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The 34th International Vegetable Training Course
Vegetables: From Seed to Table and Beyond

"Food Safety and Nutrition Security"

Food Processing and Nutritional Quality of Vegetables and Fruits

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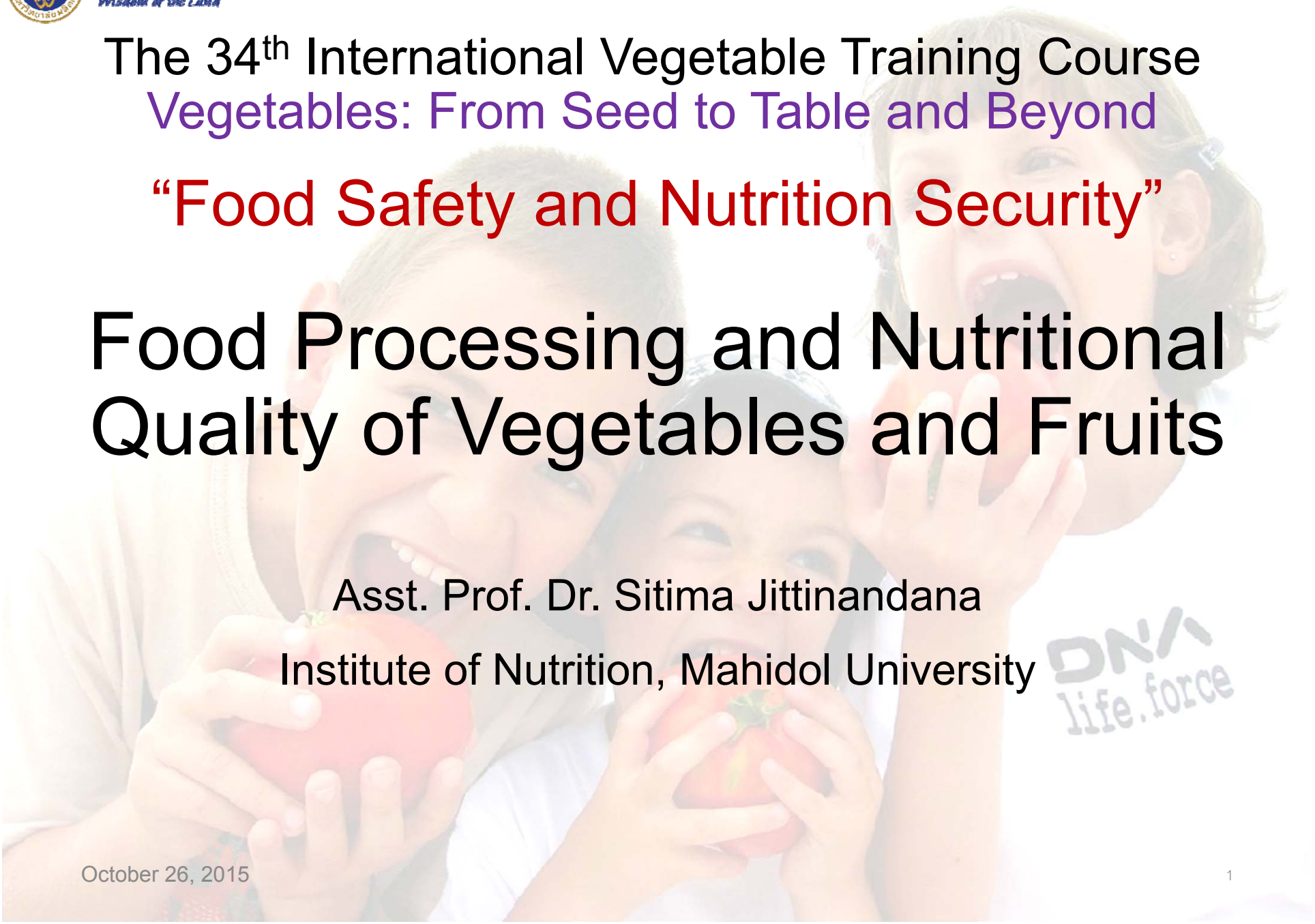


Objectives

- To overview changes of nutrients due to postharvest handling, food preparation, food processing and household cooking
- To determine appropriate preparation, processing and cooking of vegetables and fruits in order to prevent, reduce or avoid undesirable changes

Outline

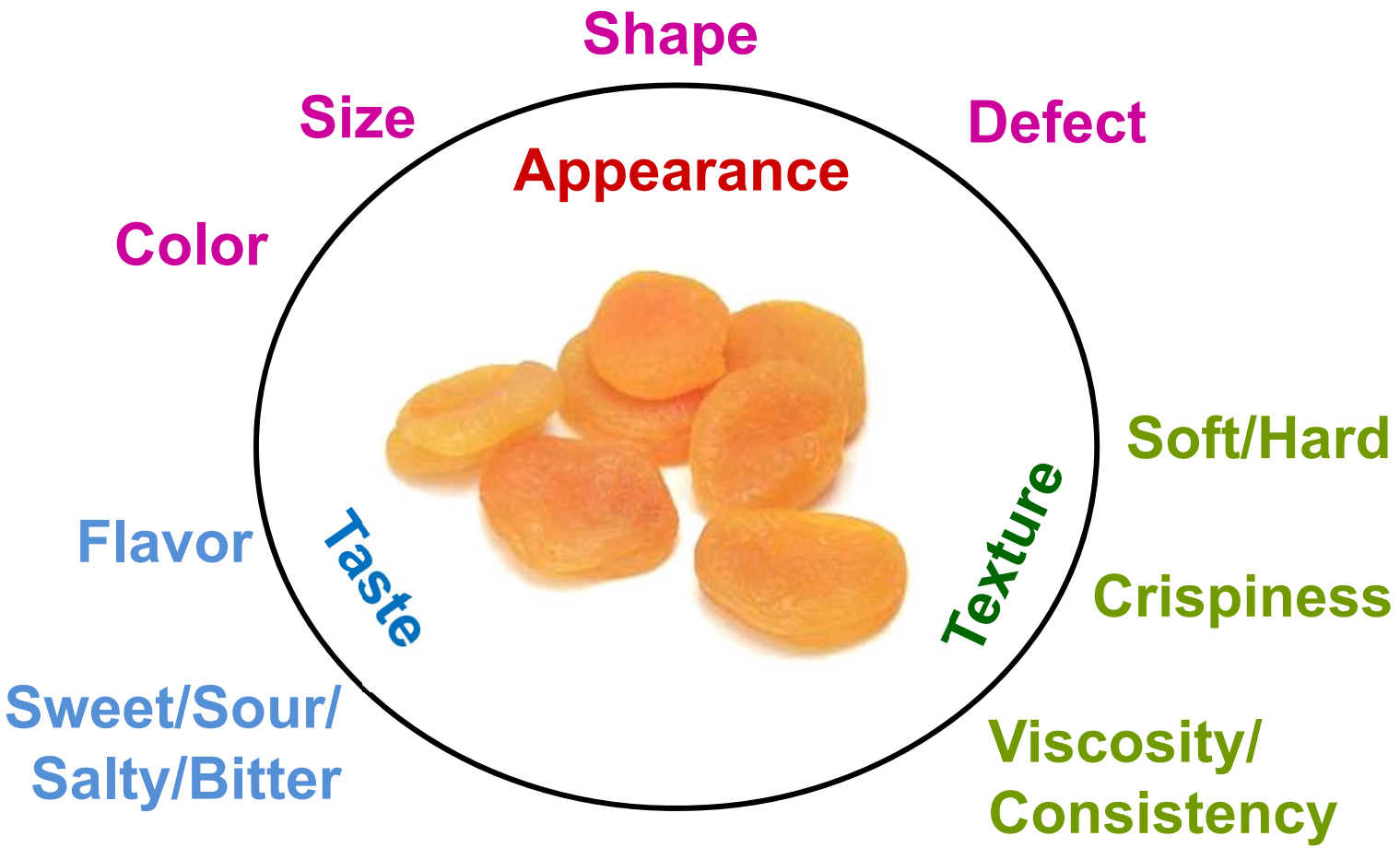
- Quality of food
- Nutrients in food
- Postharvest handling and food processing
- Changes of nutrients due to food handling, food processing, and household cooking

QUALITY OF FOOD

Quality of food

- Physical characteristics
- Chemical properties
- Nutritional quality
- Safety quality

Physical characteristics



Quality of food

- Physical characteristics
- Chemical properties
  - pH, acidity, rancidity
- Nutritional quality
- Safety quality

Quality of food

- Physical characteristics
- Chemical properties
- Nutritional quality
  - Nutrients:

    protein, fat, carbohydrate, vitamins, minerals
  - Bioactive compounds (phytochemicals)
- Safety quality

Quality of food

- Physical characteristics
- Chemical properties
- Nutritional quality
- Safety quality
  - Anti-nutrients
  - Toxic substances
  - Excessed food additives
  - Microorganisms

NUTRIENTS IN FOOD

Nutrients in food

- Protein: essential amino acids
- Fat: saturated/unsaturated fat, essential fatty acids
- Carbohydrates: sugar, starch
- Dietary fiber
- Vitamins: water-soluble, fat soluble
- Minerals: calcium, phosphorus, magnesium, sodium, iron, potassium, etc.

Nutritional value

- Most of vegetables and fruits contain at lease 60% water (usually more than 80%)
- Limiting source of macronutrients (carbohydrate, fat, protein) except
  - Legumes: rich in carbohydrate and protein
  - Tubers: rich in carbohydrate
- Main nutritional value is micronutrients (vitamins and minerals) and dietary fiber
- Source of bioactive compounds

Classification of vegetable

- Leaves
  - Leafy vegetables: cabbage, lettuce, collard
  - Stems: asparagus
  - Specialized leaves: leeks, spring onion, celery
- Legumes/grains: peas, beans, lentils, cereals
- Tubers: potato, yams
- Roots: carrots, turnips, beetroot
- Miscellaneous: cucumber, tomato, eggplant, long-green bean

Nutritional value: Macronutrients

Type	Amount (g/100 g)				
	Water	Protein	Fat	Carbo-hydrate	Dietary fiber
Cabbage	92	1.3	0.1	5.8	2.5
Pea	79	6.1	0.4	14.5	5.2
Potato	82	2.5	0.1	16.3	2.4
Carrot	88	0.9	0.2	9.6	2.8
Tomato	95	0.9	0.2	3.9	1.2

USDA National Nutrient Database for Standard Reference

Nutritional value: Vitamins

Per 100 g

Type	Carotene pro-VA (IU)	Thiamine VB1 (mg)	Riboflavin VB2 (mg)	Ascorbic VC (mg)
Cabbage	98	0.06	0.04	36.6
Pea	765	0.32	0.15	40.2
Potato	8	0.11	0.04	10.5
Carrot	16,706	0.07	0.06	6.8
Tomato	833	0.04	0.02	13.7

USDA National Nutrient Database for Standard Reference

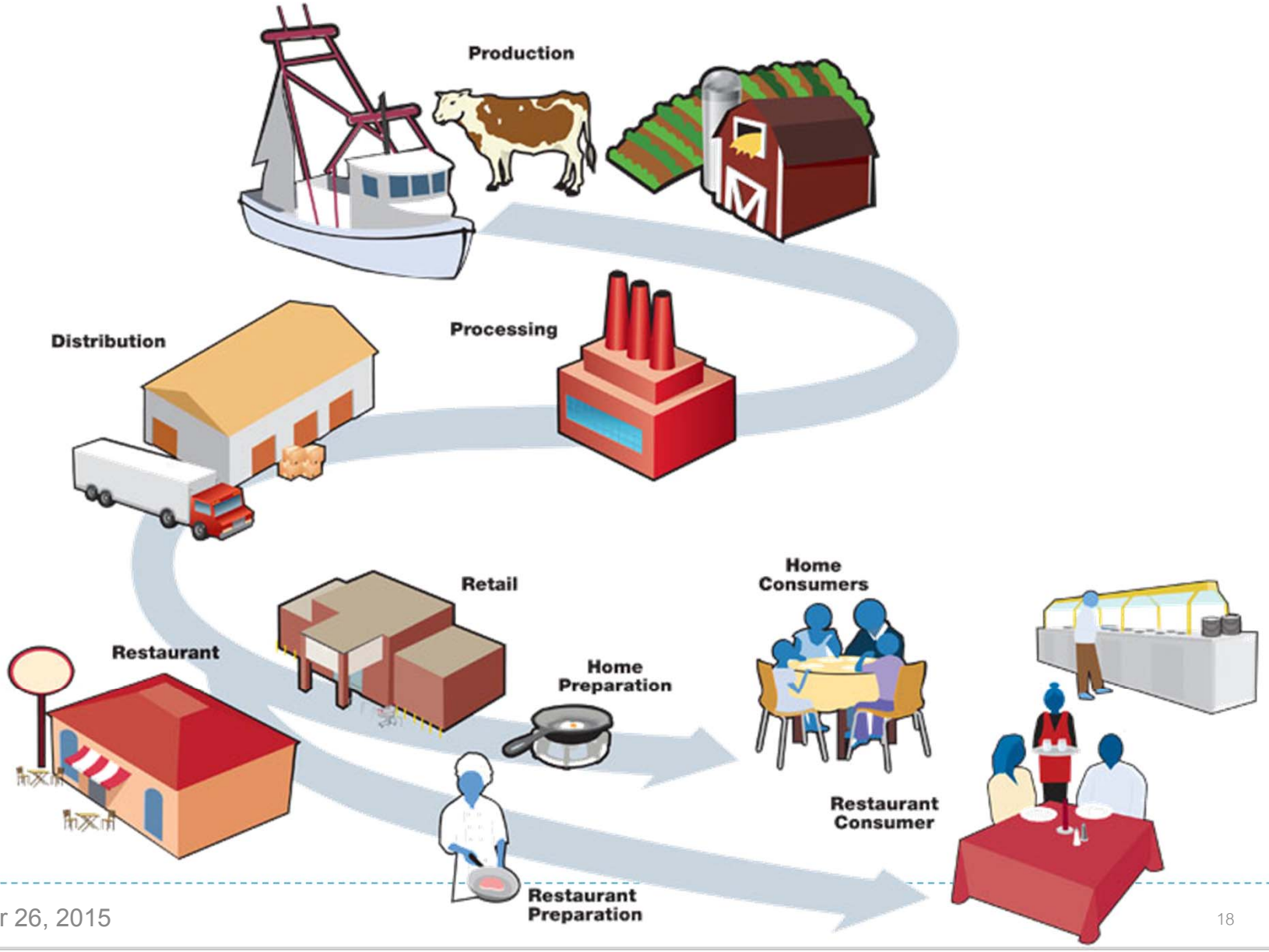
Nutritional value: Minerals

Type	Amount (μg/100 g)				
	Sodium	Calcium	Magnesium	Iron	Zinc
Cabbage	18	40	12	0.5	0.2
Pea	5	25	33	1.5	1.2
Potato	16	9	24	0.5	0.3
Carrot	69	33	12	0.3	0.2
Tomato	5	10	11	0.4	0.2

USDA National Nutrient Database for Standard Reference

POSTHARVEST HANDLING AND FOOD PROCESSING

The Food Production Chain



From farm to table

Farm

Postharvest handling

Market

Factory processing

Consumers
Home cooking

Factors affecting nutrient loss

- Raw material: maturity, growing condition, parts, postharvest handling
- Preparation method: washing, trimming, peeling, cutting, use of water
- Processing method and condition: temperature, time, water, light, oxygen, pH, ingredients
- Storage condition: packaging material, temperature, time, moisture, light, oxygen

Postharvest handling

- Washing, sorting, packaging, transportation and distribution
- Factors affect rate of deterioration of vegetable and fruits
- Postharvest factors include microbial load, presence of pests, temperature, relative humidity, mechanical damage

Postharvest handling

- Temperature abuse
  - Rate of enzymatic reaction (increase ripening)
  - Microbial growth
- Relative humidity
  - Microbial growth
- Mechanical damage
  - Bruise: enzyme-substrate
  - Microbial growth

Food distribution

- “garden fresh” VS “market fresh”
- Market fresh: rigorous distribution procedure
- “cold chain distribution”: produce is chilled after harvest, proper packaging type, low-temperature distribution, refrigerated display to maintain quality

Food preparation

- Washing
- Trimming
- Peeling
- Size reduction
- Blanching

Cleaning/Washing

- Dry washing
  - Wipe with cloth or brush
  - Air cleaning
- Water washing

Trimming/Peeling

- To remove unwanted part (trimming), skin (peeling)

- Apple peel: 5 times more VC than flesh
- Tomato skin: 3 times more VC than flesh

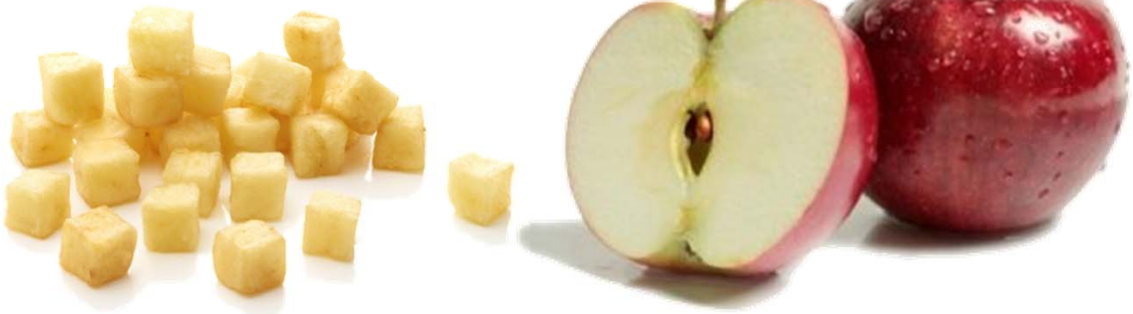
- Onion: tissue near skin contain niacin (VB3) than cortex
- Potato peel contains copper more than flesh
- Pineapple core has higher VC than flesh

Trimming/Peeling

- Outer leaves of lettuce and cabbage contain more carotene than inner leaves
- Outer parts of carrot which are likely to be removed by machine peeling are rich in carotene, thiamin, riboflavin and niacin

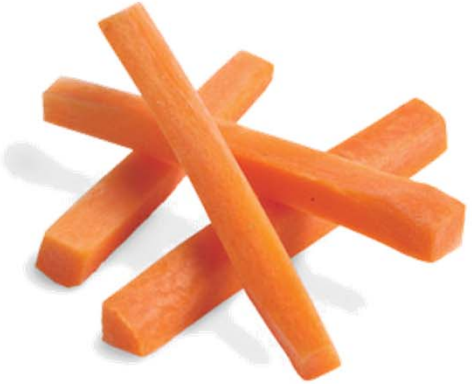
Size reduction

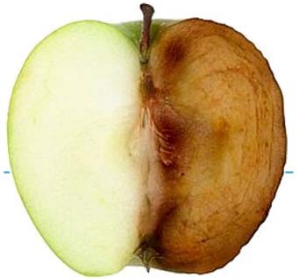
- Cutting, slicing, dicing, chopping, grinding
- Increase surface area for further processing: drying, freezing, juice extraction
- Increase ability to mix a variety of different ingredients together

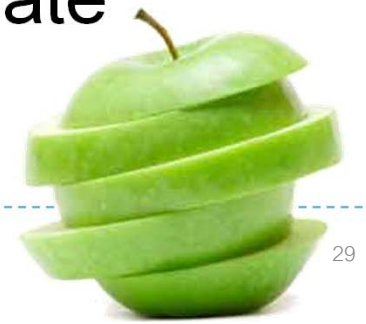


Effect of size reduction

- Increase surface area
  - Promote nutrient leaching during water washing/blanching/boiling
  - Oxidation of vitamins
  - Microbial contamination/spoilage
- Cutting of tissue
  - Enhance enzymes react with substrate







Blanching

- To inactivate enzymes that cause changes in color (by polyphenol oxidase), and nutrients (especially VC by ascorbic acid oxidase)
- Immerse in boiling water or by treatment with hot air or stream
- Subsequent cooling by cold water or cooled air

Leaching loss during blanching

- Surface area
- Blanching technique: water VS steam
- Blanching condition: time and temperature
- Food to water ratio
- Cooling method:
  cold water VS cooled air

Food processing

- To render the produce edible
- To preserve the produce by preventing spoilage from autolysis and microbiological attack
- To reduce the content of plant toxic substances

Food processing

- Heat treatment
- Drying
- Freezing
- Curing
- Fermentation
- Milling
- Juice processing

Heat treatment: Desirable effects

- Eliminate pathogenic microorganisms
- Lessen spoilage microorganisms
- Destroy anti-nutrients (e.g. trypsin inhibitor)
- Inactivate enzymes (e.g. ascorbic acid oxidase, polyphenol oxidase, thiaminase)
- Induces starch gelatinization and protein denaturation, resulting in increase digestibility and bioavailability

Heat treatment: Undesirable effects

- Loss of nutrients and bioactive compounds
- Changes of color, flavor, texture

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Food drying

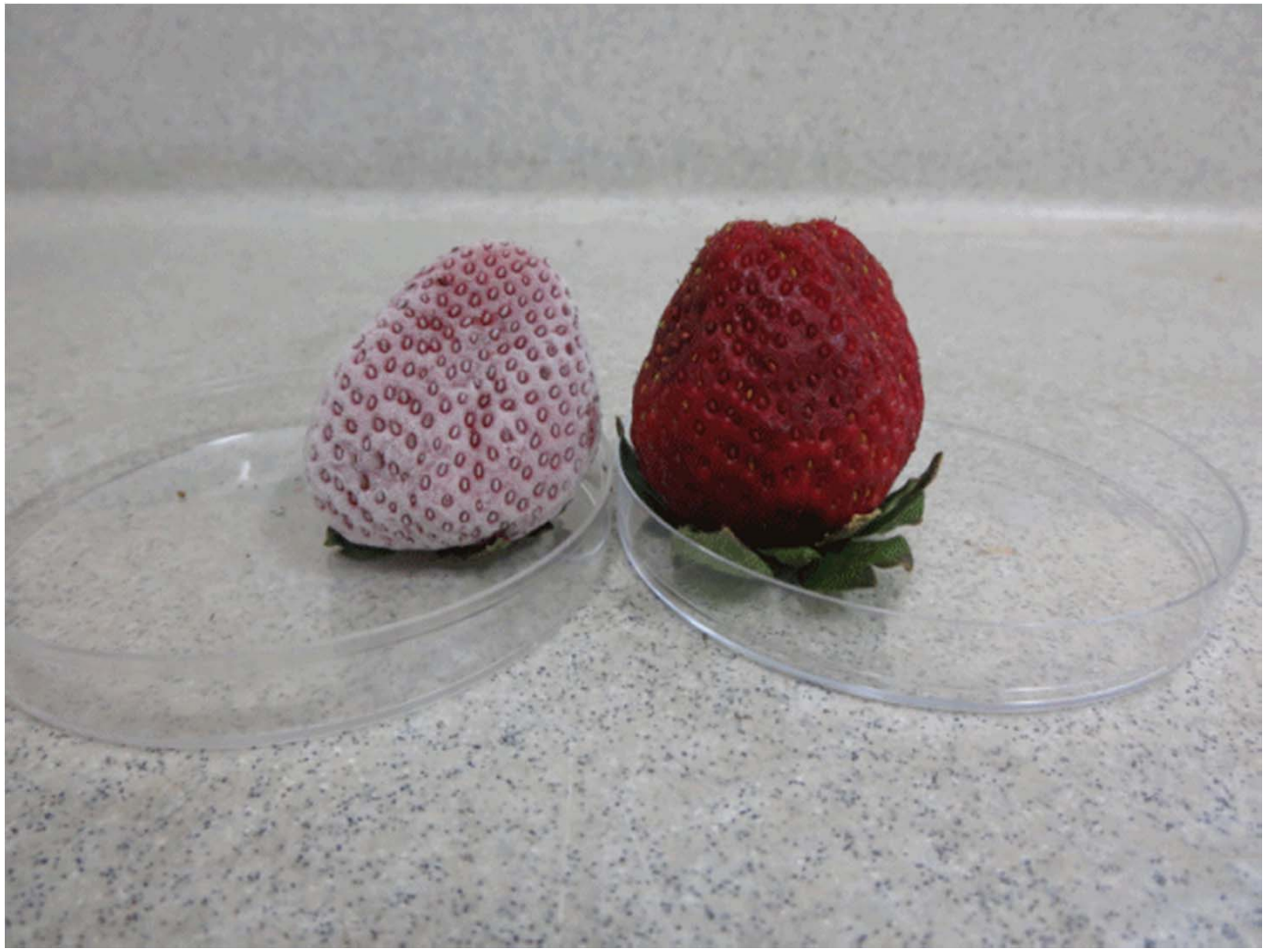
- Sun drying, solar drying, hot-air drying
- Large surface area of food
- Vitamin losses by sunlight, heat, oxygen

Food freezing

- Excellent method of preserving food quality
- Preserve taste, texture, and nutritional value better than other methods (heating process)

Nutrient loss by thawing

Frozen strawberry VS Chilled strawberry



Nutrient loss during rice milling

Nutrient	Loss (%)
Protein	15
Fat	85
Calcium	90
Thiamine	80
Riboflavin	70
Niacin	68
Pantothenic acid	62
Pyridoxine	56

FAO. 1954. Rice and rice diets- a nutritional survey.

Parboiled rice

- Partially cooked rice
- An old-age process in parts of Asia and African
- Gelatinization of starch making the grain translucent, hard, and resistant to breakage during milling

Parboiled process

1. Hydrothermal treatment of paddy before milling by

   Step 1: Soaking (steeping) of paddy in water at 50-60°C to increase moisture content to ~30%

   Step 2: Heating wet paddy by steaming

2. Drying paddy at ~ 60°C to safe moisture level for milling

Nutrients of parboiled rice

Nutrient	Brown	Polished	Parboiled
Moisture (%)	12.0	12.0	10.3
Protein (%)	7.5	6.7	7.4
Fat (%)	1.9	0.4	0.3
Fiber (%)	0.9	0.3	0.2
Ash (%)	1.2	0.5	0.7
VB1 (mg/100 g)	0.34	0.07	0.44
VB2 (mg/100 g)	0.05	0.03	-
Niacin (mg/100 g)	4.7	1.6	3.5

- No data

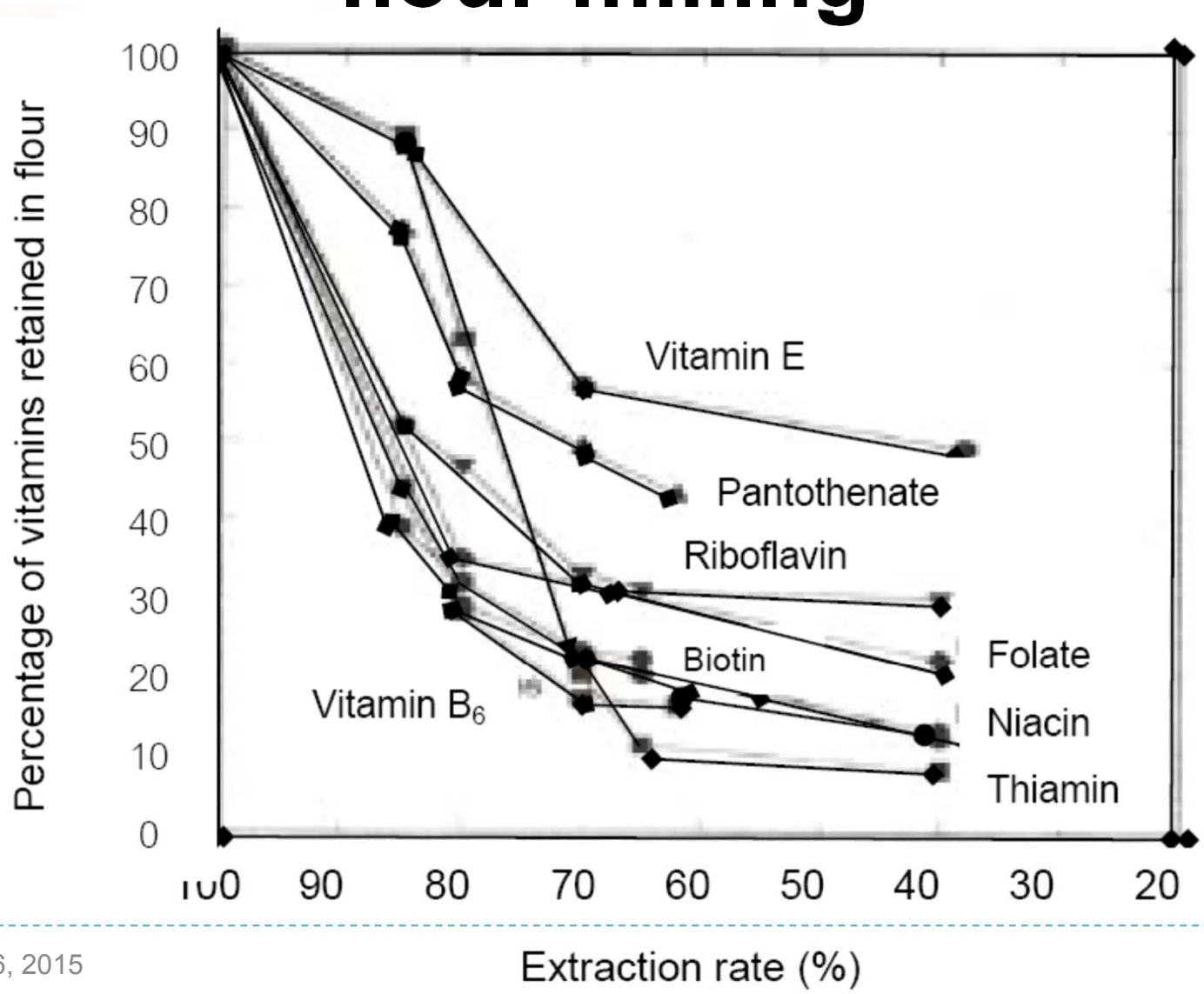
Wheat flour milling

- Extraction rate (ER):

  $$\frac{\text{weight of flour recovered}}{\text{weight of wheat milled}} \times 100$$

- VB in bran, VE in germs
- In US, 70% ER:
  vitamins decreased 40-60%
- In EU countries, 80-85% ER

Losses of vitamins during flour milling



Losses of nutrients during flour milling

	Extraction rate	VB1 (mg)	VB2 (mg)	Niacin (mg)	Protein (g)
	100	0.4	0.16	5.0	13.6
EU	85	0.35	0.08	2.0	13.6
	80	0.25	0.08	1.6	13.2
US	70	0.08	0.05	1.1	12.8
	45	0.03	0.02	0.7	11.8

Bender AE. 1978. Food processing and nutrition.

Losses of nutrients in flour (70% ER)

Nutrient	Loss (%)
Potassium	74
Magnesium	84
Calcium	50
Fat, ash, fiber, vitamins	40-60

Loss during milling needs nutrient enrichment: white wheat flour enriched with VB1, VB2, niacin, Fe, Ca, Mg, Zn

Household cooking

- Water leaching loss during preparation of raw material
- Losses during cooking and re-heating

Summary of food handling methods

Washing	Dry washing VS Wet washing
Trimming/Peeling	Amount of tissue removed
Size reduction	Degree of exposed surface area
Blanching	Water blanching VS Steam blanching
	Time and temperature
	Water cooling VS Air cooling
Domestic cooking	Time and temperature Boil VS Steam VS Fry
Factory processing	Preservation method: sterilized, pasteurized, drying, freezing Processing condition: Time and temperature

CHANGES OF NUTRIENTS DUE TO FOOD HANDLING

Nutritional loss of protein

- Water leaching and dripping
- Non-enzymatic browning reaction: amino acids, especially lysine, react with sugars
- Crosslinking: proteins react with lipid free radicals leading to decrease digestibility
- Bind with anti-nutritional substances: phytate, oxalate, tannin

Amino acid losses from blanching

Vegetable	Loss (%)	
	Steam blanching	Water blanching
Peas	13	25
Spinach	60	80

Lund. 1975. Effects of blanching, pasteurization, and sterilization on nutrients. In Nutritional Evaluation of Food Processing. Harris and Karmas (Editors).

Nutritional loss of carbohydrates

- Water leaching and dripping of sugar and starch
- Non-enzymatic browning reaction

Changes of carbohydrates during heating

Vegetable	Loss (%)	
	Water blanching	Boiling
Peas	12	7-13
Brussels sprouts		
Green beans		

Nutritional loss of fat

- Oxidation causes reduction of polyunsaturated fatty acid, increasing of free radicals
  - Oxygen
  - Light
  - Metal catalyst: copper, iron

- Polymerization: deep fat frying
- Crosslinking with protein

Nutritional loss of dietary fiber

- During milling of cereal grains and peeling of vegetables or fruits, the outer fiber-rich layers are removed

Vitamins in foods

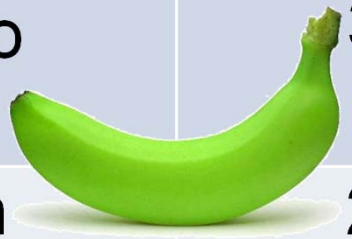
- Water soluble vitamins
  - VB group: thiamine (VB1), riboflavin (VB2), niacin (VB3), pantothenic acid (VB5), folate (VB6), biotin (VB7), and cyanocobalamime (VB12) which found only in meat and mushroom
  - VC (ascorbic acid)
- Fat soluble vitamins
  - VA (β-carotene as pro-vitamin A in plant)
  - VD
  - VE (tocopherol)
  - VK

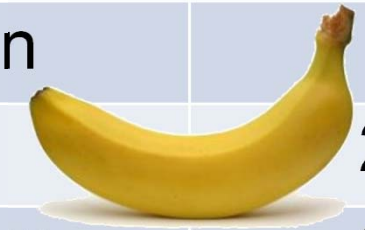
Factors affecting vitamin loss

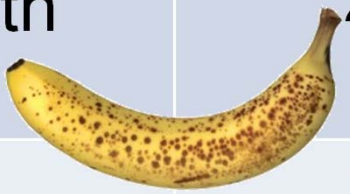
- Maturity of vegetables and fruits
  - Carotene: increase as fruits ripen (papaya)
  - VC: banana, peas, citrus, orange and mangoes have similar trend (decrease) after harvesting

VC and ripening of banana

Days after harvesting	Color of skin	VC (mg/ 100 g)
2	Green, flesh attached to skin	30
4	Pale yellow, softer flesh	29
6	Yellow, flesh being ripen	-
8	Yellow for whole fruit	24
10	Yellow for whole fruit with few brown spots	23
13	More brown spots	19







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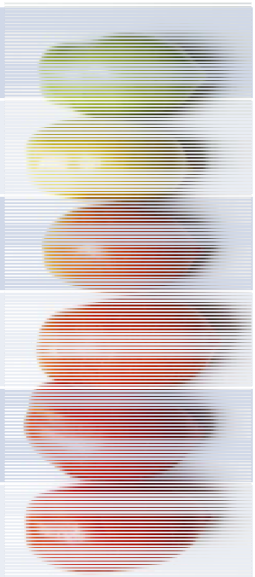
VC and degree of tomato maturity

cultivar: New Yorker

Weeks after flowering	Color	VC (mg/100 g)
2	Green	10.7
3	Green	7.6
4	Green-yellow	10.9
5	Yellow-red	20.7
6	Red	14.6
7	Red	10.1



Malewski and Markakis. 1971. J Food Sci 36:537.

Pro-vitamin A

- β-carotene is a precursor of VA
- Red-orange pigment abundant in plants and fruits
- Masked by chlorophyll in green leafy vegetables such as kale and spinach
- Sensitive to light and oxygen




Effect of cooking on carotene

Foods	Total carotene (ug/100 g)		β-carotene (ug/ 100 g)	
Carrot: Raw	8,344		4,406	
Boiling	7,296	(12.6)	2,990	(32.1)
Steaming	7,640	(8.4)	4,323	(1.9)
Shallow frying	7,416	(11.3)	4,023	(8.7)
Pumpkin: Raw	2,050		1,599	
Boiling	1,186	(42.1)	819	(48.8)
Steaming	1,314	(35.9)	1,190	(25.9)
Shallow frying	1,720	(16.1)	1,237	(22.7)

Number in parenthesis represent percentage loss compared to raw sample

Loss (%) of β-carotene from cooking

Item	Boiling 1-7 min	Steaming 2 min	Stir-frying 30 s-1 min
Water mimosa	4	59	54
Chinese water morning glory	5	20	87
Thai water morning glory	46	24	90
Pumpkin	38	-	-
Ivy gourd	50	-	-

- Not applied

Vitamin B1 (Thiamine)

- Unpolished grain, brown rice
- Loss by leaching, boiling, cooking with water
- Heat stable in neutral condition (pH 5-7)
- Destroy by thiaminase in raw fermented fish
- Bind with caffeic acid and tannic acid in fermented tea leaves

Thiamine retention in vegetables

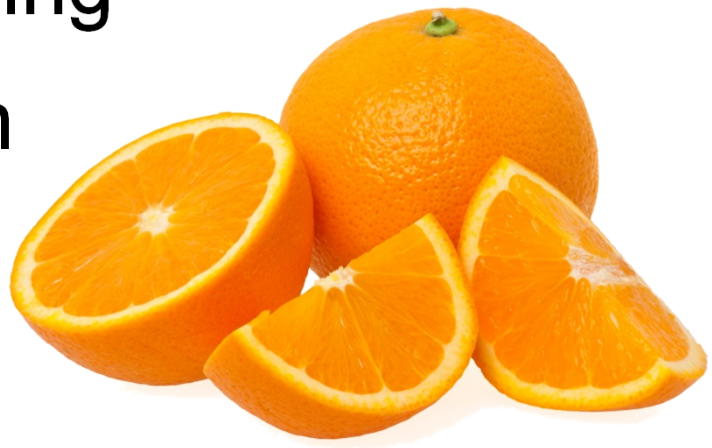
Item	Heating method	%Retention	
		Solid portion	Liquid portion
Broccoli	Microwave	76	31
	Boiling	75	33
	Steaming	90	8
Cabbage	Microwave	62	42
	Boiling	53	52
	Steaming	88	3
Carrots	Microwave	91	14
	Boiling	88	12
	Steaming	85	15
Potatoes	Microwave	91	10
	Boiling	83	14
	Steaming	92	3

Vitamin B2 (Riboflavin)

- Water leaching during soaking, blanching, boiling, cooking with water
- Heat and acid labile
- Destroy by light and base solution condition

Vitamin C (Ascorbic acid)

- Water leaching and peeling
- Most susceptible vitamin
  - Heat sensitive
  - Oxidation by oxygen
  - Oxidation by enzyme and chemicals
  - Light sensitive



Loss will not affect health status,
if we consume fruits and vegetables every day

Vitamin C loss due to peeling/trimming

- Apple peel: 5 times more VC than flesh
- Tomato skin: 3 times more VC than flesh

- Pineapple core contains VC higher than flesh

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Loss (%) of VC after harvest

	Hours after harvest				
	2	4	8	10	24
Fresh green leaves	5-18	10-30	35-60	38-66	90

	Storage condition	Storage hours	
		48	96
Lima beans in pods	Room temperature	40	70
Lima beans w/o pods		70	-
Lima beans in pods	Refrigerator	5	29
Lima beans w/o pods		16	-

- Not applied

VC in stored potatoes

	Vitamin C (mg/100 g)
Fresh	30
Storage time (months)	
1-3	20
4-5	15
6-7	10
8-9	8

Loss of vitamin C in vegetables during cold storage at 78°F

Type	Days	Loss, %
Broccoli	1	20
	4	35
Green beans	1	10
	4	20

VC loss in processed peas

Type of process		Retention of VC (db)	
		Amount (mg/100 g)	%
Raw		130	100
Cooked	12 minutes	116	89
	After 1 day storage at room temperature	90	69
Frozen	3 months and cooked 4 minutes	61	47
Canned	3 months storage	40	31

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VC loss after stage of processing

Fresh pea

Blanching
25%

Cooking 56%	Freezing 25%	Canning 37%	Air-drying 55%	Freeze-drying 30%
	Thawing 29%	Heating 64%	Cooking 75%	Cooking 65%
	Cooking 61%			

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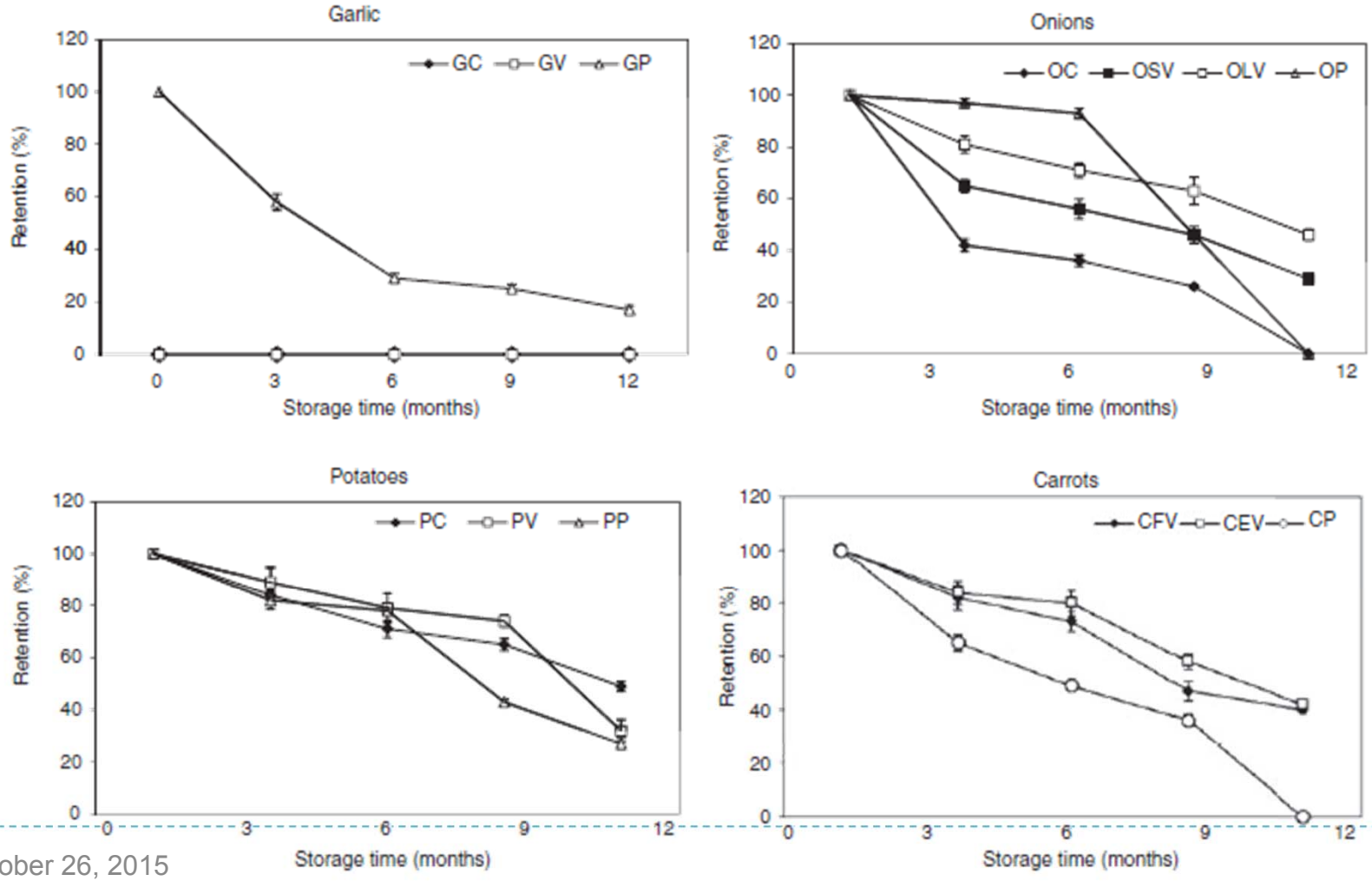
Vitamin retentions in cooked broccoli

Method	Vitamin retention, %					
	Broccoli portion			Liquid portion		
	VC	VB1	VB2	VC	VB1	VB2
Boiling	60	75	69	25	33	33
Steaming	72	90	94	6	8	8
Microwave	64	76	71	23	31	31

Impact of storage on VC

- Dehydrated vegetables stored at ambient conditions (19.6-25.6°C) for 12 months



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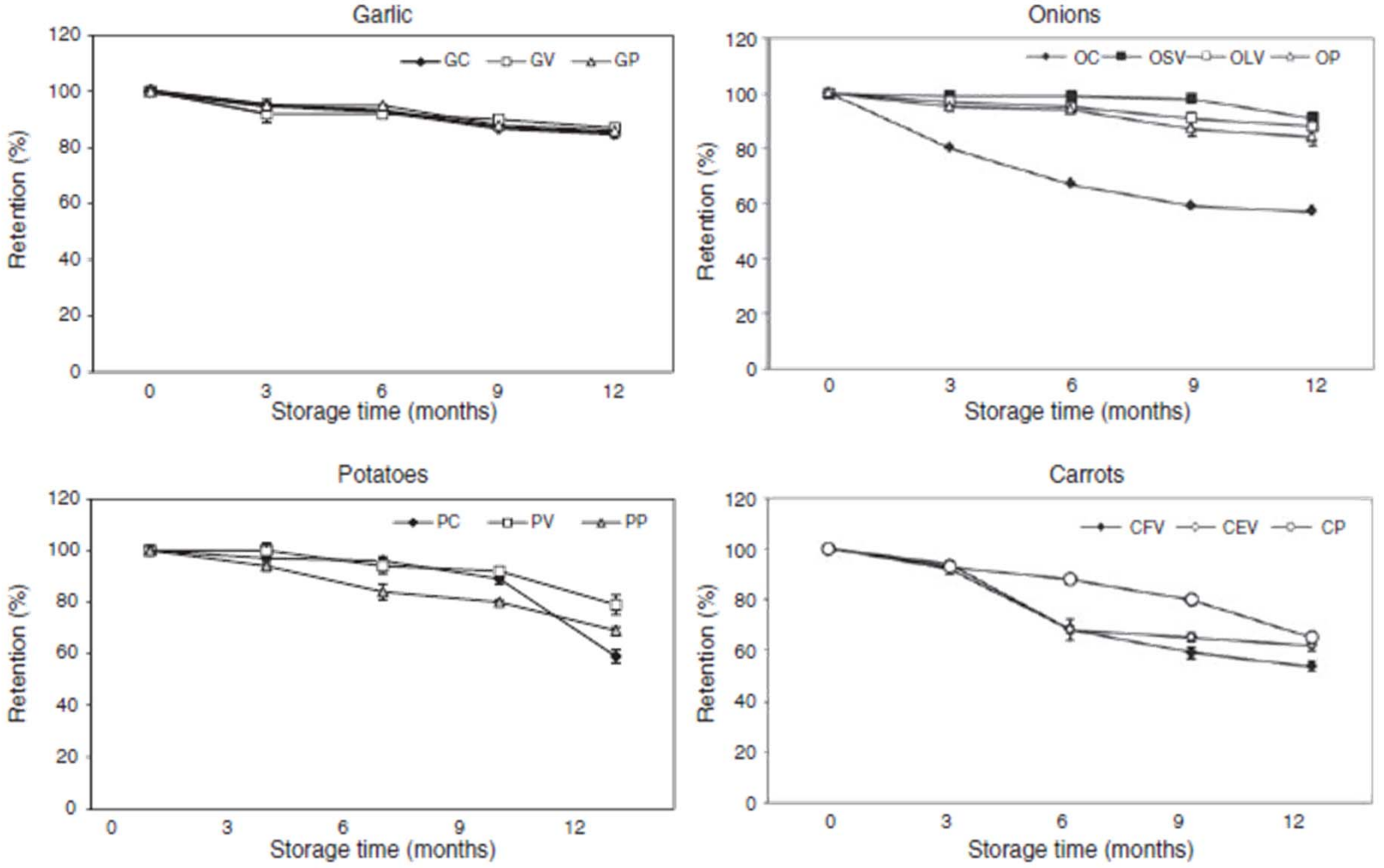
Impact of storage on VB1



Penas et al. 2013. Food Sci and Technol Inter. http://fst.sagepub.com/content/19/2/133

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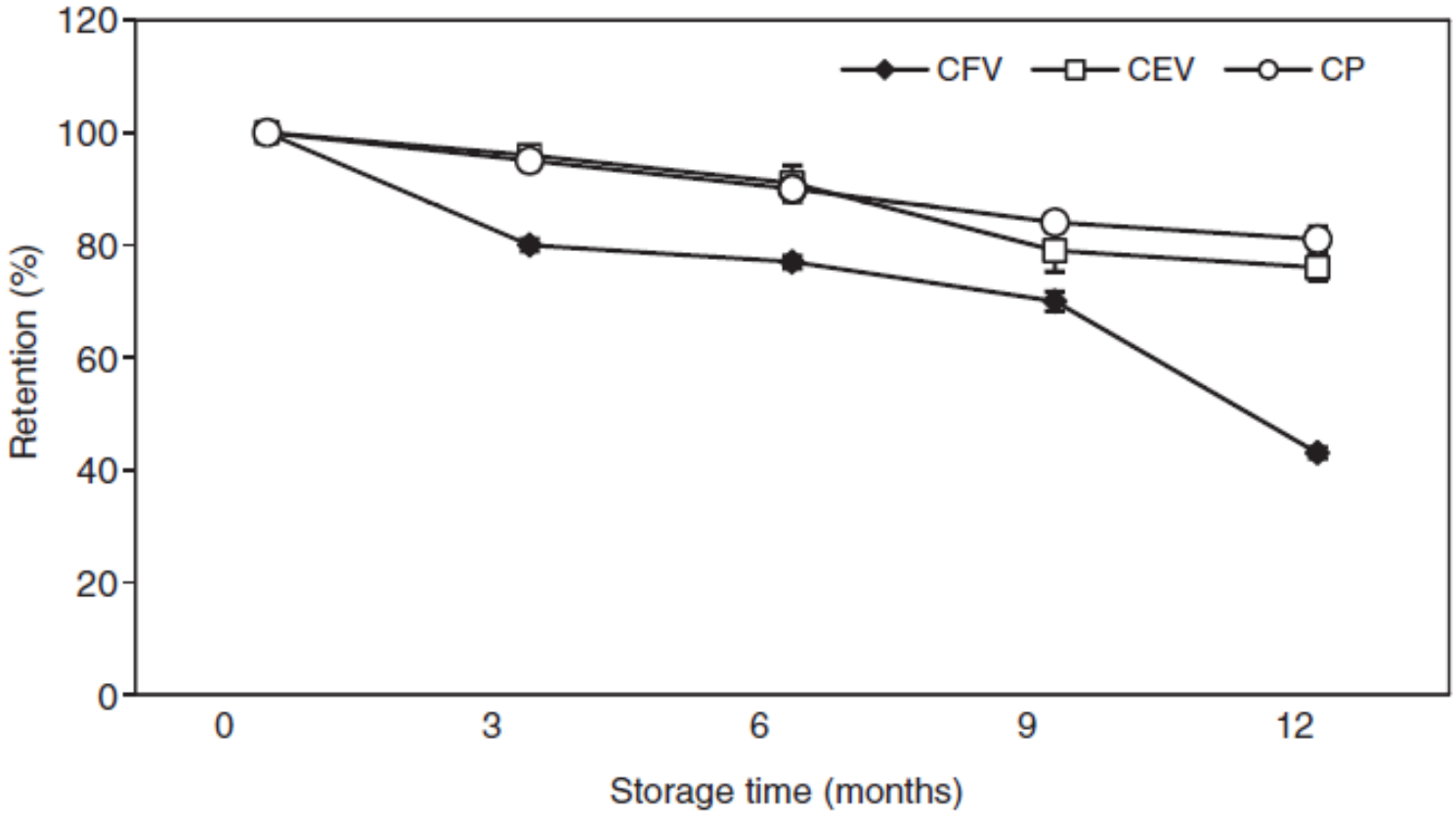
Impact of storage on β-carotene

Dehydrated carrot



Penas et al. 2013. Food Sci and Technol Inter.
http://fst.sagepub.com/content/19/2/133

Tip to decrease vitamin loss

- Purchase fresh foods and consume ASAP
- Handle fruits and vegetables with care
- Wash before cutting
- Peeling, trimming, slicing only if necessary
- Cooking for a proper period of time
- Avoid using utensil with copper and iron
- Less water is used to reduce leaching loss
- Consumption of cooking liquid to recover the loss
- Protect foods from oxygen, heat, and light

Nutritional loss of minerals

- Water leaching and dripping
- Trimming and peeling: unequal distribution of minerals in the peel and cortex
  e.g. copper in potato peel

Copper content in raw and processed potatoes

Type	Amount (mg/100 g)
Raw	0.21
Boiled	0.10
Baked	0.18
Chips	0.29
Mashed	0.10
French fried	0.27
Instant, uncooked	0.17
Potato peel	0.34

Pennington and Calloway. 1973. J Am Diet Assoc 63: 143.

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Mineral losses in blanched spinach

Mineral	Amount (g/100 g)		Loss (%)
	Raw	Blanched	
Potassium	6.9	3.0	56
Sodium	0.5	0.3	43
Calcium	2.2	2.3	0
Magnesium	0.3	0.2	36
Phosphorus	0.6	0.4	36

Mineral losses in cooked navy beans

Mineral	Amount (mg/ 100g)		Loss (%)
	Raw	Cooked	
Calcium	135	69	49
Copper	0.8	0.33	59
Iron	5.3	2.6	51
Magnesium	163	57	65
Manganese	1.0	0.4	60
Phosphorus	543	156	65
Potassium	821	298	64
Zinc	2.2	1.1	50

Meiners et al. 1976. J Agr Food Chem 24: 1126.

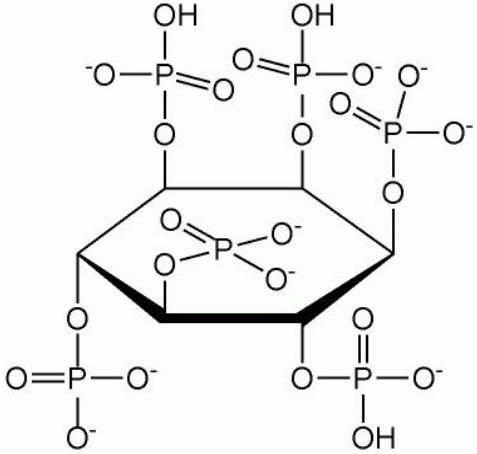
MINERALS AND INHIBITORS

Inhibitors

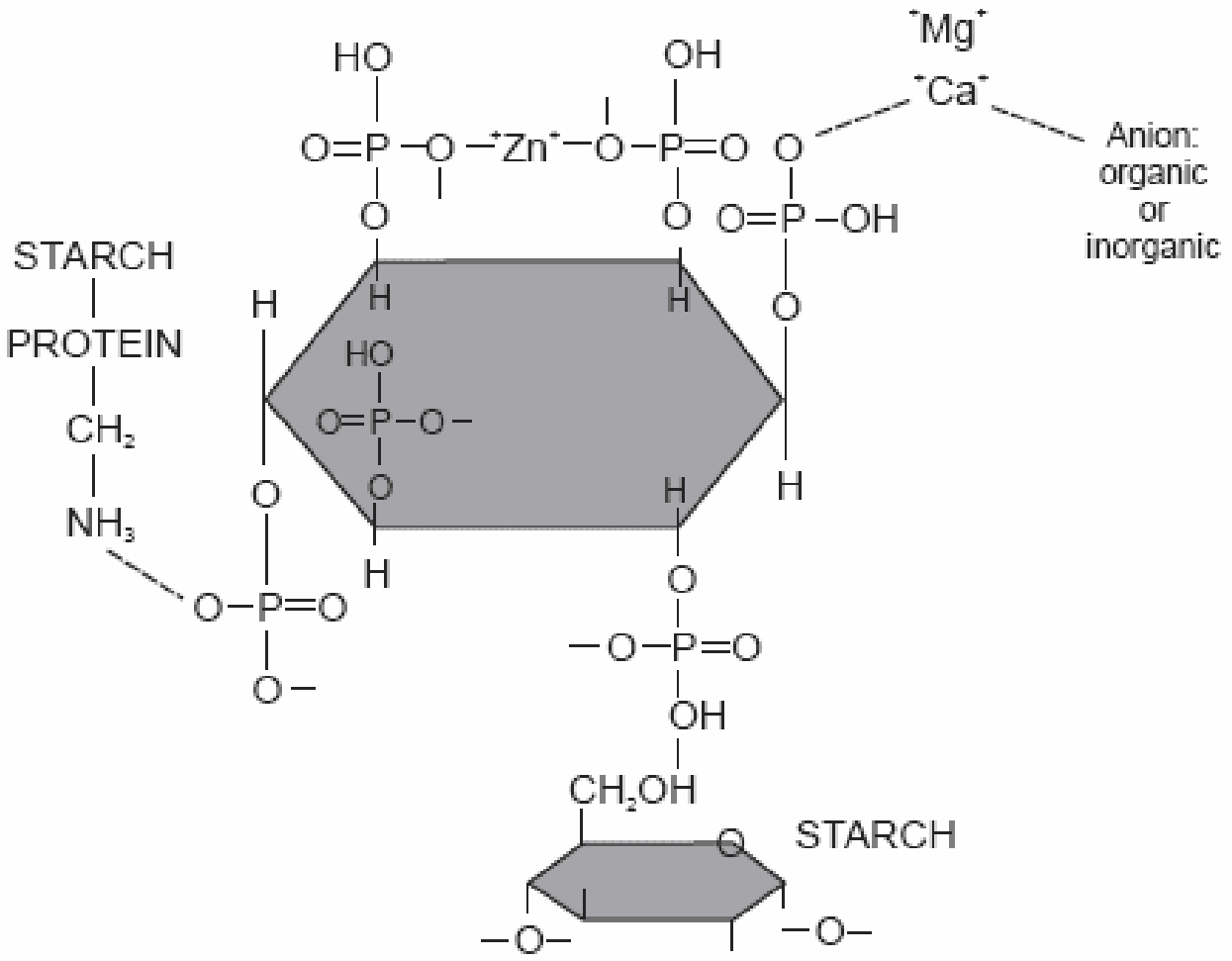
- Dietary components, which diminish bioavailability of minerals, are insoluble dietary fiber, phytate, oxalate

Phytate

- Myoinositol hexaphosphoric acid or
  1, 2, 3, 4, 5, 6-hexa, kis-dihydrogen phosphoric acid



- Occurs mainly in the form of phytate (phytic acid + minerals) or complex with protein


HO
OH
+Mg+
+Ca+
Anion:
organic
or
inorganic
O=P–O–+Zn+–O–P=O
O
O
O=P–OH
STARCH
PROTEIN
CH2
NH3
H
HO
O=P–O–
O–P=O
O–
–O–P=O
OH
CH2OH
STARCH
–O–
–O–

Phytate

- Found within the hulls of nuts, seeds, and grains
- Strong chelating agent, binding mono- and divalent metal ions
- Not break down in digestive tract of monogastric animals including human, poultry, swine, leading to reduce bioavailability of Zn, Ca, Mg, Fe
- Form complex with protein, resulting in decrease of protein digestibility

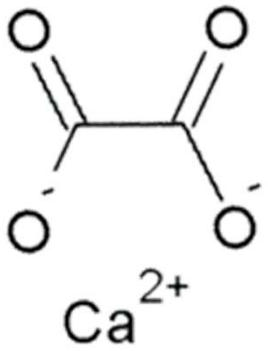
Elimination of phytate

- Dehulling seeds
- Fermentation: many bacteria possess phytase activity and by fermenting grains or beans by lactic acid bacteria

- When phytate is destroyed, bioavailability of minerals is increased

Oxalate

- Oxalic acid: Affinity of divalent metal ions, i.e. Ca, Fe, form insoluble compound, inhibiting their absorption by human body



Calcium oxylate
(Kidney stone)

Oxalate

- In body, oxalic acid combines with metals such as calcium, iron, sodium, magnesium, potassium to form crystals of corresponding oxalates, which irritate gut and kidneys

Oxalate rich foods

- Raw vegetables (mg/100 g):

  spinach (750)

  beet greens leaves (610)

  okra (146)

  parsley (100)

  leeks (89)

  collard greens (74)






Holmes RP and Kennedy M. (2000). Estimation of the oxalate content of foods and daily oxalate intake. Kidney International (4):1662.

Toxicity of oxalate

- High dose: Gastroenteritis, shock, convulsion, low plasma calcium, renal damage
- Long-term consumption of food high in oxalic acid can lead to nutrient deficiencies
- Those with kidney disorders, gout, rheumatoid arthritis are typically advised to avoid foods high in oxalic acid or oxylate

Toxicity of oxalate

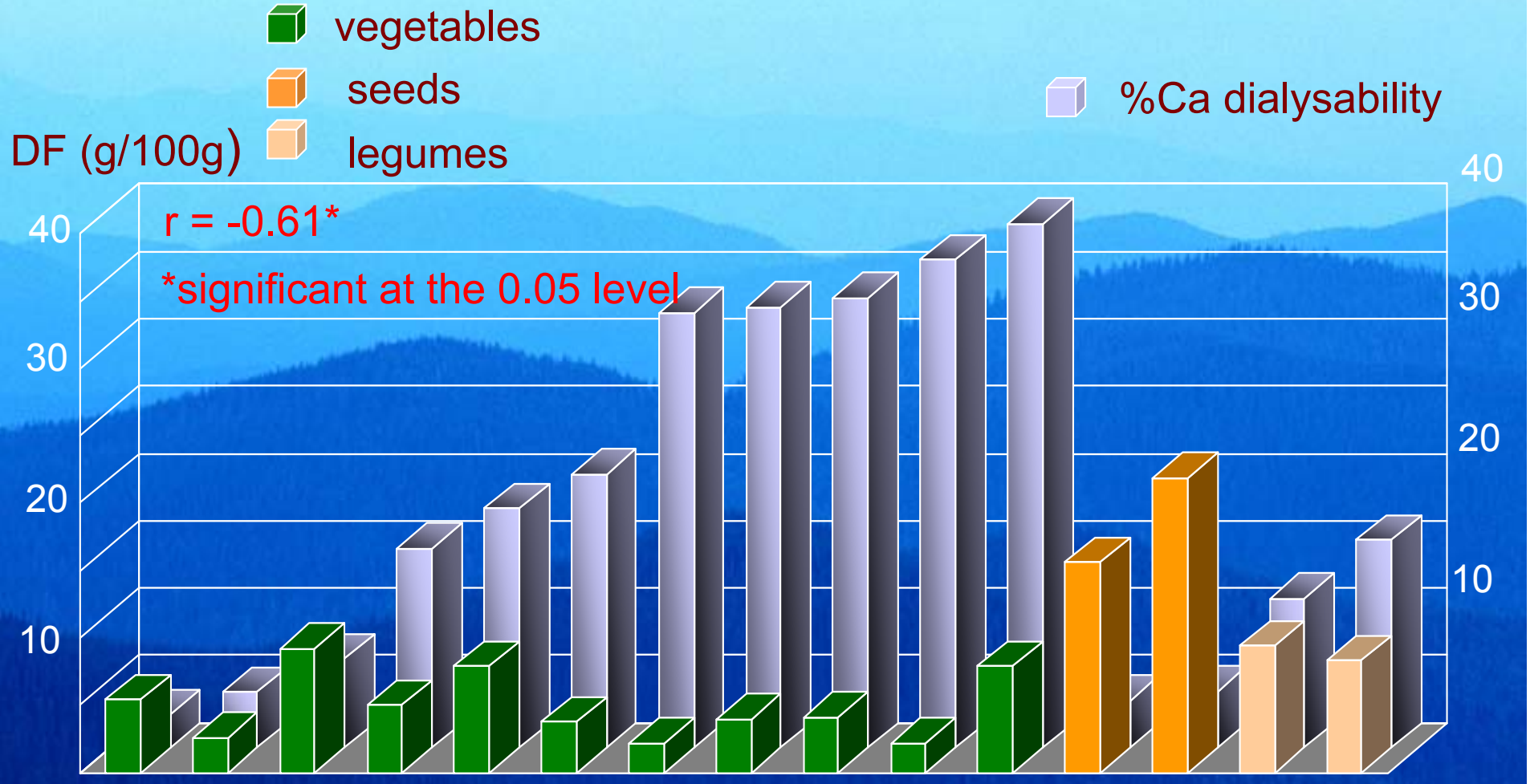
- Conversely, calcium supplements taken along with foods high in oxalic acid can cause oxalic acid to precipitate in the gut and drastically reduce levels of oxalate absorbed by body
- Calcium oxylate precipitate (kidney stones) obstruct kidney tubules

Effect of cooking on oxalate

- Cooking has a relatively small impact on the oxalate content of foods.
- no statistically significant lowering of oxalate content following the blanching or boiling of green leafy vegetables.
- A lowering of oxalate content by about 5-15% is the most you should expect when cooking a high-oxalate food.

English name (in order on the charts)	Type
Wild betal, leaves	Vegetable
Amaranth, blanched	Vegetable
Pak-paw	Vegetable
Sesbania/Cork woods, young leaves, blanched	Vegetable
Indian mulberry, leaves, blanched	Vegetable
Soybean sprout, blanched	Vegetable
Pak-chee-lao, blanched	Vegetable
Cabbage, Chinese/Flowering white cabbage, blanched	Vegetable
Tree kale, blanched	Vegetable
Celery, blanched	Vegetable
Kale, Chinese, blanched	Vegetable
Sesame seeds, black, roasted	Seed
Sesame seeds, white, roasted	Seed
Soybean seeds, cooked	Legume
Soybean, young seed, cooked	Legume

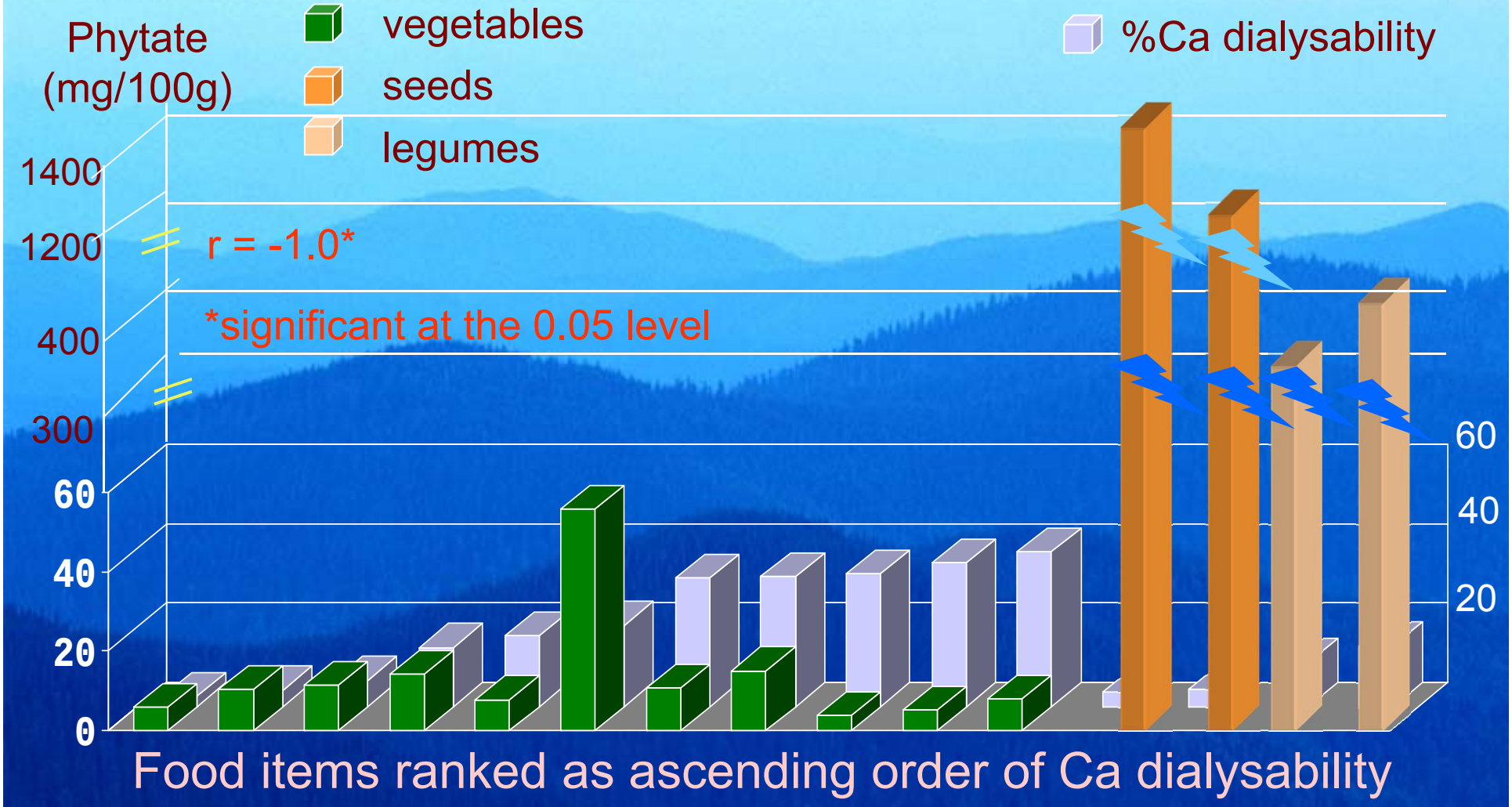
Dietary fiber content in various plant foods



Food items ranked as ascending order of Ca dialysability

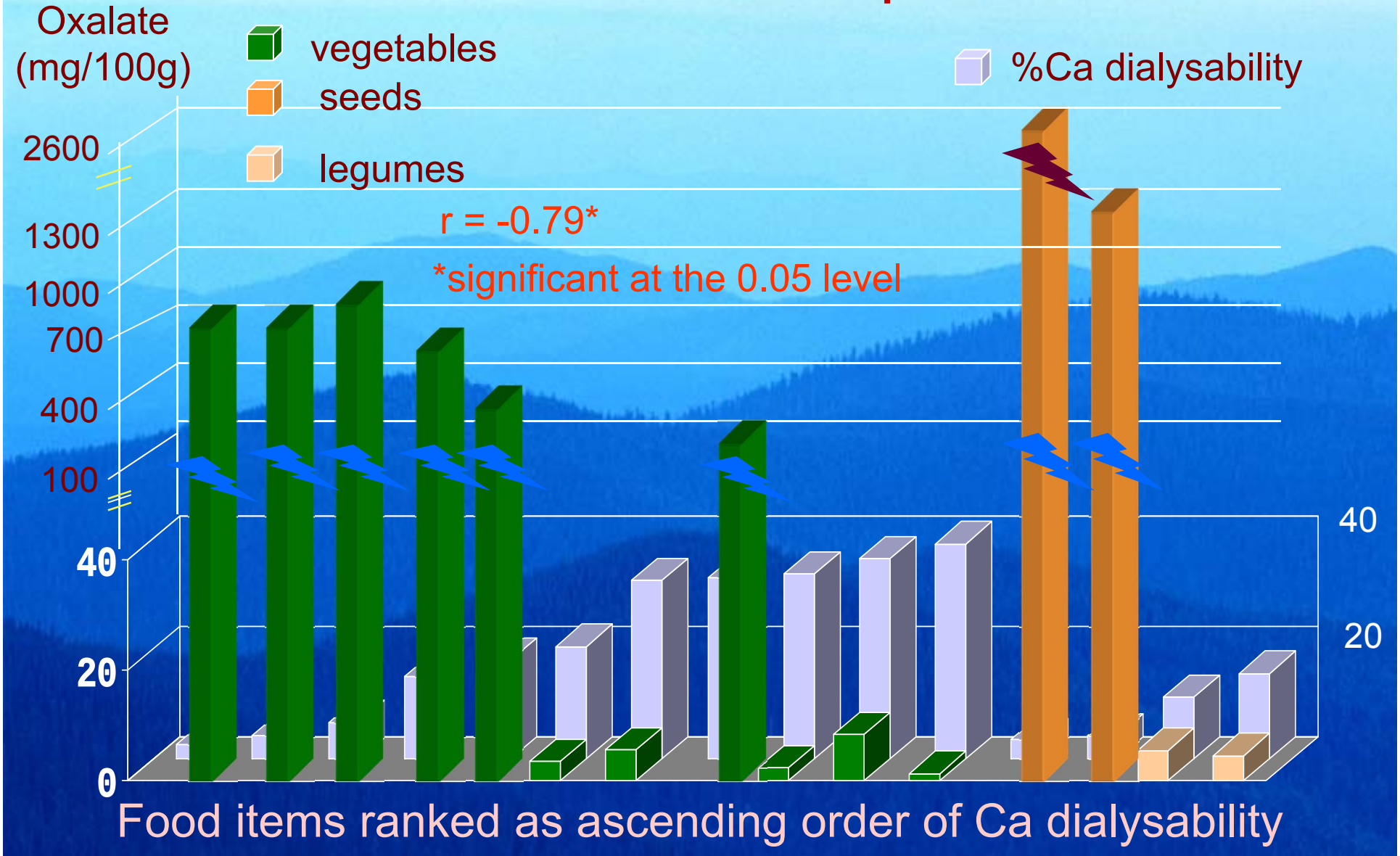
Kamchan et al. 2004. J food Comp Anal 17: 311-20.

Phytate content in various plant foods



Kamchan et al. 2004. J food Comp Anal 17: 311-20.

Oxalate content in various plant foods



Kamchan et al. 2004. J food Comp Anal 17: 311-20.

Conclusions

- Many of processing-induced nutrient losses especially vitamins in plant foods can be avoided or minimized by careful attention to the processing and subsequent storage
- Minimize nutrient loss should be balanced with food safety (from toxic substance and microorganisms) and other quality attributes

Mahidol University
Wisdom of the Land

Food Processing and Nutritional Quality of Vegetables and Fruits

- Fresh or unprocessed food VS cooked or processed food
- Processed food VS none at all
  - Fresh peas is 2 months available
  - 10 months for processed peas