The Future of Food Additives

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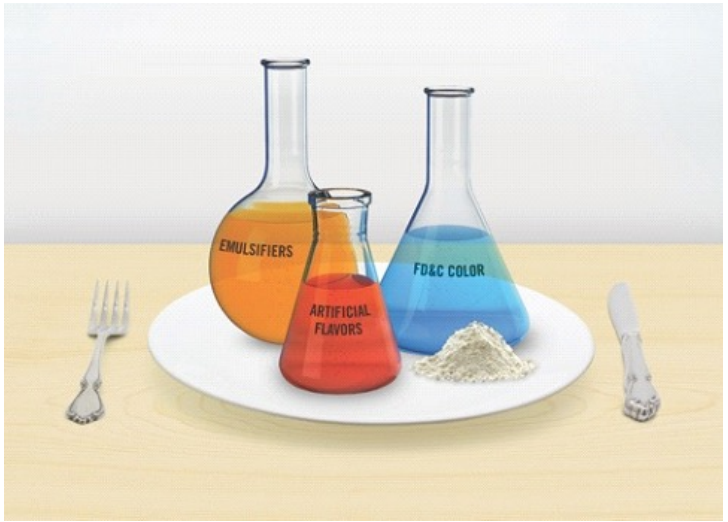
UMass Food Science



https://delinigelato.com/post/food-additives-which-to-avoid

https://www.anneliseмiller.com/education/blog-articles

Foods are made of Chemicals

INGREDIENTS: WATER (75%), SUGARS (12%) (GLUCOSE (48%), FRUCTOSE (40%), SUCROSE (2%), MALTOSE (<1%)), STARCH (5%), FIBRE E460 (3%), AMINO ACIDS (<1%) (GLUTAMIC ACID (19%), ASPARTIC ACID (16%), HISTIDINE (11%), LEUCINE (7%), LYSINE (5%), PHENYLALANINE (4%), ARGININE (4%), VALINE(4%), ALANINE (4%), SERINE (4%), GLYCINE (3%), THREONINE (3%), ISOLEUCINE (3%), PROLINE (3%), TRYPTOPHAN (1%), CYSTINE (1%), TYROSINE (1%), METHIONINE (1%)), FATTY ACIDS (1%) (PALMITIC ACID (30%), OMEGA-6 FATTY ACID: LINOLEIC ACID (14%), OMEGA-3 FATTY ACID: LINOLENIC ACID (8%), OLEIC ACID (7%), PALMITOLEIC ACID (3%), STEARIC ACID (2%), LAURIC ACID (1%), MYRISTIC ACID (1%), CAPRIC ACID (<1%)), ASH (<1%), PHYTOSTEROLS, E515, OXALIC ACID, E300, E306 (TOCOPHEROL), PHYLLOQUINONE, THIAMIN, COLOURS (YELLOW-ORANGE E101 (RIBOFLAVIN), YELLOW-BROWN E160a), FLAVOURS (3-METHYLBUT-1-YL ETHANOATE, 2-METHYLBUTYL ETHANOATE, 2-METHYLPROPAN-1-OL, 3-METHYLBUTYL-1-OL, 2-HYDROXY-3-METHYLETHYL BUTANOATE, 3-METHYLBUTANAL

https://jameskennedymonash.wordpress.com/2014/01/11/bananablueberryegg-ingredients-posters-pdfs/

Chemical names can be scary

Food Additives
Retinol
Calciferol
Tocopherol
Phylloquinone
Thiamine
Riboflavin

Chemical names can be scary

Food Additives	
Retinol	Vitamin A
Calciferol	Vitamin D
Tocopherol	Vitamin E
Phylloquinone	Vitamin K
Thiamine	Vitamin B1
Riboflavin	Vitamin B2

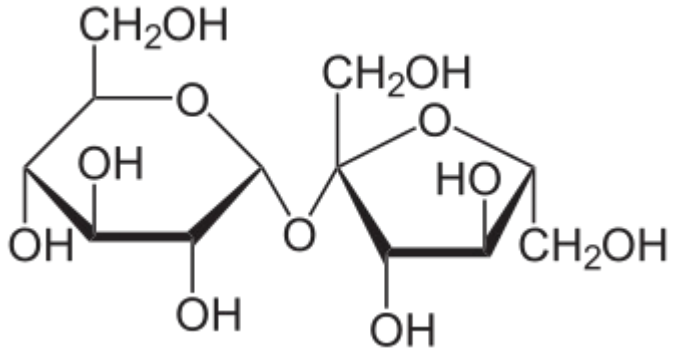
https://ubiquinol.org/blog

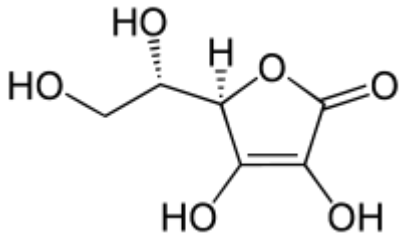
Hazard vs Risk

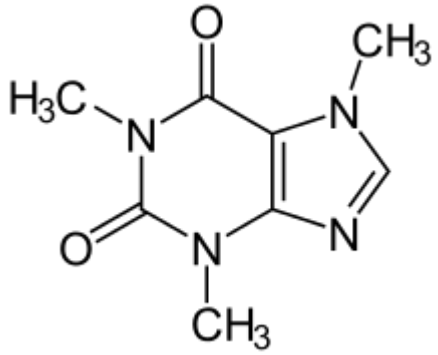
All Chemicals can be Hazardous

Defined by LD 50 (concentration given all at once)

- Water 8000 g
- Sucrose 2000 g
- Vitamin C 840 g
- Alcohol 500 g
- Salt 225 g
- MSG 15 g
- Nitrite 12.6
- Caffeine 10 g
- Capsaicin 3 g
- Aflatoxin 0.2 g
- Botulism 0.0003 g







Not all chemical have high risk because exposure is typically low

- Capsaicin LD_{50} = 3 g
  - Habanero pepper flesh has 31 mg capsaicin/g dried pepper
  - 50% risk = 100 g capsaicin = >100 dried peppers

- Ethanol LD_{50} = 500 g
  - Bottle of vodka has 237 g ethanol

Toxicity of foods is often self-limiting. You would probably stop before eating 100 habaneros or pass out before drinking more than two bottles of vodka

Acute vs Chronic Risk

- Acute is short time risk
- Chronic is long term risk
  - Usually happens when your body can not remove chemicals efficiently
    - Methyl mercury = 80 days
    - Lead = 1-1.5 months
    - Arsenic half-life = 10 hours
  - Also varies at life stage
    - Infants and toddlers most susceptible because of rapidly developing tissue

Examples of Federally Regulated Food Additives

South Australian Department of Health

Food Additive Code Numbers Current August 2006

Government of South Australia
Department of Health

100	Curcumin or Turmeric (colour)
101	Riboflavin or Riboflavin 5'-phosphate sodium (colour)
102	Tartrazine (colour)
103	Alkanet or Alkannin (colour)
104	Quinoline yellow (colour)
110	Sunset yellow FCF (colour)
120	Carmines or Carminic acid or Cochineal (colour)
122	Azorubine or Carmoisine (colour)
123	Amaranth (colour)
124	Ponceau 4R (colour)
127	Erythrosine (colour)
129	Allura red AC (colour)
132	Indigotine (colour)
133	Brilliant blue FCF (colour)
140	Chlorophyll (colour)
141	Chlorophyll-copper complex (colour)
142	Green S (colour)
143	Fast green FCF (colour)
150a	Caramel I (colour)
150b	Caramel II (colour)
150c	Caramel III (colour)
150d	Caramel IV (colour)
151	Brilliant black BN or Brilliant black PN (colour)
153	Carbon black or vegetable carbon (colour)
155	Brown HT (colour)
160a	Carotene (colour)
160b	Annatto extracts (colour)
160c	Paprika oleoresins (colour)
160d	Lycopene (colour)
160e	b-apo-8' Carotenal (colour)
160f	b-apo-8' Carotenoic acid or methyl ethyl ester (colour)
161a	Flavoxanthin (colour)
161b	Lutein (colour)
161c	Kryptoxanthin (colour)
161d	Rubixanthin (colour)
161e	Violoxanthin (colour)
161f	Rhodoxanthin (colour)
162	Beet red (colour)
163	Anthocyanins or Grape skin extract or Blackcurrant extract (colour)
164	Saffron or Crocetin or Crocin (colour)
170	Calcium carbonate (colour, anti-caking agent)
171	Titanium dioxide (colour)
172	Iron oxide (colour)
173	Aluminium (colour)
174	Silver (colour)
175	Gold (colour)
181	Tannic acid or tannins (colour, emulsifier, stabiliser, thickener)
200	Sorbic acid (preservative)
201	Sodium sorbate (preservative)
202	Potassium sorbate (preservative)
203	Calcium sorbate (preservative)
210	Benzoic acid (preservative)
211	Sodium benzoate (preservative)
212	Potassium benzoate (preservative)
213	Calcium benzoate (preservative)
216	Propylparaben or Propyl-p-hydroxy-benzoate (preservative)
218	Methylparaben or Methyl-p-hydroxy-benzoate (preservative)
220	Sulphur dioxide (preservative)
221	Sodium sulphite (preservative)
222	Sodium bisulphite (preservative)
223	Sodium metabisulphite (preservative)
224	Potassium metabisulphite (preservative)
225	Potassium sulphite (preservative)
228	Potassium bisulphite (preservative)
234	Nisin (preservative)
235	Natamycin or Pimaricin (preservative)
242	Dimethyl dicarbonate (preservative)
249	Potassium nitrite (preservative, colour fixative)
250	Sodium nitrite (preservative, colour fixative)
251	Sodium nitrate (preservative, colour fixative)
252	Potassium nitrate (preservative, colour fixative)
260	Acetic acid, glacial (acidity regulator)
261	Potassium acetate or Potassium diacetate (acidity regulator)
262	Sodium acetates (acidity regulator)
263	Calcium acetate (acidity regulator)
264	Ammonium acetate (acidity regulator)
270	Lactic acid (acidity regulator)
280	Propionic acid (preservative)
281	Sodium propionate (preservative)
282	Calcium propionate (preservative)
283	Potassium propionate (preservative)
290	Carbon dioxide (propellant)
296	Malic acid (acidity regulator)
297	Fumaric acid (acidity regulator)
300	Ascorbic acid (antioxidant)
301	Sodium ascorbate (antioxidant)
302	Calcium ascorbate (antioxidant)
303	Potassium ascorbate (antioxidant)
304	Ascorbyl palmitate (antioxidant)
306	Tocopherols concentrate, mixed (antioxidant)
307	a-Tocopherol (antioxidant)
308	ß-Tocopherol (antioxidant)
309	γ-Tocopherol (antioxidant)
310	Propyl gallate (antioxidant)
311	Octyl gallate (antioxidant)
312	Dodecyl gallate (antioxidant)
315	Erythorbic acid (antioxidant)
316	Sodium erythorbate (antioxidant)
319	tert-Butylhydroquinone (antioxidant)
320	Butylated hydroxyanisole (antioxidant)
321	Butylated hydroxytoluene (antioxidant)
322	Lecithin (antioxidant, emulsifier)
325	Sodium lactate (acidity regulator, humectant, bulking agent)
326	Potassium lactate (acidity regulator, humectant, bulking agent)
327	Calcium lactate (acidity regulator)
328	Ammonium lactate (acidity regulator)
329	Magnesium lactate (acidity regulator)
330	Citric acid (acidity regulator, antioxidant)
331	Sodium citrates (acidity regulator, emulsifier, stabiliser)
332	Potassium citrates (acidity regulator, stabiliser)
333	Calcium citrates (acidity regulator, stabiliser)
334	Tartaric acid (acidity regulator, antioxidant)
335	Sodium tartrates (acidity regulator)
336	Potassium tartrate or Potassium acid tartrate (acidity regulator, stabiliser)
337	Potassium sodium tartrate (acidity regulator, stabiliser)
338	Phosphoric acid (acidity regulator)
339	Sodium phosphates (acidity regulator, emulsifier, stabiliser)
340	Potassium phosphates (acidity regulator, emulsifier, stabiliser)
341	Calcium phosphates (acidity regulator, emulsifier, stabiliser, anti-caking agent)
342	Ammonium phosphates (acidity regulator)
343	Magnesium phosphates (acidity regulator, anti-caking agent)
349	Ammonium malate (acidity regulator)
350	Sodium malates (acidity regulator, humectant)
351	Potassium malates (acidity regulator)
352	Calcium malates (acidity regulator)
353	Metatartaric acid (acidity regulator)
354	Calcium tartrate (acidity regulator)
355	Adipic acid (acidity regulator)
357	Potassium adipate (acidity regulator)
359	Ammonium adipates (acidity regulator)
363	Succinic acid (acidity regulator)
365	Sodium fumarate (acidity regulator)
366	Potassium fumarate (acidity regulator)
367	Calcium fumarate (acidity regulator)
368	Ammonium fumarate (acidity regulator)
380	Ammonium citrate or triammonium citrate (acidity regulator)
381	Ferric ammonium citrate (acidity regulator, anti-caking agent)
385	Calcium disodium ethylenediaminetetraacetate or calcium disodium EDTA (preservative, antioxidant)
400	Alginic acid (thickener, stabiliser)
401	Sodium alginate (thickener, stabiliser, gelling agent)
402	Potassium alginate (thickener, stabiliser)
403	Ammonium alginate (thickener, stabiliser)
404	Calcium alginate (thickener, stabiliser, gelling agent)
405	Propylene glycol alginate (thickener, emulsifier)
406	Agar (thickener, gelling agent, stabiliser)
407	Carrageenan (thickener, gelling agent, stabiliser)
407a	Processed eucheuma seaweed (thickener, gelling agent, stabiliser)
409	Arabinogalactan or Larch gum (thickener, gelling agent, stabiliser)
410	Locust bean gum or Carob bean gum (thickener, stabiliser)
412	Guar gum (thickener, stabiliser)
413	Tragacanth gum (thickener, stabiliser)
414	Acacia or gum Arabic (thickener, stabiliser)
415	Xanthan gum (thickener, stabiliser)
416	Karaya gum (thickener, stabiliser)
417	Tara Gum
418	Gellan gum (thickener, stabiliser, gelling agent)

FDA has approved over 10,000 food additives

This is not 10,000 different chemical because every form of a chemical has to be approved (e.g. calcium, potassium and sodium salts of vitamin C).

Some of these additives are not intentionally added to food (e.g. pesticides)

How food additives are approved

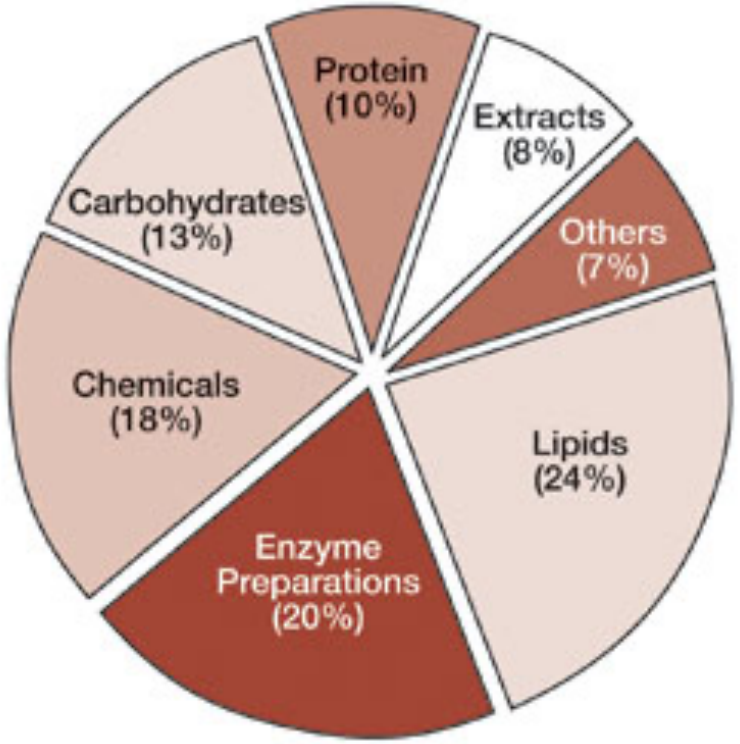
- Food Additive Petition
  - Proposed use
  - Expected exposure level
  - Safety data
    - Literature search
    - Animal experiments: Genetic, Carcinogenicity, Reproduction, Development
  - Environmental impact
- FDA reviews and approves or rejects
  - Usually for synthetic compounds not found in nature
  - Extremely expensive to obtain safety data, typically >$1 M

How food additives are approved

- Generally Recognized as Safe (GRAS) Food Additives
  - Many ingredients used before 1958 were given GRAS status due to their long history of use (reevaluated in the 1960s).
  - In 1997, FDA determined that GRAS status could be determined by outside experts
  - Sponsor notifies FDA of their intended use of the food ingredient.
  - Sponsor still needs toxicological data and intended levels of use.
  - FDA reviews petition

GRAS Ingredients

- Most GRAS ingredients come from natural foods with a consumption history or a known food component (e.g. protein or fat) from an new food source (e.g. stevia from candyleaf)
- GRAS ingredients are continuously monitor and their GRAS status can be revoked

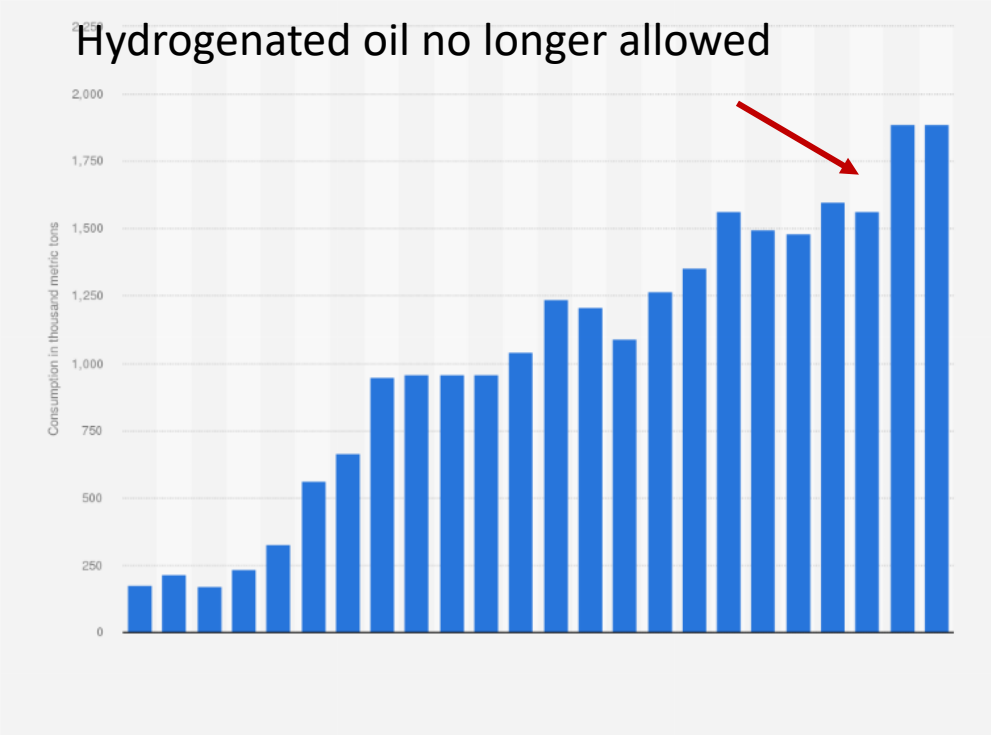


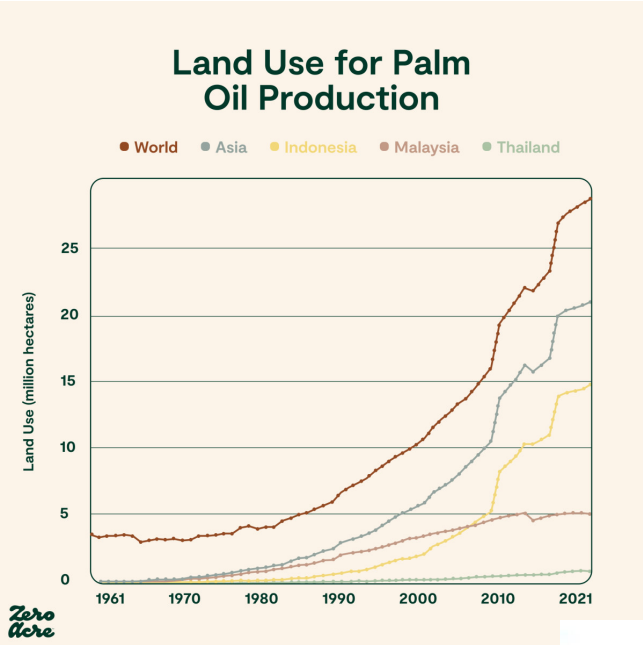
Partially Hydrogenated Vegetable Oil (PHO)

- In 2015, the GRAS status of partially hydrogenated vegetable oil was revoked by FDA
  - Reason was that *trans* fatty acids produced by partial hydrogenation were associated with increase risk of heart disease
  - The science on the risk of *trans* fatty acids in heart disease is not settled
  - However, economic alternatives to partially hydrogenated vegetable oils were available
    - Tropical oils
    - Interesterified fats for baked good
    - High oleic oils for frying
  - Companies had to remove all PHO by 2020

Wikipedia

Unintended Consequent: Palm Oil in U.S. after PHO ban





California Bans Food Additives (2023)

- Brominated vegetable oil – makes the density of oil and water the same minimizing separation (orange soda)
- Potassium bromate- Flour bleaching agent
- Propylparaben – antimicrobial agent – baked and canned goods
- Red Dye 3 – candies, beverages and frostings
  - FDA still considers safe
  - California decision based on animal studies
  - California bans usually extend nation wide.

https://www.jonesday.com

California Bans Food Additives

- Replacements
  - Brominated vegetable oil – glycerol ester of wood rosin
  - Potassium bromate- ascorbic and citric acid
  - Propylparaben – Sodium benzoate and potassium sorbate
  - Red Dye 3 – carmine – insect extract

Alternatives to Synthetic Food Additives

- Major area of current research

- Natural Colors
  - Blue – Butterfly pea flower, Spirulina
  - Red – Beet, carmine
  - Orange – Carrots, annatto
  - Yellow – Turmeric
- Natural Antioxidants
  - Tocopherols (vitamin E)
  - Rosemary extracts
- More expensive and less effective
- Can shorten shelf-life and result in food waste

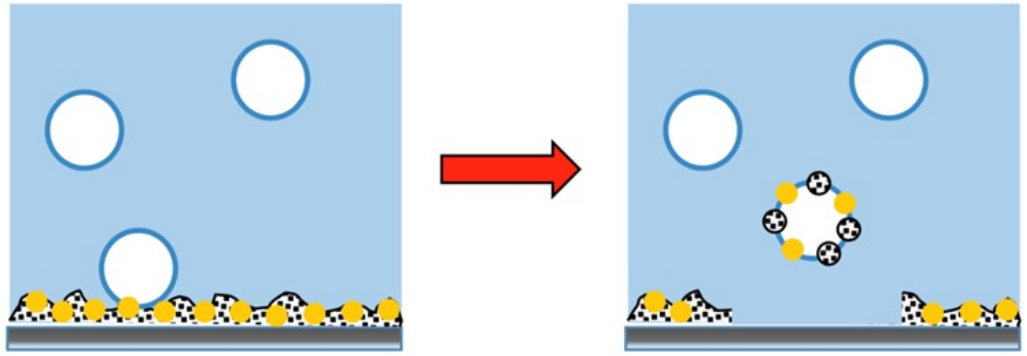
Packaging – not listed on label

- Vacuum packing now common in retails meats
  - Long time resistance due to color differences
- Modified atmosphere packaging in salad and meat
  - Gases used in headspace to decrease microbial growth

- Active packaging
  - Antimicrobial – deli meats
  - Oxygen scavengers – beer caps
  - Ethylene scavengers – decreases ripening during transportation of fruit

Processing – not listed on label

- High pressure processing
  - Kills bacterial
  - Guacamole, deli salads
- Cold plasma technology
  - Activates oxygen to kill microorganisms
  - Sprout seeds (Clean Crop Technology, Holyoke, MA)
- Microbubble technology
  - Decrease use of sanitizers and water



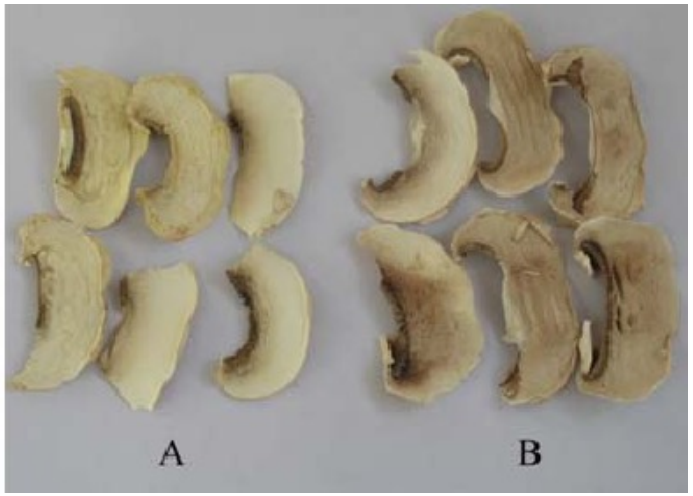
https://ag.purdue.edu/department/asec

Gene Editing

- CRISPR - Clustered Regularly Interspaced Short Palindromic Repeats
  - CRISPR changes genetics within organisms to increase or decrease metabolic pathways
  - GMO introduces new genes into an organisms to create new molecules
- Plant varieties have variations in color, flavor, nutrition and shelf-life
  - Traditional breeding attempts to find naturally occurring plants that have desired metabolic pathways to creates desirable traits
    - This can take years
    - Often accelerated by irradiating seeds to cause genetic mutations
  - CRISPR is faster and more accurate because it can modify one specific pathway at a time
    - No other pathways are change minimizing the chance of harmful products being formed

CRISPR Foods

- FDA approved
  - Superfood mustard greens – decreased bitterness but maintain nutrients
  - Sicilian Rouge tomato - increased concentration of micronutrient
  - Reduced PPO mushrooms – decreased browning
  - Short haired cattle – decrease heat related deaths (annual loss of $400 M)



https://www.discovermagazine.com/the-sciences/can-crispr-feed-the-world

Future CRISPR

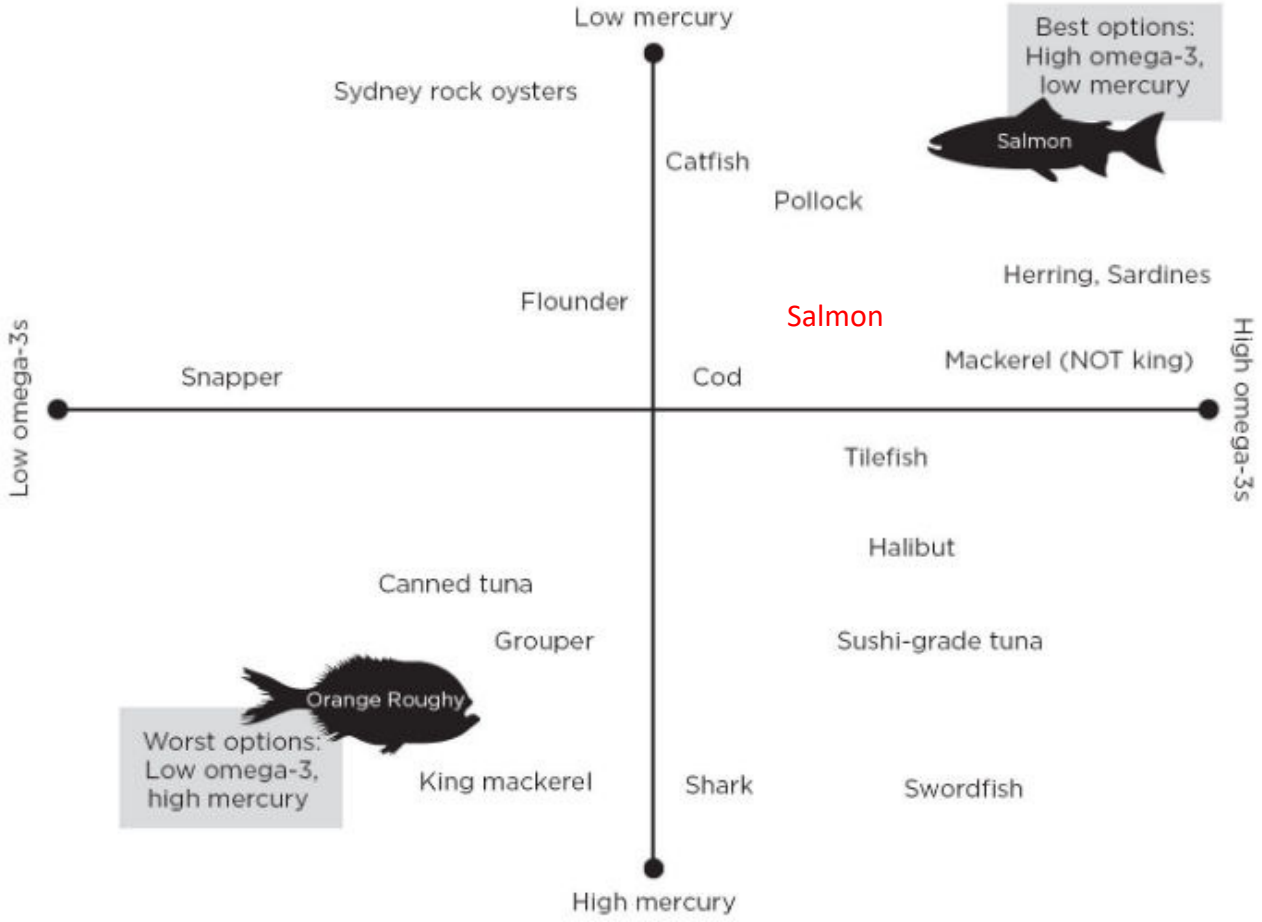
- Change/increase plant colors – make natural colors cheaper
- Improve flavor – stop off flavor development in lentils
- Increase vitamins – High vitamin D tomatoes
- Control ripening – Prevent over ripening in tomatoes
- Improve safety – remove cyanide from Cassava, remove allergenicity
- Improve nutrition – change caloric content of starch

https://www.althedahealth.com/blog/2023/07/18/the-resistant-starch-report

Risk vs Benefit

- Some foods/diets have both a risk and benefit
  - Seafood
    - Low calorie and excellent source of vitamins, mineral and omega-3 fatty acids
    - Some species are also high in methyl mercury
    - Omega-3 are good for heart health and brain development
    - Mercury causes kidney and central nervous system damage (especially in infants)
    - Risk is high in pregnant women and infants
    - Benefit is high in individual that has heart attacks

    - Selection of the correct fish species can overcome risk



https://www.shortform.com/blog/expecting-better-fish-chart/

90% Seafood eaten in the U.S. is low in mercury,[2] considered "safe options" by the FDA/EPA, which incorporates a **1,000% uncertainty facto**

Top consumed seafood species in the US	Weekly upper limit before risk[3]
1. Shrimp	1,784 oz (111.5 lbs)
2. Salmon	853 oz (53 lbs)
3. Canned Tuna - Skipjack (Light)	164 oz (10 lbs)
4. Canned Tuna - Albacore (White)	56 oz (3.5 lbs)
5. Tilapia	1,509 oz (94 lbs)
6. Farmed Catfish, Pangasius, Swai, Basa	1,154 oz (72 lbs)
7. Alaska Pollock	530 oz (33 lbs)
8. Cod	223 oz (14 lbs)
9. Crab	311 oz (19 lbs)
10. Clams	853 oz (53 lbs)

https://www.seafoodnutrition.org

Risk vs Benefit in Diets

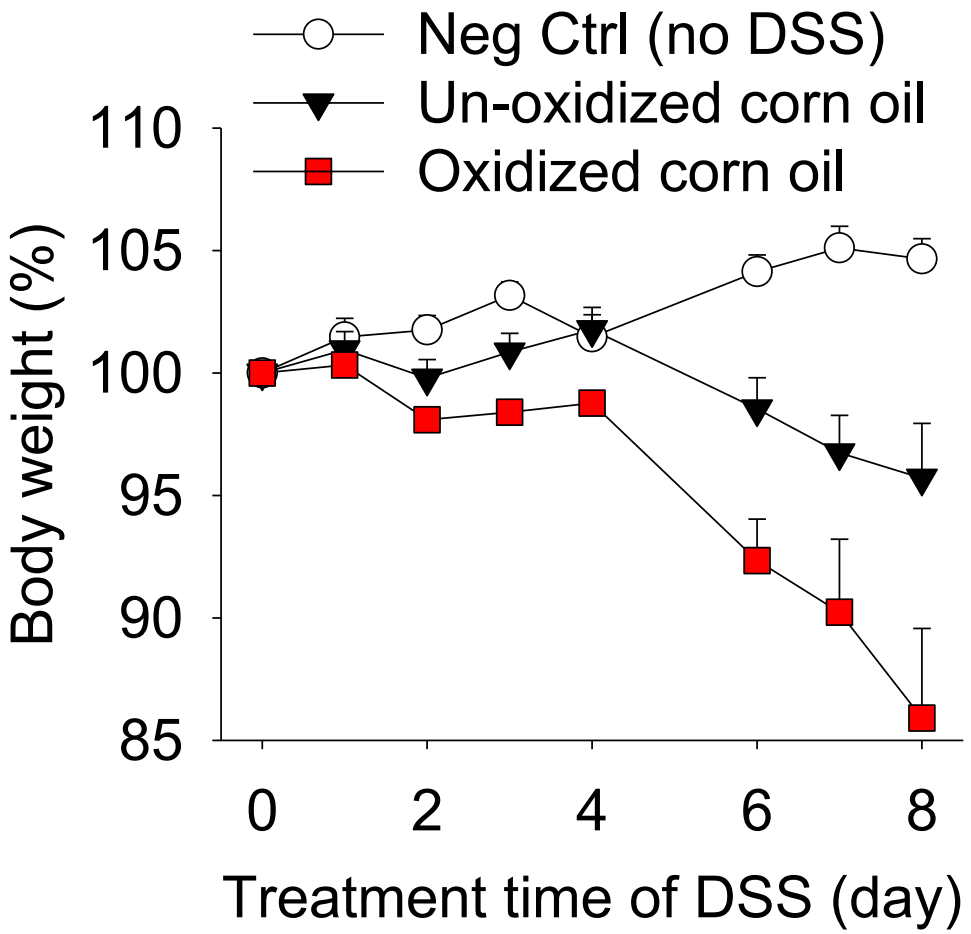
- Gluten Free
  - Benefit
    - Improves intestinal health
    - Increases nutrient absorption
  - Risk
    - Diet low in
      - Fiber
      - Iron and calcium
      - Vitamin B's, D and E
      - Mostly due to lack of enriched and whole grain flours
- Must carefully plan diet and/or take supplements
- Benefit is high for individual with Celiac disease
- Risks is higher for healthy individual on gluten free diets

https://www.goglutenfreely.com/celiac-disease-foundation-expo-products/

EDTA

- EDTA is an extremely effective antioxidant in food emulsions (mayo and salad dressings)
- Benefit
  - Increases shelf-life by decreasing rancidity
  - Protects flavor
- Risk of removal
  - Increase presence of toxic lipid oxidation products in food

Toxicity of Lipid Oxidation products in mice



Conclusions

- There is a need to continuously monitor the safety of food additives
- Many synthetic food additives can be replaced with natural alternatives but this is often more expensive and less effective
- Other technologies can be used to replace food additives
  - Packaging
  - Processing
  - Gene Editing
- Decision should be base on hazard vs risk vs benefit