Natural Colorants: Challenges and Opportunities

M. Monica Giusti
Consumer Trends

WANT TO AVOID...
- Synthetic ingredients
- Artificial colors

WANT TO SEE...
- Natural
- Healthy
- Clean labels
- “super foods”
Can we just remove them?

- We eat with our eyes first…
- People judge quality by the appearance of the product
- Consumers correlate color with (perceived) flavor or other quality characteristics
Why do we use colorants?

- Up to 85% of consumer buying decisions are potentially influenced by color.
- Color has a major impact on flavor perception and flavor acceptance.
- Effective color usage drives consumer trial and acceptance.
Colors Added to Foods

Color has been added to foods since ancient times, and by cultures all over the world:

- (1500 BC) Egyptian wall paintings showed evidence of color used in candy
  - Egyptians colored foods with saffron
- (400 BC) Pliny the Elder spoke of artificial wine color
- Incas colored foods and fabrics with cochineal
- Mayans colored their food with annatto
Food Colors History and Legislation

- (1906) Pure Food, Drug Act made improper and dangerous use of color in foods unlawful
  - Established color certification process, listed acceptable colors for food use.

- (1938) Federal Food, Drugs and Cosmetic Act
  - Made color certification process mandatory.

- (1960) The Color Additives Amendments to the FD&C Act
  - Require dyes used in foods, drugs, and cosmetics to be approved by FDA prior to their marketing
Food colorant uses

Only colorants determined to be safe by the FDA can be used (listed in 21CFR73)

- Enhance & correct colors already present
- Provide color identity to colorless foods
- Account for color loss during storage

Food colorants should never be used to...

- Hide defects
- Deceive consumers
Color Additives

According to the FDA, a color additive is

- “any dye, pigment or other substance made or obtained from a vegetable, animal, mineral or other source capable of coloring a food, drug or cosmetic or any part of the human body.”
Classes of Food Colorants in USA

- **“Natural”** colorants – Colors Exempt from Certification
  - Colors from natural sources
  - Plant, animal or minerals pigments
  - OR… Nature identical

- **Synthetic** colorants – Certified Colorants
  - Chemically synthesized
  - EVERY batch must be FDA certified
Synthetic Colorants Concerns

- Synthetic colors have been scrutinized for their potentially negative side effects
  - Allergies
  - Hypersensitivity
  - “The Southampton study”, UK – since 2007
    - Established a link between tested synthetic colorants and hyperactivity in children (ADHD)

- Regulatory changes in Europe, concerns all over the world.
Regulatory Status: Europe

The European Food Safety Authority

- Warning labels / Restrictions

“consumption may have an adverse effect on activity and attention in children.”

FDC Red 40, Yellow 6

Beetroot red, Annatto, Paprika
Warning in the US?

- FDA created an expert panel to decide if warning labels were needed in foods containing synthetic dyes.

- FDA decided in 2011 not to require warnings at this time, but recommended re-evaluation of the safety of all synthetic dyes.
Demand for Natural Colorants is Growing

• Demand of natural colorants has grown faster than the demand for synthetics
  ◦ ~ 4% annual growth*

• Several US companies are already transitioning from synthetic to natural colorants

<table>
<thead>
<tr>
<th>Chemical Group</th>
<th>Pigments</th>
<th>Coloration</th>
<th>Occurrence (examples)</th>
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<tr>
<td>Tetrapyrroles</td>
<td>Chlorophylls</td>
<td>Blue–green</td>
<td>Broccoli, lettuce, spinach</td>
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<tr>
<td>Isoprenoid /</td>
<td>B-carotene</td>
<td>Yellow-orange</td>
<td>Carrots, melons, peaches</td>
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<td>Tetraprenoids</td>
<td>Lycopene</td>
<td>Orange-red</td>
<td>Tomatoes, watermelon</td>
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<td>Polyphenols</td>
<td>Anthocyanins</td>
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<td>Berries, red apple, red radish</td>
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<td>Flavonols</td>
<td>White–cream</td>
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<td>N-heterocyclic</td>
<td>Betalains</td>
<td>Purple/red-orange</td>
<td>Beets, cactus pear</td>
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Could we just use red to get red, and blue to get blue…???

- Replicating the colors from nature is not an easy task!
Could we just use red to get red, and blue to get blue...???

- Replicating the colors from nature is not an easy task!
- Pigments can interact with the matrix and change color
- Pigments may not be stable under the processing or storage conditions
- Colors are affected by texture
- Only certain colorants can be used in foods
Colors exempt from certification

- Listed in the code of Federal Regulations 21CFR73
  - Approved compounds and extracts obtained from natural sources
  - Fruit and vegetable juice concentrates
  - Approved synthetic compounds that are “nature identical”
- Are commonly referred to as “natural” colors
List of Colors Exempt from Certification

- Annatto extract
- Dehydrated beets (beet powder)
- Canthaxanthin
- Caramel
- [beta]-Apo-8'-carotenal
- [beta]-Carotene
- Cochineal extract; carmine
- Sodium copper chlorophyllin
- Toasted partially defatted cooked cottonseed flour
- Ferrous gluconate
- Ferrous lactate
- Grape color extract
- Grape skin extract (enocianina)
- Fruit juice
- Vegetable juice
- Paprika
- Paprika oleoresin
- Mica-based pearlescent pigments
- Riboflavin
- Spirulina extract
- Titanium dioxide
- Tomato lycopene extract; tomato lycopene concentrate
- Turmeric
- Turmeric oleoresin

A total of 38 are listed, with 26 for use in human food.
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Sodium copper chlorophyllin:

- Water soluble!!
- Mg\(^{2+}\) replaced with Cu\(^{2+}\)
- Restricted use: < 0.2% for dry mix citrus based beverages.

**Identity.** (1) The color additive sodium copper chlorophyllin is a green to black powder prepared from chlorophyll by saponification and replacement of magnesium by copper. Chlorophyll is extracted from alfalfa (*Medicago sativa*) using any one or a combination of the solvents acetone, ethanol, and hexane. (CFR 21 Part 73.125)
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- Caramel
- [beta]-Apo-8' carotenal
- [beta]-Carotene
- Carmines; cochineal extract; carmine (a)
- Sodium copper chlorophyllin
- Toasted partially defatted cooked cottonseed flour
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- Ferrous lactate
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(a) Identity. (1) The color additive dehydrated beets is a dark red powder prepared by dehydrating sound, mature, good quality, edible beets. CFR 21, Part 73.40

Should be used according to GMPs.
Betalains

- From yellow to purple-red
- Water soluble
- Limited distribution in nature
- Not very susceptible to pH
- Change color with light, heat, oxygen
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Carotenoids or related pigments
Carotenoids

- Colors range from yellow to orange to intense red
- Fat soluble
- Beta carotene: precursor to vitamin A
Commercial Forms of Carotenoids

- MANY!!!! Nature identical and from nature
- Physical properties
  - Liquid suspension in vegetable oil
  - Semi-solid suspension 25% in hydrogenated vegetable oil
  - Beadlet-water dispersible
  - Emulsion, beverage type

Annato
Canthaxanthin beadlets
β-carotene suspensions and beadlets
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Approved over the last decade
Recently Approved

- **Mica-based pearlescent pigments**
  - Platelets of potassium aluminum silicate (mica) with titanium dioxide
  - Exhibit a pearlescent color effect from transmittance, reflection and interference of light
  - Restricted use in cereal, confectionary, spirits, alcohol.

- **Spirulina extract:**
  - Filtered aqueous extract from *Arthospira platensis*, a cyanobacteria. Phycocyanins are pigments present and can provide green to blue colors to confectionary products, according to GMP.
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Anthocyanins are approved as colorants in EU
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- **Fruit juice**
- **Vegetable juice**
- Carrot oil
- Paprika
- Paprika oleoresin
- Mica-based pearlescent pigments
- Riboflavin
- Saffron
- Spirulina extract
- Titanium dioxide
- Tomato lycopene extract; tomato lycopene concentrate
- Turmeric
- Turmeric oleoresin
Anthocyanin Sources

Berries & most fruits:
Simple pigments

Other Sources:
Complex pigments
Fruit & Vegetable Juice Concentrates

- Pigments expressed and concentrated using:
  - Water as solvent
  - Physical means of extraction / concentration
  - Processes / aids already approved for juice manufacture
- Source must be edible
- NOT approved
  - Alcohol / other solvents
  - Use of resins that separate based on chemical means / affinity
Anthocyanin Colors

- Chemical Structure
- Matrix composition
  - Enzymes or pro-oxidants
  - pH
  - Metals
  - Co-pigmentation
  - Bisulfite
- Other stresses
  - Temperature
  - Light
  - Oxygen
- Anthocyanin applications are typically in the red shades under acidic pH.
- Anthocyanin–rich materials express different colors in pH 6-8

Concentration: 90-100 mg Cy-3-glu eq/L
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Caramel Colors

• Produced from heat treatment of sugars
  ◦ Glucose, fructose, lactose, malt syrup, molasses, starch hydrolysates
  ◦ Salts, acids or alkalis can produce a variety of colors.

• Many different applications:
  ◦ Baking, desserts and confectionary
  ◦ Sauces, soups and seasonings
  ◦ Beverages
  ◦ Snacks and cereals
  ◦ Meats and poultry
Other natural sources of colorants

Other natural sources:

- Turmeric
  - From tubers of a plant ("Curcuma longa")
  - Yellow to orange
  - Curry pigments

- Cochineal / carmine
  - Source: dried insects
  - Colors range form orange to brick red
  - Used in foods and many cosmetics!!!
Natural Colorants: Food Colorants from Natural Sources

Gregory T. Sigurdson, Peipei Tang, and M. Mónica Giusti

Transitioning to Colorants from Natural Sources

Challenges:

- Finding the “Right” color
- Compatibility with matrix
- Color and pigment stability
- Possible undesirable aromas / flavors

Opportunities:

- There are many options to consider, and more to be studies
- Consumer perception / increased demand
- Standardizing formulations!!!
- Added value: potential health benefits?
Trends Towards Color from Naturals Sources

- Proportion of consumers that report to be very/extremely concerned about food colorings

CA 35%
US 31%
MX 41%
BR 67%
RU 76%
CN 72%
IN 60%
AU 43%

INNOVA Market Insights
The C6-C3-C6 skeleton of flavonoid compounds – C – C – C –

- Isoflavones
  - Phytoestrogens

- Anthocyanins
  - Natural colorants
  - Phytonutrients

- Pro-anthocyanidins
  - Protect the urinary tract

Areas of work
- Analytical
- Horticultural
- Processing
- Bioavailability
- Health benefits

Flavonoid Research

- Potent antioxidants
- Abundant in nature
- Antibacterial, anti-allergic, antiviral and anti-inflammatory
Stabilization and color enhancement of anthocyanins

- The anthocyanin chemical structure
- Horticultural factors
- Copigmentation
- Metal complexation
- Anthocyanin-protein interactions
- Pyranoanthocyanins
- Microencapsulation
Anthocyanin Sources

Berries:
Simple pigments

Other Sources:
Complex pigments
Horticultural Factors Affecting Phenolic Accumulation

- Plant domestication can alter (reduce) anthocyanin and phenolic content
- Cultivar selection and growing conditions can affect pigment composition
- Insect infestation on blueberry induced phenolic accumulation and altered anthocyanin profile
Anthocyanin color may be enhanced and stabilized by co-pigments.
Color stability of anthocyanins in the presence of ascorbic acid and copigmentation

PACN Formation

Anthocyanins + Vitamin C

Day 0

Day 10

(1) = cyanidin
(2) = pyruvic acid
(3) cyanidin-3-galactoside pyruvic acid adduct
Metal Chelation Affects Anthocyanin Color and Stability

- Evaluate the effect of anthocyanin structure on color expression of chelate
- Investigate stability of chelates
Anthocyanin Encapsulation in Cold-Setting Gel

- Proved the feasibility of this encapsulation system for anthocyanins
- Compared color retention due to varying anthocyanin chemical structures

Collaboration with Kaletunc, FABE

Pectin-alginate gel
Anthocyanin Bioavailability and Bioactivity

- Anthocyanin stability in the GIT
  - Starting from the oral cavity
- Chemoprotective effects of anthocyanins on colon cancer
- Biotransformations in saliva
- Impact of pH on absorption of anthocyanins in the stomach
- Anthocyanin penetration in the skin
Some Practical Considerations

- Universal color solutions do not exist.
- Work with suppliers you trust
  - Colorant companies will work with you!
  - Solutions will be based on application and needs
- Creating new products will be easier than color matching old formulations
  - Some changes in the process may be needed
- Costs may increase, but customers may be willing to pay more
JFS Feature Article (Nov 2017)

“Establishing Standards on Colors from Natural Sources”

Expert Scientific Committee provided guidelines to protect safety and consumer trust.
Using colors from natural sources

YOU CAN AVOID…
- Synthetic ingredients
- Synthetic colors

YOU WILL HAVE…
- Ingredient from natural sources
- Healthier ingredients
- Cleaner labels
- And perhaps “super foods”
Thank you!

Global Foods Forum