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34TH INTERNATIONAL VEGETABLE TRAINING COURSE
"VEGETABLES: FROM SEED TO TABLE AND BEYOND"

Bioactive compounds (phytochemicals) in vegetables & fruits

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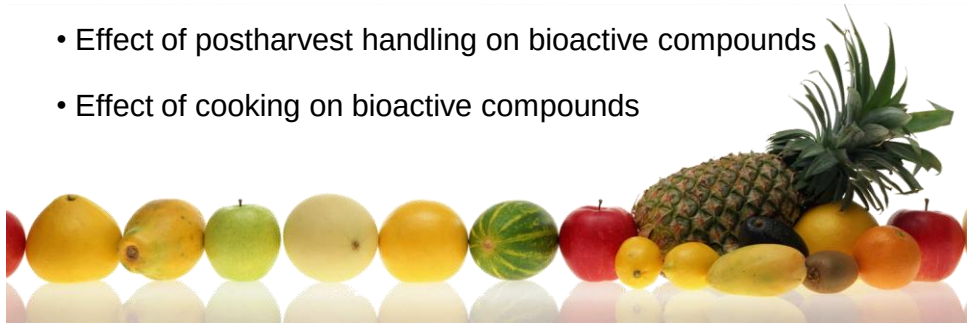
Course outline

- What are bioactive compounds?
- Types and sources of bioactive compounds and their health benefits
- Factors affect bioactive compound contents
- Effect of postharvest handling on bioactive compounds
- Effect of cooking on bioactive compounds



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FAO/WHO recommends to consume 400 g of fruits and vegetables per day.

Eat at least 5 portions of fruits and vegetables

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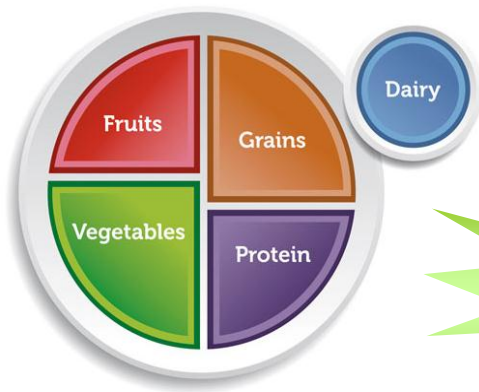
USDA ChooseMyPlate.gov
United States Department of Agriculture



Why??

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Because

Fruits and vegetables are sources of

- vitamins
- minerals
- fiber
- bioactive components

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Consumption of fruits and vegetables reduces risk of cancers and cardiovascular diseases 50 and 33 percent, respectively.

Lower blood pressure
Control blood glucose
Lower risk of digestive problems
etc.

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Dr. Ann Kulze, M.D.

Medical Advisory Board for the Wellness Councils of America and Prevent Cancer Foundation

www.drannwellness.com/video.cfm?VideoID=78

Professor Richard Mithen

Institute of Food Research (England)

foodandhealth.ifr.ac.uk/research-themes/food-bioactives/

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Phytochemicals

- It is found in fruits and vegetables
- Give color in the plants and act as plant protectors
- Maintain and improve health
- Four key features of phytochemicals

  Anti-inflammatory power: inflammation is the key of chronic diseases

  Antioxidant power

  Immune boosting power

  Detoxify property

- Examples: flavonoids, glucosinolates and n-3 polyunsaturated fatty acid

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What is bioactive compounds?

- Extranutritional constituents: occur in small quantities in food
- Plant-based bioactive compounds = **"Phytochemicals"**
  - Phyto means "plant" in Greek
  - Secondary metabolites synthesized by plants
  - Do not provide nutritive value
  - Function of bioactive compounds in plants:
    - Protect against stress
    - Plant hormones
    - Pigments (green, yellow, orange, etc.)
    - Photosensitizing and energy transferring compounds

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Where are the bioactive compounds accumulated?

- Leaves
- Flowers
- Fruits

- Roots/Tubers
- Bulb
- Bark/stem/ heart wood

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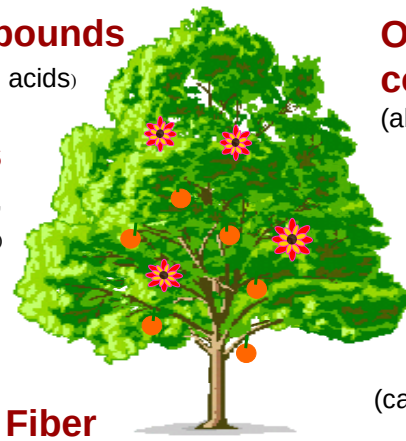
Major classes of bioactive compounds

Phenolic compounds
(flavonoids, phenolic acids)

Phytosterols
(stigmastanol, campasterol)

Terpenoids
(carotenoids)

Fiber
(soluble/insoluble fiber)



Organosulfur compounds
(allicin)

Glucosinolates
(isothiocyanates, indoles)

Alkaloids
(capsaicinoids, caffeine)

Betalains
(betaxanthin, betacyanin)

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Fiber

Sources: grains, wheat bran, oat bran, barley, nuts, seeds, beans , peas, fruits and vegetables

Mechanism of action:

- attracts water and turns to gel during digestion: slows digestion
- adds bulk to the stool and appears to help food pass more quickly through the stomach and intestines

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Fiber

Health benefits:

- Weight management and lower risk of obesity
- Diabetes prevention and management
- Lower blood cholesterol
- Management of gastrointestinal tract
- Lower risk of colon cancer

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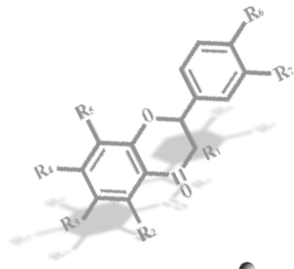
Phenolic compounds

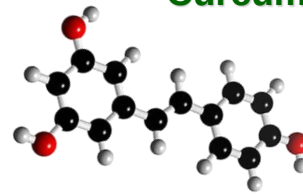
Flavonoids

- Flavonols
- Flavones
- Flavonones
- Flavanols
- Isoflavones
- Anthocyanins



Non-flavonoid compounds

- Phenolic acids
- Stilbenes
- Curcuminoids



Water soluble compounds

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Flavonoids	Sources
Flavonols	Onion, kale, broccoli, apple
Flavones	Parsley, celery, chili/pepper
Flavonones	Orange, grapefruit, lemon
Flavanols	Apple, tea, cocoa
Isoflavones	Soybean
Anthocyanins (Pigments: blue, purple, red)	Grape, blue berry, strawberry

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Health benefits:

- Prevention disorder of gastric and duodenal ulcers
- Reduce risk of cancers and act as anti-cancer agents
- Lower blood cholesterol
- Heart disease prevention
- Prevention of osteoporosis

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Phenolic acids

Two major subclasses:

hydroxybenzoic acids and hydroxycinnamic acids

Sources: Coffee
Grains
Fruits
Vegetables
Nuts

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Health benefits:

- Prevention or treatment of cancers
- Prevention of atherosclerosis
- Lower blood glucose

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Stilbenes

Resveratrol

Sources: grape, peanut, itadori tea

Health benefits:

- ✓ Increase metabolism: burn fat and calories
- ✓ Prevention of coronary disease
- ✓ Defense against cancers: chemopreventive and chemotherapeutic activity

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Curcumin

Bright yellow pigment

Sources: turmeric

Health benefits:

- ✓ Prevention of cancers (skin and colon cancer)
- ✓ Prevention Alzheimer's disease
- ✓ Lower risk of cardiovascular diseases
- ✓ Reduce risk or treatment of diabetes mellitus

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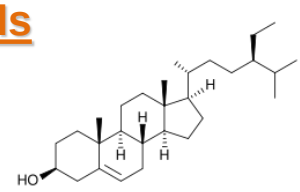
Phytosterols

Fat soluble compounds

Sources: Nuts
Seeds
Beans
Vegetable oils
Margarine



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Phytosterol contents in some nuts and seeds

Type of Nut/Seed	Total Phytosterols (mg/100g)
Almonds	89-208
Cashew nut	80-158
Hazelnut	54-121
Macadamia	96-187
Pistachio	279-297
Pumpkin seed	94-265
Sesame seed	**400-404**
Sunflower seed	176-322

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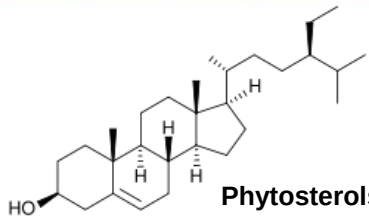
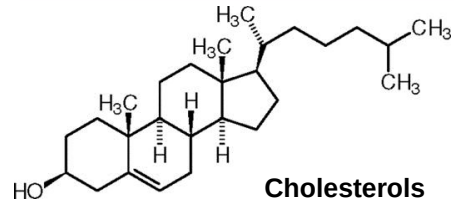


Phytosterols

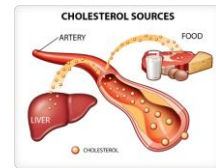


Cholesterols

Competitively absorption between cholesterols and phytosterols

"Phytosterols are easier to absorb than cholesterols."

Health benefits:



- **Lower blood cholesterol**
- **Reduce the risk of cardiovascular diseases**

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Carotenoids

Fat soluble compounds

Pigments: yellow-orange-red

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Carotenoids

Carotenes	Xanthophylls	Lycopene
β-carotene	Lutein	
α-carotene	Zeaxanthin	
	β-cryptoxanthin	

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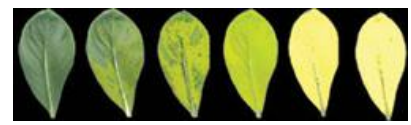
Sources: Fruits and vegetables
(also green leafy vegetables)



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Examples of major contributors of carotenoids in North American diet

Carotenoid	Food source	Amount
β-Carotene	Apricot, dried	17600
	Carrots, cooked	9771
	Spinach, cooked	5300
	Green Collard	5400
	Canteloupe	3000
	Beet Green	2560
	Broccoli, cooked	1300
	Tomato, raw	520
α-Carotene	Carrots, cooked	3723
Lycopene	Tomatoes, raw	3100
	Tomato juice	10000
	Tomato paste	36500
	Tomato ketchup	12390
	Tomato sauce	13060
β-Cryptoxanthin	Tangerine	1060
	Papaya	470
Lutein	Spinach, cooked	12475
	Green collard	16300
	Beet, green	7700
	Broccoli, cooked	1839
	Green peas, cooked	1690

Gac fruit contain lycopene 70 times more than tomato.

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Health benefits:

Carotenes: β-carotene & α-carotene

- Convert to vitamin A
- Reduce risk of cardiovascular diseases
- Reduce risk of cancers
- Reduce risk of osteoporosis
- Improve immune function

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Xanthophylls: lutein & zeaxanthin

- Pigments in macula and retina (eyes)
- Protect tissues from phototoxic damage
- Prevention of cancers

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Lycopene

- Reduce risk of cardiovascular diseases
- Reduce risk of cancers, particularly prostate, breast, cervical, ovarian and liver cancers
- Reduce the risk of osteoporosis
- Protective effect in hypertension
- Improvement of sperm motility

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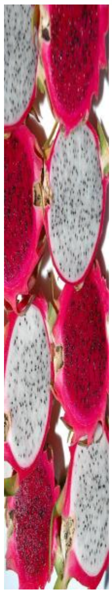
Betalains

Water soluble compounds

Pigments: yellow (betaxanthins)

red-violet (betacyanins)

Sources: yellow beet, red beet, dragon fruit, cactus pear, Swiss chard, Amaranth leaves



Health benefits:

Reduce risk of cancers and act as chemopreventive agent

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Allicin

Organosulfur compounds

Sources: Garlic
Shallot
Onion
Scallion
Chinese leek
Chinese chive

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Health benefits:

Prevention and treatment of cancers

Reduce risk of atherosclerosis

Reduce blood cholesterol

Reduce fat deposition

Decrease blood pressure

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Isothiocyanates

Sulforaphane

Sources: Cruciferous vegetables (e.g. broccoli, cauliflower, kale, turnips, collards, Brussels sprouts, cabbage, radish, and watercress)

Mustard

Wasabi

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Health benefits:

Potential compounds which can inhibit carcinogenesis and tumorigenesis

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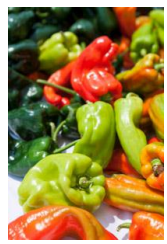
Capsaicinoids

Fat soluble compounds

Give pungent taste (hot)

Sources: **pepper and chili**



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Health benefits:

- Reduce pain sensation
- Cancer prevention
- Weight reduction (increase energy expenditure)
- Inhibit platelet aggregation
- Reduce the incidence of cardiovascular diseases

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Example:
Bioactive compounds in plants

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Rice

Japonica rice

Indica rice

Basmati rice

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Dehusking and milling

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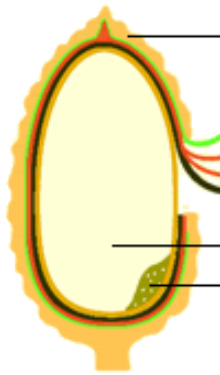
Bioactive components in rice



γ-aminobutyric acid
Vitamin E
γ-Oryzanols
Phenolic acids
Anthocyanins

γ-aminobutyric acid (GABA)

Carbohydrate
Anthocyanin

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Comparison of bioactive components and antioxidant activities in different rice

Red rice VS White rice

Dehusked | Undermilled | Milled

(Finocchiaro *et al*., 2007)

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Bioactive components and antioxidant activities in different rice

Rice	Ferulic acid[1]	Anthocyanin[1]	Vitamin E[1]	γ-Oryzanol[1]	AA[2]
Red rice					
Dehusked	120.8	76.00	50.4	470	12.33
Undermilled	52.9	17.95	30.7	255	2.53
Milled	25.6	2.47	14.7	90	2.34
White rice					
Dehusked	66.2	Not detected (nd)	43.4	744	1.01
Undermilled	11.1	nd	10.1	191	0.88
Milled	5.9	nd	10.2	58	0.83

[1] unit in mg/kg,
[2] antioxidant activity unit in mmolTrolox/kg

(Finocchiaro *et al*., 2007)

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Bioactive compounds in Chinese kale

Isothiocyanates

- Phenolic compounds (Flavonoids)
- Carotenoids





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Bioactive compounds in bitter gourd

- Charantin
- Vicine

} Lower blood glucose

- Cucurbitacins: induce appotosis
- Phenolic compounds






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Bioactive compounds in pumpkin






- **Carotenoids (lutein, β-carotene)**
- Phenolic compounds (flavonoids, phenolic acid)
- Cucurbitacins
- Vitamin C

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Bioactive compounds in tomato

- **Carotenoids (lycopene)**
- Vitamin C
- Phenolic compounds (flavonoids)




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Bioactive compounds in pepper/chili

Capsaicinoids: pungent taste

Carotenoids

capsanthin
β-cryptoxanthin,
antheraxanthin,
violaxanthin

lutein & violaxanthin

anthocyanin

Flavonoids: high flavonoid content

Phenolic acids

Vitamin C

Vitamin E

Chlorophyll

capsanthin &
capsorubin

Combination of carotenoids & chlorophyll

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Bioactive compounds in *Allium* species (e.g. garlic, shallot, onion)

- ✓Organosulfur compound: allicin
- ✓Flavonoids (flavanols, anthocyanins)
- ✓Phenolic acids
- ✓Saponins (terpene/steroid + sugar)

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Bioactive compounds in turmeric

- **Curcumin**
- Carotenoids (β-carotene)
- Phenolic acids
- Phytostrols
- Vitamin C

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Bioactive compounds in black pepper

Piperine: alkaloids (antitumor activity)

Flavonoids

Phenolic acids

Phytosterols

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Bioactive compounds in berry

- ✓ Phenolic compounds (flavonoids, phenolic acid)
- ✓ Vitamin C
- ✓ Carotenoids (Goji berry)

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Bioactive compounds in guava

- ➢Vitamin C
- ➢Phenolic compounds (flavonoids, catechin)
- ➢Carotenoids (lycopene)

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Bioactive compounds in pineapple

- ✓Carotenoids (lutein and zeaxanthin)
- ✓Phenolic compounds (phenolic acids, catechin)
- ✓Saponins
- ✓Phytosterols




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Bioactive compounds in mango

- ➢ Carotenoids (lutein, zeaxanthin, β-carotene)
- ➢ Phenolic compounds (flavonoids, tanin, phenolic acids)
- ➢ Vitamin C





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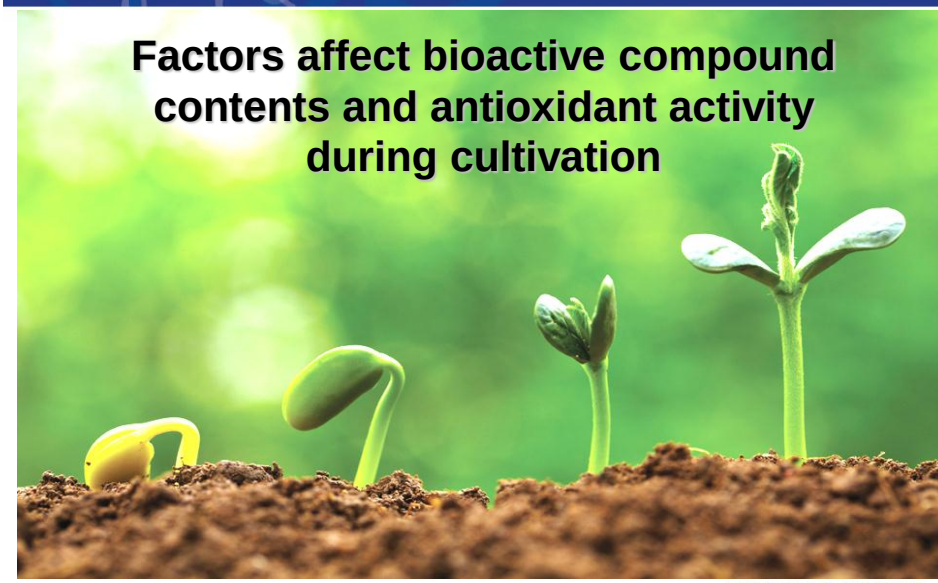

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Effect of genotypes with varying flesh colour on bioactive components and antioxidant activities in sweet potato


Orange


Light orange


Yellow


Purple


Light purple


White

(Teow *et al*., 2007)

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Bioactive components in different sweet potato genotypes

Sample	Phenols (mg/g)	Total anthocyanin (mg/g)	β-carotene (µg/g)
Xushu 18	0.003	ND (Not detected)	0.2
11-12	0.011	ND	1.5
13-1	0.033	ND	2.3
11-16	0.118	ND	13.0
12-7	0.130	ND	29.8
12-17	0.108	ND	11.8
Beauregard	0.211	ND	**92.3**
Hernandez	0.517	ND	**167**
Covington	0.183	0.038	**120**
11-5	0.168	0.017	**77.1**
11-20	0.472	ND	**226**
13-14	0.130	ND	**44.9**
13-15	0.140	ND	**127**
12-9	0.248	0.030	22.3
13-6	0.257	0.069	56.6
NC415	**0.792**	**0.430**	6.3
12-5	**0.477**	**0.246**	46.9
13-17	**0.571**	**0.322**	31.3
13-18	**0.949**	**0.531**	5.4

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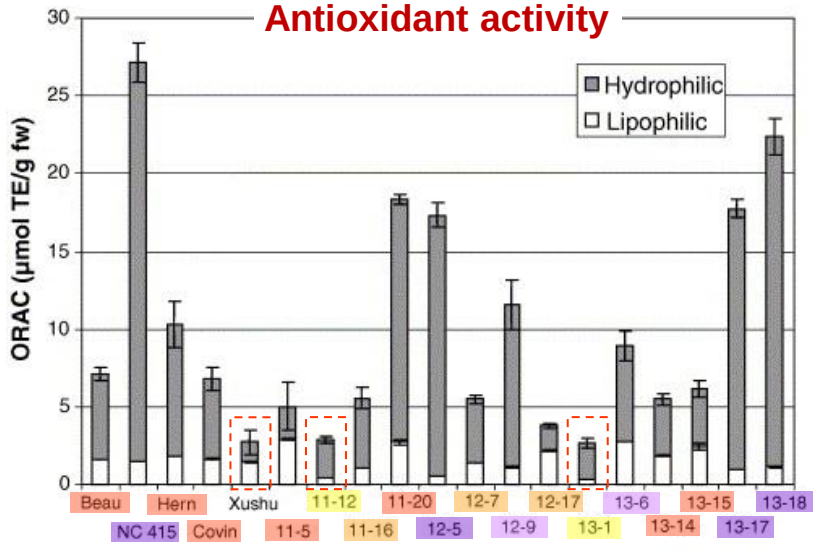
Antioxidant activity



(Teow *et al*., 2007)

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Genotypes (flesh color) affected bioactive compounds (amount and type) and antioxidant activities.

(Teow *et al*., 2007)

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Effect of genotype, cultivated area and year on bioactive components in chickpea

Three different genotypes

Three different areas

Two different years of cultivation (2003 and 2004)

(Nikolopoulou *et al*., 2006)

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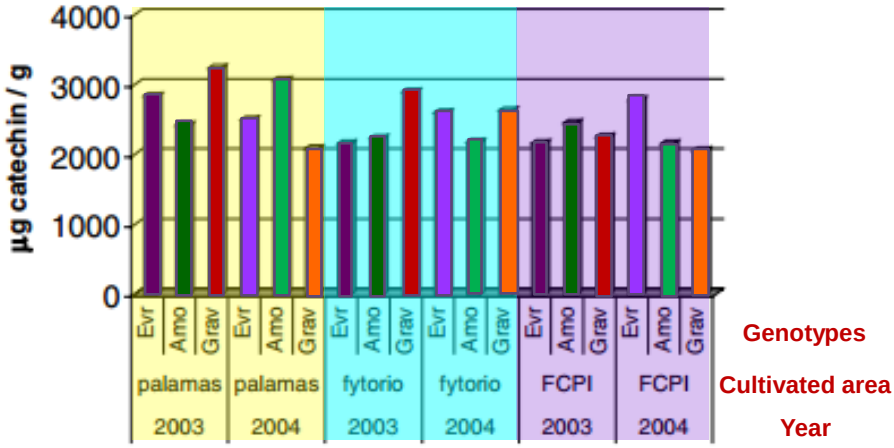
Tannin contents in chickpeas



Evr = Evros, Amo = Amorgos, Grav = Gravia

(Nikolopoulou *et al*., 2006)

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Genotypes, cultivated areas and years of cultivation affected tannin contents.

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Effect of different environment on bioactive components in lettuce

Green house

Open-air grown

(Romani *et al.*, 2002)

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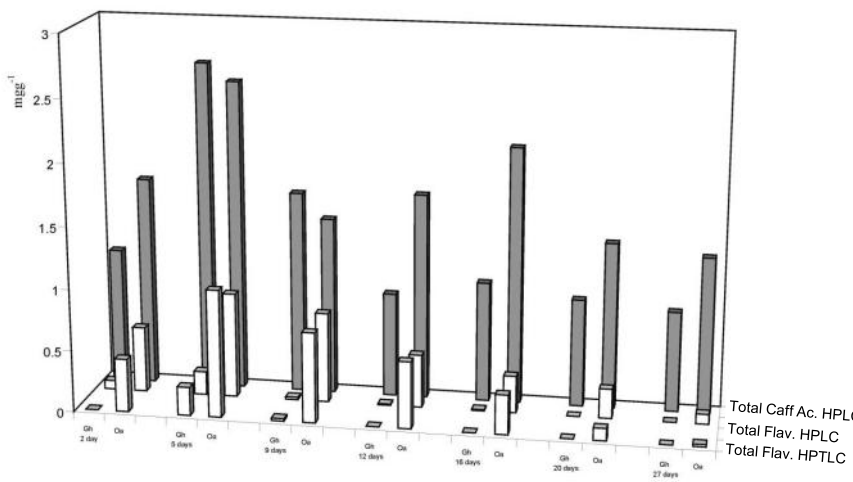

Gh = Green house
Oa = Open air

(Romani *et al.*, 2002)

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Effect of maturity and season on bioactive components and antioxidant activities in strawberry

Maturity: 10 stages

Season: Summer vs Winter

(Ferreyra *et al.*, 2007)

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Anthocyanins = red color

SG = small green

LG = large green

W = white

5-100%R = 5-100% red

BR = bright red

PR = purple red

(Ferreyra *et al.*, 2007)

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Total phenols

SG = small green

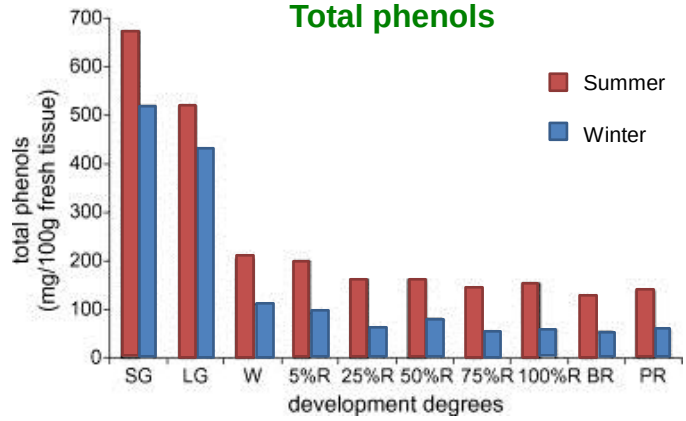
LG = large green

W = white

5-100%R = 5-100% red

BR = bright red

PR = purple red



(Ferreyra *et al.*, 2007)

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Vitamin C

SG = small green

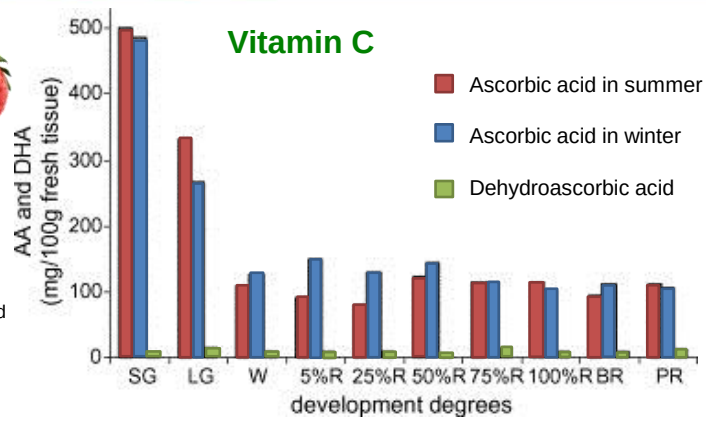
LG = large green

W = white

5-100%R = 5-100% red

BR = bright red

PR = purple red



(Ferreyra *et al.*, 2007)

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SG = small green

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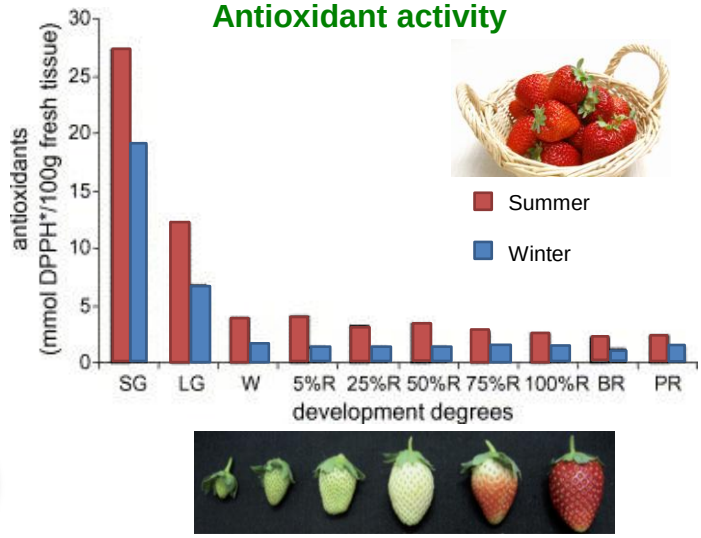
Antioxidant activity



(Ferreyra *et al*., 2007)

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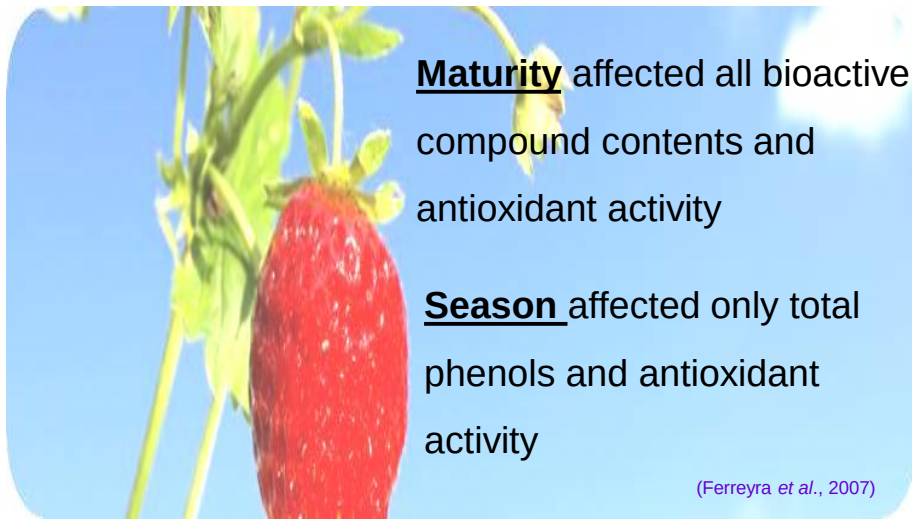

Maturity affected all bioactive compound contents and antioxidant activity

Season affected only total phenols and antioxidant activity

(Ferreyra *et al*., 2007)

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Effect of fruit tissue on bioactive components in nectarine

Nectarine (white-,yellow-flesh)

Peel

Flesh

(Gil *et al*., 2002)

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Bioactive compounds and antioxidant activities in peel and flesh tissues in white-/yellow-flesh nectarines

White cultivar	Fruit tissue	Total phenolics[1]	Ascorbic acid[1]	β-carotene[2]	β-cryptoxanthin[2]	Antioxidant activity[1]
Arctic Star	peel	875	93	570	Not detected (nd)	393
	flesh	154	42	40	nd	84
Arctic Queen	peel	904	160	170	30	553
	flesh	303	78	100	nd	145
Arctic Snow	peel	929	200	310	50	984
	flesh	454	122	40	nd	402
Fire Pearl	peel	418	134	50	80	230
	flesh	91	69	20	50	46
Brite Pearl	peel	2020	191	280	80	1447
	flesh	901	95	80	nd	837

Yellow cultivar	Fruit tissue	Total phenolics[1]	Ascorbic acid[1]	β-carotene[2]	β-cryptoxanthin[2]	Antioxidant activity[1]
Red Jim	peel	1403	130	1870	240	981
	flesh	415	55	730	140	317
August Red	peel	755	118	2730	270	459
	flesh	287	58	1280	140	159
Spring Bright	peel	829	114	3070	310	471
	flesh	247	35	850	210	126
May Glo	peel	629	119	1920	250	277
	flesh	155	61	580	80	62
September Red	peel	427	78	1990	280	283
	flesh	138	53	1310	150	120

[1] unit in mg/kg, [2] unit in µg/kg

(Gil *et al*., 2002)

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Different fruit tissue accumulated different amount of bioactive compounds and antioxidant activities.

Bioactive compound contents and antioxidant activities were different depended on cultivar/genotypes.

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Effect of fertilizer on bioactive components and antioxidant activity in cassava tubers

Empty fruit bunch compost
(N: 1.46%, P: 1.47%, K: 2.58%)

Vegetable waste vermicompost
(N: 2.32%, P: 1.54%, K: 1.06%)

Inorganic fertilizer
(N: 15%, P: 15%, K: 15%)

Medan
Sri Pontian

Omar *et al.*, 2012

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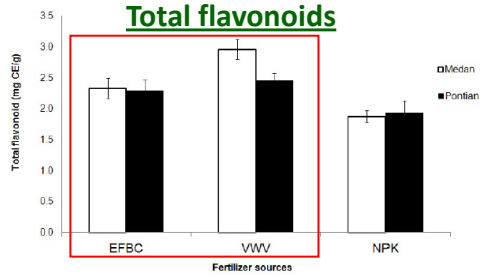
Total flavonoids



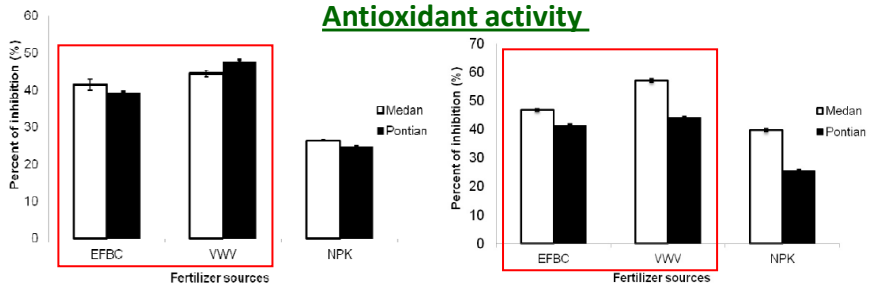
Organic fertilizer

EFBC = Empty fruit bunch compost

VWV = Vegetable waste vermicopost

NPK = Inorganic fertilizer

Antioxidant activity



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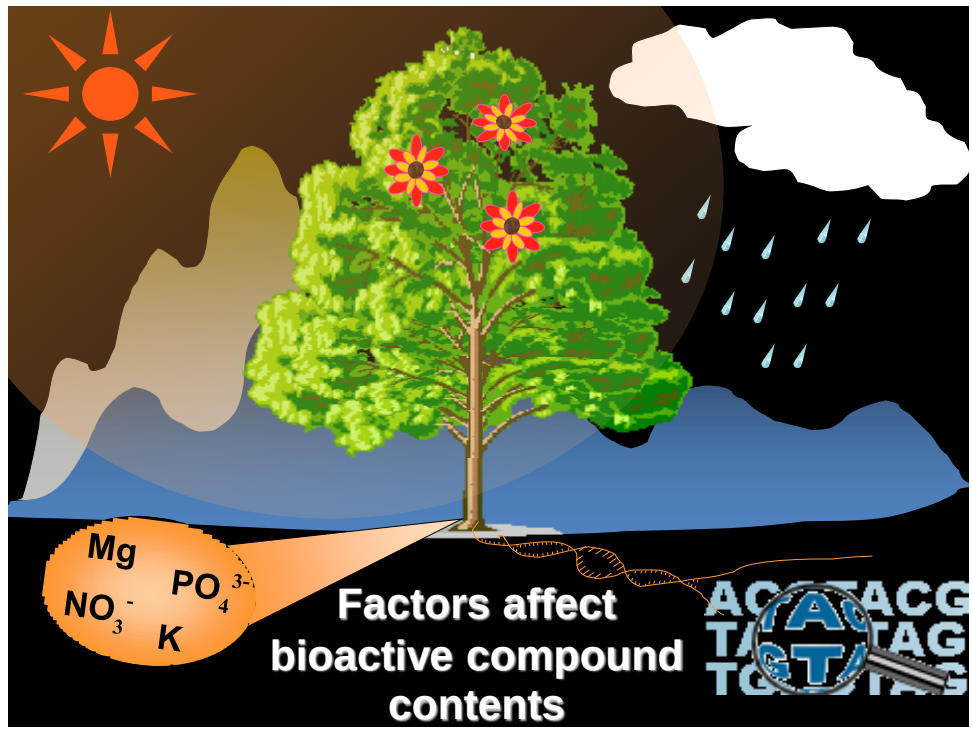

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Effect of postharvest handling on bioactive compounds

Postharvest handling: The stage that occurring in the period after harvest

- Cleaning
- Packing
- **Processing**
- **Storage**
- Transportation
- Distribution

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Post harvest handling: Processing

- **Changes glucosinolate content in broccoli heads by shredding**
- **Comparisons on bioactive components and antioxidant activity of fresh, freeze-dried and hot-air-dried tomatoes**

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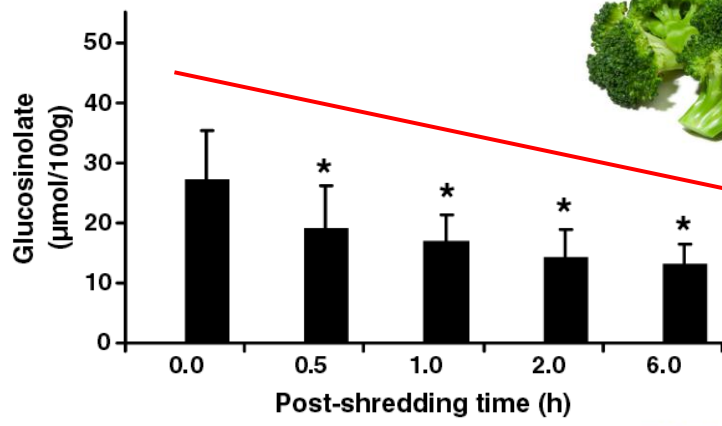
Changes glucosinolate content in broccoli heads by shredding



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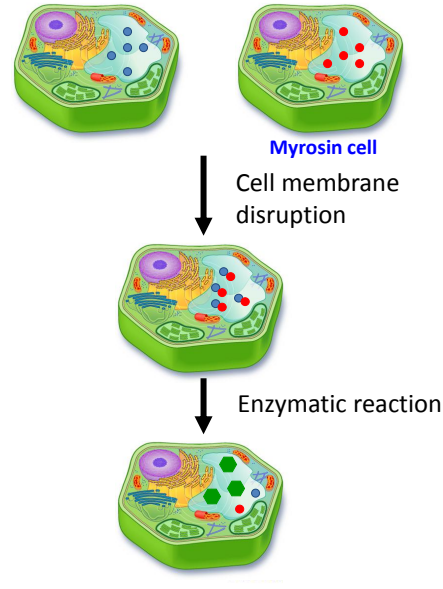
Glicoraphanin ●
(Glucosinolate)

Myrosinase ●
(enzyme)

Sulforaphane ⬢
(Isothiocyanate)



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Comparisons on bioactive components and antioxidant activity of fresh, freeze-dried and hot-air-dried tomatoes

Fresh

Freeze-dried

Hot air-oven dried

(Chang *et al.*, 2006)

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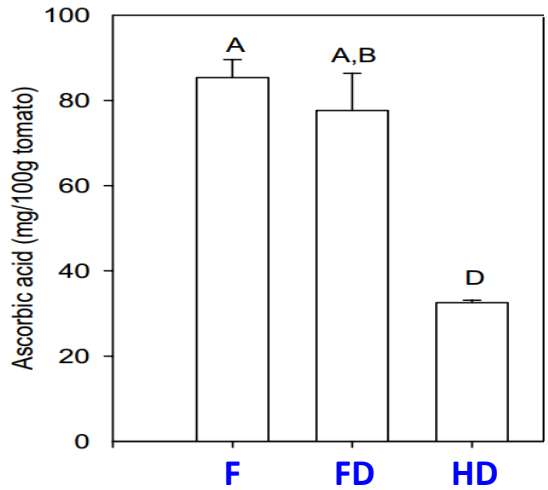
Vitamin C



F = Fresh, FD = Freeze dried, HD = Hot-air-dried

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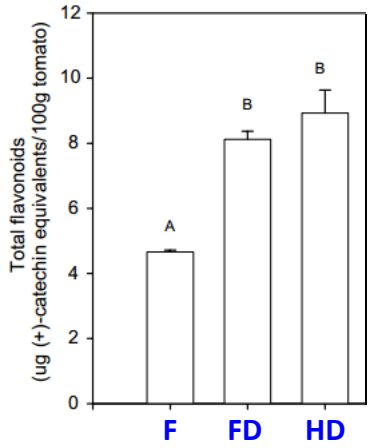
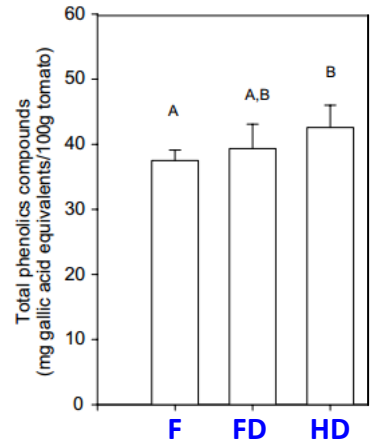
Total flavonoids and total phenolics





F = Fresh, FD = Freeze dried, HD = Hot-air-dried

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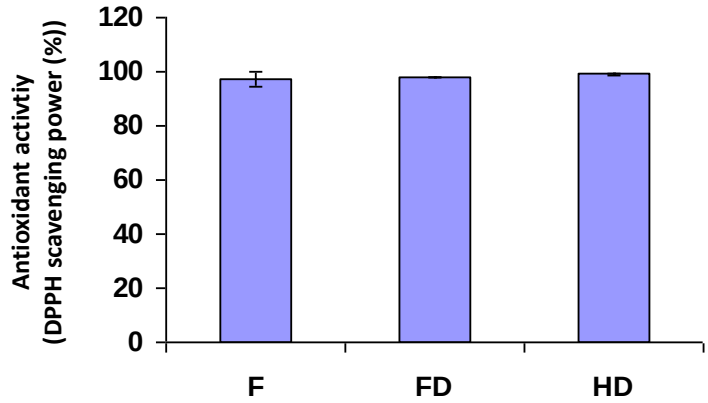
Antioxidant activity



F = Fresh, FD = Freeze dried, HD = Hot-air-dried

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- Different food processes affect phytochemical contents and antioxidant activity in different ways.
- Drying processes reduced vitamin C, particularly a high temperature process.
- Flavonoids & phenolic acids: high temperature of hot-air-drying process or very low temperature of freeze drying process would deactivate enzyme that is the cause of browning reaction.

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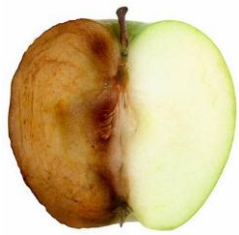
Enzymatic browning reaction



is a process of becoming brown.

- Desirable: developing flavor in tea
- Undesirable: fresh fruit and vegetables

Enzyme: Polyphenol oxidase (PPO)

Phenolic compounds

Oxygen

Water

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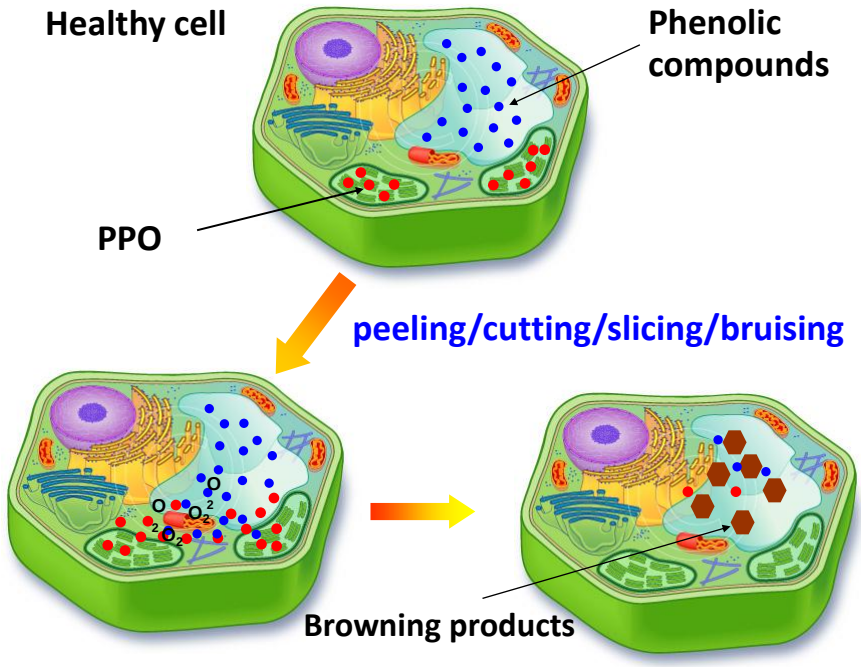

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The techniques for preventing enzymatic browning

- Dip in acid solution: lemon juice
- Thermal process: blanching
- Keep in low temperature (reducing rate of reaction)
- Remove oxygen: vacuum pack, flush with nitrogen
- Use chemicals such as sulfites and citrates

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Post harvest handling: Storage

- Changes in phenolic acids,carotenoids, total phenolics and antioxidant activities in sweet potato during storage

Stored at 15 °C and 80-85%RH in the dark

0, 4, 8 months

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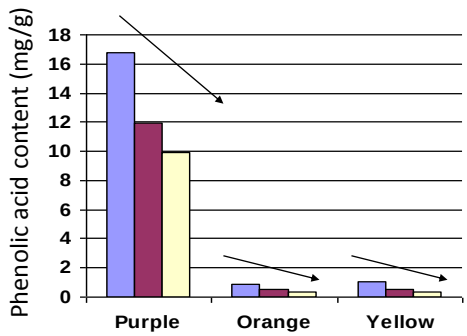
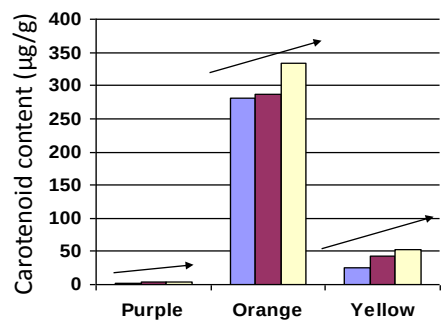
Phenolic acids



Carotenoids



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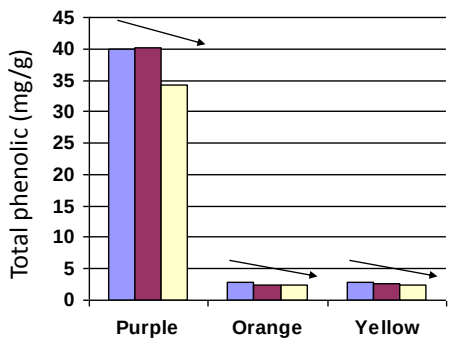
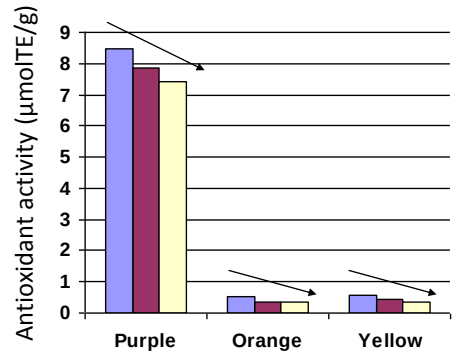
Total phenolics



Antioxidant activity



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Effect of cooking on bioactive compounds

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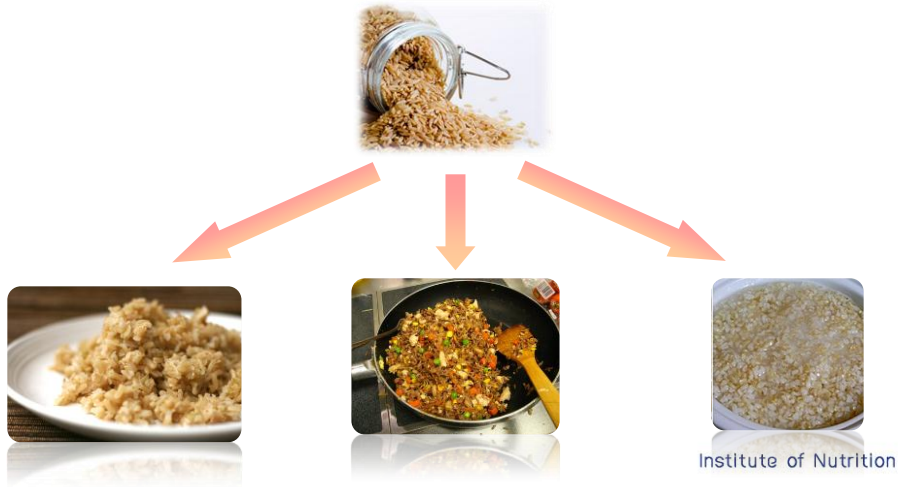
Effect of cooking, frying and boiling on bioactive compounds and antioxidant activities in rice



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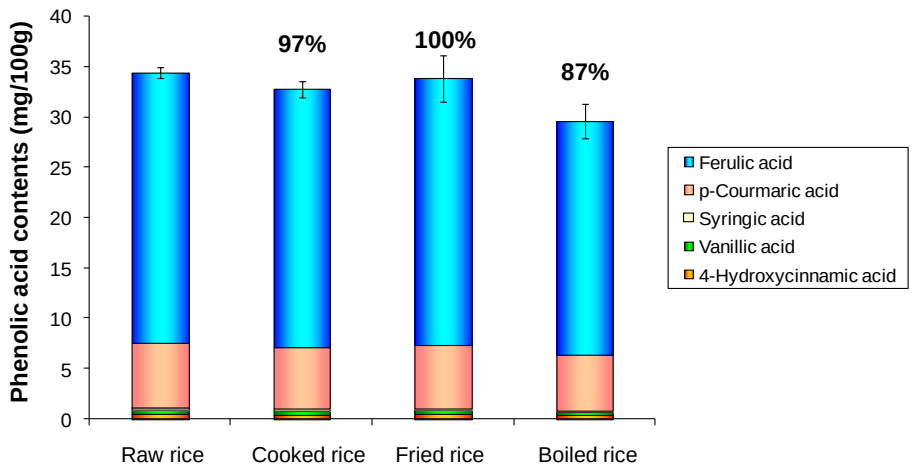
Phenolic acids in rice with different cooking methods



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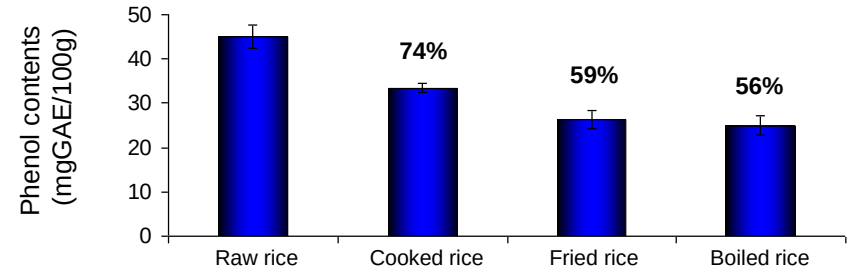
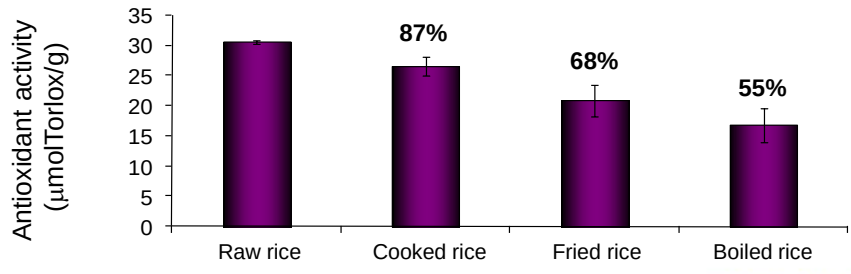
Phenol contents and antioxidant activities in rice with different cooking methods





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Effect of different cooking methods on carotenoids, phenols and antioxidant activities in colored peppers

5 varieties of color peppers

- **Raw**
- **Microwave Heating 5 min**
- **Boiling**
  - **5 min**
  - **30 min**
- **Stir-frying 5 min**

(Chuah *et al*., 2008)

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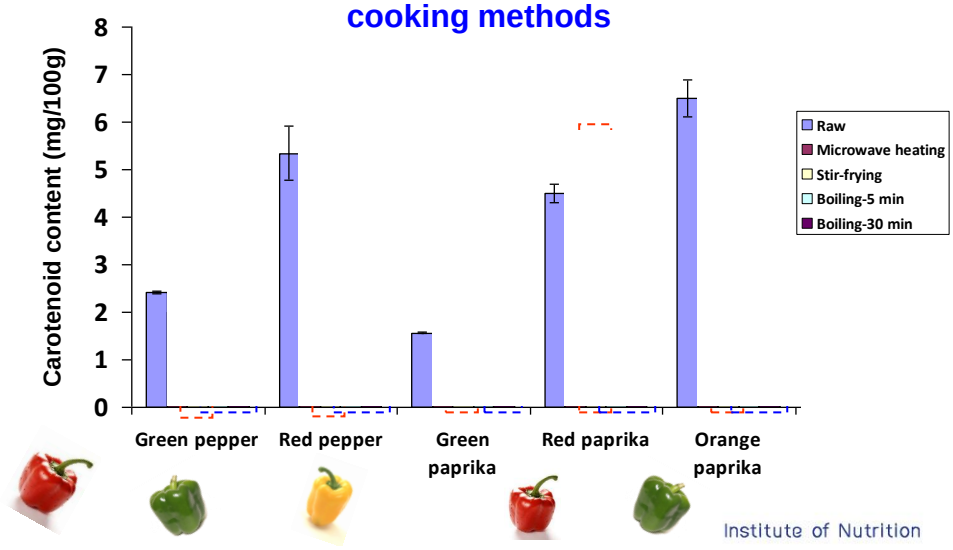
Carotenoid contents in colored peppers with different cooking methods



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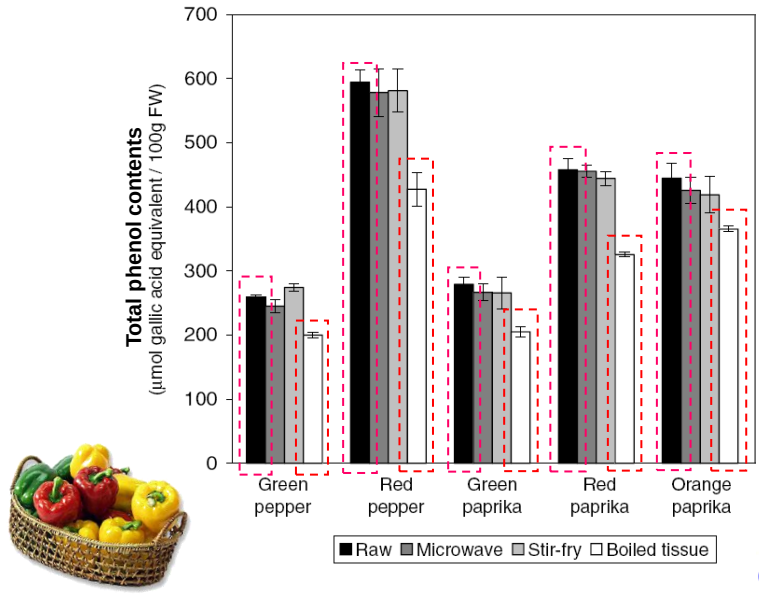
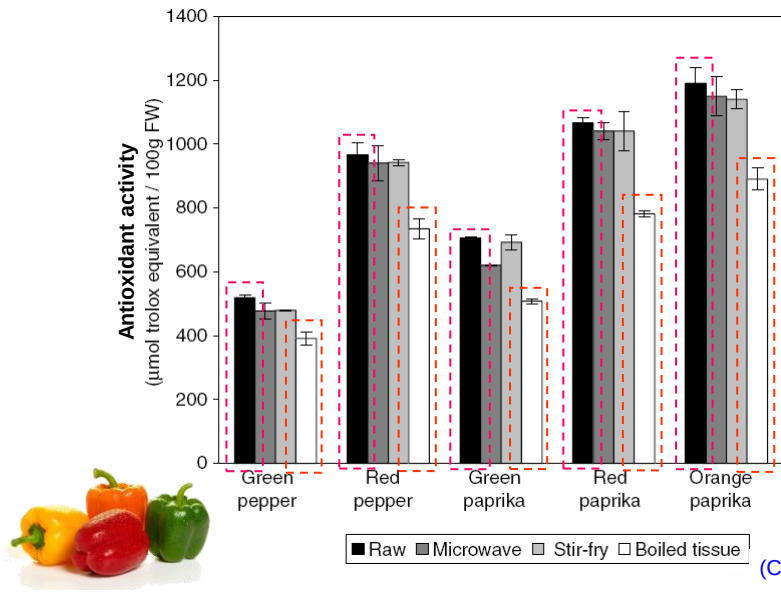
Change in total phenol contents of colored peppers after 5 minutes of cooking



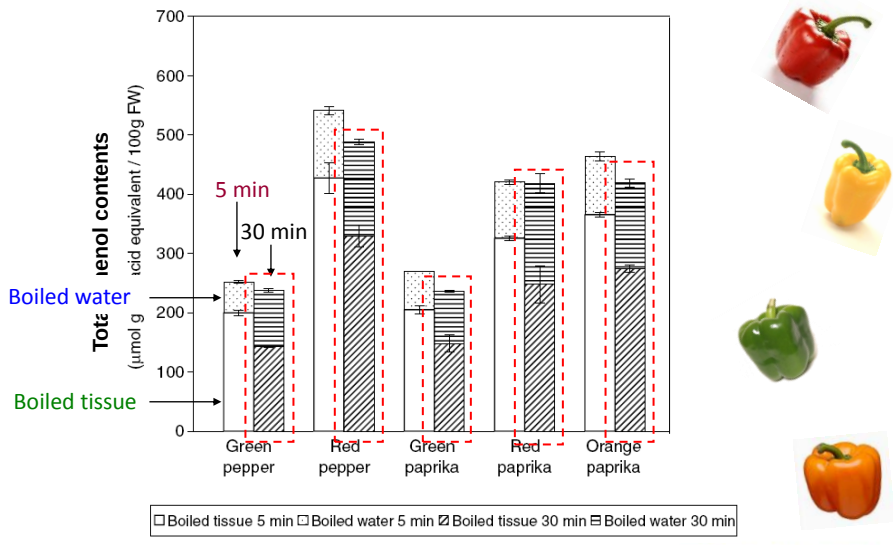
(Chuah *et al.*, 2008)

Change in antioxidant activities of colored peppers after 5 minutes of cooking



(Chuah *et al.*, 2008)

Change in total phenol contents of colored peppers after 5 and 30 minutes of boiling



(Chuah *et al.*, 2008)

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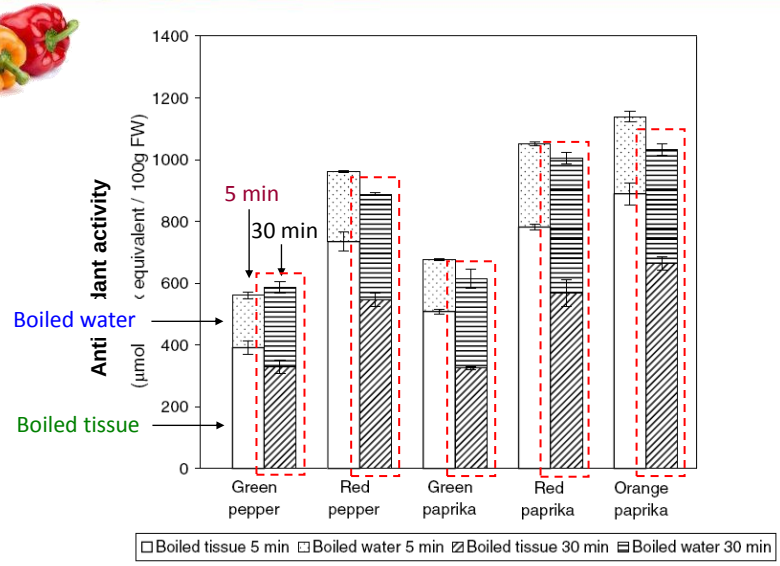
Change in antioxidant activities of colored peppers after 5 and 30 minutes of boiling



(Chuah *et al*., 2008)

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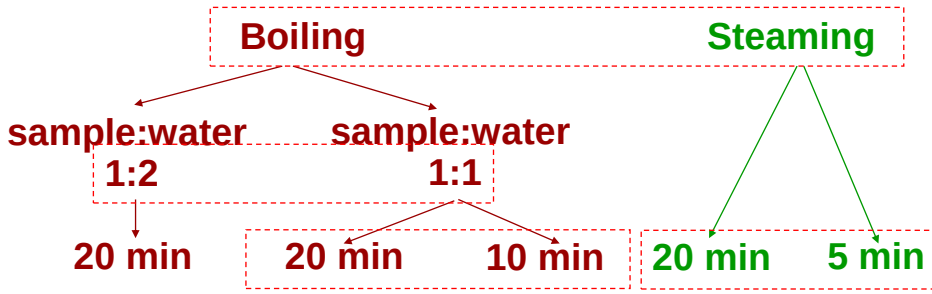
Effect of boiling and steaming on phenols and antioxidant activities in red cabbages

(koda and kissendrup)



(Podsędek *et al*., 2010)

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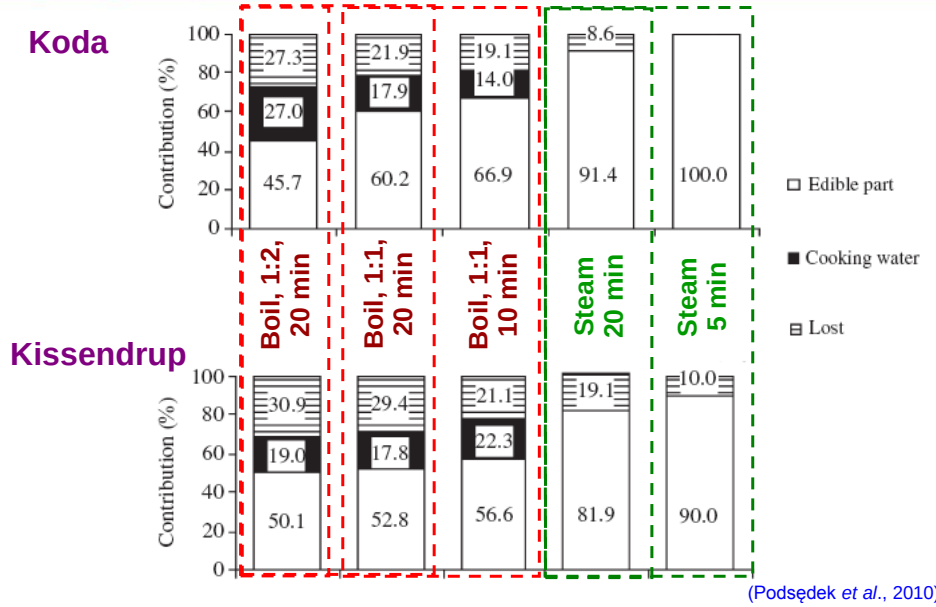
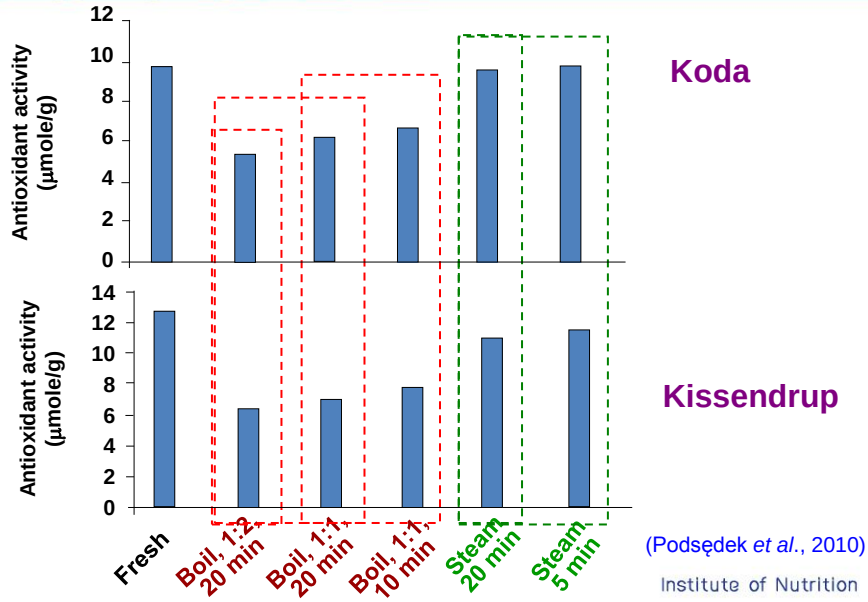
Phenol contents in edible part, cooking water and lost observed in red cabbages



(Podsędek *et al*., 2010)

Effect of different cooking methods on antioxidant activities in red cabbage



(Podsędek *et al*., 2010)

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Effect of cooking time on carotenoids, phenols and antioxidant activities in broccoli



Floret **Stem**

Conventional cooking (boiling)

0, 30, 60, 90, 120, 300 seconds

(Zhang and Hamauzu, 2004)

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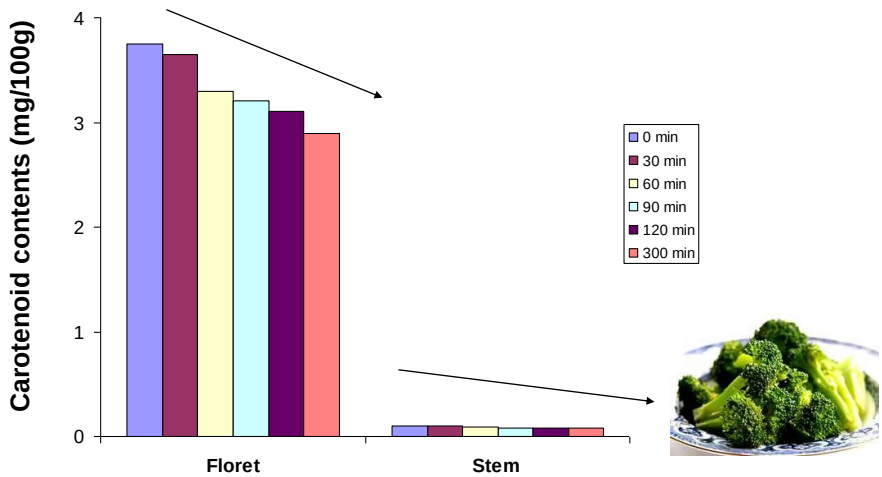
Carotenoid contents in broccoli floret and stem



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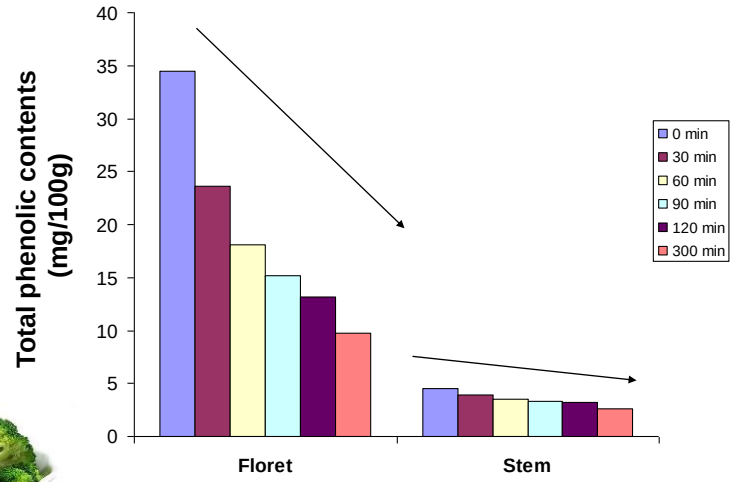
Total phenolic contents in broccoli floret and stem



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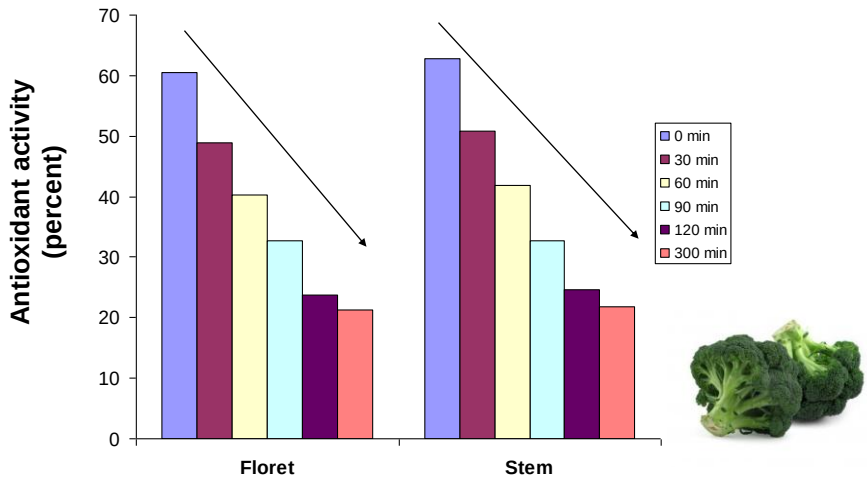
Antioxidant activities in broccoli floret and stem



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Effect of size of white saffron on total phenols and antioxidant activities during blanching

White saffron

↓

Whole vs Grated

↓

Blanching

(Pujimulyani *et al*., 2004)

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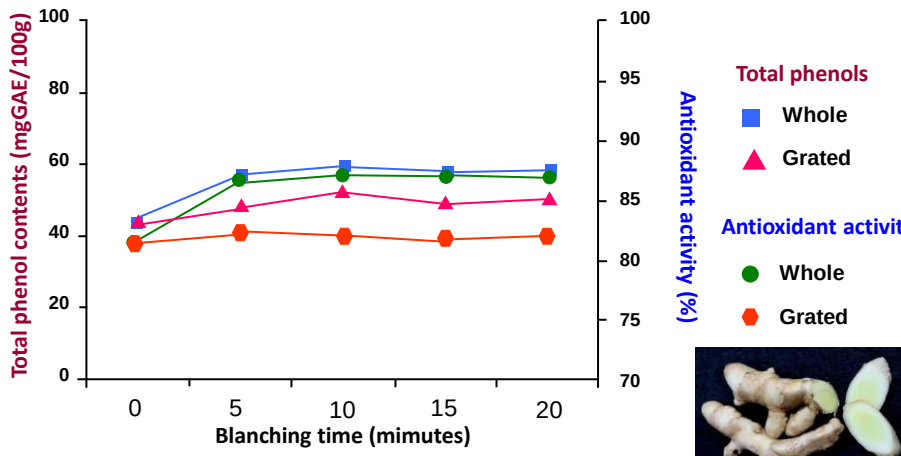

(Pujimulyani *et al*., 2004)

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Factors affect bioactive components and antioxidant activities during cooking

- Plant material (genotype, part of plant material)
- Types of bioactive components
- Method/condition of cooking
  - Temperature
  - Time
  - Size
  - Ratio of sample to water (blanching or boiling)

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Types of bioactive components

Water soluble compounds

- Phenolic compounds
- Betanins

Fat soluble compounds

- Carotenoids
- Phytosterols

Water soluble compounds are easily to loss by cooking methods that use water as media compared to fat soluble compounds.

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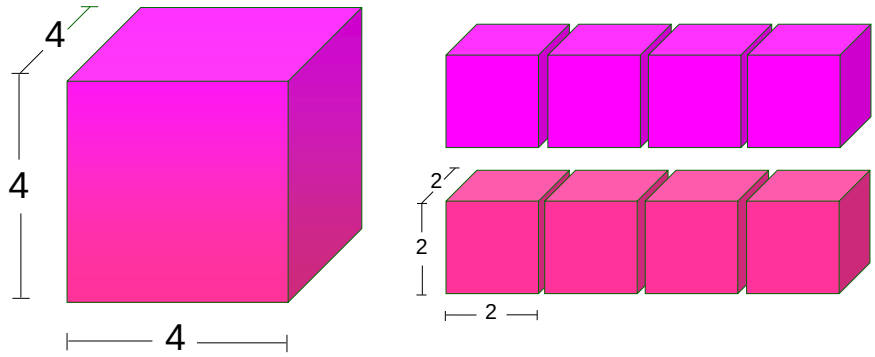
Size



Surface area:

16x6 = 96 cm^2

4x6 = 24 cm^2 per cube

24x8 = 192 cm^2

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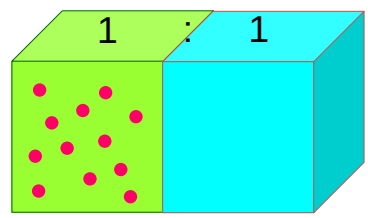
Ratio of sample to water: Diffusion

Concentration

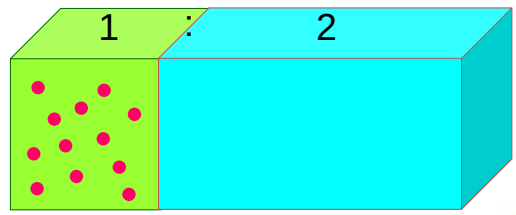
6/1 = 6

Concentration = $\frac{\text{Amount}}{\text{Volume}}$



Concentration

6/1 = 6



4/1 = 4

8/2 = 4

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Think back of what we eat



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Thai cuisine







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Local edible plants

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Could you share traditional dish(es) in your country?

What are the ingredients in them?

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Pakistan





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Solomon Islands




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Republic of Kiribati

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Burkina Faso

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Jordan




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Eat Various Foods and Do Not Always Eat the Same Dishes Repeatedly




Obtain various nutrients and bioactive components.




Also decrease accumulation of toxic substances from foods in our body.

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Thank you

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