

## The Power of the Plant: How Fruit and Vegetables work as Nutraceuticals and Supplements?

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Department of Nutrition and Food Science  
Molecular and Environmental Plant Sciences Program  
Director-Plant Bioactives & Bioprocessing Research Lab  
Texas A&M University, College Station

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### Points to cover

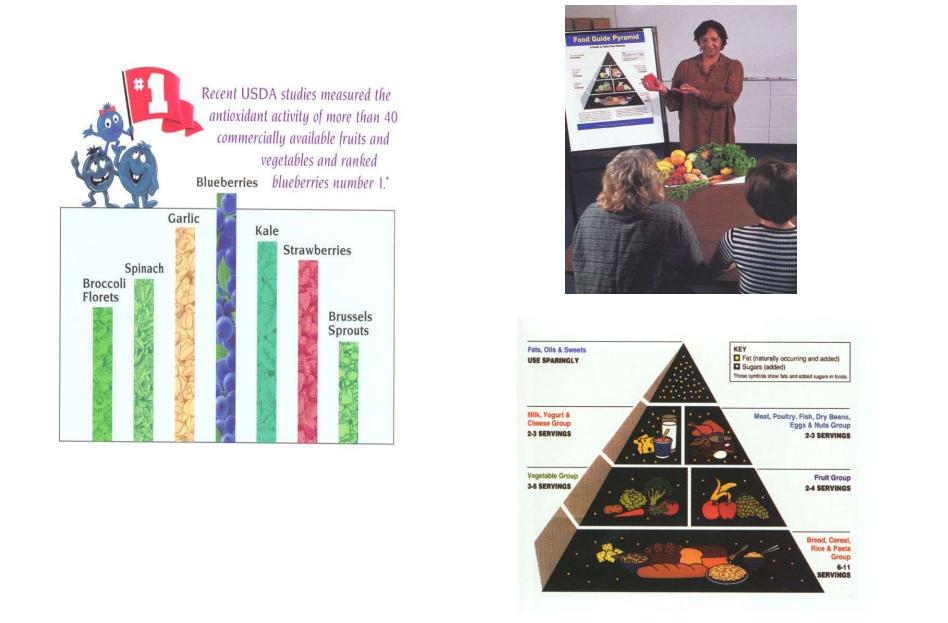


- Molecular mechanisms & Oxidative stress
- Proposed concepts and model of chronic diseases
- Nutraceuticals in plants
- Case studies/examples
- Final thoughts

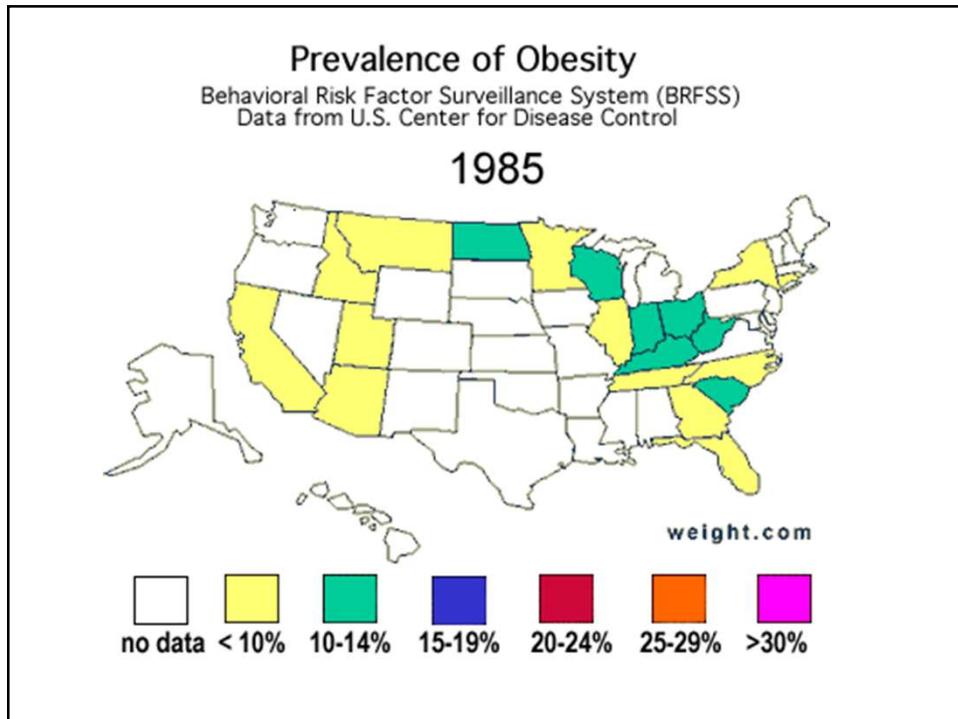


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## Revalue of known crops

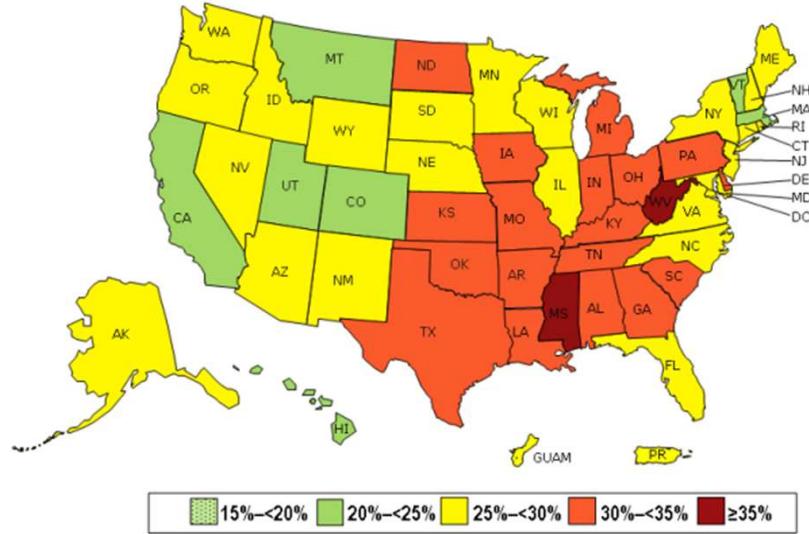


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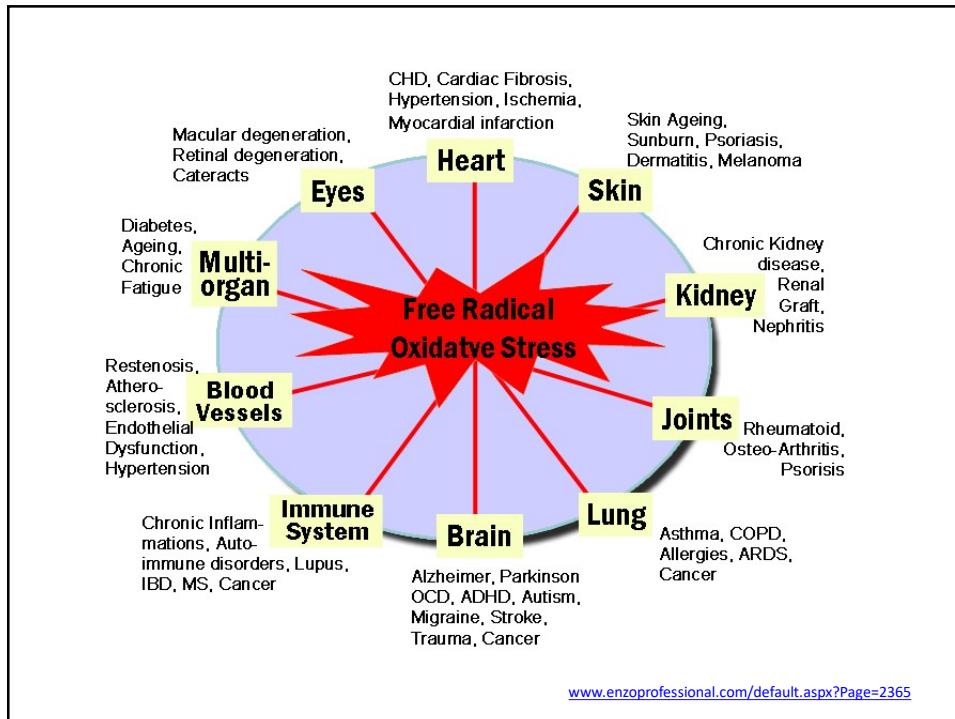
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Prevalence\* of Self-Reported Obesity Among U.S. Adults by State and Territory, BRFSS, 2013



Source: Behavioral Risk Factor Surveillance Systems, CDC.

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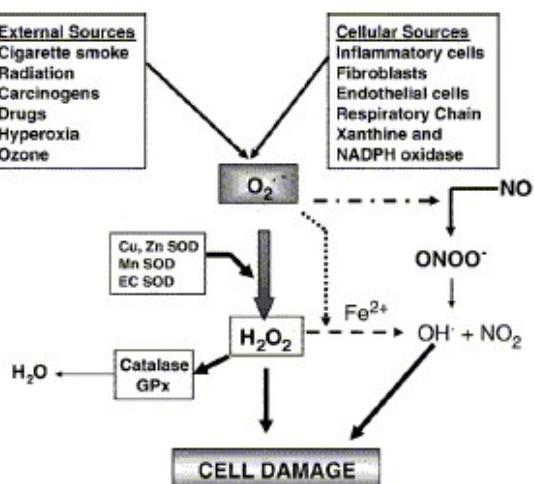
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## Oxidative Stress

- It is generally believed that an **imbalance between the production of reactive oxygen species (ROS)** and antioxidant defenses, in favor of the former, leads to an oxidative stress and, in turn, to the oxidation of biologically relevant macromolecules
- The production of **ROS is an unavoidable** consequence of aerobic metabolism
- **ROS** is the term used to describe forms of oxygen that are energetically **more reactive** than molecular oxygen
- **ROS are toxic molecules** because they are able to oxidize various cellular components including DNA, proteins, and membrane lipids, leading to the oxidative destruction of the cells
- ROS play a role as signals** in the cells

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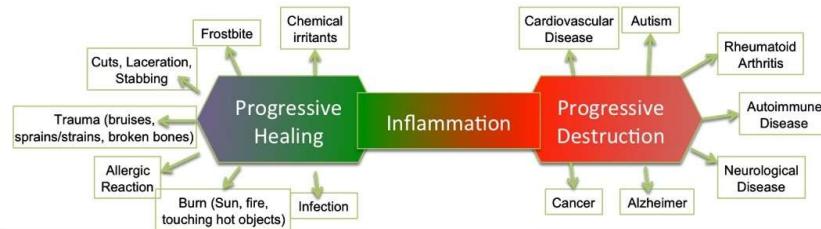
## Cellular generation of reactive oxygen species and antioxidant defense system



[www.glisodin.org/glisodin\\_monograph.htm](http://www.glisodin.org/glisodin_monograph.htm)

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## Oxidative stress strongly associated to inflammation



<http://clinicscienceblogmary.wordpress.com/2013/04/08/the-role-of-inflammation-in-health-and-disease/>

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## Plenty of research, a lot of confusion as well

- Nutraceuticals
- Bioactives
- Functional foods
- Dietary supplements
- Botanicals
- Herbal medicine
- etc

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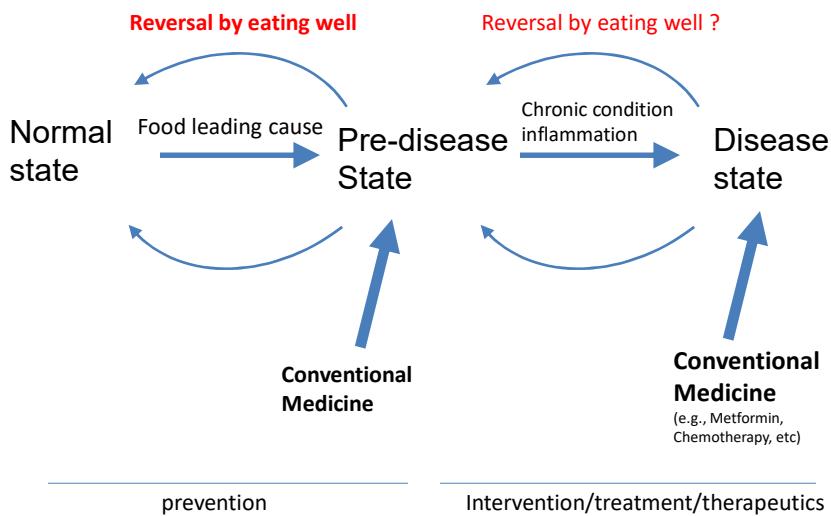
## The medicinal action of phenolics is due to...

- Antioxidant capacity
- Free radical scavenging
- Chelation of redox active metal ions
- Modulation of gene expression
- Interactions with the cell signaling pathways

(Soobratee et al., Mutation Research, 2005, 200-213)

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## Relationship between chronic disease, food and medicine



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## 49

### *Vegetable-Containing Juices: Carrot, Kale, and Sprout Juices for Prevention and Therapeutics*

Daniel A. Jacobo-Velázquez, Erika Ortega-Hernández, and Luis Cisneros-Zevallos

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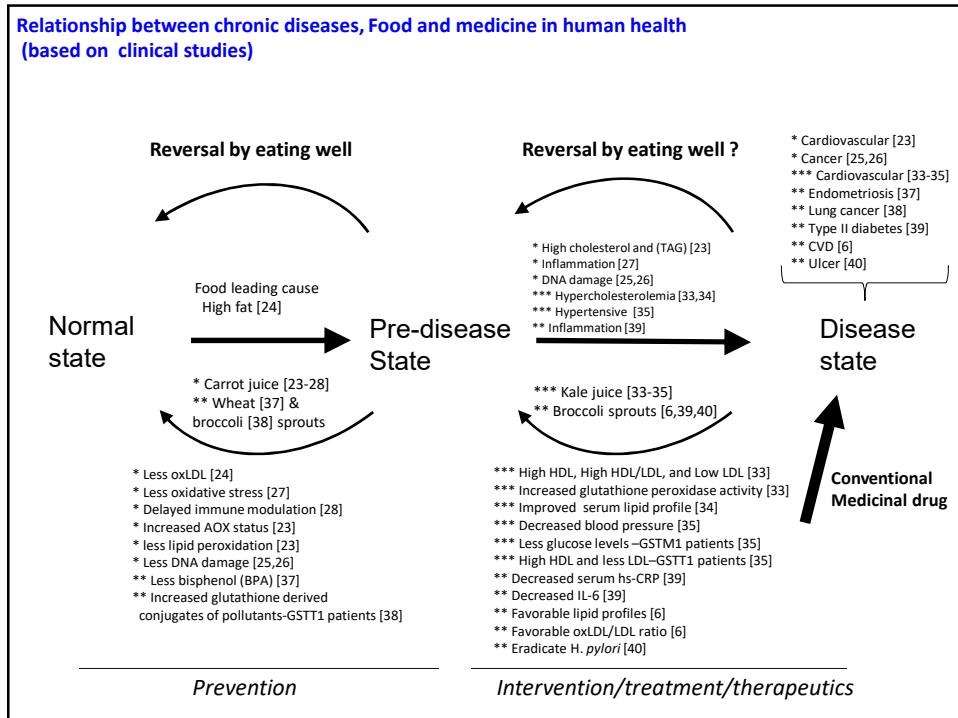
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Handbook of Functional Beverages and Human Health; Shahidi, F., Alasalvar, C., Eds, 2016, pp 609-626

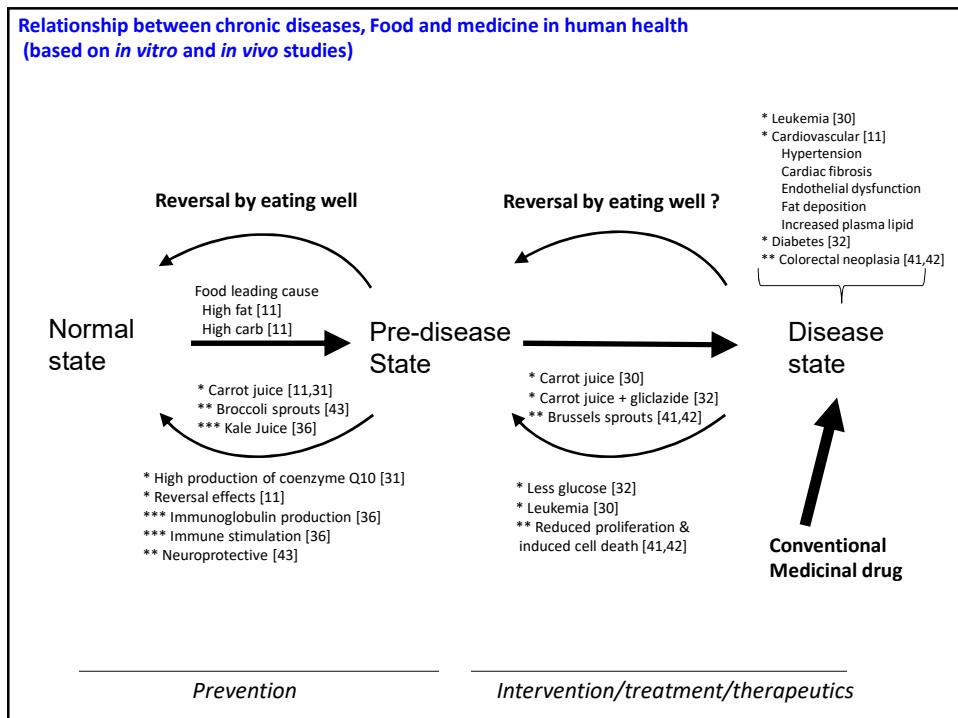
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### *Golden Berry and Selected Tropical (Açaí, Acerola, and Maqui) Juices*

Coralia Osorio, Maria Elisa Schreckinger, Prerna Bhargava, Woo Young Bang,  
Daniel A. Jacobo-Velázquez, and Luis Cisneros-Zevallos

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Handbook of Functional Beverages and Human Health; Shahidi, F., Alasalvar, C., Eds, 2016, pp 251-269

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Aguaymanto (Golden berry)



Acerola



Açaí

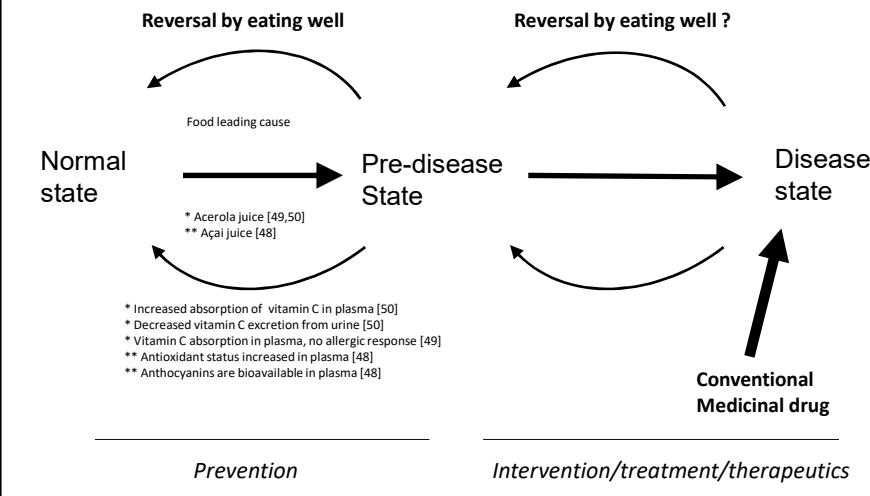


Maqui



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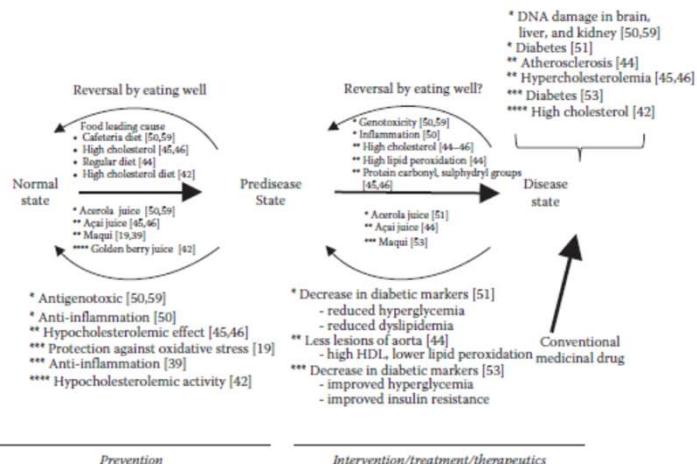
**Relationship between chronic diseases, Food and medicine in human health  
(based on clinical studies)**



*Handbook of Functional Beverages and Human Health. CRC Press Taylor & Francis Group. In press*

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**Relationship between chronic diseases, Food and medicine in human health  
(based on *in vitro* and *in vivo* studies)**



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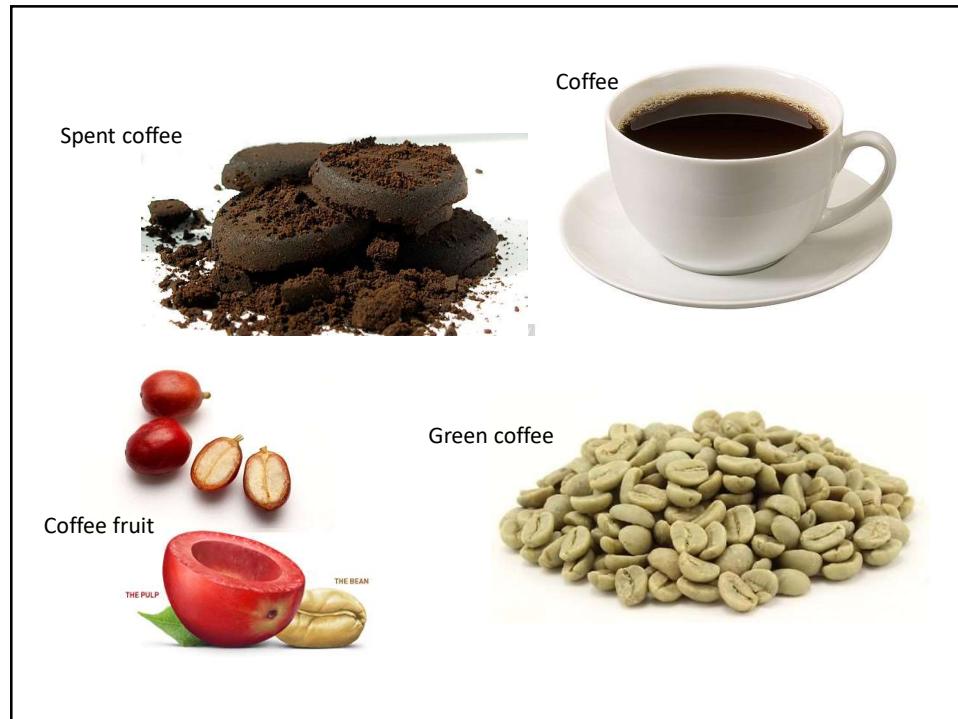
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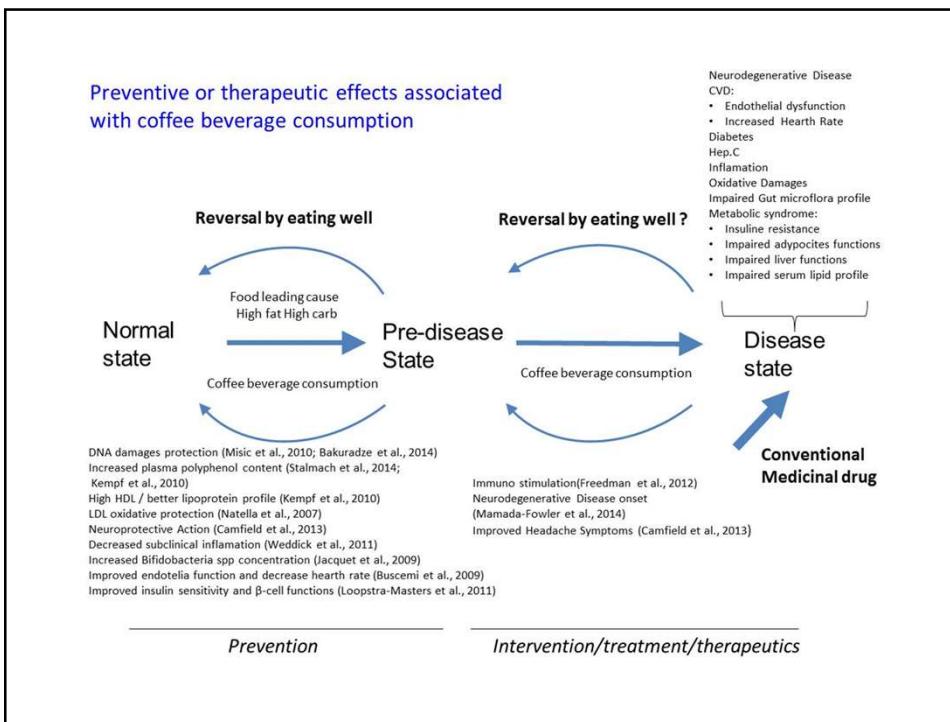
## Coffee other than coffee: Green coffee and byproduct for prevention and therapeutics (*unpublished, 2018*)

Federica Galli, Leonardo Lombardini, Luis Cisneros-Zevallos

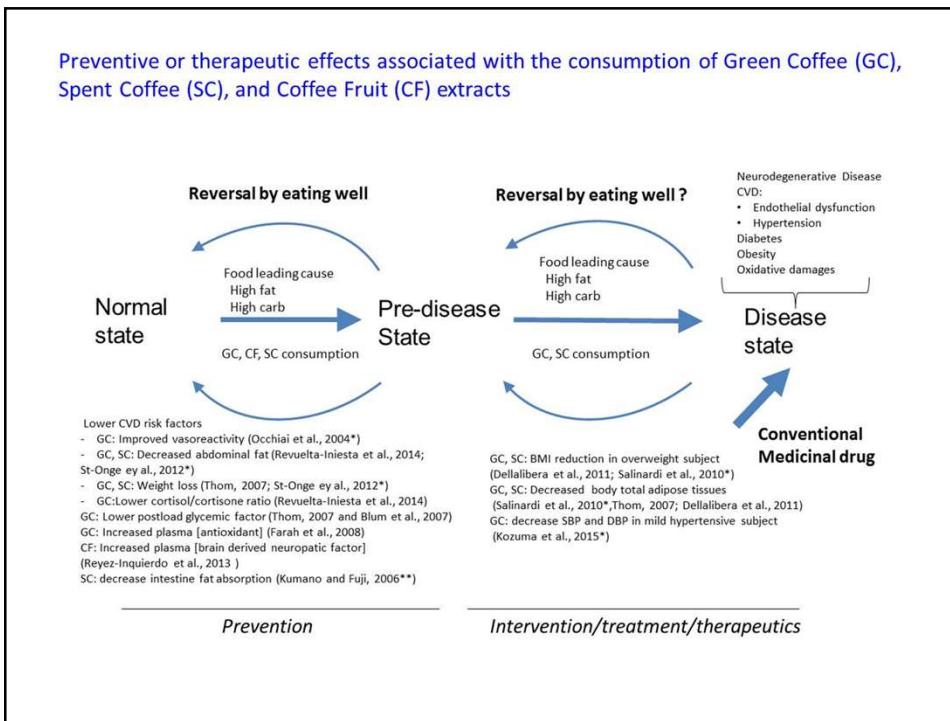
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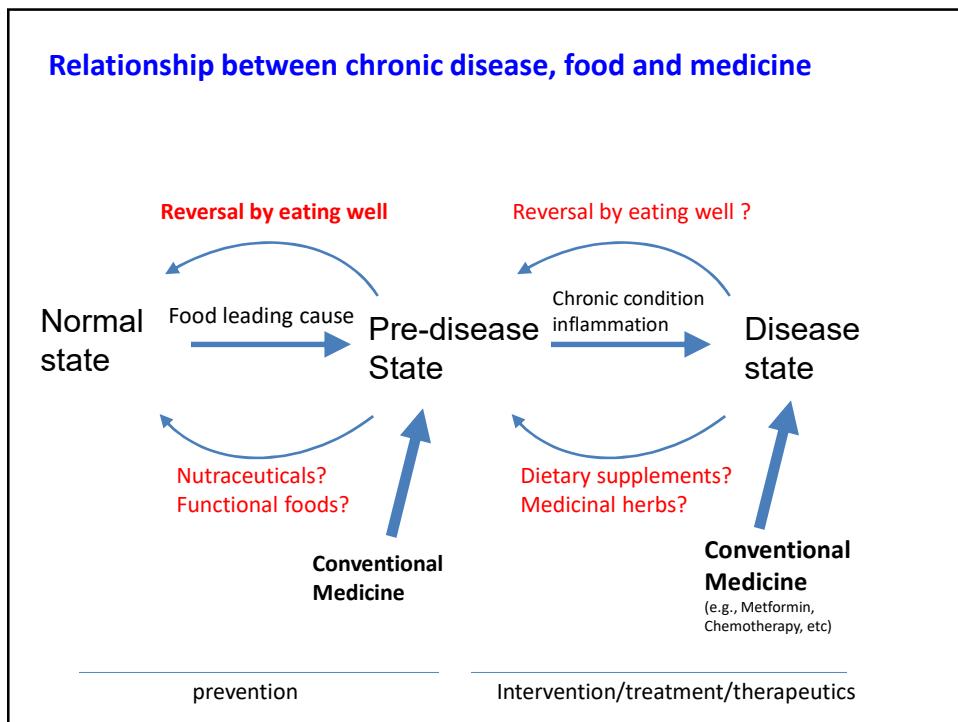
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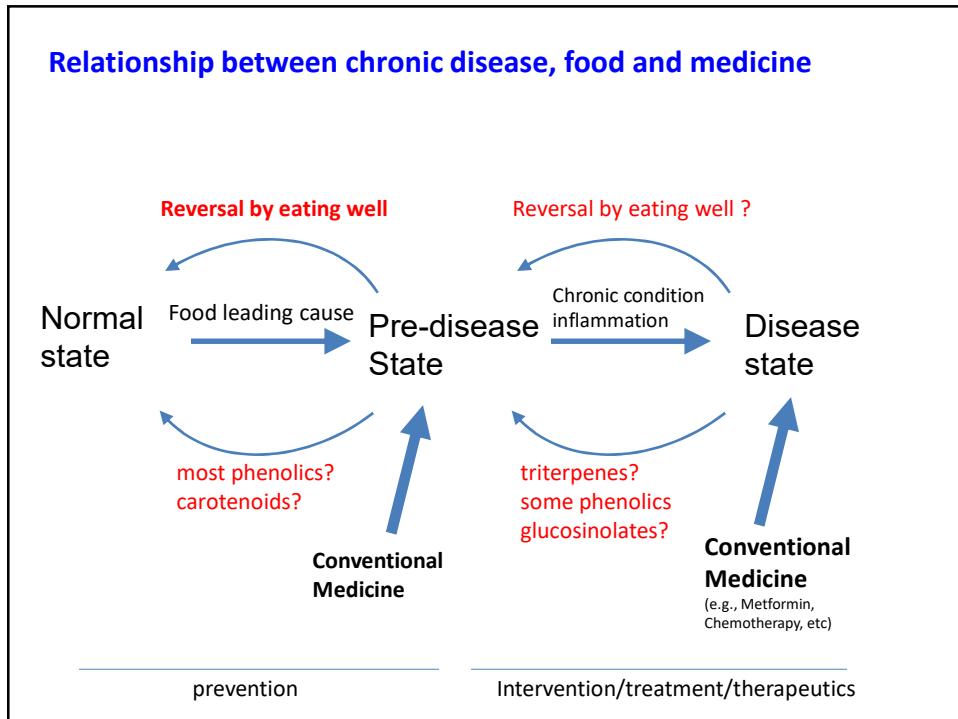
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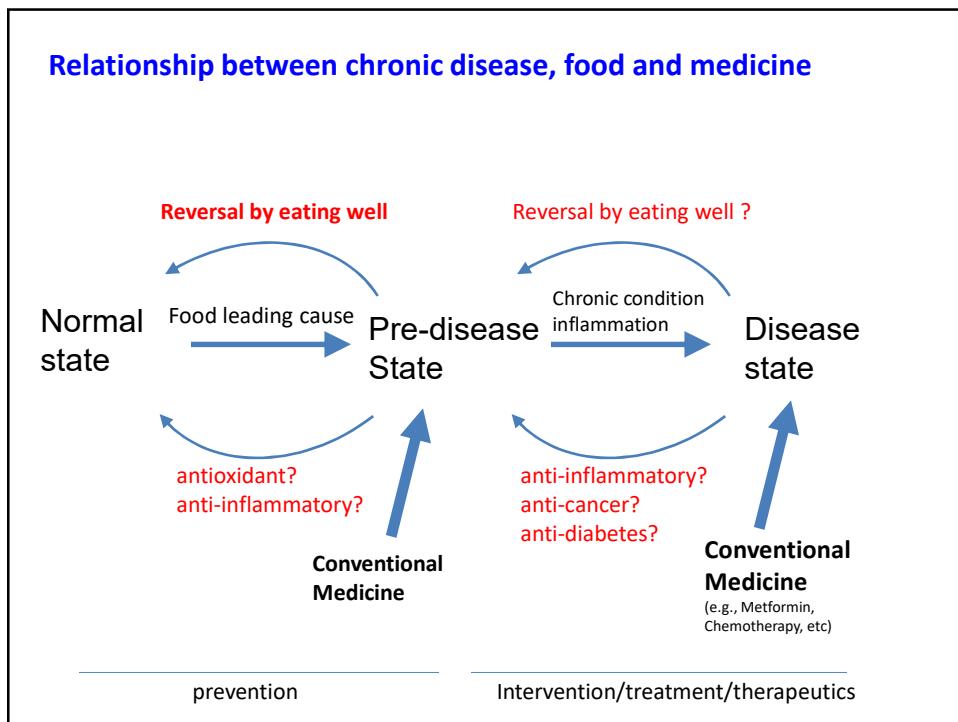
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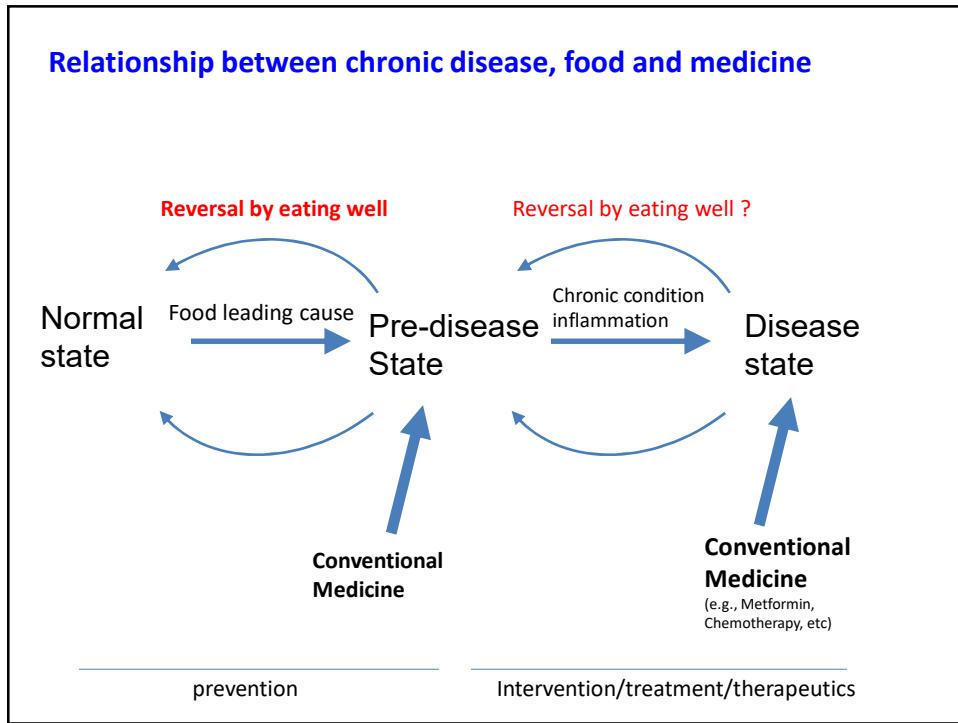
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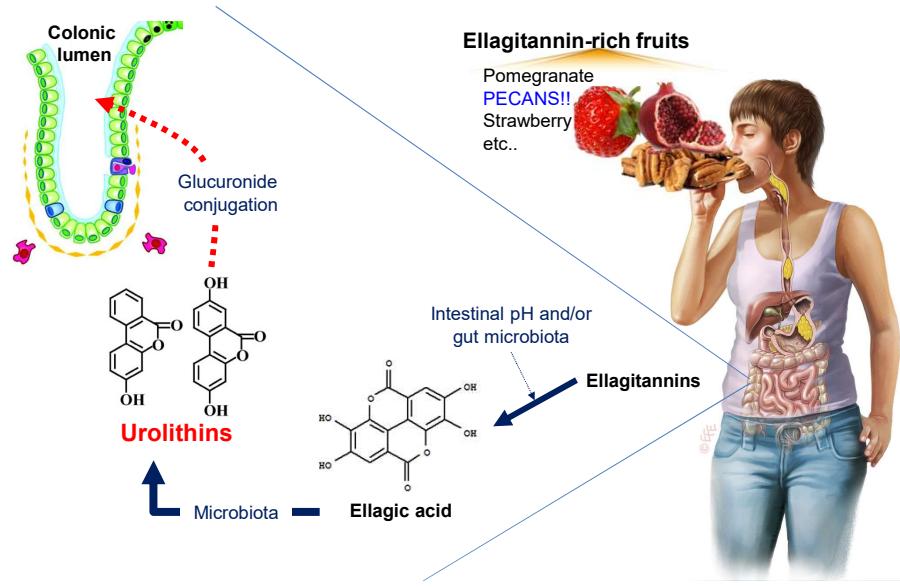
## Pecans



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## Urolithins

Bio available metabolites of Ellagitannin  
Phenolic antioxidants



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## What we propose for this year.....

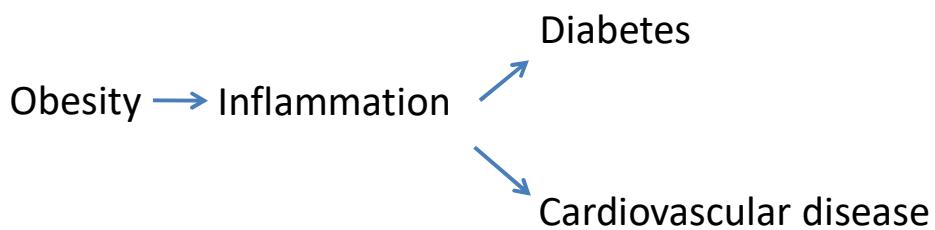
- Study effects against Diabetes
  - **Hypothesis:** We believe that urolithins have the ability to revert insulin resistance and glucose insensitivity in muscle, hepatic and pancreatic cells **in similar way to Metformin!**



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## Metabolic Syndrome

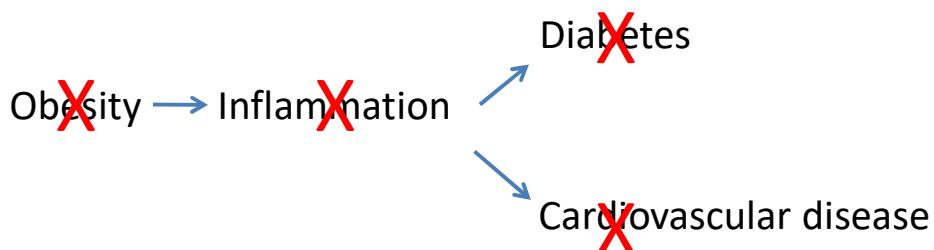
- Takes place when being **overweight** and **obese** increase the chance for **heart** disease and other health problems such as **diabetes** and **stroke**.



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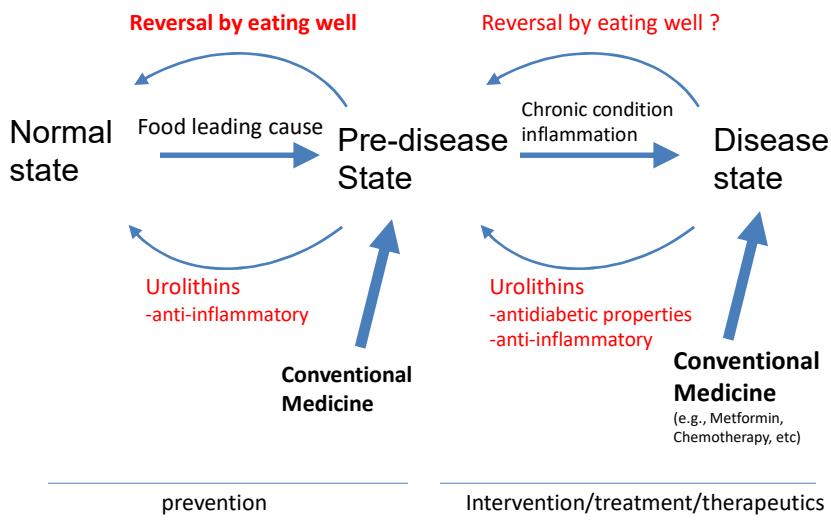
# Metabolic Syndrome

- Takes place when being **overweight** and **obese** increase the chance for **heart** disease and other health problems such as **diabetes** and **stroke**.



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## Relationship between chronic disease, food and medicine



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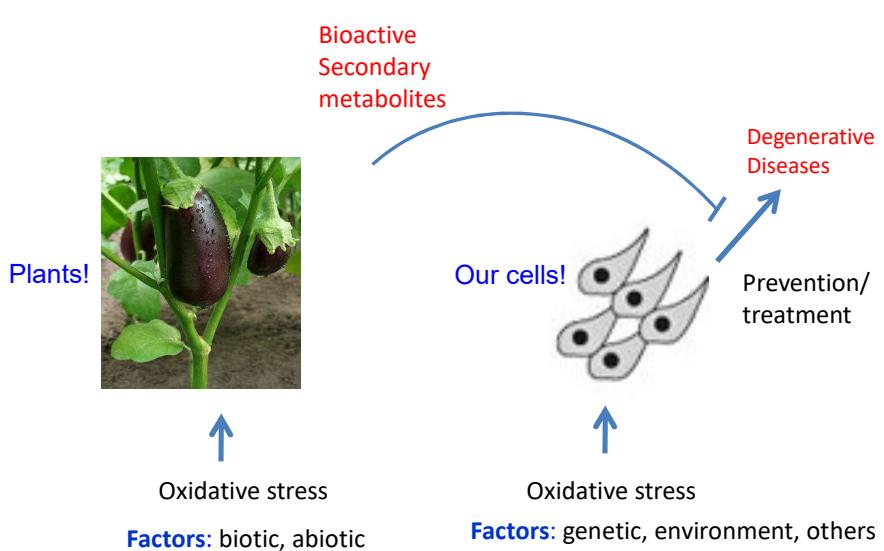
## First functional fruit?

Plum Ranks At  
The Top in USDA Antioxidant Study  
May 22, 2008



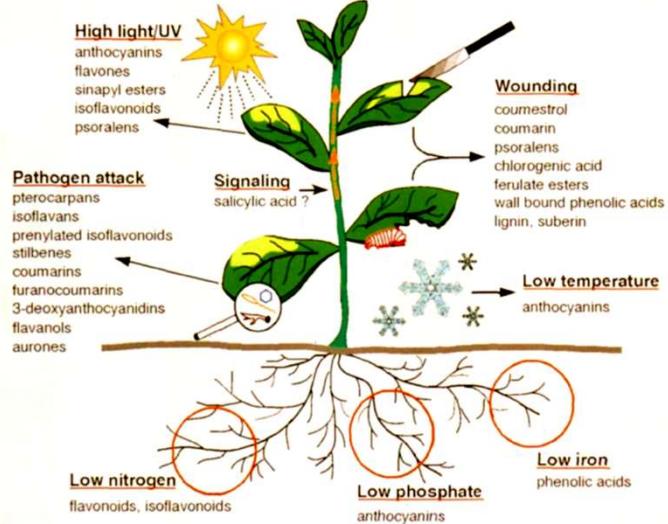
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## Where is the link? .....Oxidative Stress



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Examples of stress-induced phenylpropanoids



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Plants adapt to the environmental stresses affecting the nutraceutical content

Pre-harvest

Genotype



Cultivation Practices

Climatic Conditions

Harvesting stage

Post-harvest



UV/radiation

Light

Wounding

Water stress

Temperature

Altered gas

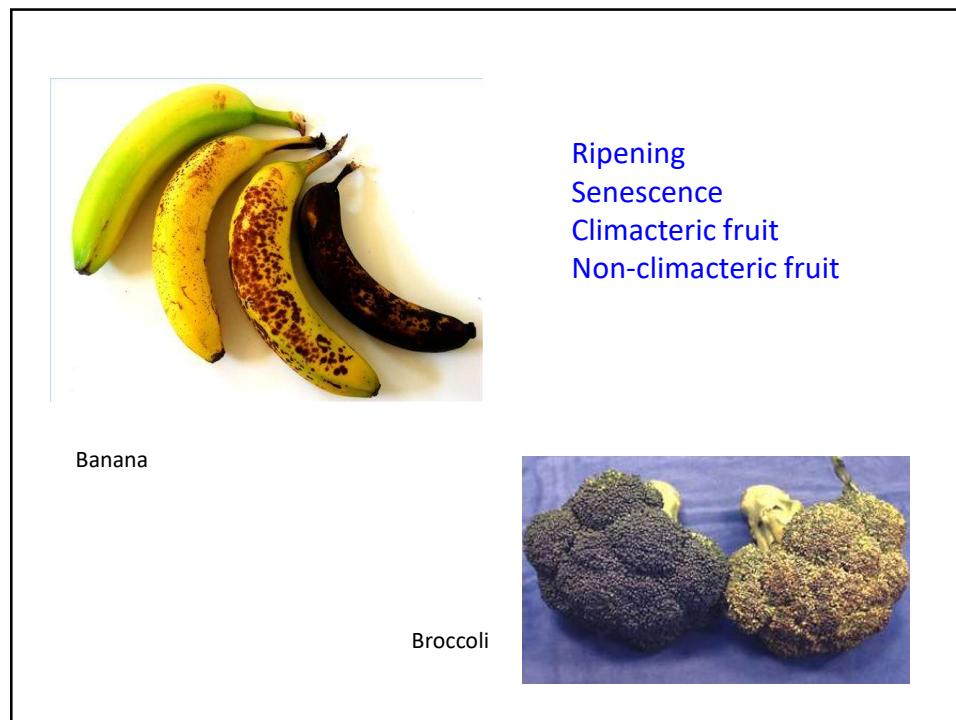
Chemicals

Hormones

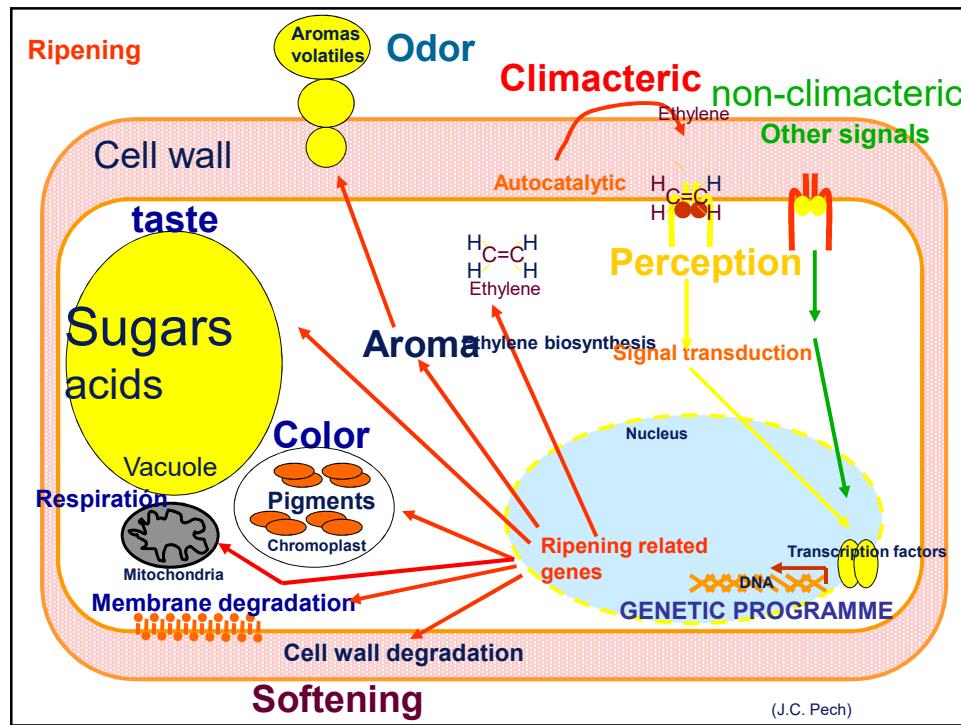
Pressure/gravity

Biotic

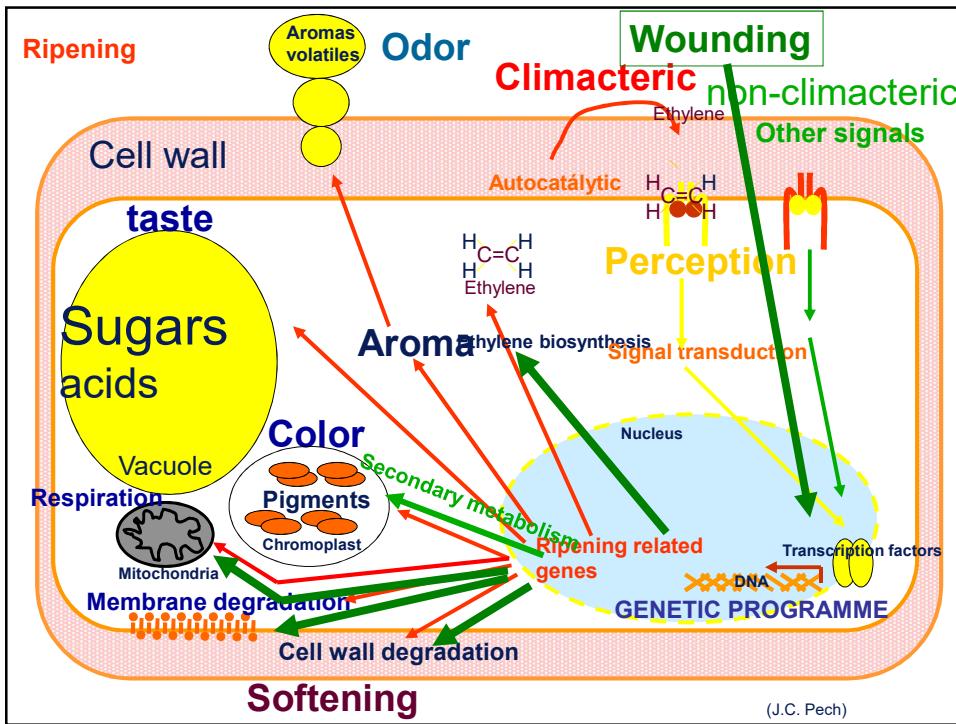
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**JFS: Concise Reviews and Hypotheses in Food Science**

**The Use of Controlled Postharvest Abiotic Stresses as a Tool for Enhancing the Nutraceutical Content and Adding-Value of Fresh Fruits and Vegetables**

L. CISNEROS-ZEVALLOS

**ABSTRACT:** This paper proposes a concept based on applying postharvest abiotic stresses to enhance the nutraceutical content of fresh fruits and vegetables. We hypothesize that selected abiotic treatments, such as wounding, phytohormones, temperature, low or high light, altered gas composition, heat shock, and water stress, among others, will affect the secondary metabolism of fresh produce and increase the synthesis of phytochemicals with nutraceutical activity or reduce the synthesis of undesirable compounds. Controlled stresses may be used to enhance the health benefit properties of fresh-cut or whole fresh produce and by the food processing and dietary supplement industries to obtain healthier processed products or enhance extractable nutraceutical yields.

**Keywords:** abiotic stresses, fruits, vegetables, nutraceuticals, value-added, postharvest

**Introduction**

The trend of consumers to associate high quality fruits and vegetables with healthy diet, safety, and convenience. The fresh fruit and vegetable industry is one of the most important sectors of the food economy, with estimated sales in 1999 of approximately \$76 billion. The fresh-cut industry sales represented \$10 to \$12 billion in 2000, with a projected growth of 5% per year until 2005 (Lachance 2002). In the U.S. retail market (Garrett 2002). Additionally, there is an increasingly growing market for nutraceuticals and functional foods, products that have been developed to provide health benefit properties. The estimated value of \$85 billion (Lachance 2002). In the U.S. alone, this figure is approximately \$24 billion with an annual rise to \$35.4 billion. The nutraceutical market is estimated to be the fastest growing category are antioxidants, such as vitamin C and E, carotenoids, and phenolic compounds. Among other plant secondary metabolites with high value and commercial relevance are those that reduce cancers and cardiovascular diseases (Scheerens 2001). These antioxidants can be used for controlling degenerative oxidation reactions caused by reactive oxygen and free radical species in living tissues. In this way, they can be used in food processing, food preservation and storage (Halliwell and others 1992; Yen and others 1997). A recent review on nutraceuticals and human health has been published (Giovannini and others 2002).

Enhancing the health benefit properties of fresh produce will add value and create new opportunities for growers and processors by reducing costs and increasing revenues. To accomplish this, there is a need to provide technologies that can ensure the delivery of high quality products with high levels of the desired nutraceuticals.

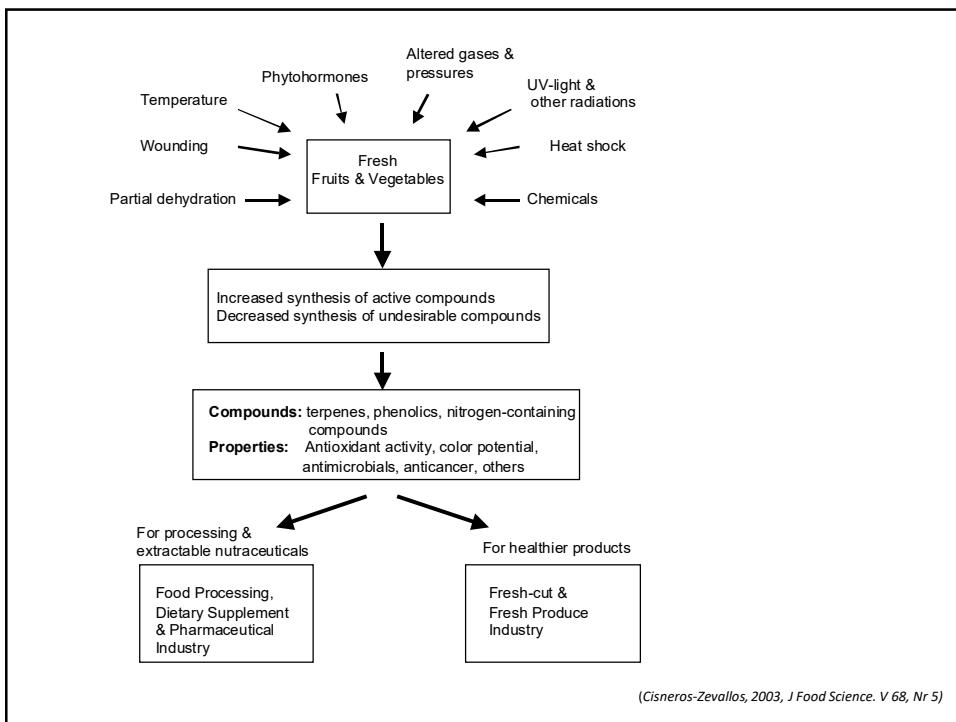
Plants, when exposed to unfavorable environments, such as water deficit, cold, heat stress, oxygen deficiency, and air pollution, undergo some degree of damage and experience a feedback loop that may affect the plant's genetic potential. Plants adapt to unfavorable conditions through genetically determined stress resistance (Drew 1998).

Postharvest abiotic stresses may affect the levels of secondary metabolites in crop tissues. For example, anthocyanin accumulation in apple skins is induced by wounding (Sapers and others 1986), apples (Curry 1997), foraging and biotic stress (Arakawa 1991), and strawberries (Given and others 1988).

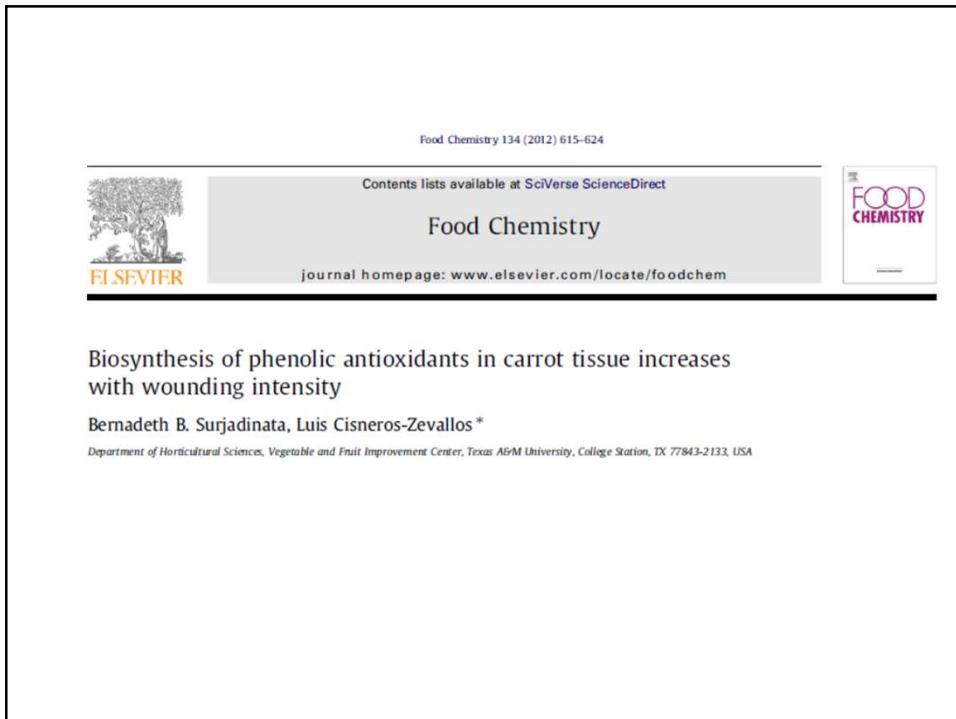
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1560 JOURNAL OF FOOD SCIENCE—Vol. 68, Nr. 5, 2003

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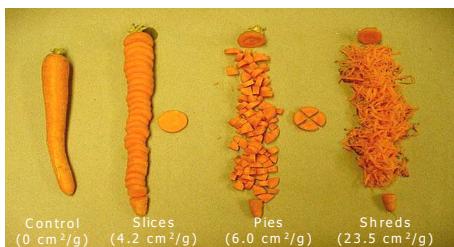
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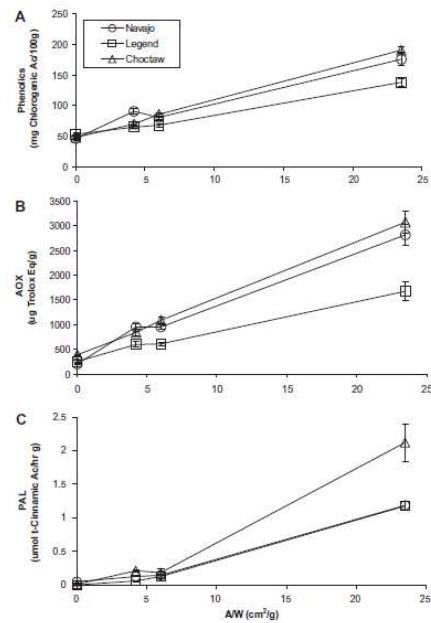
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## Increase in antioxidant activity

Wounding intensity (Area/Wt)



*Surjadinata and Cisneros-Zevallos, 2012. Food Chem*



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## Wounding effects on different types of produce

Lettuce, celery, onions, carrots, jicama, bell peppers, asparagus, cabbage, apples, tomatoes, nectarines, radishes, potatoes, pears



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## Plants as Biofactories: Physiological Role of Reactive Oxygen Species on the Accumulation of Phenolic Antioxidants in Carrot Tissue under Wounding and Hyperoxia Stress

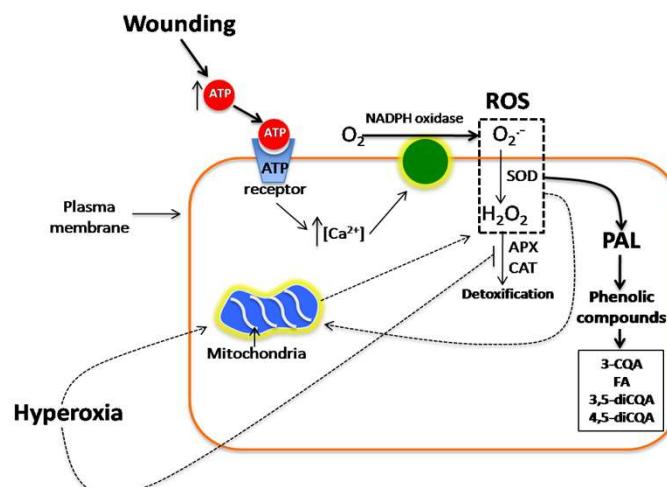
Daniel A. Jacobo-Velázquez,<sup>†,ll</sup> Ginés B. Martínez-Hernández,<sup>‡</sup> Silvia del C. Rodríguez,<sup>§</sup> Cong-Mei Cao,<sup>†</sup> and Luis Cisneros-Zevallos<sup>\*,†</sup>

<sup>†</sup>Department of Horticultural Sciences, Texas A&M University, Vegetable & Fruit Improvement Center, College Station, Texas 77843-2133, United States

<sup>‡</sup>Postharvest and Refrigeration Group, Department of Food Engineering, Technical University of Cartagena, Paseo Alfonso XIII, 48, 30203 Cartagena, Murcia, Spain

<sup>§</sup>Instituto de Ciencia y Tecnología de Alimentos, Facultad de Agronomía y Agroindustrias, Universidad Nacional de Santiago del Estero, 4200 Santiago del Estero, Argentina

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Jacobo-Velazquez et al., 2011. *J Agr Food Chem*

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## Plants as Biofactories: Glyphosate-Induced Production of Shikimic Acid and Phenolic Antioxidants in Wounded Carrot Tissue

Alejandro Becerra-Moreno,<sup>†</sup> Jorge Benavides,<sup>†</sup> Luis Cisneros-Zevallos,<sup>\*§</sup>  
and Daniel A. Jacobo-Velázquez<sup>\*,†</sup>

<sup>†</sup>Department of Biotechnology and Food Engineering, School of Biotechnology and Food, Centro de Biotecnología-FEMSA, Tecnológico de Monterrey-Campus Monterrey, E. Gárra Sada 2501 Sur, CP 64849, Monterrey, NL, Mexico

<sup>\*</sup>Department of Horticultural Sciences, Vegetable and Fruit Improvement Center, Texas A&M University, College Station, Texas 77843-2133, United States

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Blocking Enzymes and adding substrates...

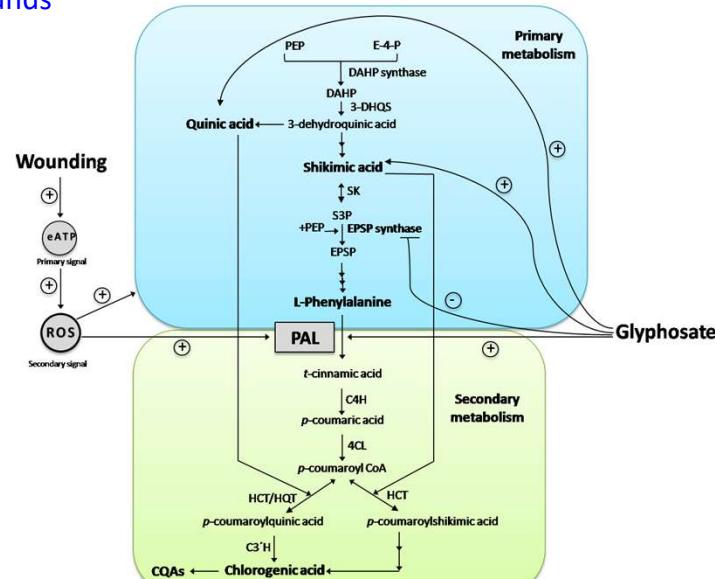
High levels of shikimic acid from Star anise



Intermediate compound before the phenolic metabolism

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## Plants as biofactories: High levels of shikimic acid and phenolic compounds



Becerra-Moreno et al., 2012. J Agri Food Chem  
5-enolpyruvylshikimate-3-phosphate (EPSP) synthase

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In the News....



### Tortured Veggies Better For You? Discovery News (May 28, 2010)

Most of us make carrots into a salad. Luis Cisneros-Zevallos makes carrots into biofactories capable of producing five times more antioxidants than they otherwise would. He does it not through genetic modification, but rather by using a carrot's natural response to changes in its environment. And by "changes in its environment" he really means assaulting them with knives, shredders, and ultraviolet light...



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# The New York Times



## Are Baby Carrots as Healthful as Other Carrots?

By Roni Caryn Rabin January 20, 2017 5:05 am

"Wounding" fresh produce "sends a signal to the cells, which perceive that as if they were under attack or facing adverse conditions," explained Luis Cisneros-Zevallos, author of one such study and director of the Plant Bioactives & Bioprocessing Research Lab at Texas A&M University in College Station. **"As a result, oxidative stress increases in the cell," he said, and cells "start synthesizing antioxidant molecules to protect the cell from that stress."**

[https://well.blogs.nytimes.com/2017/01/20/are-baby-carrots-as-healthful-as-other-carrots/?\\_r=0](https://well.blogs.nytimes.com/2017/01/20/are-baby-carrots-as-healthful-as-other-carrots/?_r=0)

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## Final Thoughts

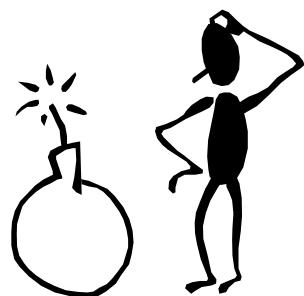
- The need to revisit the role of Food as medicine and many other terms used in the literature including nutraceuticals, dietary supplements, etc
- The need to standardize research studies including preventive and therapeutic strategies
- Plant bioactives may have multiple effects in preventing and treating diseases
- The content of plant bioactives may be enhanced by simple stresses and obtain final products that are healthier
- Others

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## A brilliant future for plant natural products



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Collaborative work among different groups

Dr. Daniel Jacobo-Velazquez, Dr Claudia Delgadillo, Dr Ivan Torres, Dr Ricardo Elesbao, Dr Margareth Veloso,

Funding from Heifer International, Texas Pecan Board, California Stone fruit Industry, Texas Department of Agriculture

## Questions?

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