

**Take Two Onions and Call Me in the Morning:
*The Possibilities and Pitfalls of Breeding Allium
Vegetables for Health Related Traits***



Irwin Goldman
University of Wisconsin-Madison



17 years



8 years



Crop Breeding



Pumpkin Regatta



Teaching, Mentoring



Plant-Based Folklore

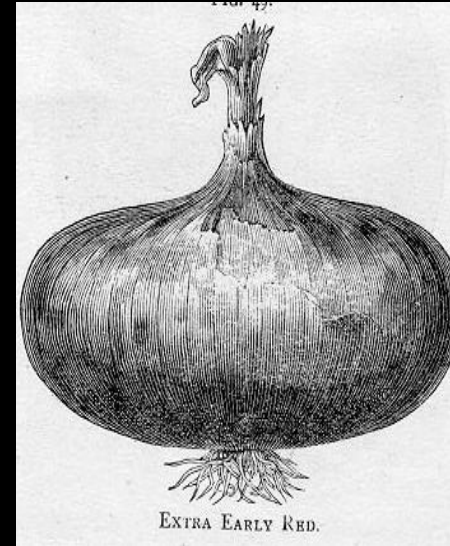
- Rice deters demons affecting fertility of the newlyweds
- Tomato used to treat eye diseases
- Seeds from *Apiaceae* species used to derive medicines
- *Alliums* used for infections and to improve circulation



**Let your food be your
medicine and your
medicine be your
food**

-Hippocrates

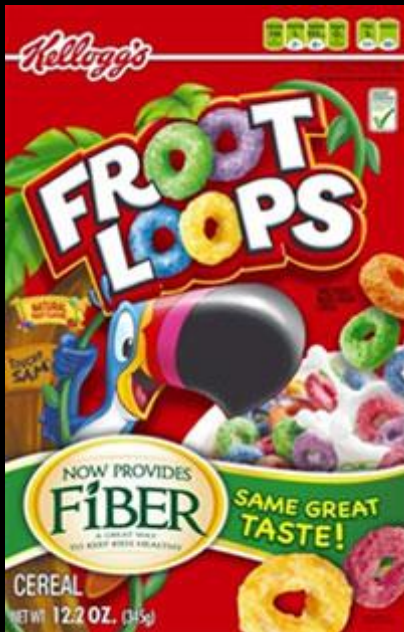
Coincidence?





Functional Foods

Demonstrable health benefit beyond nutrition



Functional Foods

- **Similar in appearance to conventional food**
- **Demonstrated physiological benefit beyond nutritional value**
- *Example: antioxidant function of carotenoids, beyond Vitamin A nutrition*
- **Therefore, the molecule is multi-functional**

Dysfunctional Foods?

Demonstrable emotional benefit
beyond a doubt





BAIT WINE BEER

STOP-N-GO

ICE CHEESE GROCERIES DELI

PROANE CYLINDERS
NO DRINKING FLAMMABLE GAS

ICE



MOLSON

WE HAVE Vintage FLAVENOIDS yummy

Closed

GEORGES DUBOUE
LE HÉROÏQUE NOUVEAU EST ARRIVÉ!

399 + UP

Onion and Garlic: Ancient Food, Medicine, and Art

ca. 2,500 B.C.E.



ca. 2,500 B.C.E.



ca. 16th century



ca. 1,400 C.E.



Grete Herbal


A Close Connection



Is There a Public Relations Problem?



Monomolecular Drugs



**ENBREL® (etanercept)
HELPS YOUR PATIENTS
GAIN MORE ACTIVE LIVES**

- Breakthrough Science
- Significant Efficacy
- Tolerability
- Comprehensive Support

The 20th Century



The Pomegranate



Ancient Egypt



Ancient Rome



Botticelli, 1487

Modern Marketing



Health Benefits?

Cheat
death.



You need more than luck to live longer. You need antioxidants. And POM Wonderful 100% Pomegranate Juice is loaded with them. It helps guard your body against free radicals, unstable molecules that emerging science suggests aggressively destroy healthy cells in your body and contribute to disease. POM Wonderful 100% Pomegranate Juice is supported by \$23 million of medical scientific research from leading universities, which has uncovered encouraging results in prostate and cardiovascular health. So drink a glass a day and cheat death. Live life.

POM Wonderful 100% Pomegranate Juice. The Antioxidant Superpower.™

POM
WONDERFUL
pomegranatejuice.com

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FTC Ruling

- The FTC complaint alleged that the POM's claims were false and unsubstantiated because many of their scientific studies did not show benefits from using POM products for treating or preventing heart disease.

Evidence?

- Reasonable consumers" would interpret the advertisements for POM products as claims that drinking eight ounces of POM Juice daily could treat, prevent or reduce the risk of certain diseases."
- But "expert testimony demonstrated that there was insufficient competent and reliable scientific evidence to support claims"

Snake Oil?



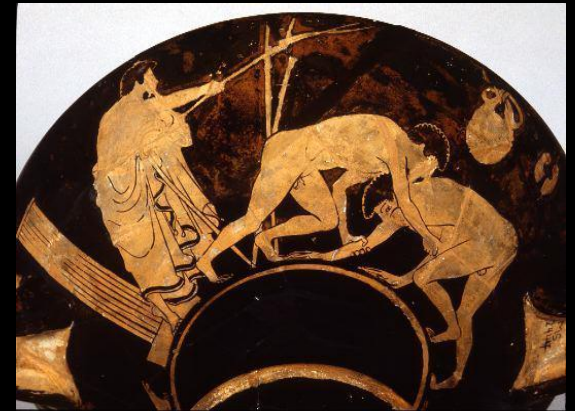




•Egyptian use of *Alliums*
for heart ailments



•Olympic athletes use
Alliums for circulation



•Blood clots in horses
treated with onion and
garlic



**Is onion a
functional
food?**



?

Leonard Pike and Bhimu Patil, Texas A&M University





Onion breeding Nursery
Randolph, WI

To get here takes between 12 and 20 years





May to September

2016



September to April



April to September

2017

15 cycles of breeding in a 30 year career

Compared to 90 cycles of tomato, bean, corn, etc.

Defense Compounds

- Sulfur stored as ACSOs
- Tissue disruption initiates lysis of ACSOs
- Causing formation of thiosulfinates
- These compounds deter many pests



Sulfate



ACSOs



Alliinase

Thiosulfinates



Pest resistance

Fenwick and Hanley, 1986

Flavor and Medicine

- **Thiosulfinates confer flavor to food**
- **Also mask other flavors**
- **Exhibit a range of unique bioactivities**
- **Including many of interest to human health**



Sulfate



ACSOs



Alliinase

Thiosulfinates



Flavor, Medicine

Block, 1985, Lawson, 1998

Onion: compounds and potential benefits

Compound	Potential Health Benefit
Oligofructose	Digestive health, probiotic
Thiosulfinates	Antithrombotic, Antimicrobial
Sulfides, ACSOs	Anticancer, Antidiabetic
Flavonoids	Antioxidant, Antithrombotic



Cardiovascular Health

Lipid lowering

Blood pressure lowering

Antioxidant

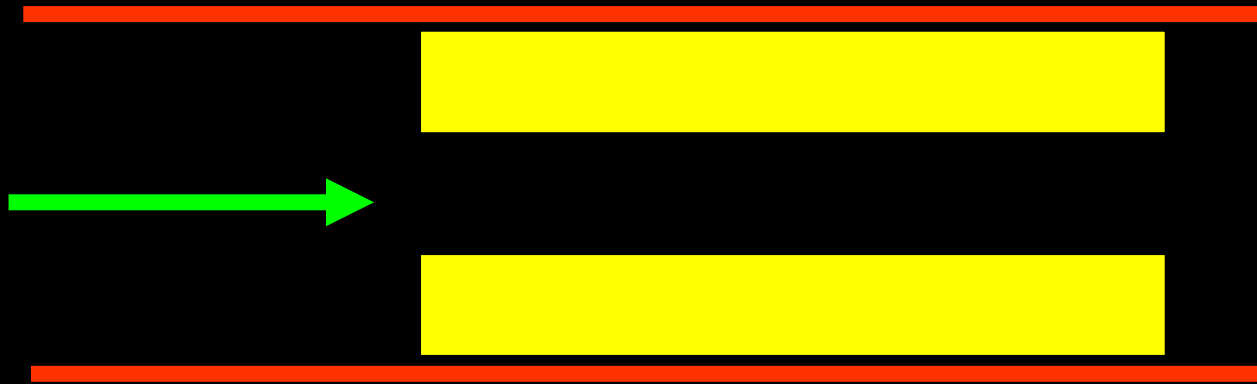
Antithrombotic or Antiplatelet

AHA, 2000

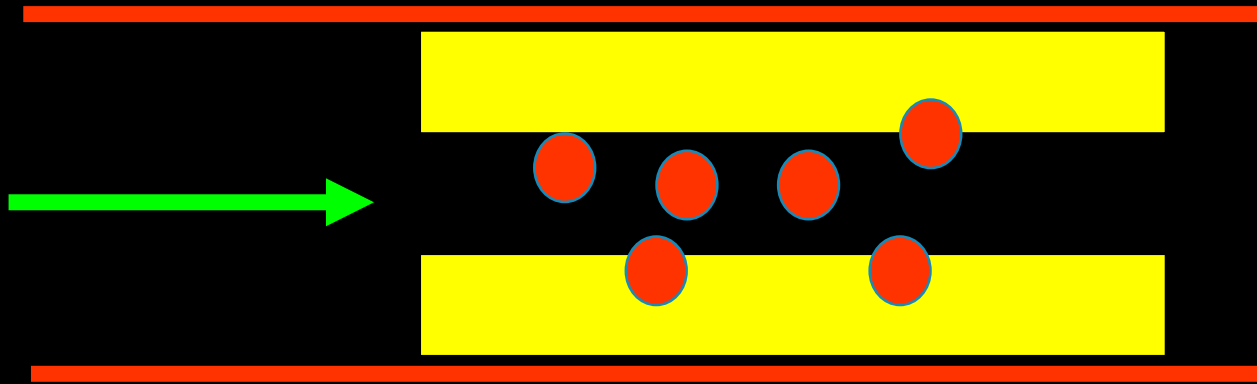


**Cardiovascular disease claims
one life every 33 seconds**

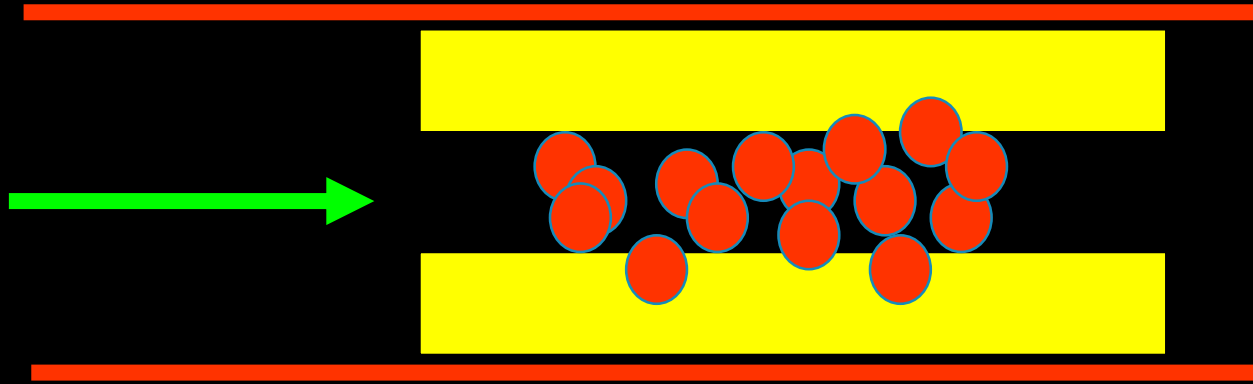
Every dollar can change a life. Donate today.



Plaque in coronary artery



Platelets in coronary artery



Platelet aggregate in coronary artery

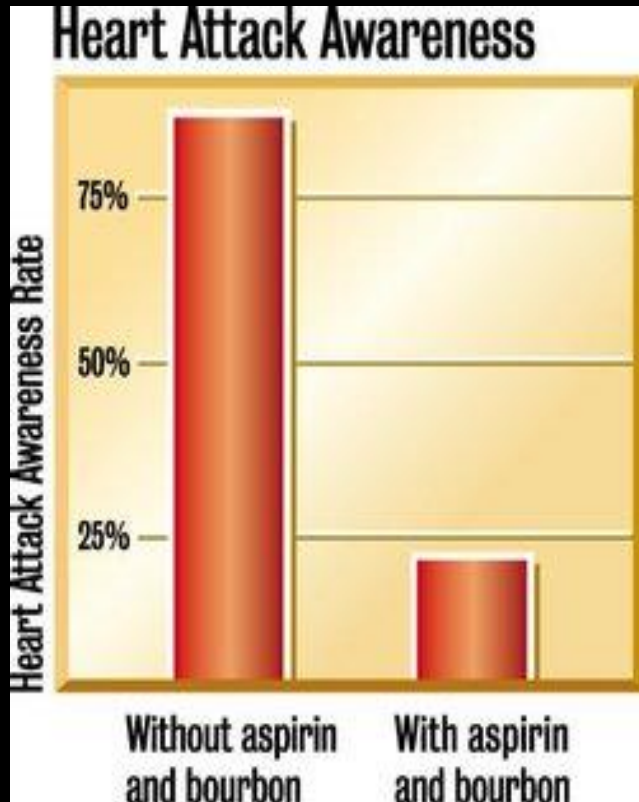
...Heart attack and stroke

Aggregating Platelets

- ***A major cause of heart attack and stroke***
- **Approximately 25% of US public has some form of cardiovascular disease**
- **Preventive measures: aspirin**
- **Preventive measures: diet?**
- **Preventive measures: onion?**



Aspirin Taken Daily With Bottle Of Bourbon Reduces Awareness Of Heart Attacks



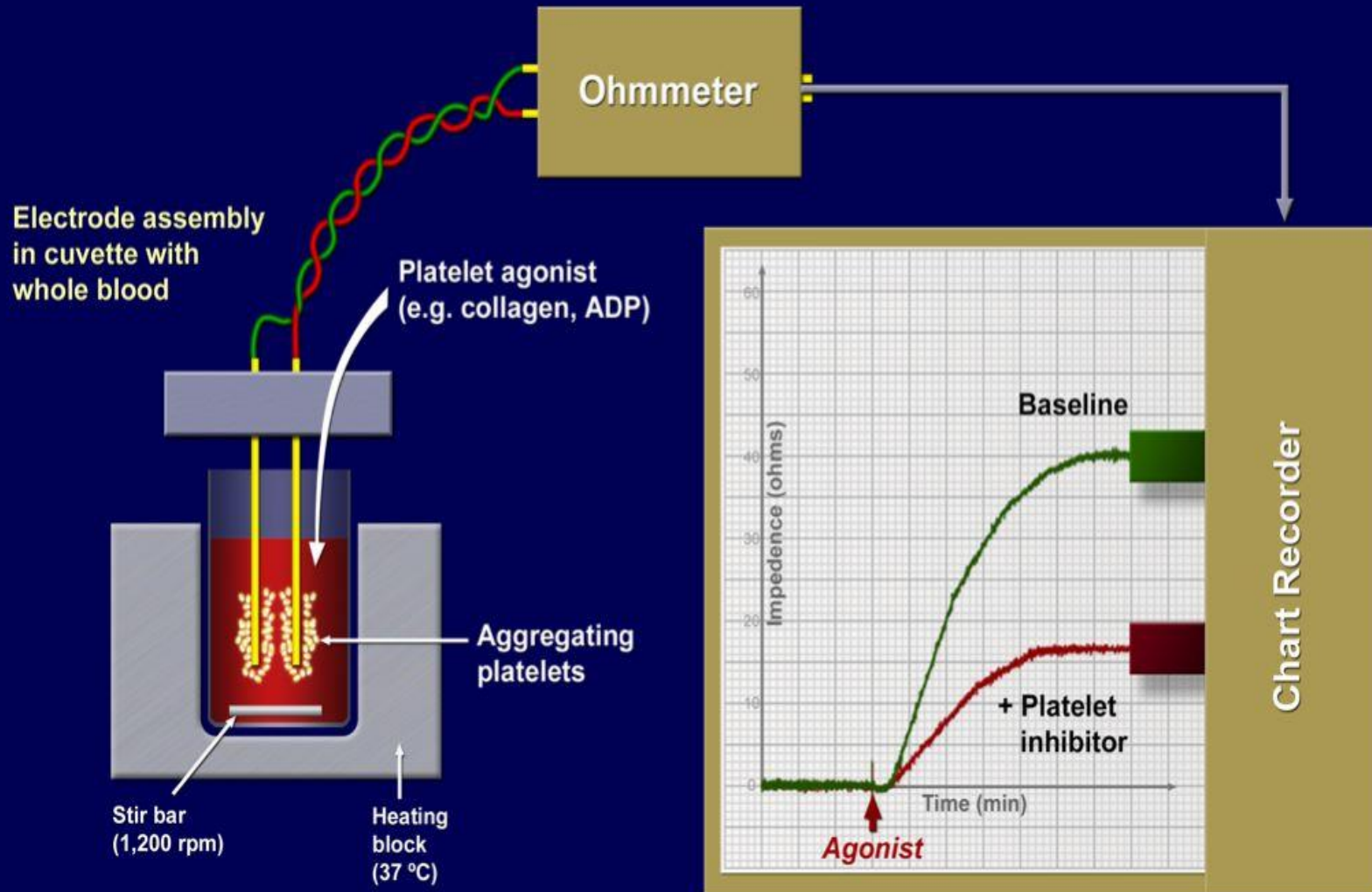
“...According to Katzeff, test subjects who were administered a single aspirin tablet in the morning, followed by a fifth of bonded Kentucky bourbon over the next several hours, were 85 percent less likely to realize they were having a heart attack than subjects who did not take aspirin with bourbon.”

-The Onion



Schematic of a Whole Blood Platelet Aggregometer

Shanmuganayagam D and Folts JD, *Methods in Enzymology* 335: 369-380, 2001.





Whole

γ Glutamyl-S-allylcysteine
 γ Glutamyl-S-t-1-propenylcysteine

Alliin
 Methiin

Cycloalliin

Crushed

Alliinase
Sulfenic Acids

Allicin + Allyl methanethiosulfinate + Pyruvic Acid

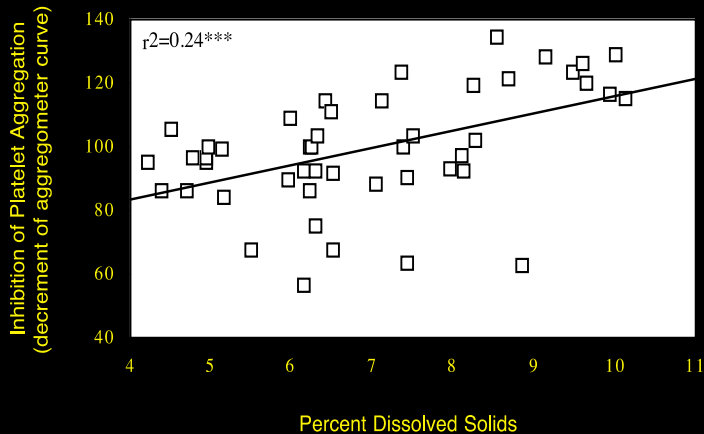
Processed

<p>aqueous</p> <p>S-Allylcysteine S-1-Propenylcysteine Glutamic acid</p>	<p>steam distillation</p> <p>Diallyl trisulfide Diallyl disulfide Allyl methyl trisulfide Allyl methyl disulfide</p>	<p>oil or solvent incubation</p> <p>2-Vinyl-4H-1,3-dithiin 2-Vinyl-4H-1,2-dithiin E-Ajoene</p>
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Correlations

Phenotypic / Genetic

From F₃ families derived from BYG x Ailsa Craig cross
 Traits measured at 90 days postharvest



Goldman et al., 1996

Trait

Pungency

OIAA

Solids

0.57**

0.43**

0.96

0.84

Pungency

0.60**

0.47

Galmarini and Havey, 2000

S Fertility

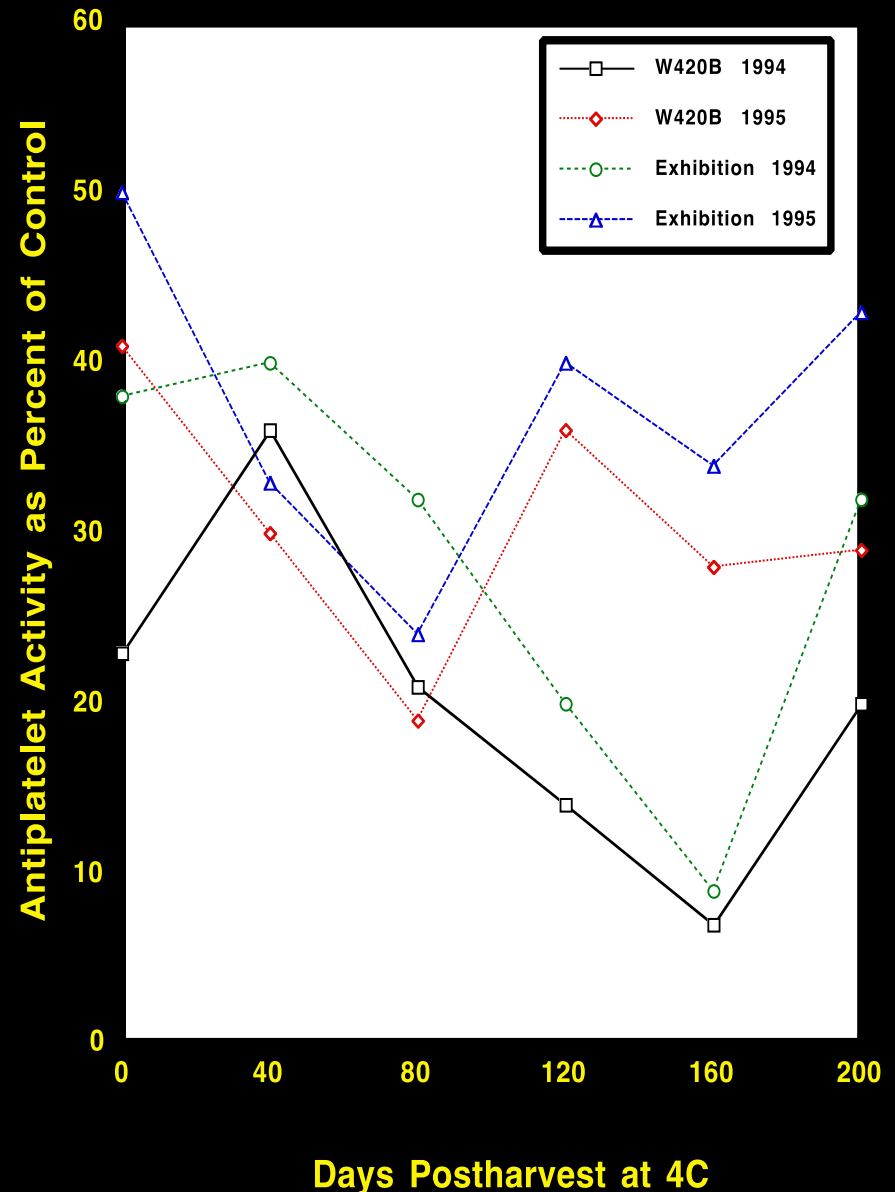
Greenhouse-grown onion, 4 accessions

Sulfate	OIAA % control	Root S mg/kg
2 mM	61	1,544
7 mM	66	15,209
12 mM	57	20,853

Orvis, 1997

Postharvest

- Bulb storage for long periods common
- Certain genotypes show increases
- All generally increase from 0-90 days



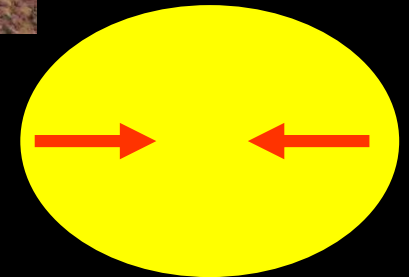
Debaene, 1999

Life Cycle

Umbel

Flower Stalk

Bulb

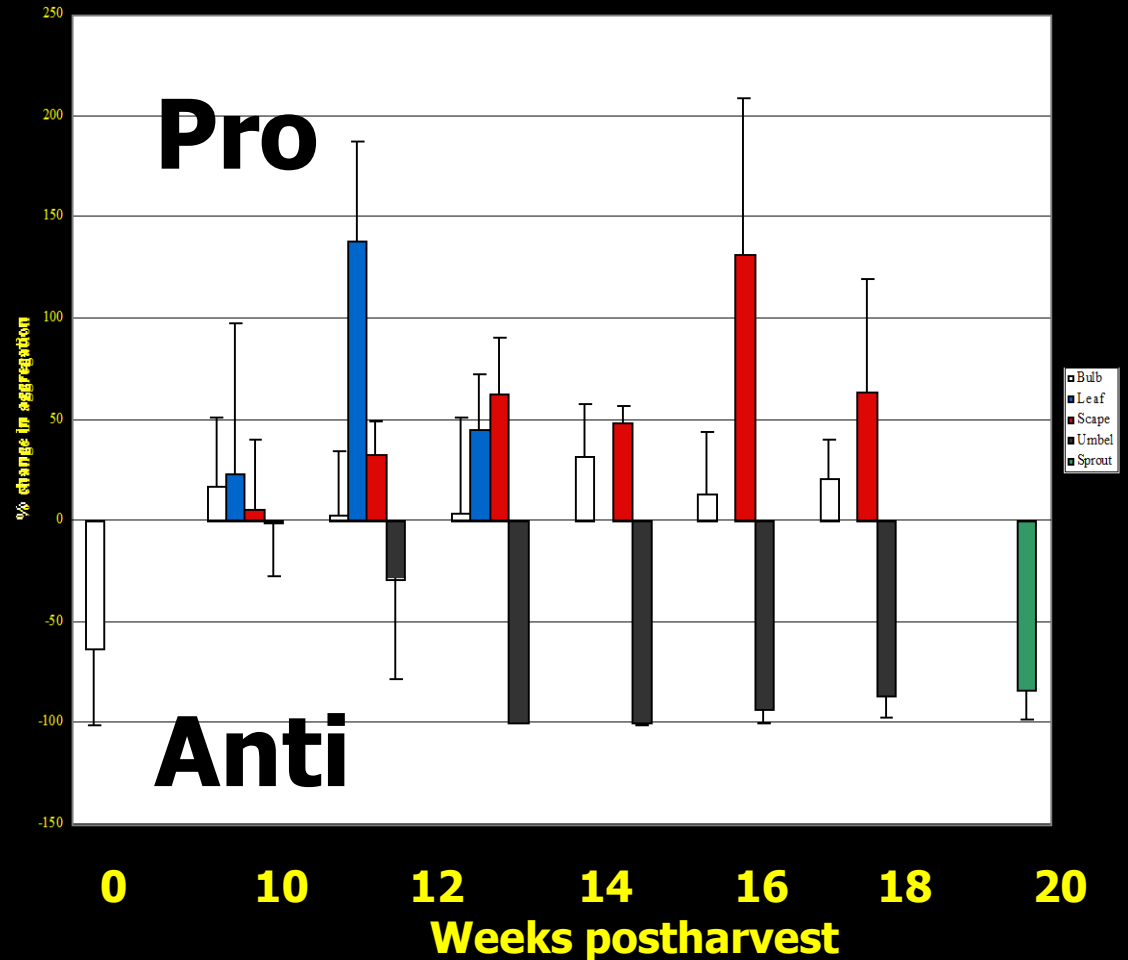


ACSO cycling
Lancaster et al., 1986

Life Cycle

- **Bulb, no inhibition**
- **Scape, no inhibition**

- **Umbel inhibits**
- **Sprout inhibits**



Briggs, 2000

You are what you eat

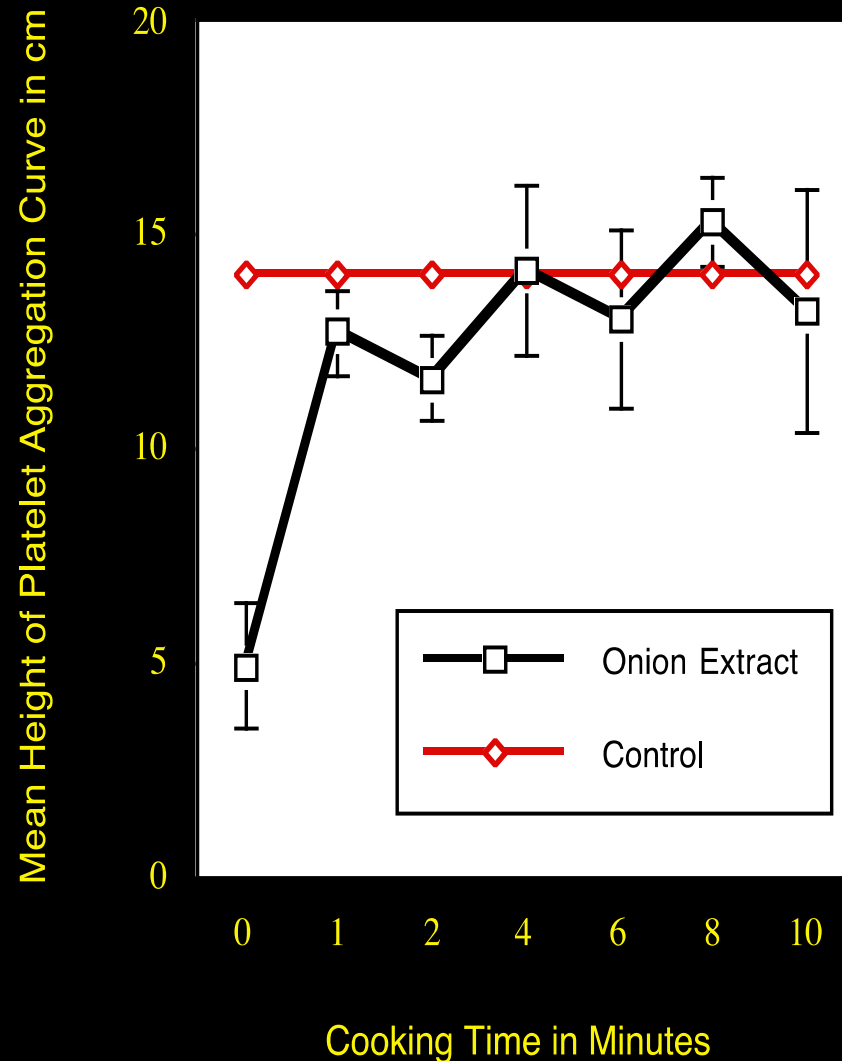
-mom

**You are what you
don't excrete**

-modern medical science

Cooking

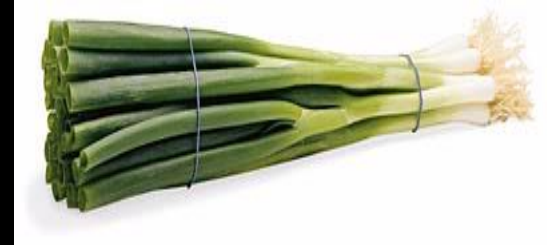
- **>1 minute of boiling eliminates all in vitro OIAA**
- **Suggests volatility of OSCs, heat-killing of alliinase**

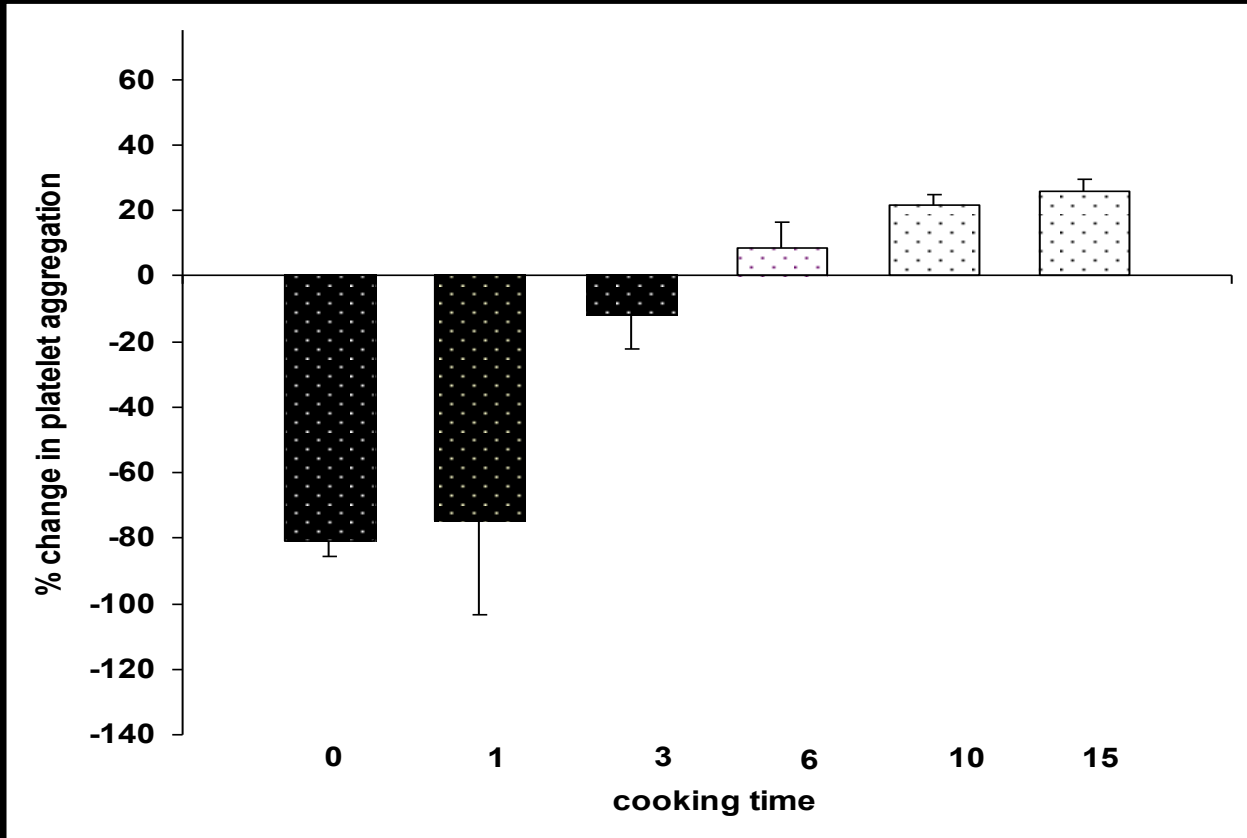


Kopelberg and Goldman, 1995

Fresh vs. Cooked Onion

- **Chen et al. (2000): reduction in platelet aggregation with feeding of Welsh onion juice**
- **Rats fed 28 days**
- **Boiled Welsh onion juice had no effect, and in some cases promoted aggregation**





Hansen, Folts, and Goldman, 2012

Pungency Paradox

- **More pungent = more efficacy**
- **More pungent = more difficult to eat raw**
- **But cooking eliminates medicinal benefit**
- **So the best onion is the weakest onion**

Seminis / Monsanto Release

Mild mannered
with a
sweet
disposition.



The fall-to-spring sweet onion.SM

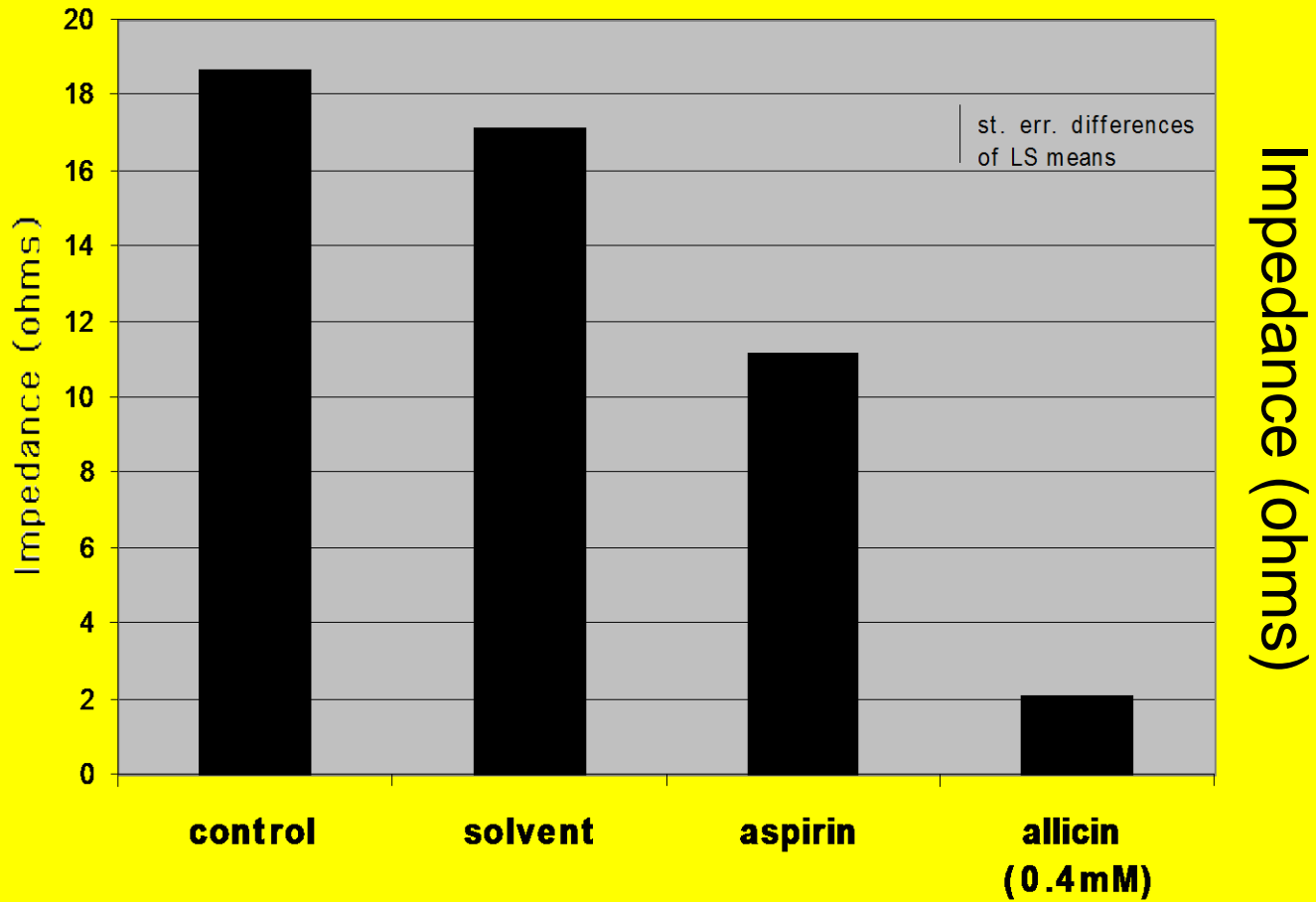
Crossing with Mild, Intermediate Day Types



July jewels: A harvest worker (above left) loads onions into burlap bags at Joe Nelson's farm on Highway 28 between La Mesa and Chamberino. Nelson (above right) displays one of his sweet summer bulbs.



More Potent than Aspirin in Vitro

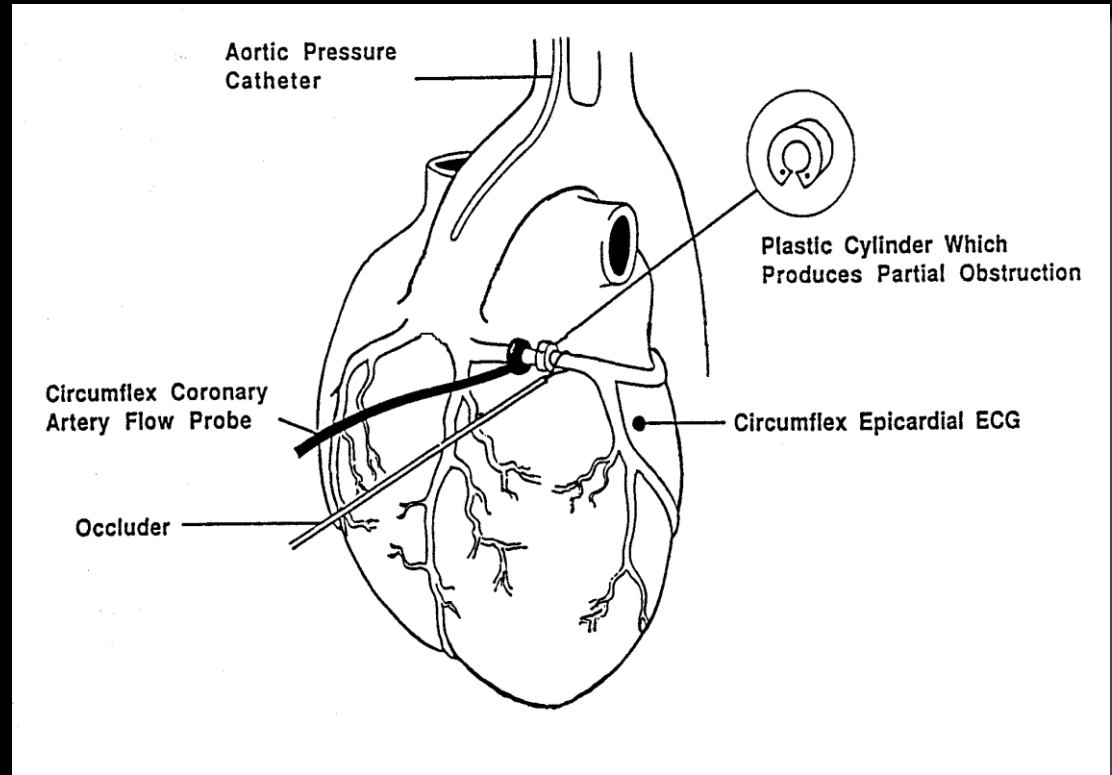


Briggs, 2000

Folts' in vivo Coronary Thrombosis Model



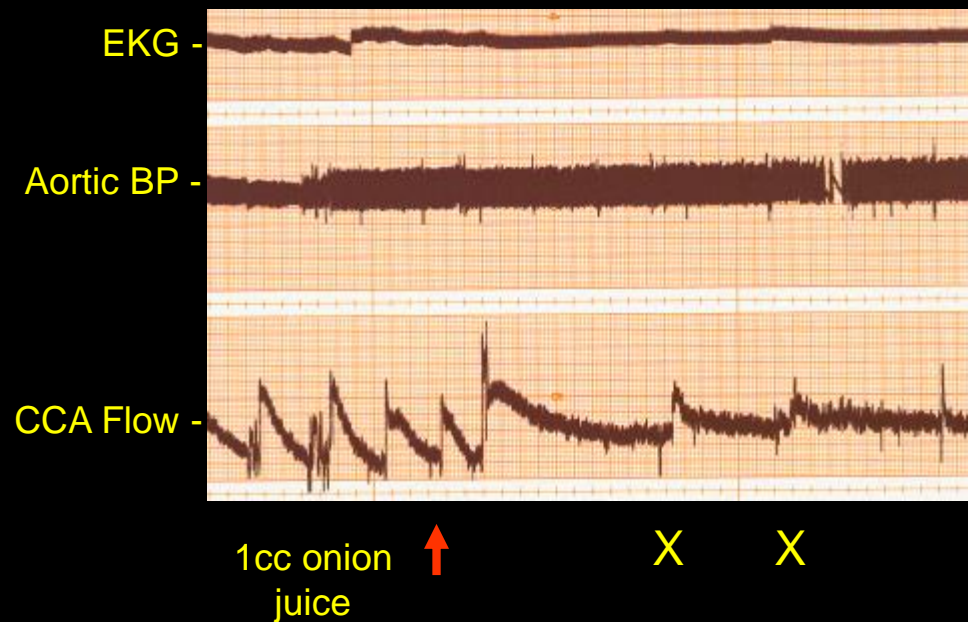
Canine



Measure blood flow through
constricted
coronary artery

Onion Inhibits Platelet Aggregation *in vivo*

A dosage of 1cc juice given intravenously inhibited CFRs within 5 minutes



Also inhibited intragastrically at 2 g/kg

Little Sis Onions



QTL Detection in F₃M Families

30 days postharvest

Trait	Linkage Group	cM	LOD	R-square
SSC	F	14	2.81	21.3
PUNGENCY	B	42	2.63	20.1
OIAA	-	-	-	-

90 days postharvest

Trait	Linkage Group	cM	LOD	R-square
SSC	F	16	4.22	30.2
PUNGENCY	E	40	4.17	29.9
OIAA	E	40	2.8	21.2

Galmarini et al., 2001, agrees with earlier findings about increased pungency in storage

Linkage of Key Traits

The strong phenotypic and genetic correlations revealed by this study may be the result of linkage among genes that independently control these traits or to pleiotropic effects of the same genes...

Galmarini et al., 2001

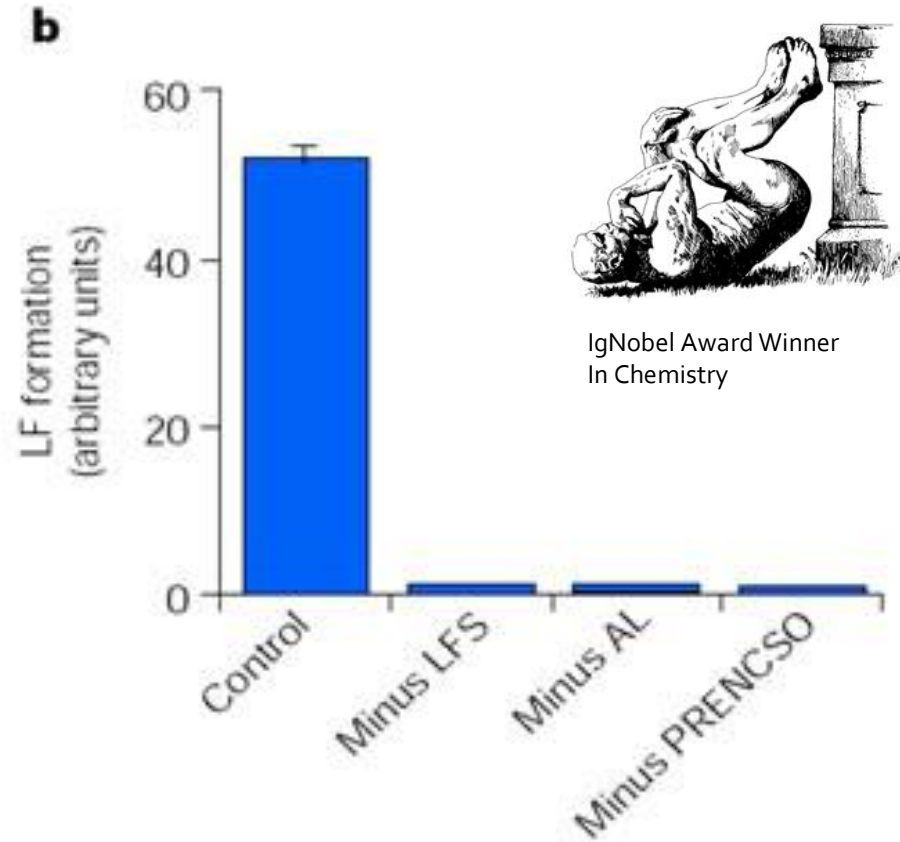
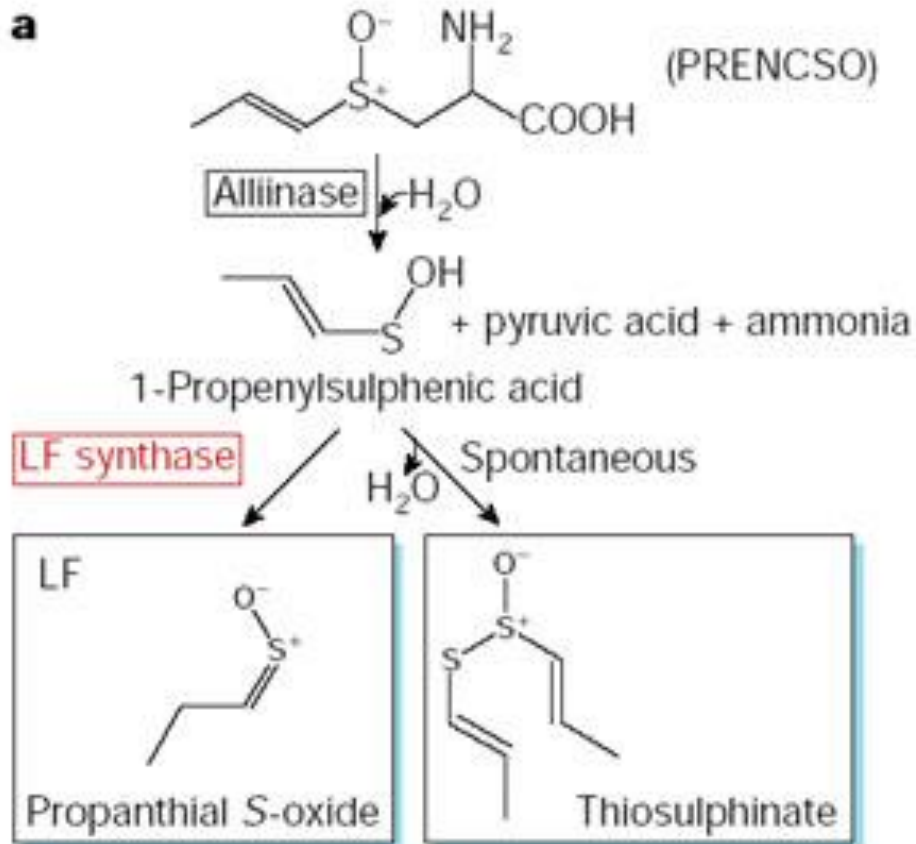
Storage Onions with Low Pungency

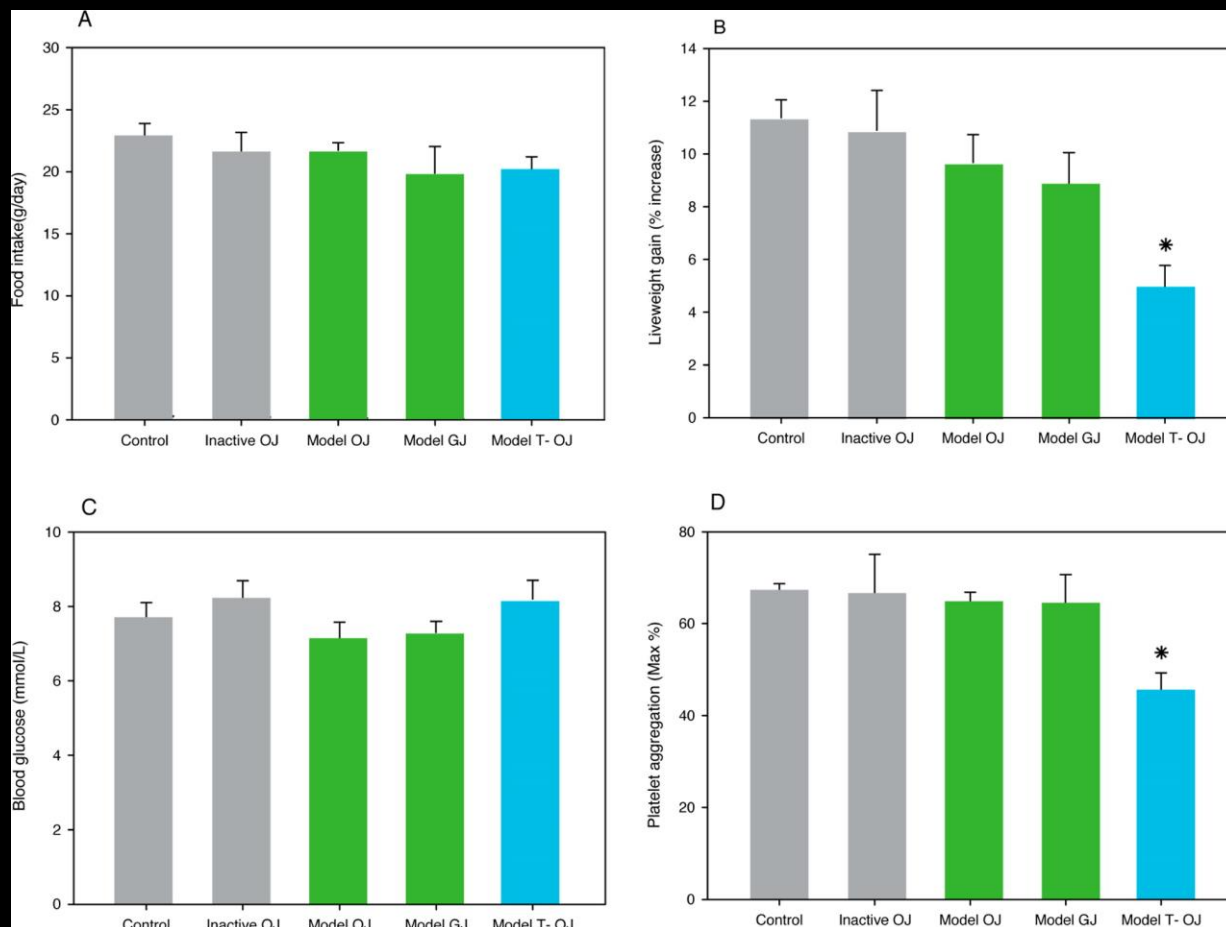
- EverMild by Seminis
- US8704045B2 patent by Nunhems; issued in 2014, covers four different inbred lines of low pungency long storage onions and the F₁ hybrids produced from them
- Broken linkages between these traits?

Tearless Onion

- Colin Eady in New Zealand knocked out alliinase with RNAi, 2007
- House Foods Group in Japan irradiated LF synthase to produce a tearless onion in 2015

Existence of LF Synthase





Thomson et al. 2013

Rats fed tearless onions had inhibition of platelet aggregation

Tearless onions had thiosulfinates profiles more similar to garlic

60
MINUTES

CBS NEWS



- *French Paradox*
- **1991 piece on CBS' *60 Minutes***
- **French eat up to 15% of calories from saturated fat, yet 40% lower incidence of heart disease than U.S.**
- **Has been explained by French wine consumption, among other things**

**Spawned herbal
supplements
containing grape
seed / grape
skin extracts**

***Reflects 'magic
bullet' approach
to health***

MELLEN

Medical Products, Inc.

THE ANTIOXIDANT NUTRITIONAL SUPPLEMENT WITH A HEART™



FRENCH
paradox



All the Benefits of Red Wine without the alcohol™

Red Wine Marc Extract 30 Capsules



A Deep History and Connection



A Deep History and Connection

- Clear health benefits present, *the raw commodity is a value-added product*
- Well documented through human history and modern science
- Though cooking and processing raises additional questions that should be addressed
- Breeding has helped develop cultivars that can deliver these valuable compounds
- And clinically-relevant studies need to be conducted in order to fully assess the health value