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Increasing Beta-Carotene in Potatoes to Combat Vitamin A Deficiency

Boyce Thompson Institute
Mission: To advance and communicate scientific knowledge in plant biology to improve agriculture, protect the environment, and enhance human health
Vitamin A Deficiency is a Serious Problem World-wide

• Not a problem in the U.S.
• Global Statistics
  – Prevalence: 1/3 of children under the age of five
  – Mortality: 670,000 children under five annually
  – Blindness: 250,000 to 500,000 children in the developing world go blind each year
• Adding vitamin A or a vitamin A precursor (β-carotene) to the diet could prevent these problems
Golden Rice: Metabolic Pathway Engineering to Produce Beta-Carotene

In Golden Rice

Genetically Engineered

geranylgeranyl-PP

phytoene synthase
(daffodil or maize)

crt1
(bacterial)

phytoene

zeta-carotene

crt1
(bacterial)

lycopene

α-carotene

β-carotene

In Humans

β-carotene ➔ Vitamin A

Refs:
Ye et al, 2000
Paine et al., 2005

Ingo Potrykus, Peter Beyer
Another Metabolic Engineering Approach to Increase β-Carotene: Reduce conversion

Golden Rice
- Rice grains do not normally make β-carotene
- Introduce genes to allow synthesis of β-carotene precursor (lycopene)

Potato
- Makes β-carotene, but transforms it to zeaxanthin
- Reduce the amount of enzyme that catalyzes this reaction (β-carotene hydroxylase)
- Increases β-carotene up to 30X

Ref: Van Eck et al., 2007
Increase β-carotene by using a naturally occurring gene variant

β-carotene is produced in chloroplasts and chromoplasts

- Chloroplasts are prevalent in green tissue (leaves)
- Chromoplasts are prevalent in colored tissue (e.g. flowers)
- Plastids in grains & tubers are specialized for carbohydrate storage

**Spontaneous mutation in cauliflower causes high accumulation of β-carotene**

- Single semi-dominant allele (*Or*)
- Retrotransposon inserted into *Or* gene
- Converts proplastids and non-colored plastids into chromoplasts

*Li et al., 2001*
The Cauliflower *Or* Gene Increases β-carotene Accumulation in Potato

β-carotene is detectable only in transformed line

Cold storage further increases β-carotene in transformed line

Refs:
Lopez et al. 2008
Li et al. 2012
Why do we need approaches in addition to Golden Rice?

• Combining technologies could result in even higher β-carotene levels

• Need for other crop plants
  – Rice is a traditional crop – acceptance of golden color?
  – Other vegetables, including root vegetables, are important in Africa

• Acceptance of GM crops
  – Regulatory Delays
    • Proof of principle for golden rice demonstrated in 2000
    • Significant improvements in 2005 (Syngenta)
    • Expected to be approved for distribution in the Philippines in 2014 or 2015 (!)
  – Non-GMO approach theoretically possible via targeted mutagenesis of Or gene or β-carotene hydroxylase