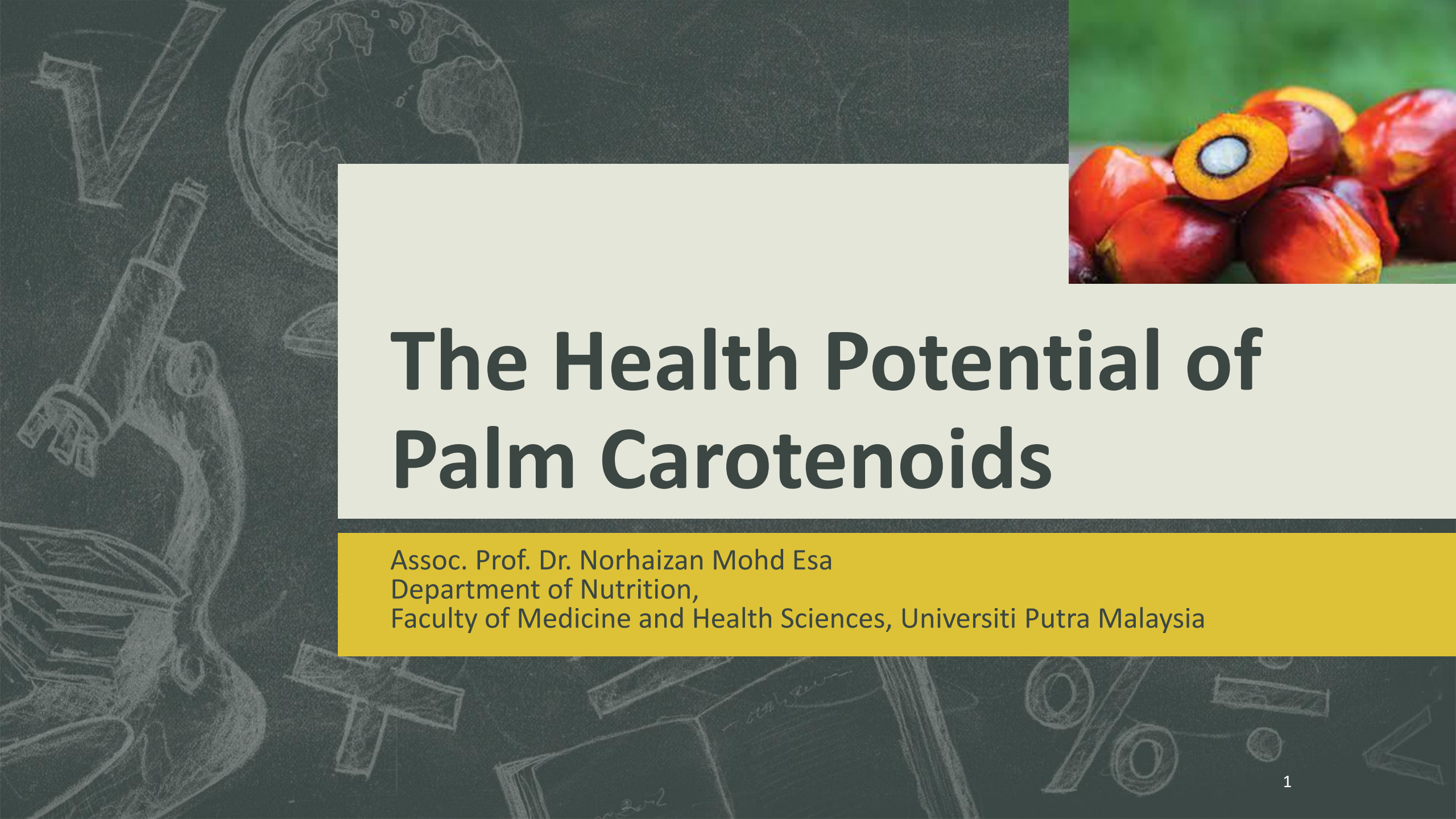




The Health Potential of Palm Carotenoids

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Content

- Introduction of carotenoids
 - Classification
 - Sources
- Health potential of palm carotenoids (α and β -carotene)

Classification of carotenoids

- fat-soluble pigments

Carotenoids



Xanthophylls

- Lutein
- Zeaxanthin
- Cucumin
- **Cryptoxanthin**



Carotene

- Lycopene
- **Carotene**
(α , β , γ , δ)



Pro-vitamin

Sources of carotenoids



- Organic pigmented produced by the fungi, several bacteria, and plastids of algae and plants.
- Carotenoids are abundantly found in deeply pigmented fruits and vegetables, in which the orange-yellow vegetables and fruits are rich in β -carotene and α -carotene.
- α -cryptoxanthin, lycopene, and lutein are found in orange fruits, tomatoes, and tomato products, and dark green vegetables, respectively.
- Egg yolk is a highly bioavailable source of zeaxanthin and lutein

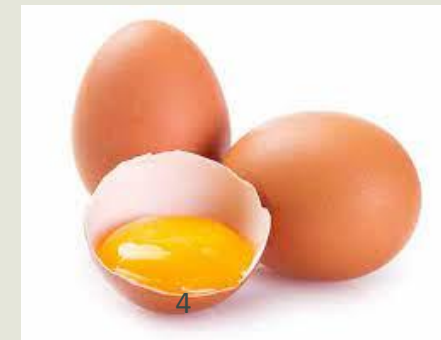


Table 1. Carotenoids content in some common foods.

Food Source	Carotenoids (µg/100 g)							References
	Lutein	Zeaxanthin	Lutein and Zeaxanthin	Lycopene	α-Carotene	β-Carotene	β-Cryptoxanthin	
Apples (with skin)	100–840				30			[40,43,44]
Apricot, raw	0–141			0.5	0–37	140–6939	28–231	[45]
Asparagus, raw	610–750				12	493		[40,44,46]
Avocados			270		28	53	36	[40,47]
Basil, raw			7050					[48]
Blackberry	270				9	100		[49]
Blueberry	230					49		[49]
Broccoli, raw	830–4300				1	414–2760		[45]
Brussels sprouts, boiled			1541					[45,47]
Carrot, raw	110–2097				530–35,833	1161–64,350		
Corn, cooked	202	202						[50]
Cress, raw	7540							[51]
Frozen corn, boiled from frozen			684					[47]
Cucumbers (with skin)	160					138		[40,44,46]
Egg whole, cooked	237	216	353					[47,50]
Egg yolk, cooked	645	587						[50]
Egg whole, raw	288	279	504					[47,50]
Egg yolk, raw	787	762	1094					[47,50]
Frozen green beans, cooked			564					[47]
Jackfruit				37–111		40–772		[52]
Kale, cooked			18,246					[47]
Leek, raw			3680					[48]
Lettuce, raw	1000–4780							[48]
Mango	100					300–4200	0–1640	[40,45]
Melon, cantaloupe					27	1595	0	[40]
Orange juice	67				8	13	34	[40,53]
Orange	64–350		129		0–400	0–500	14–1395	[40,45,47]
Orange pepper, raw		1665						[50]
Papaya	20–820			2080–4750	0–60	71–1210	60–1483	[40,45]
Parsley, raw	4326		5562					[47,50]
Peas, green, boiled			2593					[47]
Pepper, bell, green, raw	340–660				22	198	1	[54]
Pineapple						171–476		[40]
Pistachio nuts, raw			1404					[47]
Pumpkin, cooked			1014					[47]
Spinach, raw	2047–20,300		12,197			840–24,070		[40,47]
Sweet potatoes, white flesh (cooked)						25–157		[55]

Tan and Norhaizan, 2019

Table 1. Cont.

Food Source	Carotenoids (µg/100 g)							References
	Lutein	Zeaxanthin	Lutein and Zeaxanthin	Lycopene	α-Carotene	β-Carotene	β-Cryptoxanthin	
Squash, boiled			2249					[47]
Strawberry	6–21					5		[40,43]
Tomato, raw	40–1300			21–62,273		36–2232		[45]
Watermelon	0–40			2300–7200	0–1	44–324	62–457	[45]

Tan and Norhaizan, 2019

TABLE 2. Minor components of crude palm oil

	ppm
Carotenoids [7]	500-700
Tocopherol and tocotrienols [4, 8]	600-1,000
Sterols [9]	326-527
Phospholipids [10,11]	5-130 ^a
Triterpene alcohol [12, 13]	40-80 ^a
Methyl sterols [13]	40-80
Squalene [14, 15]	200-500
Aliphatic alcohols [7]	100-200
Aliphatic hydrocarbon [14, 15]	50

a. Estimated

Choo (1994)

Table 1 Health benefits of phytonutrients found in red palm oil^a

Phytonutrient (amount)	Composition ^b and health benefits
Vitamin E (717–863 ppm)	<i>Composition:</i> α -tocopherol (19%), α -tocotrienol (29%), γ -tocotrienol (41%), δ -tocotrienol (10%) <i>Health benefits:</i> anticancer, antiangiogenic, antioxidant, antiatherosclerotic, cardioprotective, and neuroprotective properties; inhibits cholesterol synthesis; aids in diabetes management
Carotenoids (600–750 ppm)	<i>Composition:</i> phytoene (0.2%), phytofluene (0.6%), β -carotene (41.0%), α -carotene (41.3%), <i>cis</i> - α -carotene (10.2%), ζ -carotene (0.6%), γ -carotene (0.8%), δ -carotene (0.8%), neurosporene (0.2%), β -zeacarotene (1.3%), α -zeacarotene (0.5%), lycopene (1.0%) <i>Health benefits:</i> provitamin A activity; cardioprotective and anticancer activity; prevents night blindness
Phytosterols (325–365 ppm)	<i>Composition:</i> cholesterol (6.6–11.5 ppm), campesterol (76–83 ppm), stigmasterol (59–64 ppm), β -sitosterol (187–218 ppm), unknown (<6 ppm) <i>Health benefits:</i> cholesterol-lowering properties, anticancer activity, enhances immune function
Squalene (14–15 ppm)	<i>Health benefits:</i> cardioprotective, radioprotective, and anticancer activity; inhibits cholesterol synthesis
Ubiquinone (18–25 ppm)	<i>Health benefits:</i> enhances production of cellular energy; antioxidative properties; cardioprotective and anticancer activity

Abbreviation: ppm, parts per million.

^aAdapted from Loganathan et al.¹³

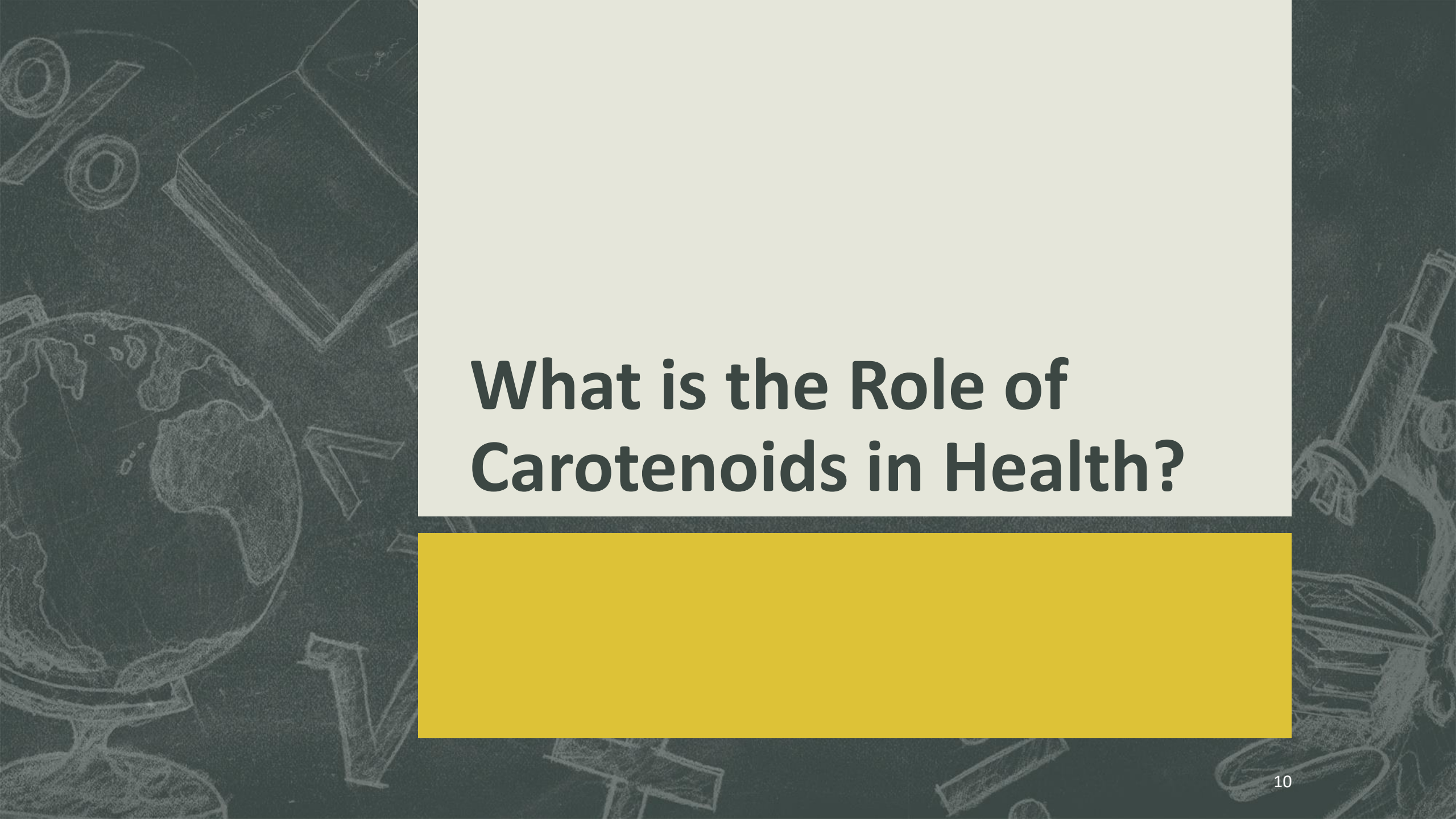
^bComposition obtained from Tay et al.⁶

TABLE 3. Retinol equivalents (RE) of red palm oil compared with other foods

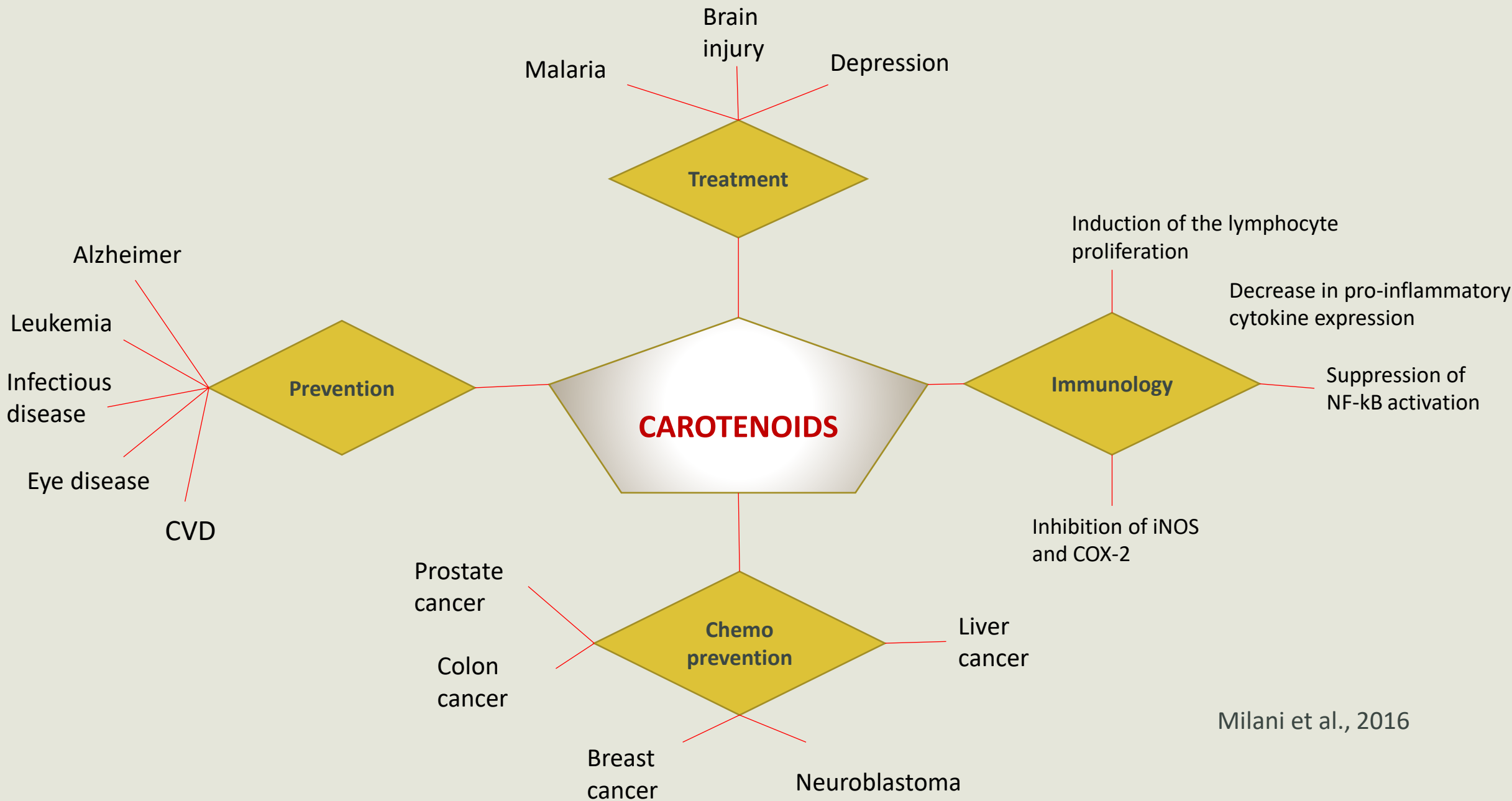
	RE ^b	Relative quality ^a	
		>RPO	< RPO
Fish liver oils (preformed retinol)			
Halibut	900,000	30	
Shark	180,000	6	
Cod	18,000		1.7
Fruits and vegetables (carotene derived)			
Red palm oil	30,000		
Carrots	2,000		15
Leafy vegetables	685		44
Apricots	250		120
Tomatoes	100		300
Bananas	30		1,000
Orange juice	8		3,750

Source: Ref. 24.

Tan (1987)



What is the Role of Carotenoids in Health?



Milani et al., 2016

Biological activities of the main carotenoids used in the treatment of various diseases

Generals benefits of carotenoids from palm oil (α , β carotene)

- Pro-vitamin A
 - Support vision
 - Immune function
 - Supporting cell growth
 - Fetal development
- Antioxidant
 - Metabolic syndrome
 - Cognitive function
 - Bone strength
 - Cancer



As Pro-vitamin A

- Few studies have reported the potential of red palm oil (RPO) as the precursors of vitamin A and its effect in alleviating vitamin A deficiency (VAD) is similar compared to vitamin A supplements.
- According to a meta-analysis studied by Dong et al., (2017) the results showed that supplementation with a low level of red palm oil (≤ 8 g RPO) to children and adults lead to an increase in serum retinol levels and β -carotene levels, but the serum α -carotene levels have no significant differences upon consumption of RPO

Recommended vitamin A intake

- Children: 400-450 µg/day
- Adolescent and adults: men and women - 600µg/day
- Pregnancy: 800 µg/day
- Lactation: 850 µg/day

µg retinol = 1 RE

1 µg β-carotene = 0.167 µg RE, (1/6 µg)

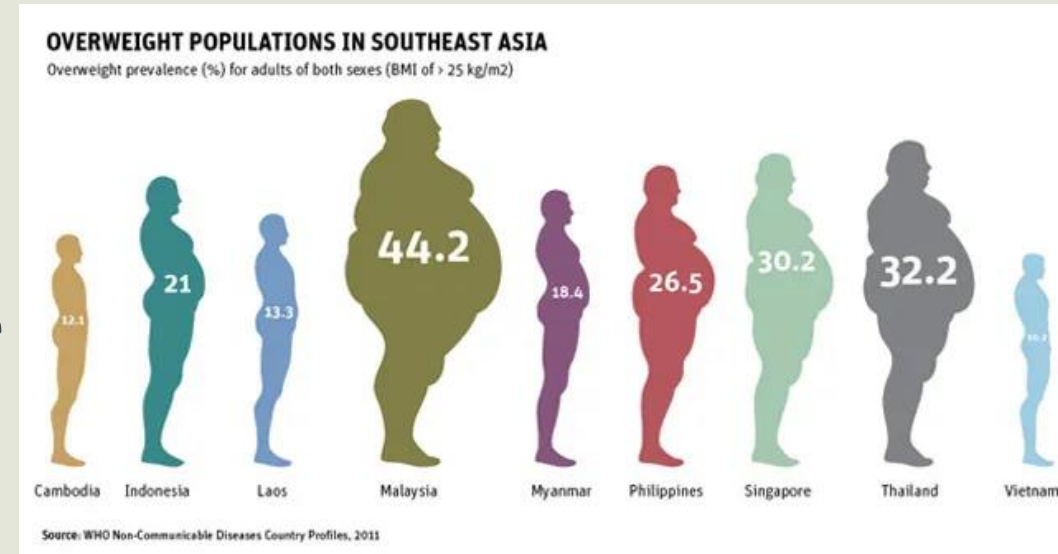
1 µg other pro-vitamin A carotenoids = 0.084 µg RE, (1/12 µg)

Pro-vitamin A and Obesity

- According to a meta-analysis studied by Yao et al., (2021), carotenoids show promising effects in overweight or obese subjects.
- Possible mechanism
 - Block the formation of adipocytes
 - Decrease fat accumulation, and
 - Be involved in the inflammatory response

The association between carotenoids and subjects with overweight or obesity: a systematic review and meta-analysis†

Nan Yao,^a Shoumeng Yan,^a Yinpei Guo,^a Han Wang,^a Xiaotong Li,^a Ling Wang,^a Wenyu Hu,^a Bo Li^{*a} and Weiwei Cui ^{*b}



Food Funct., 2021, **12**, 4768

Carotenoids and Metabolic Syndrome (MetS)

- Serum levels of carotenoids, particularly α - and β -carotene, as well as retinyl esters, were **inversely** associated with MetS

Carotenoids, vitamin A, and their association with the metabolic syndrome: a systematic review and meta-analysis

May A. Beydoun, Xiaoli Chen, Kanishk Jha, Hind A. Beydoun, Alan B. Zonderman, and Jose A. Canas

Nutrition Reviews® Vol. 77(1):32–45 2018

- Dietary intakes of alpha and beta-carotene were significantly associated with the **reduced risk** of mortality from coronary heart disease (CHD) (Gao et al., 2021).
- Intakes of α -carotene, β -carotene, β -cryptoxanthin, lycopene, lutein with zeaxanthin, and total carotenoids were **inversely** associated with hypertension in US adults. The intake of total carotenoids was suggested at least 100 $\mu\text{g/kg}$ per day for general adult population (Li et al., 2019)
- High intake of total carotenoids, β -carotene, β -cryptoxanthin, lycopene and lut-zea may be associated with a low risk of developing preeclampsia (PE) (Kang et al., 2022)

Carotenoids and Bone Health

- Higher intake of β -carotene and β -cryptoxanthin were associated with lower risk of osteoporosis. A very high intake of lutein + zeaxanthin was also associated with lower risk of osteoporosis.

Dietary carotenoid intake and osteoporosis: the National Health and Nutrition Examination Survey, 2005–2018
Kan et al (Archives of Osteoporosis, 2022, 17 (2))

- Meta-analysis suggests that β -carotene intake was inversely associated with fracture risk, which was consistently observed for case-control and cohort studies.

Effects of β -carotene intake on the risk of fracture: a Bayesian meta-analysis

Tesfaye Getachew Charkos¹, Yawen Liu¹, Kemal Sherefa Oumer¹, Ann M. Vuong² and Shuman Yang¹

BMC Musculoskeletal Disorders (2020) 21:711

Carotenoids and Type 2 Diabetes Mellitus

- Higher dietary intakes and circulating concentrations of total carotenoids, especially β -carotene, were associated with a lower risk of T2D.

Dietary Intake and Circulating Concentrations of Carotenoids and Risk of Type 2 Diabetes: A Dose-Response Meta-Analysis of Prospective Observational Studies

Yi-Wen Jiang,^{1,2} Zhong-Han Sun,^{1,2,3} Wen-Wei Tong,⁴ Kun Yang,⁴ Kun-Quan Guo,⁴ Gang Liu,⁵ and An Pan^{1,2,6}

Adv Nutr 2021;12:1723–1733.

- Higher concentrations of serum β -carotene were significantly associated with an increased risk of cardiovascular mortality among individuals with T2D (Qiu et al., 2022)

Carotenoids and Cognitive Function

- Higher α -carotene levels in blood were associated with higher global cognition scores in a US population at risk for cognitive decline.
- α -carotene, β -carotene, β -cryptoxanthin, lycopene, lutein with zeaxanthin, and total carotenoid intake may be inversely associated with the risk of depressive symptoms in the U.S. adults.

Associations between dietary carotenoid intakes and the risk of depressive symptoms

Honghan Ge¹, Tingting Yang², Jing Sun¹ and Dongfeng Zhang^{1*}

Food & Nutrition Research 2020, **64**: 3920

Higher circulating α -carotene was associated with better cognitive function: an evaluation among the MIND trial participants

Xiaoran Liu^{1,2*} , Klodian Dhana^{1,2} , Jeremy D. Furtado³, Puja Agarwal¹ , Neelum T. Aggarwal^{4,5}, Christy Tangney^{6,7} , Nancy Laranjo⁸, Vincent Carey^{8,9}, Lisa L. Barnes^{4,5} and Frank M. Sacks^{8,10}

Journal of Nutritional Science (2021), vol. 10, e64, page 1 of 9

Table 3
 Cognitive performance with long-term β -carotene supplementation [14].

Parameter	Placebo (n = 2021)	β -carotene (n = 2031)	Mean difference
Verbal memory ^a , mean z score (SD)	− 0.032 (0.74)	0.031 (0.73)	0.063 (95% CI 0.02–0.11; p = 0.007)
TICS, mean points (SD)	34.23 (2.80)	34.41 (2.73)	0.18 (95% CI 0.01–0.35; p = 0.04)
Global score ^b , mean z score (SD)	− 0.024 (0.71)	0.023 (0.69)	0.047 (95% CI 0–0.09; p = 0.03)

CI = confidence interval; SD = standard deviation; TICS = Telephone Interview Cognitive Status.
^a Combination of immediate and delayed recalls of 10-word list and East Boston Memory Test.
^b Global score (primary outcome) including verbal memory, TICS and category fluency.

The Physicians' Health Study II found that long-term (18 years) β -carotene supplementation (50 mg on alternate days) helped to maintain cognitive performance in a generally healthy population.

Carotenoids and Cancer



- The carotenoids and vitamin E tocotrienols of RPO both is said to have a beneficial effect on the consequences of chemotherapy (Loganathan et al., 2017; Oguntibeju et al. 2009)
- Colonic tumor biomarker ACF (aberrant crypt foci) on the **rat subjects** with azoxymethane-induced colon cancer, supplementation of RPO for 13 weeks could decrease the number of ACF in the subjects. In contrast, glutathione S-transferase activity was found to increase in the liver.
- RPO's anticancer properties can induce apoptosis in highly malignant **mouse mammary epithelial cell** at treatment doses.

The relationship between carotenoids intake and prevention of diseases

The relationship between carotenoids intake and prevention of diseases

Carotenoid	Disease	Clinical effect	Reference
Dietary carotenoids (combined)	Colorectal cancer	No significant effect	Panic <i>et al.</i> , 2016
β -carotene	Prostate cancer	No significant effect	Wang <i>et al.</i> , 2015
α -carotene, lycopene	Prostate cancer	Decrease in the risk of prostate cancer, but not at an advanced stage	Wang <i>et al.</i> , 2015
Tomatoes rich in carotenoids	Prostate cancer	Modest effect in the prevention of prostate cancer	Chen <i>et al.</i> , 2013a,b
Lycopene	Benign prostatic hyperplasia (BPH) or prostate cancer	No significant effect	Ilic and Missob, 2012
Lycopene	Cardiovascular disease	Improvement of endothelial function	Gajendragadkar <i>et al.</i> , 2014
Higher doses of lycopene	Prostate cancer	Reduced risk of prostate cancer	Chen <i>et al.</i> , 2015
β -carotene	Oral cavity cancer and laryngeal cancer	46 and 57% reduction in the risk of cancers respectively	Leoncini <i>et al.</i> , 2015
Lycopene and β -cryptoxanthin	Laryngeal cancer	Reduction in the risk of cancer	Leoncini <i>et al.</i> , 2015
Combination of lycopene, α -carotene and β -cryptoxanthin	Oral and pharyngeal cancers	26% reduction in the rate of cancers	Leoncini <i>et al.</i> , 2015
Micronutrients (α -carotene, β -carotene, β -cryptoxanthin, lutein, lycopene, zeaxanthin and canthaxanthin)	Parkinson's disease	No significant effect	Takeda <i>et al.</i> , 2014
Vitamin A or β -carotene supplementation	Maternal or infant mortality in pregnancy	No significant effect on birthweight indicators, preterm birth, stillbirth, miscarriage or fetal loss	Thorne-Lyman and Fawzi, 2012
Vitamin A or β -carotene supplementation	Pregnancy in HIV-positive women	Protective against low birthweight, no significant effects on preterm delivery or small-for-gestational age. Possible harmful effects through increased HIV transmission	Thorne-Lyman and Fawzi, 2012
β -carotene	Non-melanoma skin cancer	No significant effect	Greenberg <i>et al.</i> , 1990
β -carotene	Breast cancer	Significant decrease in breast cancer risk	Aune <i>et al.</i> , 2012
β -carotene and vitamin A	Cardiovascular disease	No effect and can even stimulate disease	Omenn <i>et al.</i> , 1996
Curcumin	Major depressive disorders	Anti-depressant effect	Al-Karawi <i>et al.</i> , 2016
Curcumin	Skin diseases	Therapeutic benefits for skin health	Vaughn <i>et al.</i> , 2016
Curcumin	Cardiovascular complications	Prevention of ventricular arrhythmias	Wongcharoen and Phrommintikul, 2009
Astaxanthin	Cardiac diseases	Therapeutic role in the management of myocardial injury	Ciccione <i>et al.</i> , 2013

Carotenoids	Source	Disease	<i>In vitro/ in vivo</i> study	^a Dose of interest	Biochemical/clinical effects	Ref.
β-carotene (derived from carrots, apricots, mangoes, red pepper, kale, spinach, broccoli)	Natural	Leukaemia	U937, HL-60 cell lines (<i>in vitro</i>)	20 μM	Cell cycle arrest in the G1 phase; induction of apoptosis, Antioxidant properties	Upadhyaya <i>et al.</i> , 2007
	Natural	Colon cancer	COLO 320 HSR, WiDr, LS174 cell lines (<i>in vitro</i>)	25 μM	Cell cycle arrest in the G2/M phase; reduction of the percentage of Bcl-2 and Bcl-xl positive cells	Palozza <i>et al.</i> , 2002
	Natural	Gastric cancer	AGS cell line (<i>in vitro</i>)	100 μmol·L ⁻¹	Induction of apoptosis	Jang <i>et al.</i> , 2009
	Natural	Adenocarcinoma	WiDr cell line (<i>in vitro</i>)	50 μM	Induction of apoptosis by its pro-oxidant properties	Palozza <i>et al.</i> , 2001
	Natural	Neuroblastoma	BE(2)C cell line, male BALB/c v/v mice (<i>in vitro/ in vivo</i>)	20 μM	As a chemotherapeutic agent regulating the invasion and metastasis of neuroblastoma via hypoxia inducible factor- 1 α (HIF-1α)	Kim <i>et al.</i> , 2014
	Natural	Hepatocarcinoma, Prostate cancer	SK-Hep1, B16F10, PC-3 cell lines (<i>in vitro</i>)	20 μM	Inhibition of proliferation. Decrease in VEGF secretion	Chen <i>et al.</i> , 2012
	Natural	Cervical cancer	Chinese women (clinical)	Vitamin diet (8.22% for α-carotene, 6.81 % for β-carotene)	Antioxidant compounds (e.g., α-carotene, β-carotene, and vitamins E and C) are beneficial in reducing the risk of cervical cancer	Guo <i>et al.</i> , 2015
	Natural	Prostate cancer	Finnish men (clinical)		High concentration of serum β-carotene was associated with low risk of prostate cancer	Karppi <i>et al.</i> , 2012
	Natural	HCV infection	HCV patient (clinical)		Decrease in serum retinol, β-carotene, and retinol binding protein 4 (RBP4) was associated with early stages of HCV infection	Kataria <i>et al.</i> , 2016

Carotenoids	Source	Disease	<i>In vitro/in vivo</i> study	^a Dose of interest	Biochemical/clinical effects	Ref.
	Natural	Age-related macular degeneration (AMD)	Patients (clinical)	Food intake	Low intake of n-3 fatty acid, α -tocopherol, zinc, vitamin D, vitamin C, β -carotene and lutein was associated with neovascular AMD; but no change for retinol or cryptoxanthin	Aoki <i>et al.</i> , 2016
B-carotene, canthaxanthin, phytoene	Natural	Skin tumours	Female SKH-h ⁻¹ mice (<i>in vivo</i>)	3.3 mg (β -carotene) 100 mg (canthaxanthin) 168 mg·kg ⁻¹ ·week ⁻¹ (phytoene)	β -carotene decreased the number of skin tumours	Mathews-Roth, 1982
α -carotene (AC) and β -carotene (BC) [AC derived from carrots, bananas, pumpkins, peppers, avocados, apricots]	Natural	Hepatocarcinoma	SK-Hep-1 cell line (<i>in vitro</i>)	2.5 μ M	Inhibition of cell invasion. Anti-tumour effects of AC were stronger than those of BC at the same concentration	Chen <i>et al.</i> , 2013a,b
β -carotene	Both forms [natural (derived from <i>Dunaliellasalina</i>) and synthetic]	Breast cancer	HaCat, MDA-MB-231 Cells (<i>in vitro</i>)	10 μ g·mL ⁻¹	Induction of apoptosis using both natural and synthetic sources. Natural β -carotene generated considerable higher rates of cell mortality as compared to synthetic form	Olmos <i>et al.</i> , 2015
Crocin (s), crocetin	Natural	Liver damage	Male Kunming mice (<i>in vivo</i>)	400 mg·kg ⁻¹	Low levels of serum alanine transaminase (ALT), aspartate transaminase (AST) and alkaline phosphatase (ALP)	Chen <i>et al.</i> , 2016
Crocin	Natural	Breast cancer	MCF-7 cells (<i>in vitro</i>)	50 μ g·mL ⁻¹ (IC ₅₀ : 60 μ g·mL ⁻¹)	Induction of apoptosis; activation of caspase-8	Lu <i>et al.</i> , 2015
Crocin, crocetin	Natural (derived from <i>Crocus sativus</i>)	Breast cancer	MCF-7 and MDA-MB-231 cells (<i>in vitro</i>)	>200 μ M (IC ₅₀ for MCF-7: 350 μ g·mL ⁻¹ ; IC ₅₀ for MDA-MB-231: 500 μ g·mL ⁻¹)	Inhibition of the proliferation	Chryssanthi <i>et al.</i> , 2007

(continues)

- β -carotene significantly decreased the severity of **colitis in rats**, lower proinflammatory cytokines and also significantly **increased** the abundance of **Faecalibacterium**, the levels of which negatively correlated with the levels of inflammatory cytokines (Zhu et al., 2021).

Table 4

Large carotenoid supplementation trials: effect of β -carotene on lung cancer and gastric cancer, and effect of β -carotene and lutein/zeaxanthin on age-related macular degeneration.

Study	Population	Supplementation	Key results
Linxian [84–86]	29,584 men and women in China	β -carotene 15 mg + vitamin E + selenium (5 years)	Lung cancer mortality HR 0.98 (95% CI 0.71–1.35, $p = 0.88$) Gastric cancer mortality RR 0.79 (95% CI 0.64–0.99); 10 years after stopping supplementation HR 0.89 (95% CI 0.79–1.00, $p = 0.043$)
PHS [87,88]	22,071 US male physicians	β -carotene 50 mg every other day (12 years)	Lung cancer RR 0.9 (95% CI 0.7–1.2) Gastric cancer RR 0.9 ^a
ATBC [89]	29,133 Finish male smokers	β -carotene 20 mg (5–8 years)	Lung cancer RR 1.18 (95% CI 1.03–1.36, $p = 0.01$) Stomach cancer RR 1.25 ^a (p-value not stated)
CARET [90]	18,314 US men and women smokers and asbestos workers	β -carotene 30 mg + vitamin A (4 years)	Lung cancer RR 1.28 (95% CI 1.04–1.57, $p = 0.02$)
AREDS1 [91]	3640 US men and women	β -carotene 15 mg + vitamin C + vitamin E + zinc	Progression to advanced AMD OR 0.66 (99% CI 0.47–0.91)
AREDS2 [11]	4203 US men and women	Lutein 10 mg + zeaxanthin 2 mg	Progression to advanced AMD among people with lowest dietary lutein/zeaxanthin intake, HR 0.74 (95% CI 0.59–0.94, $p = 0.01$)

AMD = age-related macular degeneration; AREDS = Age-Related Eye Disease Study; ATBC = Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study; CARET = Beta-Carotene And Retinol Efficacy Trial; CI = confidence interval; HR = hazard ratio; Linxian = Linxian General Population Trial; OR = odds ratio; PHS = Physicians' Health Study; RR = relative risk.

^a Estimated based on number of cases of cancer reported in β -carotene and placebo groups.



The variation in results between these population-based supplementation trials:

- different doses and formulations
- administration with different combinations of other nutrients, and
- the effect of differences in diet and lifestyle factors.

Conclusion

- Natural foods is better than supplements.
- Moderation
- **PREVENTION IS BETTER THAN CURE**

Thank You



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