
C. High cost
D. High per-capita consumption in many countries impacted by vitamin A deficiency

1 m

Quick Review

In terms of how it is cultivated, PVA Maize…

A. Requires more fertilizer than conventional varieties
B. Is cultivated in the same way as conventional varieties
C. Produces significantly lower yields than conventional varieties
D. Cannot be cultivated in as wide a range of environments as conventional varieties

1 m

Quick Review

The “Biofortification Priority Index” is a system for rating:

A. The suitability of certain crops for biofortification initiatives in certain countries

B. The levels of different vitamins and minerals in a biofortified crop

C. The amount of funding that local governments give to biofortification versus other interventions

D. The prevalence of biofortified crops as a percentage of all crops grown in a country

1 m

Quick Review

Alternate

- *What factors make PVA maize a good crop for biofortification interventions?*
- *What is the "Biofortification Priority Index"?*
- *Name some of the countries where PVA maize has already been released.*

5 m

Unit Objectives - Review

You should now be able to:

- Describe the effects of Vitamin A deficiency on human health
- Identify populations particularly vulnerable to Vitamin A deficiency
- Describe the nutritional characteristics of PVA Maize
- Describe the agronomic qualities of maize that make it a good crop for biofortification
- Define “Biofortification Priority Index”
- Explain key benefits of PVA Maize
- Summarise key challenges with PVA Maize adoption

Unit 4

Breeding PVA Maize

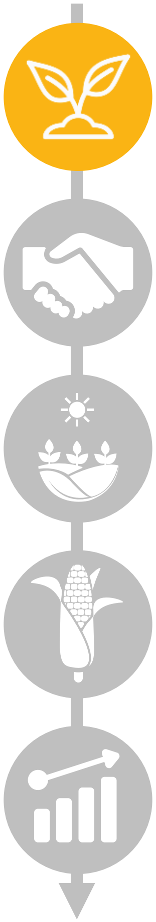
Unit Objectives

By the end of this unit, you should be able to:

- List the factors nutritionists consider while setting micronutrient targets for biofortified crops
- Identify causes of micronutrient loss
- List the characteristics that farmers and consumers find desirable in maize varieties
- Explain the significance of maize being a “hybrid” crop
- Outline the key steps of the breeding process and summarize what happens at each step

Breeding PVA Maize Varieties

How Biofortification Works



- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Setting Micronutrient Targets

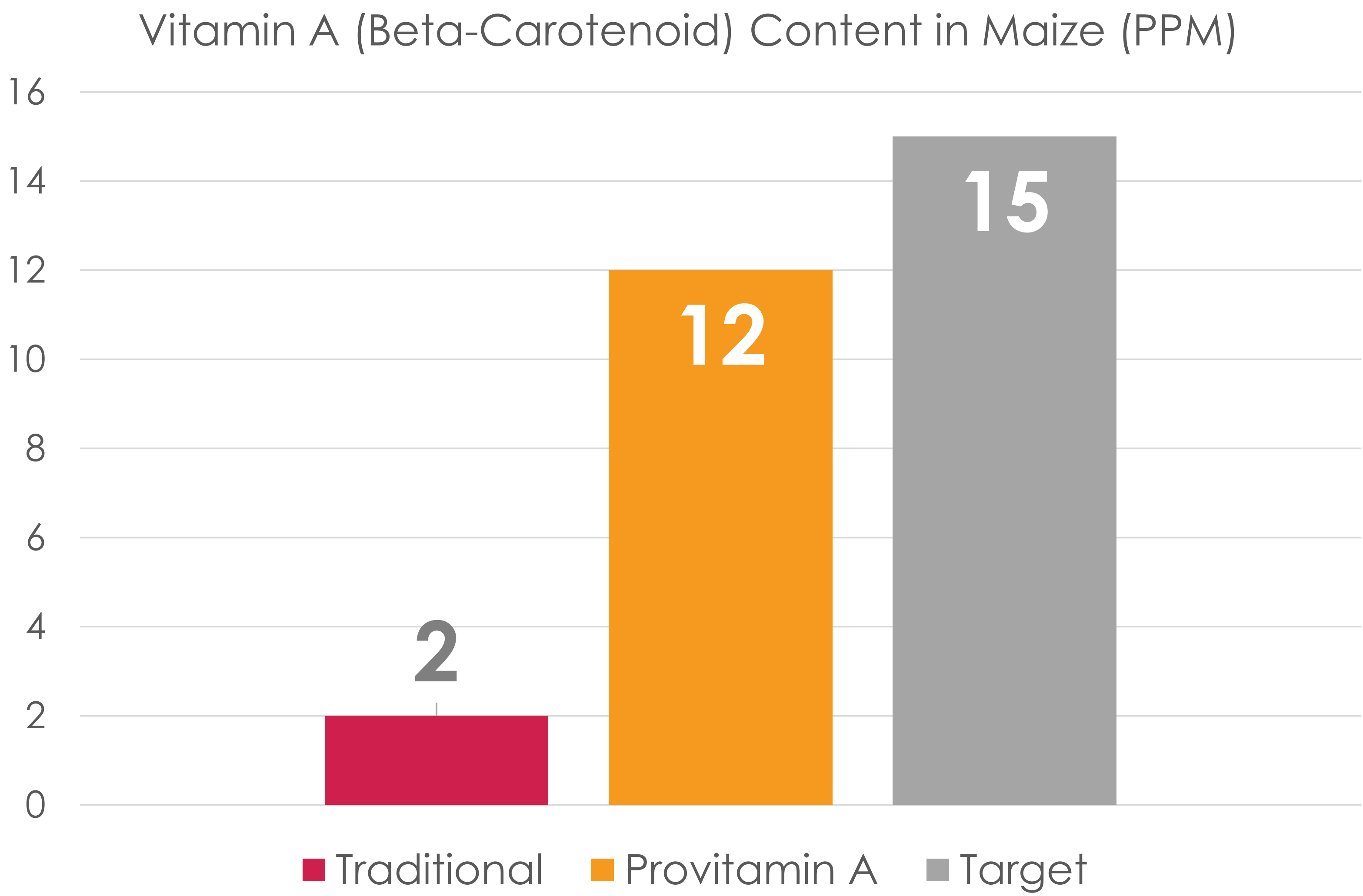
Nutritionists evaluate numerous factors

- Requirements to avoid micronutrient deficiency
- Ability of body to absorb ingested nutrients
- Quantities of crop consumption by the target population

Targets by Population

- Target for pVACs set as **50% of Estimated Average Requirement (EAR)**
- Requirements calculated based on needs of preschool children 4–6 years old and non-pregnant, non-lactating women of reproductive age

How much more nutrition?



Accounting for Losses

Targets must account for:

- Losses during storage and processing
- Losses from common methods of preparation

Photo: CIMMYT

Quick Survey

Of the following methods for preparing maize, which do you imagine would retain the most provitamin A?

- *Cooking (as flour)*
- *Boiling*
- *Frying*
- *Heating (as popcorn)*
- *Roasting (without husk)*

2 m

Quick Survey

Of the following methods for preparing maize, which do you imagine would retain the most provitamin A?

- *Roasting (without husk)* ***87%***
- *Heating (as popcorn)* ***80%***
- *Cooking (as flour)* ***75%***
- *Boiling* ***70%***
- *Frying* ***65%***

Discussion

Besides nutrition, what qualities of a crop might be important to farmers?

What qualities might be important to consumers?

5 m

Other Desirable Traits

Farmers

- High yield
  - Ideally produce more than 1 ear per stalk
- Early maturity
- Tolerance to pests, diseases, herbicides and drought
- Marketability
- Storage durability

Other Desirable Traits

Consumers

- Taste
- Texture
- Color/appearance
- Ease of preparation
- Price

Discussion

Does it seem reasonable to expect breeders to produce maize varieties that meet nutritional targets while satisfying the demands of farmers and consumers? Do you expect there will be some compromise / trade-offs?

5 m

Quick Review

Nutritional targets for biofortified crops must account for:

A. Nutrients gained during processing and preparation
B. Supplementation and food fortification
C. Tolerance to pests and diseases
D. Nutrients lost during processing and preparation

1 m

Quick Survey

Which agronomic quality do you think farmers in the communities you work with would find most important?

A. Yield
B. Disease/Pest Resistance
C. Storage Durability
D. Early Maturity

1 m

Quick Survey

Which quality do you think consumers in the communities you work with would find most important?

A. Taste

B. Cooking Time

C. Price

D. Nutrient Content

1 m

Quick Review

Alternate

- *What factors must nutritionists consider when they set micronutrient targets?*
- *What traits do farmers find desirable? Consumers?*

3 m

The Breeding Process

Breeding Biofortified Crops

Steps in process include:

1. **Screening existing varieties** for micronutrient content and agronomic traits
2. **Breeding new varieties** (crosses, selection) with best traits of “parent” varieties
3. **Laboratory testing** to measure micronutrient levels
4. At least 3 years of **field testing** to verify crop performance in the target environment
5. Submitting promising lines to **national partners** for further testing and release to farmers

Screening

- Researchers at CIMMYT, IITA and other institutions screened more 1200 varieties to identify those ones with higher content of pVACs
- Initial screening found ranges of 0.5 to 10 ppm pVACs (3% to 66% of target)

Case Study: CIMMYT Gene Bank

- CIMMYT gene bank in Mexico holds 28,000 maize seed samples from 100+ countries

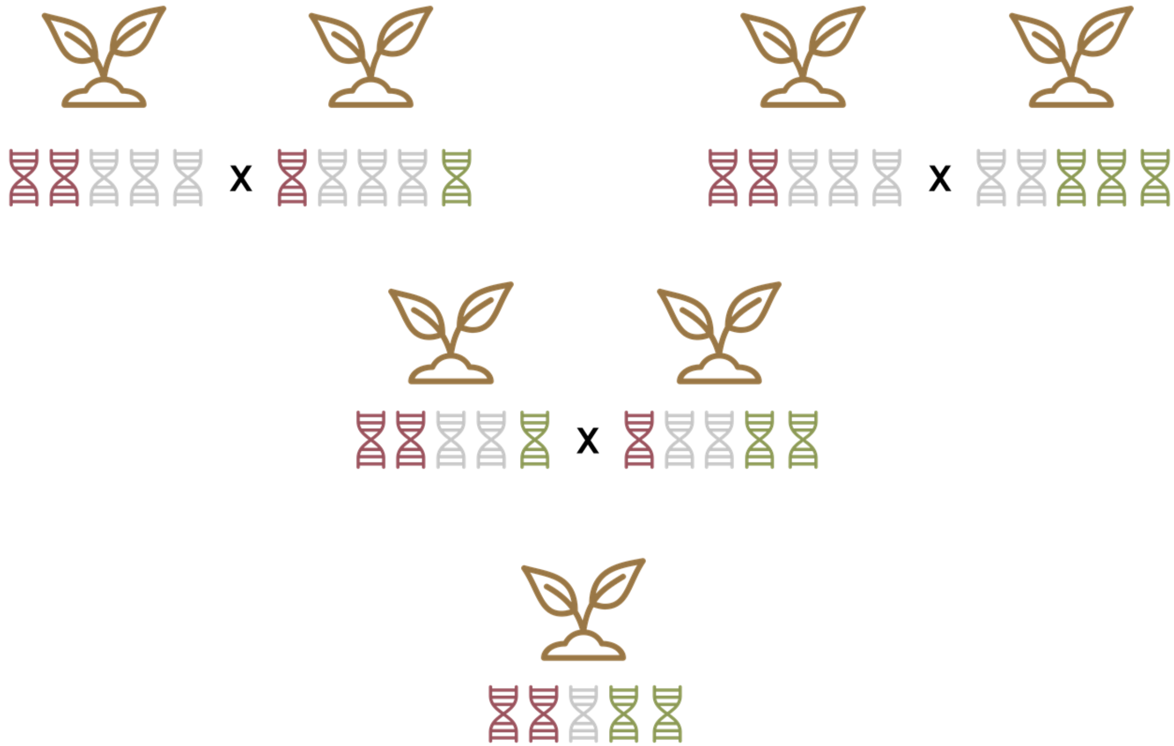
- Landraces (varieties developed by farmers over generations)
- Wild relatives of crops (e.g., teosinte)
- Improved/biofortified varieties

Case Study: CIMMYT Gene Bank

- CIMMYT ensures all seed samples meet international phytosanitary standards to avoid spreading seed-borne pathogens
- Advices on design of experiments
- Data made available to anyone per open-access policy

Breeding Maize

- Maize reproduces by cross-pollination
- All plants have male (tassel) and female (silk) parts
- In nature, wind or insects carry pollen from male parent's tassel to female parent's silk



Breeding

- High pVAC varieties are crossed with other maize varieties that have qualities desired by farmers and consumers
- Eventually, this produces a variety that meets both agronomic and nutritional targets

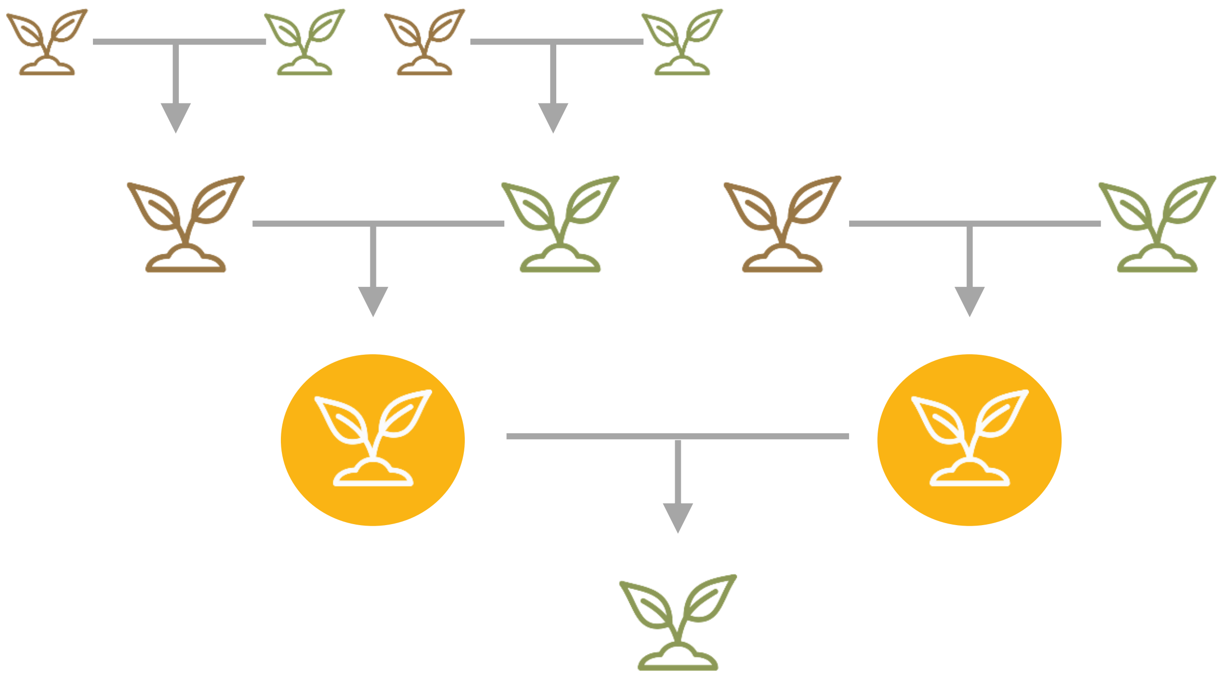
Breeding Maize

- When crossing different varieties, we typically want to dictate which variety is “male” parent and which is “female”
- Breeders remove tassels from plants intended to serve as “female” parents

Photo: CIAT

Breeding Maize

- Silk actually tubes that carry pollen to seed, inside protective sheave
- The “ear” of corn will grow from the fertilized seed



Breeding "Hybrid" Crops

- "Hybrid" lines are result of crossing two or more specific varieties of maize over multiple generations
- Might not be able to pass desirable traits to subsequent generations (even if pollinated by plant of same variety)

Breeding "Hybrid" Crops

- Producing a high pVAC hybrid may require many generations of breeding in controlled environment
- To ensure quality, farmers typically must buy new seed from certified suppliers each season
  - Cannot simply replant seed

Quick Review

What is a tassel?

A. Male part of the maize plant
B. Female part of the maize plant
C. Silk of the maize
D. Fertilised seed of the maize
E. Special biofortified fertiliser for maize

1 m

Quick Review

What are hybrid crops?

A. Crops that are genetically modified to include traits from other types of crops, such as beans or cassava
B. Crops that can grow on the same field with other crop varieties
C. Crops that can be cooked together with other types of crops and animal products
D. Crops that are specifically biofortified to contain a variety of vitamins and micronutrients
E. Crops produced by crossing two or more specific varieties over multiple generations

1 m

Quick Review

Alternate

- *What is a tassel and silk of the maize?*
- *What is a “hybrid” crop?*
- *Why is it not recommended to replant the seeds of the hybrid crop?*

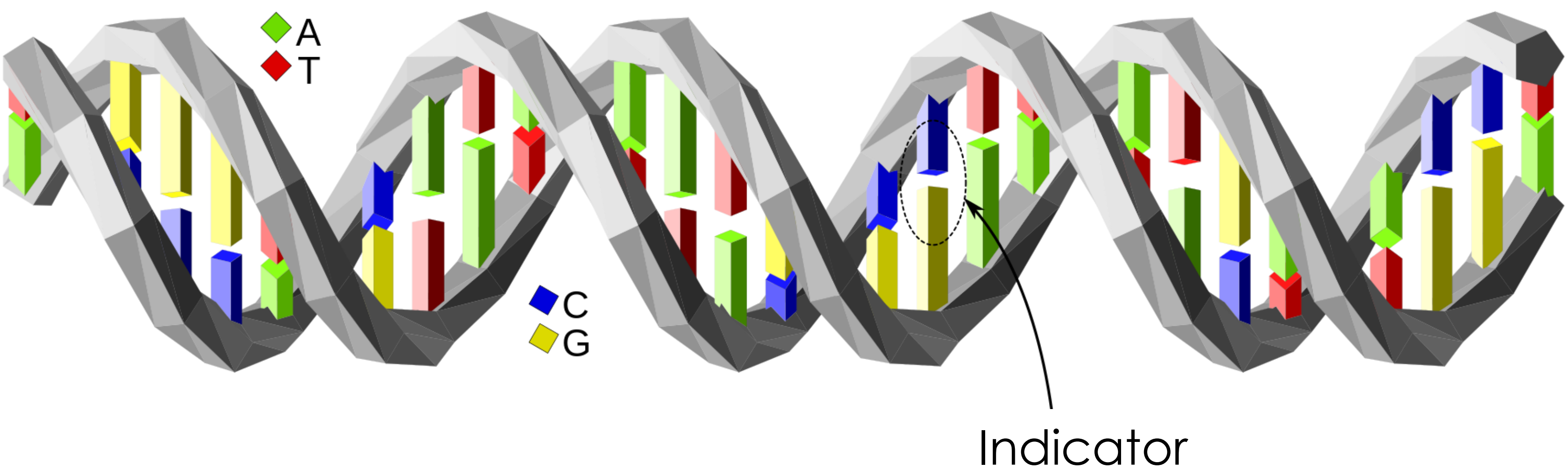
3 m

Laboratory Testing

- Plants tested each season to measure pVACs content
- Biochemists and food scientists continually developing faster, more precise, higher-throughput tests to reduce time and cost of development

Genetic "Markers"

- Researchers identified certain genes (lcyE, crtRB1), that indicate high concentration of provitamin A carotenoids
- By looking for these "markers" researchers quickly identify crosses with high vitamin A content, without having to wait to test for pVACs after plants have grown
- Greatly speeds up breeding process



Field Testing

- pVAC content of maize influenced by environmental factors such as soil and precipitation.
- New varieties tested in local farmers' fields
- Evaluated for yield, tolerance to pests / diseases, nutritional content, etc.
- Compared to the best local varieties

Participatory Appraisal

- During field testing, breeders consult farmers to confirm that crops meet agronomic needs
- Ideally, biofortified varieties perform as well or better than popular varieties, providing farmers incentive beyond nutritional value

Photo: CIMMYT / Peter Lowe

Approval by National Partners

- Seeds of the best-performing varieties multiplied and offered to national governments
- Governments test varieties and, upon approval, make them available to farmers, seed companies, etc.

Approval by National Partners

- First PVA Maize lines bred by partnership of CIMMYT, IITA, and the Zambia Agriculture Research Institute (ZARI) in 2007
- Over 40 PVA maize varieties have been released in various African and Latin American countries

Brainstorming

National Partners

What are some concerns that national partners might have about biofortified crops like PVA Maize?

5 m

Quick Survey

How long would you imagine it takes to develop a biofortified crop then get it out to the public?

2 m

Quick Survey

How long would you imagine it takes to develop a biofortified crop then get it out to the public?

Breeding process alone can take **3 to 8 years**, while overall process of breeding, testing and approval can take **6 to 10 years**

“Fast Tracking” Crops

During breeding process, varieties are developed that might not meet target, yet provided enough benefits versus traditional varieties to justify “fast-tracking” release to the public

PVA Maize Releases

There have been three "waves" of biofortified maize

1st Wave
2012/13

2nd Wave
2015/16

3rd Wave
current/2018

50% **66%** **100%**

percent of target provitamin A increments

Activity (Groups)

Explaining Biofortification

- Divide into groups
- As a group, decide how you would explain the biofortification process to a typical smallholder farmer or policymaker who might not be familiar with the strategy or the underlying science.
- The explanation must be less than 1 minute
- Be prepared to share your explanation with the class

You have 5 min to discuss in your groups

30 m

Quick Review

Which of the following steps in the breeding process happens <u>first</u>?

A. Screening Seeds

B. Field Testing

C. Laboratory Testing

D. Release to Partners

1 m

Quick Review

How long does it usually take to get a newly developed biofortified crop variety to market?

A. 6 months to a year

B. 1 to 3 years

C. 6 to 10 years

D. 10 to 15 years

1 m

Quick Review

"First wave" PVA maize varieties contained what percentage of the target vitamin A levels?

A. 25%
B. 50%
C. 66%
D. 100%
E. 125%

1 m

Quick Review

Alternate

- *What are the steps in the breeding process?*
- *How long does it take for a biofortified crop variety to reach the market?*
- *What could be done to fast track biofortified crop varieties to market?*

3 m

Unit Objectives - Review

You should now be able to:

- List the factors nutritionists consider while setting micronutrient targets for biofortified crops
- Identify causes of micronutrient loss
- List the characteristics that farmers and consumers find desirable in maize varieties
- Explain the significance of maize being a "hybrid" crop
- Outline the key steps of the breeding process and summarize what happens at each step

Unit 5

Fostering Demand for PVA Maize

Unit Objectives

By the end of this unit, you should be able to:

- Outline the steps for “scaling” and “anchoring” PVA maize in local food systems
- List key activities for introducing a new crop
- Differentiate between different seed systems
- Explain the role of private sector partners for promoting hybrid crops
- Summarise advantages of PVA maize for the farmers
- Summarise advantages of PVA maize for the consumers

Steps to Achieve Scale

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Achieving Scale

- Once a biofortified crop becomes a regular part of local food system, supply will be self-sustaining
- Requires acceptance among farmers and consumers, support of private and public sector partners

Introducing Biofortified Crops

1. Variety release
2. Seed production and dissemination
3. Direct promotion to farmers, consumers
4. Farmer and consumer education
5. Engaging partners
6. Technical support and research

Variety Release

Variety Release

- Researchers work with governments and other stakeholders to breed biofortified staples for specific populations
- After breeders meet goals, government conducts additional review/testing
- Government manages release to public
- Researchers provide technical support

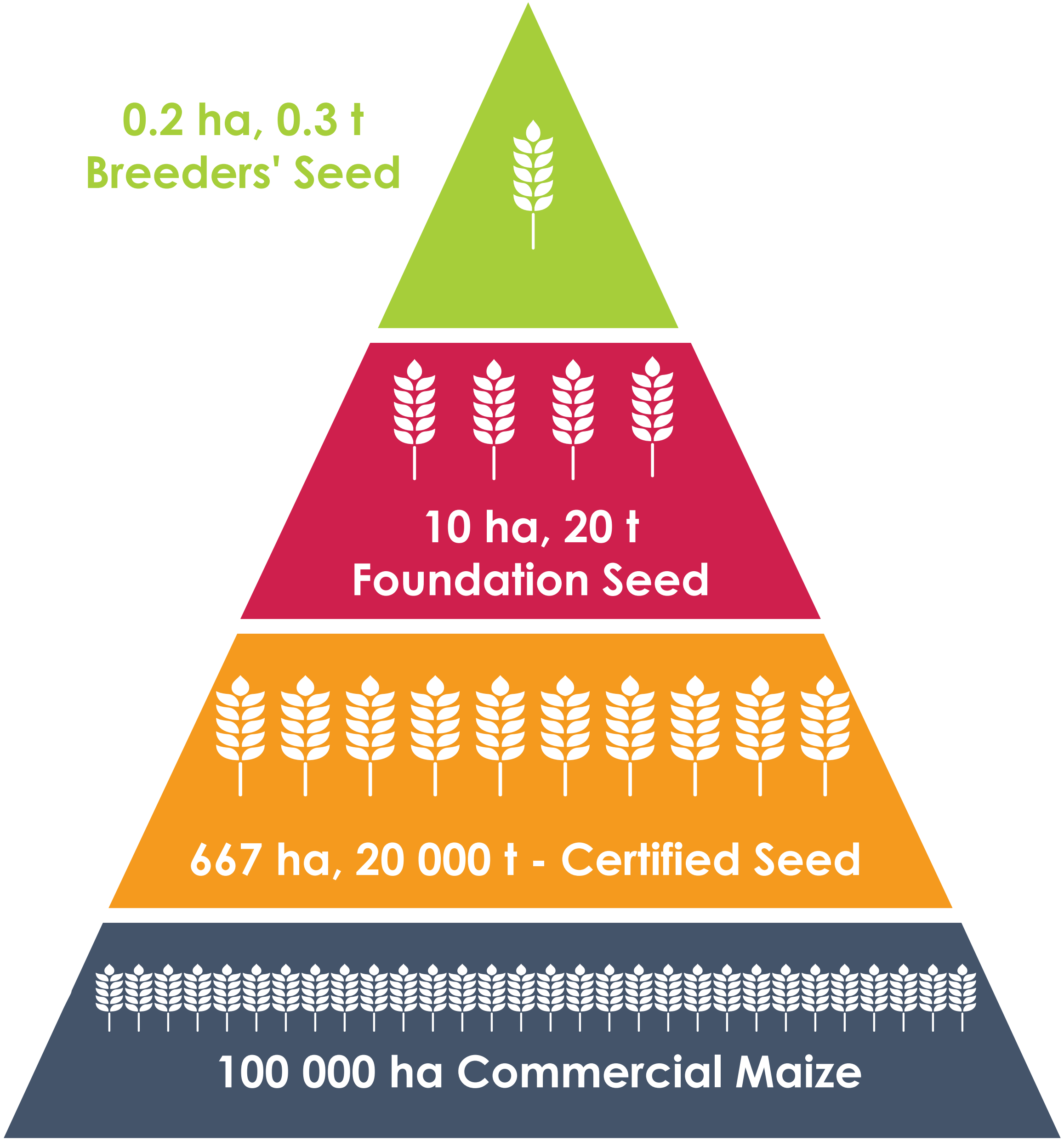
Seed Systems

Seed Systems

- **Seed systems** and strategies for introducing/scaling biofortified varieties vary by the type of crop
- Types of crops:
  - Vegetatively propagated
  - Self-Pollinated
  - **Hybrid** (Cross-Pollinated)

Open-Pollinated vs. Hybrid Crops

- Maize reproduces by cross-pollination
- If plants are allowed to openly pollinate in the field, seeds might not have same qualities as parent plants
- Only way to guarantee same quality year over year is to purchase **hybrid** seed bred under carefully controlled conditions



Seed Classes

- Breeders' seed
  - Controlled pollination
  - Small quantities
- Foundation seed
  - Extra-isolated fields
  - Strict quality standards
- Certified seed
  - Isolated fields
  - High quality standards
- Half of seed saved as reserve stock

Hybrid Seed Systems

- Most farmers not in a position to breed hybrids on their own
  - Requires isolated fields, access to parent lines, quality control
- Creates incentive for commercial suppliers
- Absent private sector involvement, public sector support is critical for supply

Open Pollination vs. Hybrid

Hybrid

- Higher cost
- Reliably high yield, quality
- Recycling seeds will lead to significant drop in quality, need to purchase new seed each year (typically from a commercial supplier)

Open Pollination

- Lower cost
- Inconsistent yield, quality
- Less penalty for recycling seed (in terms of quality and yield) but quality is generally lower to begin with

Discussion

What do you think are some potential advantages and disadvantages of PVA Maize being a "hybrid" crop?

5 m

Strengthening Seed Systems

- Multiplication of sufficient, high-quality seed is a crucial first step towards scaling
- Without planting material to “prime the pump”, there will be no biofortified crops.

Seed Companies

- In countries with robust private seed systems, companies are a natural partner
- Hybrid crops have inherent commercial potential, as farmers must buy new seed year after year

Food Processors

- PVA Maize can be used in various products:
  - Flour
  - Meal
  - Grits
  - Porridge/Cereal
  - Snacks
- Generating demand among processors ensures robust market for surplus grown by farmers

Photo: PABRA

Benefits of Private Sector Involvement

- Involving private sector
  - Shortens the time to market
  - Lays the groundwork for sustainability
  - Contribute to research, testing
- Small and medium-size companies can help create demand for biofortified food even before supply reaches scale
- Multinational companies slower to develop interest, but can have massive impact

Direct Promotion

- Biofortification proponents can work with partners to promote crops directly to farmers and consumers during early stages of introduction

Discussion

During the initial introduction, what could be some of the ways to disseminate seeds?

What are the places/ channels we could use?

What would be the most effective in your area?

5 m

Dissemination of Seed

During initial introduction, seeds disseminated directly to farmers via:

- Local markets
- Schools
- Places of worship
- Health centers
- Extension workers

Case Study: Zambia

- Biofortified PVA Maize varieties were licensed to private companies in Zambia for commercialization of seed production and distribution
- Private sector had well-established distribution channels, but many rural households could not afford large quantities of seed at market rates

Case Study: Zambia

To ensure availability, HarvestPlus:

- Worked with seed companies to ensure availability of smaller, affordable pack sizes
- Partnered with the Zambia National Farmers Union and government extension services to disseminate information to farmers about the availability of PVA maize seed in their local areas
- Worked with Zambian government's Farmer Input Support Program (FISP) to broker 50% subsidy for orange maize seed and fertilizer to farmers considered economically disadvantaged
- Quantity of orange maize seed distributed under FISP grew 400% between the first and second year of inclusion

Discussion

What are some key lessons we can draw from the Zambian case study?

5 m

Quick Review

In terms of reproduction/seed systems, maize can be described as what type of crop?

A. Vegetatively Propagated
B. Self-Pollinated
C. Hybrid
D. Bioengineered

1 m

Quick Review

Which of the following statements is true of hybrid crops?

A. Seeds can be replanted with little risk of losing desirable traits

B. Seeds must be purchased from suppliers every year

C. They are the least attractive crop type for private sector investment

D. All of the above

1 m

Quick Review

Alternate

- *For biofortification to work as an intervention we need to obtain the buy-in/support of what groups?*
- *Why are hybrid crops attractive for private sector investment?*

5 m

Promoting Farmer Adoption

Farmer Demand for PVA Maize

- Maize already appreciated by farmers for a number of reasons
- High yield
- Source of income
  - Robust local, regional and international markets

Promotion to Farmers

- Farmers are key to biofortification
  - Often part of target population
  - After fulfilling household food needs, sell surplus to larger population via rural and urban retail outlets
- May hesitate to plant crop for which market has not been tested

Demonstrations

Demonstration trials have been key to adoption:

- Local field demonstrations allow farmers to study crops firsthand
- Small promotional seed packs allow farmers to try new variety with minimal risk

Promotion to Farmers

- Nutritional benefits add additional value:
  - Benefits to farmer's household from eating PVA Maize
  - Potential to use nutritional benefits to drive consumer demand for PVA Maize
- Income from selling maize can be used to buy other nutritious foods

Case Study: Zambian Farmers

- Survey of 242 Zambian farmers following demonstration found strong preference for agronomic and consumption qualities of orange PVA Maize varieties vs. white and yellow
  - Comparable yields
  - Larger cob size
  - Superior taste
- 97% said they would grow orange maize in the next season
  - Those already growing orange maize planned to devote 4x more land in following season
- Willing to pay an average of 40% premium for PVA Maize seed vs. white varieties maize varieties.

Strengthening Markets

- Maize has gone from subsistence crop to commercial in many countries
  - 20–50% of rural households sell surplus maize
- Critical to create markets for surplus PVA Maize
  - Grain buyers
  - Millers
  - Processors

Activity (Groups)

Promoting to Farmers

- Divide into groups
- Each group is to prepare a 2-min presentation to a group of farmers to explain the advantages of planting biofortified crop (can be any biofortified crop – we are just talking about generalities, not specifics of any one crop)
- **You have 10 minutes**
- Once complete, groups will deliver their explanation. Facilitator will play the role of a farmer, and group should be ready to address the farmer's concerns.

40 m

Quick Review

For farmers, desirable qualities of PVA maize include:

A. Low yield
B. Nutritional value
C. Source of income (selling surplus)
D. All of the above
E. B and C

1 m

Quick Review

According to Zambia study, farmers preferred orange PVA maize over white and yellow for what reason?

A. Comparable yields
B. Larger cob size
C. Superior taste
D. All of the above
E. None, they did not prefer orange PVA maize

1 m

Quick Review

Alternate

- *Why could farmers be hesitant to plant biofortified crops?*
- *What are the advantages of PVA maize from the farmers perspective?*
- *Why did the farmers in the Zambia study prefer orange PVA maize over white and yellow?*

Promoting Consumer Demand

Consumer Demand

- Biofortification cannot counter deficiencies unless consumers regularly purchase and eat biofortified foods
- Consumer acceptance research focuses on:
  - Sensory evaluation
  - Willingness to pay

Demand for Maize

- Major consumer staple in many African countries
- #1 staple in Tanzania, Ghana, Mexico and Central America
- Growing demand in Asia
- Demand expected to increase by 2.6% per year due to population growth, rising incomes

Maize Varieties

- Comes in many colors (white, yellow, red, purple)
- Most widely available / consumed white and yellow varieties only provide carbohydrates with limited amounts of micronutrients

Photo: USDA

Discussion

When consumers go to the market, how do they select maize?

What kind of characteristics or qualities are they looking for when evaluating maize?

3 m

Sensory Evaluation

- Researchers studying consumer acceptance of orange, high-pVAC varieties
- Evaluate
  - Taste
  - Texture
  - Appearance

Activity (Whole Group)

PVA Maize Sensory Test

- Participants should examine the samples of biofortified and conventional maize varieties
- Could you detect any obvious differences?

15 m

Case Study: Zambia & Ghana

- Studies compared consumer preference for *nshima* (Zambia) and *kenkey* (Ghana) made with orange maize to white and yellow maize

Case Study: Zambia & Ghana

- Even without nutrition information, consumers preferred orange maize
- After learning about nutritional benefits, customers willing to pay a premium

Brainstorming

Nutrition Messaging

What do you think might be some effective methods for delivering nutrition information about biofortified crops?

Which members of a community should we target, specifically?

How much of an impact would you expect nutrition messaging to make on farmer adoption and consumer acceptance?

5 m

Nutrition Messaging

- Education / awareness of nutritional benefits essential for driving acceptance of PVA maize
- Can be delivered via:
  - Radio, Television
  - Community Leaders
  - Extension Agents
  - Social Media
  - Events
  - Music, Film

Photo: S.Quinn (CIP) CC BY-NC 2.0

Activity (Groups)

Developing Messages

- Divide into groups
- Design one of the following for PVA maize for a specific audience (farmers, consumers, women, families):
  - 30 to 60-second “radio” message
  - One-page pamphlet
  - Series of three SMS messages
- **You have 10 minutes**
- Share your message with the class

30 m

Quick Review

All of the following can help drive consumer demand for PVA maize <u>except</u>:

A. Breeding PVA maize for superior taste and sensory qualities

B. Educating consumers on the nutritional benefits of biofortified crops

C. Having community leaders endorse biofortified crops

D. All of the above

1 m

Quick Review

Alternate

- *What characteristics do consumers consider when they select PVA maize?*
- *What can we do to generate consumer demand for PVA maize?*
- *What are some of the channels for marketing PVA maize?*

3 m

Unit Objectives - Review

You should now be able to:

- Outline the steps for "scaling" and "anchoring" PVA maize in local food systems
- List key activities for introducing a new crop
- Differentiate between different seed systems
- Explain the role of private sector partners for promoting hybrid crops
- Summarise advantages of PVA maize for the farmers
- Summarise advantages of PVA maize for the consumers

Unit 6

Scaling PVA Maize

Unit Objectives

By the end of this unit, you should be able to:

- Outline the strategic goals of biofortification interventions
- Identify potential partner organizations for supporting PVA maize over the long term
- Recognize the potential impact of policies, regulations and trade on biofortification initiatives
- Explain the importance of integrating biofortification into international standards

How Biofortification Works

- **Researchers** breed new varieties of staple crops with higher micronutrient content
- **National partners** (governments, private companies, NGOs, etc.) make new varieties available to farmers
- **Farmers** grow biofortified crops to feed their families and sell at market
- **Consumers** purchase and eat biofortified crops
- Eventually, as cultivation and consumer demand scale, supply of micronutrient-rich, biofortified staples becomes self-sustaining

Implementation

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

Achieving Scale

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

Discussion

We have discussed how proponents can directly support biofortified crops during the initial introduction, but how could they become self-sustaining over the long term?

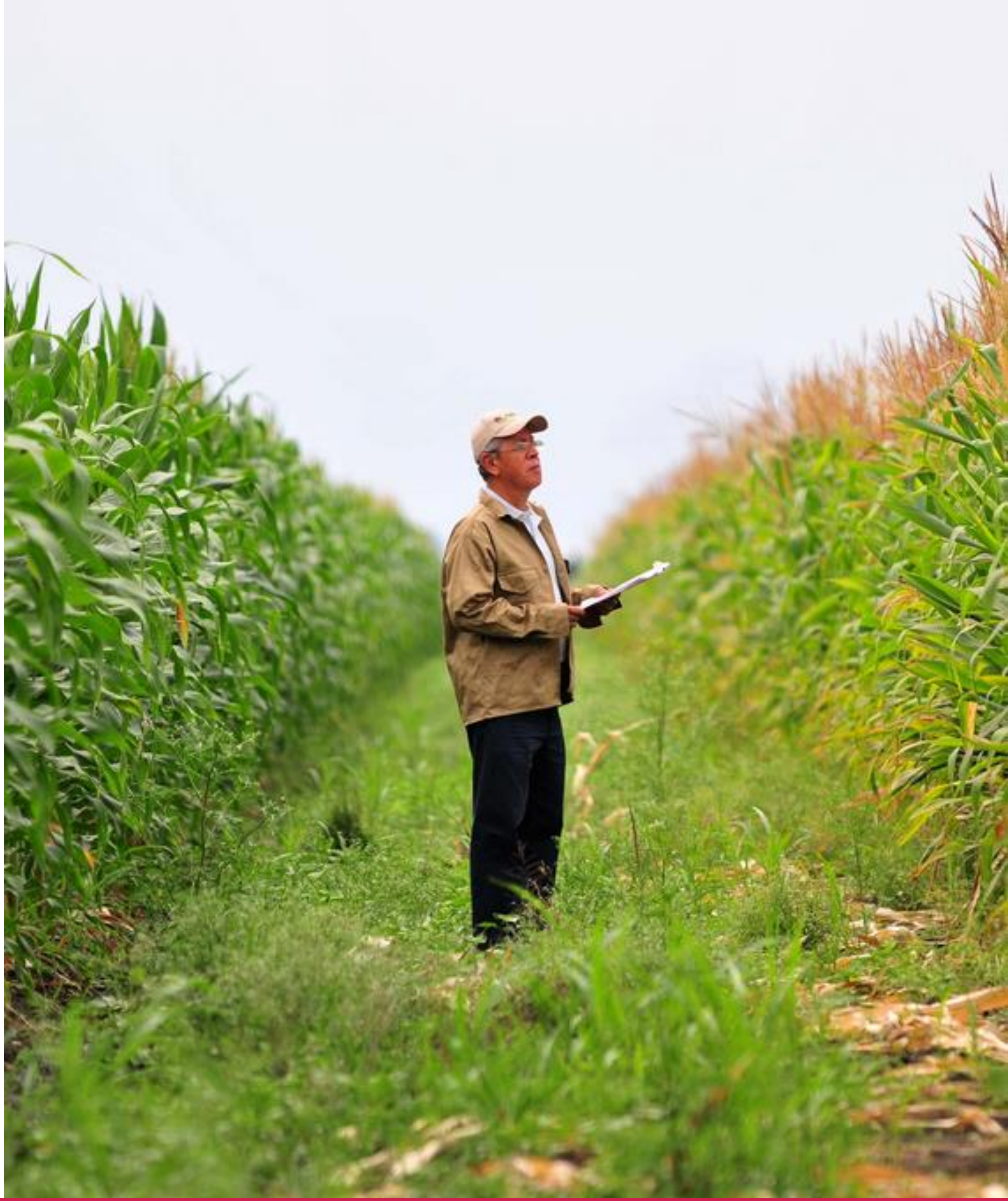
5 m

Scaling Up Operations

- Goal is for biofortified crops to reach sustainable market share in order to ensure long-term supply
- Scale back direct support/financing, allow demand among farmers and public to sustain biofortification

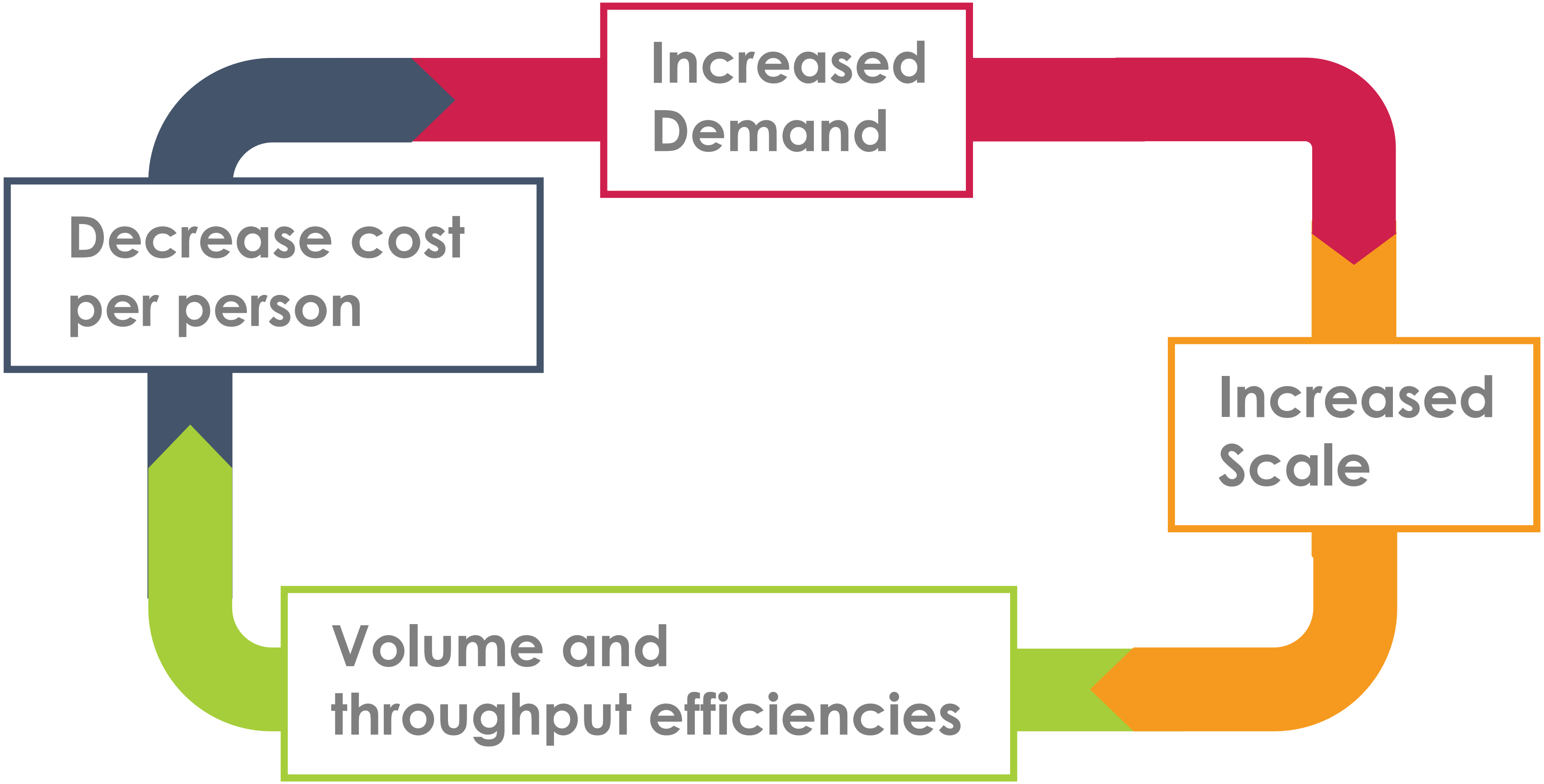
Strategic Goals

- Mainstream biofortified varieties into crop pipeline
- Achieve critical level of demand / market share
- Transfer ownership to public and private sector partners
- Reduce need for specific funding for biofortified crop development



Virtuous Cycle

Demand drives **scale**, which can make biofortification more **cost-effective** and **sustainable**

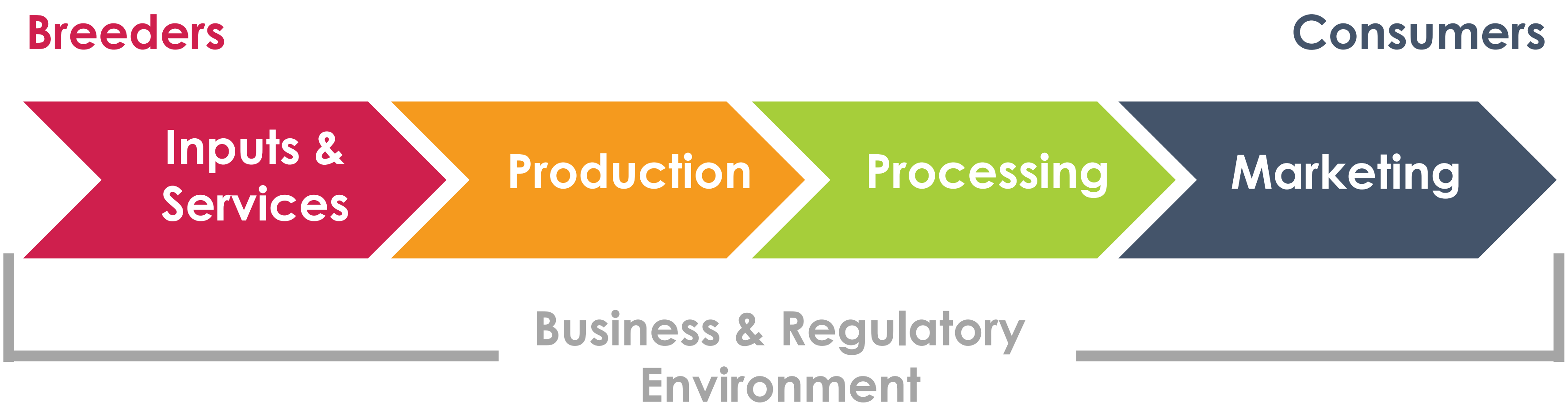


Expanding Partnerships

- Cooperating with partner organizations and forming multi-stakeholder platforms can accelerate introduction and scaling of biofortified crops
- Partners might include
  - Local governments
  - Private companies
  - Other participants in value chain
  - Multilateral institutions
  - NGOs

Value Chains

- When scaling up biofortification, reach out to stakeholders across existing value chains.
- A **value chain** consists of all the activities that add value to an agricultural commodity as it is brought to market.



Brainstorming

Value Chains

Who are some participants in maize value chains?

How could the different types of stakeholders potentially support biofortification?

What incentive(s) might they have for doing so?

5 m

Value Chain Stakeholders

Besides farmers and consumers, value chains may include…

- **Input Dealers** – Includes not only seed companies but makers of fertilizer, pesticides, equipment, etc.
- **Aggregators** – Buy crops from smallholder farmers to resell in bulk to food processors, etc.
- **Food processing companies**
- **Retailers** and Market Operators
- **Financial Institutions** – Some offer specialized products for farmers, including smallholders

Reducing Risk of Investment

- Proponents broker agreements between companies, NGOs and government to ensure market for seeds
  - Technical assistance
  - Marketing support
  - Limited purchase guarantees

Commercial Food Processors

- Using PVA Maize and other biofortified crops in processed foods can increase nutritional value
- Developing interest in PVA Maize among commercial food processors can ensure market for surplus crops

Multilateral Institutions and NGOs

- Can incorporate biofortified seed, crops into existing food programs
- Promote adoption
- Help with distribution
- Create market for surplus

Photo: Brookings

Discussion

Which types of organizations and participants in the value chain would seem like the most natural partners to support biofortification in the communities where you work?

Capacity Building

- Proponents and researchers need to provide capacity building to enable partners to better support biofortification

- Seed companies
- NGOs
- Retailers

- Community Organizations
- Extension agents
- Policymakers

Technical Support and Research

- Breeders and proponents can advise & assist farmers, partner organizations
- Collect feedback from local stakeholders
- Conduct research, gather data to refine strategy, guide next wave of crop development

Brainstorming

Technical Support and Research

What types of information can we provide to other stakeholders?

What types of information might we want to collect?

7 m

Discussion

In your own experience, how long does it take for new crops and agricultural practices to go from new/novel to mainstream?

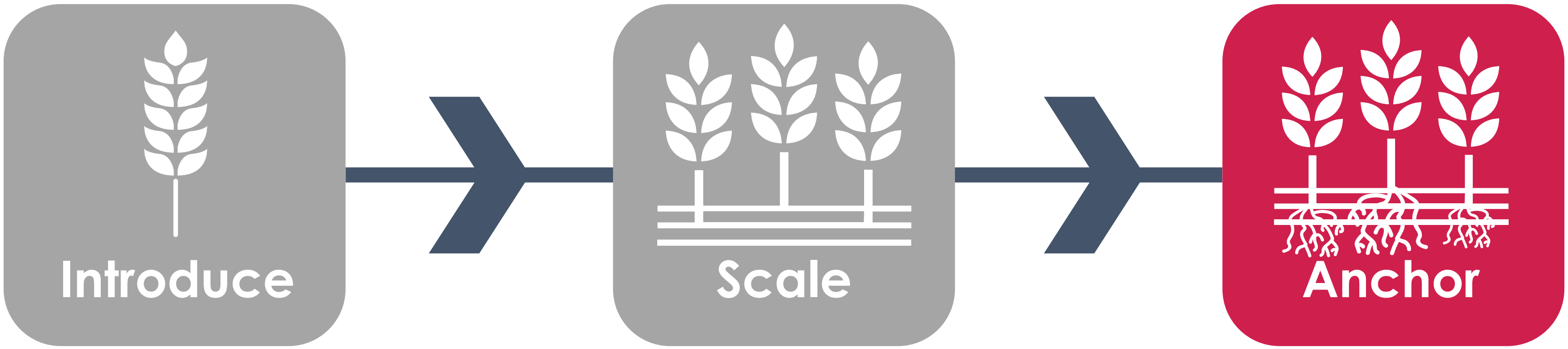
What could we do to accelerate mainstreaming of biofortification?

How long do you imagine it might take in the communities where you work?

10 m

Anchoring

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain



Ensuring Sustainability

Once scale is achieved, need strategic-level support to ensure sustainability

- Policy
- Regulation
- Trade

Activity (Groups)

Explaining PVA Maize Benefits

In less than a minute, how might you explain the benefits of PVA maize adoption to a typical policymaker / local government representative who might not be familiar with the strategy?

You have 5 min to discuss in your groups

30 m

Discussion

What could a local government do to support adoption of PVA maize?

What kind of policies and regulations could be introduced / modified to help adoption of PVA maize?

10 m

Policy

- Help local and national government to enact policies and support mechanisms for continued engagement in biofortification as a solution for malnutrition
- Incorporate biofortification into regional, global initiatives
- Add biofortification as a requirement for future variety releases by private suppliers, other research organizations
  - Tanzania National Agricultural Policy (2013) Promotes production and utilization of crops with high nutrient contents in areas experiencing nutritional problems

Regulation

- Food labeling
  - Standardize labeling, health claims
  - Reduce false claims
- Develop official standards
  - Add minimum micronutrient levels to agronomic requirements for new crop release
- Proponents, breeders can assist certification authorities

Activity (Groups)

Labeling

- Divide into groups
- Each group should design a label for PVA maize
  - Convey essential information for consumers as succinctly as possible
  - Give sense of benefits
  - Include an appropriate, distinctive symbol
- **You have 10 minutes**
- Share your results with the group

30 m

Codex Alimentarius

- Efforts underway to integrate biofortification standards into “Codex Alimentarius”

- Food standards maintained jointly by WHO and FAO
- Recognized by World Trade Organization (WTO) as its reference organization

Trade

- Maize is a major source of foreign income for countries that export it
- Profitable business environment and viable business models along biofortification value chain will ensure sustainability
- Incorporating biofortification in national, regional and international agreements and standards can facilitate cross-border marketing
- Regional agreements for the testing and release could reduce trade barriers, allow spread of PVA maize into new countries

Discussion

How amenable do you think the governments that you work with would be to adopting and enforcing biofortification standards?

What opportunities are there for trade in the regions where you work?

Implementation

- **Introduce** – Encourage adoption of crop among the target groups (farmers, consumers)
- **Scale** – Work with partners to promote crop and achieve necessary market share for long-term sustainability
- **Anchor** – Strengthen support for crop through policy and business models to ensure it remains part of value chain

Implementation

- 3-stage approach (introduce/scale/anchor) is not a "master plan"
  - Not everything can be figured out before starting delivery operations
  - Continue to adapt approach while learning more about farmer and consumer preferences, market conditions, etc.
- Stages build on each other
  - Successful introduction of biofortified varieties necessary condition for scaling up / reaching market penetration
  - Successful scaling / achieving market penetration lays foundation for incorporation of biofortification into policy, regulatory and business frameworks

Quick Review

An effective, sustainable way for policymakers to support PVA maize would be to:

A. Implement minimum nutrition standards for future maize releases

B. Ban the cultivation and marketing of non-biofortified varieties

C. Subsidize exports on a large scale

D. Implement fines for mislabeling regular maize as PVA

1 m

Quick Review

Breeders and advocates can help to “anchor” biofortified crops by:

A. Providing direct, permanent subsidies to farmers over the long term

B. Offering technical assistance as local stakeholders assume greater responsibility

C. Demanding that national partners and regional institutions impose tariffs on non-biofortified varieties

D. Setting a specific date for withdrawing support, to ensure local stakeholders take responsibility

1 m

Quick Review

Alternate

- *What are some of the strategic goals for biofortified crops?*
- *Who could we partner with to help promote PVA maize adoption?*
- *What could local and national governments do to support biofortified crops adoption?*
- *Is export trade a major factor for anchoring PVA maize?*

5 m

Unit Objectives - Review

You should now be able to:

- Outline the strategic goals of biofortification interventions
- Identify potential partner organizations for supporting PVA maize over the long term
- Recognize the potential impact of policies, regulations and trade on biofortification initiatives
- Explain the importance of integrating biofortification into international standards

Unit 7

Integrating PVA Maize into a Healthy diet

Unit Objectives

By the end of this unit, you should be able to:

- Review the nutritional benefits of eating PVA maize
- Compare different methods of preparing PVA maize in terms of nutrition
- Name some of the other nutrients contained in PVA maize

Activity (Groups)

Cooking with PVA maize

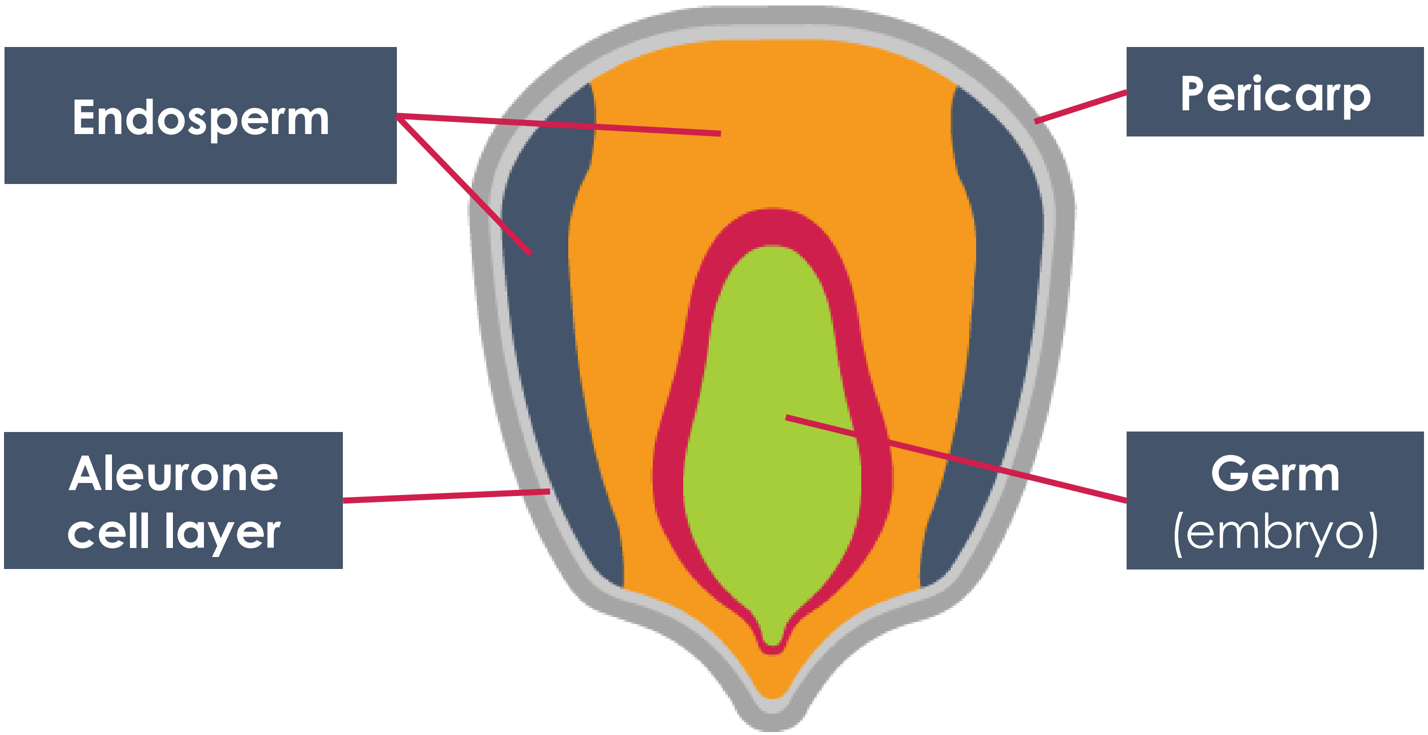
- Divide into groups
- Each group will prepare a different recipe from the participant guide using PVA maize
- Share with the class and discuss the results

Maize as Food

- Introduced to Africa in the 1500s
- Since become a major staple crop
  - 30–50% of low-income household food expenditure in eastern and southern Africa.
  - #1 staple of Tanzania, with average per-capita consumption of 73kg/year

The Maize Kernel

- provitamin A carotenoids concentrated in endosperm
- Minerals in maize are mainly found mainly in germ and pericarp, yet many processing methods remove the germ aimed at improving the shelf life



Methods of Preparation

- Boiled
- Roasted on the cob
- Popcorn
- Canned or frozen
- Porridge
- Fermented gruel
- Milled (grits, meal or flour)
- Lime-cooking (grits, tortillas)
- Fried (for chips, etc.)

Micronutrient Losses

- Most losses of pVACs are from storage and milling rather than cooking
- Carotenoids are sensitive, and can be lost due to high temperature, high oxygen, UV light
  - More stable in whole grains than processed grains
  - Losses similar whether stored as ears or shelled grains
- Prolonged cooking, toasting, roasting, frying, drying can levels of pVACs
- Not all varieties have same degradation rate

Processing

- Processing of orange maize in general is not different from any other maize varieties
- Traditional processing still more common than industrial processing in developing countries

Photo: UNICEF Ethiopia/2014/Nesbitt CC BY-NC-ND 2.0

Milling

- **Milling** is the grinding of maize grains into coarse whole-grain pieces or fine flour
  - Removes much of the bran and germ
  - Can reduce nutritional value

Mitigating Losses

- Micronutrient losses can be mitigated by changing processing / cooking methods
- Encourage consumption of whole-grain products over milled products

Vitamin A Toxicity

- While it is possible for humans to consume too much vitamin A, PVA Maize does **not** pose a danger for vitamin A toxicity
- Generally only a danger from consuming large amounts of supplements

Other Nutrients

Endosperm

- Carbohydrates
- Protein
- Vitamin E

Aleurone cell layer

- Dietary fiber
- Phenolics
- Minerals
- Phytosterols
- Phytate

Pericap

- Iron
- Zinc

Germ

- Healthy fats
- Antioxidants
- Vitamins
- Minerals

Case Study

- Study of Zambian children, found porridge prepared with PVA Maize was as efficacious as supplementation
  - 400mg retinyl palmitate/d
  - Resulted in improved serum concentration

Photo: Bioversity international

Quick Review

Whole grain maize…

A. Is more nutritious than processed maize

B. Can cause Vitamin A toxicity if it is not boiled

C. Is indigestible unless treated with lime

D. All of the above

1 m

Quick Review

Milling…

A. Makes PVA Maize more nutritious by improving vitamin A absorption
B. Has no effect on nutrition
C. Makes PVA Maize less nutritious by removing the germ
D. Does not affect pVAC content but decreases calcium, iron and zinc content

1 m

Quick Review

Alternate

- *What are some of the ways maize could be cooked?*
- *What other micronutrients are contained in PVA maize?*
- *What causes micronutrient loss in PVA maize? Which cause is most significant?*

5 m

Unit Objectives - Review

You should now be able to:

- Review the nutritional benefits of eating PVA maize
- Compare different methods of preparing PVA maize in terms of nutrition
- Name some of the other nutrients contained in PVA maize

Unit 8

Conclusion

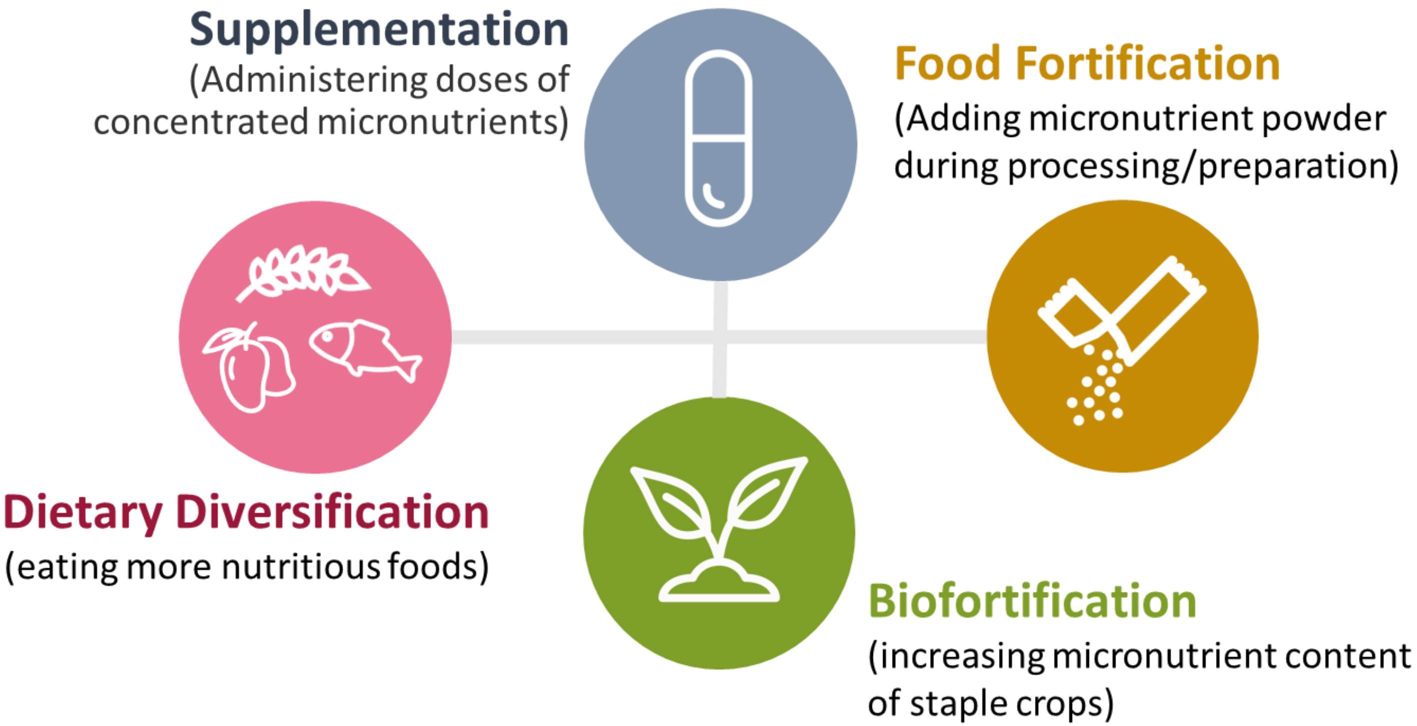
Biofortification: Results

15 years of studies confirm:

- Increasing nutrients in staple crops through biofortification can alleviate micronutrient deficiencies in real-world (non-experimental) conditions
- Crop breeding can increase nutrient levels enough to improve human nutrition without reducing yield
- Farmers are willing to grow biofortified crops and consumers are willing to eat them, as much or more than conventional popular varieties
- Biofortified crops can reach rural populations with limited access to diverse diets or other micronutrient interventions
- Biofortification is cost-effective per World Bank standards

Future Development

- Current breeding efforts focus on:
  - Developing climate smart maize that is higher yielding and tolerant to drought and heat
  - Improve carotenoid stability, to reduce the rate and pace of carotenoid degradation in storage and end-use
- In addition to PVA Maize, both CIMMYT and IITA are also breeding for white maize with higher zinc content



Key Takeaways

- Biofortification offers a cost-effective solution for the complex problem of micronutrient deficiency
- In combination with other interventions, biofortification can alleviate malnutrition for millions of people

Zinc Rice
Up to 60% of daily zinc

Yellow Cassava
Up to 40% of daily vitamin A beta-carotenoids

Iron Pearl Millet
Up to 80% of daily iron

High-Iron Beans
Up to 50% of daily iron

Orange-Fleshed Sweetpotato
Up to 100% of daily vitamin A (beta-carotenoids)

Zinc Wheat
Up to 50% of daily zinc

Pro-Vitamin A Maize
Up to 25% of daily vitamin A (beta-carotenoids)

Key Takeaways

- Biofortification involves breeding varieties of staple crops with higher micronutrient content
- Accomplished through selective breeding (<u>not</u> GMO)

Key Takeaways

- Vitamin A deficiency is a serious health issue, especially among pre-school aged children
- VAD can cause blindness
- Consuming biofortified Pro Vitamin A Maize has been shown to help alleviate Vitamin A deficiency

Key Takeaways

- Biofortification requires the support of farmers, consumers and local/international partners to succeed
- Developing crops with good agronomic and sensory qualities can drive adoption
- Nutrition messaging is key

Key Takeaways

- During initial introduction, direct, intensive support is critical
- Long-term sustainability requires scale / market share to anchor biofortified crops in national food systems

Objectives (Recap)

You should now be able to:

- Explain how biofortified provitamin A maize can address vitamin A deficiency among poor populations
- Describe the process used to develop new PVA Maize varieties
- Outline a strategy for promoting PVA maize to farmers, consumers and partner organizations
- Describe how PVA maize can be integrated into a healthy diet
- Summarize key studies demonstrating the effectiveness of PVA maize for addressing vitamin A deficiency

Discussion

How might you apply the information presented in this training to your own work?

Any questions, in general?

Sources

- HarvestPlus Evidence Brief, June 2017
  - http://www.harvestplus.org/sites/default/files/publications/HarvestPlus%20Evidence%20Brief_06%202017.pdf
- HarvestPlus Vitamin A Maize Post-Harvest Handling and Processing Training Guide
- du Plessis, Jéan “South Africa Ministry of Agriculture Maize Production Guide”, 2003
- E.D. Nafziger “Growth and Production of Maize: Mechanized Cultivation” University of Illinois
- John F. MacRobert, Peter Setimela, James Gethi and Mosisa Worku Regasa “CIMMYT Maize Hybrid Seed Production Manual”May 2014

Sources

- IITA Maize Production Manual, April 1982
- Thai Agricultural Standard “Good Agricultural Practices for Maize” 2010
- “How a Corn Plant Develops” Iowa State UP, 1986
- Semaana, Hillary Rugema “SASAKAWA Global Maize Production Manual” 2000
- Kansas State University Corn Production Handbook, 2007
- “Growing Maize in Nigeria” USAID / IITA
- Voto Mobile Maize Production Manual

Building Nutritious Food Baskets

Combating hidden hunger though nutritious food baskets

The Building Nutritious Food Baskets: Scaling up Biofortified Crops for Nutrition Security seeks to reduce hidden hunger by catalyzing sustainable investment for the production and utilization of biofortified crops (Orange-fleshed sweetpotato (OFSP); vitamin A (yellow) cassava, vitamin A (orange) maize and high iron/zinc beans) at scale. The project is implemented in Nigeria and Tanzania, to demonstrate how biofortified crops can be scaled up through a multi-crop ("food basket") approach. BNFB draws on complementary expertise for scaling up through a partnership between CGIAR centers and programs, regional organizations and other public and private sector agencies to create a movement that will eventually reach the target populations. BNFB's hypothesis is that scaling up is dependent on supportive policy environment, strong institutional capacities and availability of proven technologies.