



Plant-Based Foods for Skin Health: A Narrative Review



Vivien W. Fam, PhD, RDN; Prae Charoenwoodhipong, MS; Raja K. Sivamani, MD, MS; Roberta R. Holt, PhD; Carl L. Keen, PhD; Robert M. Hackman, PhD

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ABSTRACT

The potential role of plant-based foods in the promotion of skin health is an emerging area of nutrition research. Plant-based foods are rich in bioactive compounds, including vitamin C, vitamin E, beta carotene, polyphenols, and phenolic acids, which can contribute to oxidant defense, lower inflammation, and promote structural support of the skin. Epidemiological studies have associated higher intakes of select fruits and vegetables with positive skin health. Beneficial effects of certain fruits, vegetables, nuts, legumes, and polyphenolic-rich beverages on the skin have been reported, with each of these providing a unique phytochemical composition. Although most studies use extracts, this review will focus on data from whole foods and minimally processed products. Collectively, the evidence to date suggests a promising future for plant-based dietary interventions that promote skin barrier health and function. However, additional research is required to address issues such as the optimal quality and duration of intake as well as potential mechanisms. Studies in the above areas will help formulate specific targeted dietary recommendations.
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SKIN, THE LARGEST ORGAN IN THE HUMAN BODY, acts as a barrier to protect internal organs and cells from external elements. It also helps regulate body temperature, mediates sensations of touch, and produces vitamin D, a key regulator of bone, immune, and vascular health.³ Both intrinsic and extrinsic factors affect skin health and aging.⁴ An individual's genetic background influences intrinsic factors such as skin pigmentation, skin thickness, microvasculature structure, and sex hormones.⁴ Extrinsic factors such as smoking, diet, sleep, exercise, chronic diseases, and environmental factors including temperature, pollution, humidity, and UV radiation (UVR) can increase inflammation and oxidative stress that accelerate skin aging.⁴⁻⁶ Indeed, repeated UVR exposure can increase pro-inflammatory cytokines that contribute to the development of wrinkles and adverse pigmentation of the skin.⁷ Moreover, age- or obesity-related induction of protein glycation and inflammation can increase skin rigidity and impair skin repair.⁸

Suboptimal nutrition can adversely affect skin health, as evidenced in studies of micronutrient deficiencies. For example, deficiencies of vitamin A and vitamin C (VitC) can lead to thickening of the skin.⁹ Poor wound healing has been observed with deficiencies of VitC and essential fatty acids,⁹⁻¹¹ and petechiae can be a result of vitamin E and vitamin K deficiencies.⁹ Inadequate intakes of riboflavin, niacin, pyridoxine, biotin, zinc, and essential fatty acids can lead to various forms of dermatitis.^{9,12} Classic studies on pellagra¹³

and acrodermatitis enteropathica¹⁴ identified niacin and zinc deficiencies, respectively, as causative factors. Although the data on micronutrient deficiencies are extensive, data on how specific foods or diets can influence skin health in well-nourished populations are limited.

Epidemiological studies suggest that abundant dietary intakes of specific plant-based foods are key in the maintenance of skin barrier health and function. A robust intake of vegetables, olive oil, and legumes was correlated with lower actinic skin damage caused by long-term UVR exposure among 2000 people aged 70 and older in Australia, Greece, China, Japan, and Sweden.¹ Better adherence to the Dutch Healthy Diet Index guidelines that promote a diet rich in fruits and include yogurt, milk, and vegetables was significantly associated with fewer wrinkles in women.² Among Japanese women, a significant inverse association has been observed between wrinkling and green and yellow vegetable intake.¹⁵ In contrast, diets consisting mainly of meat, refined grains, snacks, soft drinks, coffee, and alcoholic beverages were associated with more wrinkling in women.²

Plant-based foods are rich in polyphenols, carotenoids, and select vitamins typically not found in appreciable amounts in other food categories. However, each food has a unique nutrient profile that provides an array of bioactive compounds that either alone or synergistically may afford protection for the skin.

Given this information, we conducted a preliminary survey of recent literature on the potential effects of plant foods on

skin barrier health and function. A majority of the trials discussed used study designs of dietary components and foods individually, at times, above dietary recommendations. However, the goal of this review is to spark interest in this field, as well as provide an overview of the available data for both the public and nutrition professionals who have an interest in the role of diet for the maintenance of skin barrier health and function. This review aims to provide more specificity in terms of the fruits and vegetables that may improve skin barrier function and meet the recommendations of the 2020-2025 Dietary Guidelines for Americans (DGAs).

METHODS

Articles were identified on PubMed and Google Scholar using the following key terms (or combinations of them): “fruit,” “vegetable,” “nut,” “legume,” “bean,” “food,” “skin,” “wrinkle,” “erythema,” “hydration,” “elasticity,” “aging,” “photoaging.” All studies available in English were reviewed. Eligibility criteria for clinical trials included dietary interventions and skin parameter measurements relevant to wrinkles, erythema, hydration, and elasticity. Studies focused on plant-based foods and beverages that were whole or processed into extracts were considered. Extracts were equated to equivalent quantities as whole foods or beverages to deduce feasibility of consumption. Isolated compounds were not considered. Dermatological skin diseases such as acne and psoriasis were not considered. Animal or in vitro studies were included for select plant-based foods or relevant bioactive compounds that supported potential mechanisms of action for the clinical trials.

RESULTS

Twenty studies involving 13 plant-based foods were identified, including 8 fruits and vegetables, 2 nuts and legumes, and 3 polyphenolic-rich beverages. Products used in dietary interventions included whole foods, nutritional pastes, beverages, juice, and extracts (Table). For the included trials, study participants were adults between 18 and 86 years old. Most studies reported the Fitzpatrick skin phototype (FSPT), a standard tool used to categorize an individual's skin type based on melanin pigmentation and factors and potential skin reaction to UVR exposure. Individuals with FSPT I and II have less melanin pigmentation and increased sensitivity to harmful effects of UVR such as sunburn and premature aging, and individuals with FSPT III and IV tend to tan.¹⁶

Fruits and Vegetables

Fruits and vegetables are rich in bioactive compounds including carotenoids,¹⁷ vitamins, and polyphenols.¹⁸ These are distributed to the skin and promote oxidant defense and structural integrity and reduce inflammation to help protect against UVR-induced damage.^{18,19} Many fruits and vegetables are excellent sources of VitC, with reduced intake of VitC associated with dry or wrinkled skin in women.²⁰ VitC is a cofactor for prolyl and lysyl hydroxylases that are important for collagen synthesis. It also functions as a major circulating antioxidant that can quench reactive oxygen species (ROS) derived from UVR.²¹ A number of fruits and vegetables are also substantial sources of carotenoids. Supplementation of

RESEARCH SNAPSHOT

Research Question: What is the evidence for plant-based food intake for skin health in humans?

Key Findings: Consumption of select fruits and vegetables rich in vitamins and polyphenols, nuts and legumes abundant in mono- and poly-unsaturated fats, as well as polyphenolic-rich beverages, can improve skin health. Beneficial skin effects vary but include an improvement in hydration, hyperpigmentation, wrinkles, erythema, collagen, and elasticity. More clinical studies are needed to determine the amount and duration of consumption for each food to elicit beneficial effects and to understand the underlying mechanisms.

carotenoids in the range of 24 to 25 mg per day for 12 weeks in healthy men and women aged 20 to 57 was observed to significantly reduced UV-induced erythema.^{22,23} In another study, carotenoid supplementation also inhibited an increase in UVR-induced CD45+ inflammatory cells.²⁴ In addition, the intake of 13.1 mg of carotenoids daily for 26 days significantly reduced oxidative stress-induced lymphocyte DNA damage in young adults.²⁵

Mangos. Mangos (*Mangifera indica* L) are rich in carotenoids (especially beta carotene) as well as VitC and the phenolic gallic acid.²⁶ Ataulfo mangos have the highest VitC content among the mango varieties commonly found in the United States,²⁷ with 85 g providing an estimated 107 mg of VitC (143% of the recommended dietary allowance [RDA] for adult women).²⁸ This mango variety is also rich in beta carotene, with 85 g providing 2219 μ g (16% of the RDA for adult women). Ataulfo mangos are 4 times higher in beta carotene than the reference level reported by the US Department of Agriculture (USDA) Food Data Central (FDC) #169910 (640 μ g/100 g of raw mango).²⁸ A significant decrease in deep facial wrinkles was seen in postmenopausal women aged 50 to 70 with FSPT II or III after consuming 85 g (0.5 cup) of fresh-frozen Ataulfo mangos 4 times a week for 16 weeks.²⁹ Curiously, those who consumed 250 g (1.5 cups) in the same intake pattern had an increase in wrinkles. This may have been due to the amount of sugar present in the fruit. Glucose and fructose are known to increase glycation of collagen and elastin fibers, which disrupt the integrity of the subcutaneous tissue supporting the skin.³⁰

Mangos are also the primary dietary source of the polyphenol mangiferin. Ataulfo mangos have been found to contain 183 to 996 μ g/g of mangiferin depending on harvest date, which is higher than 4 other mango varieties tested.²⁷ UV-irradiated mice fed a mango extract containing 13.5% of mangiferin for 12 weeks showed a significant decrease in wrinkle length, along with an increase in collagen bundles and inhibition of collagen fiber damage through a reduction in inflammation.³¹ Supplementation of mangiferin to mice also resulted in a decrease in the pro-inflammatory indices of inducible nitric oxide synthase, interleukin-1 β , and interleukin-6 and inhibition of nuclear factor-kappa B subunit 2 and I κ B phosphorylation in the skin.³²

Table 1. Overview of dietary clinical studies examining the effects of plant-based foods and extracts on skin parameters

Plant-based item	Country / first author (year)	Study design	Subjects	Smokers	BMI ^b	Age (y)	Intervention	Form and intake of product	Location of skin	Fitzpatrick skin phototype	Effects ^f
Fruits and vegetables											
Mango	USA / Fam (2020) ²⁹	Randomized parallel arm—16 wk	32 postmenopausal women	Excluded	(1) 26.4 ± 4.0; (2) 22.9 ± 2.6	All range: 50-70; (1) 61 ± 5.1; (2) 60 ± 5.3	(1) 85 g (0.5 cup) fresh-frozen mangos; (2) 250 g (1.5 cups) fresh-frozen mangos	Fresh-frozen mangos, 4 times/wk	Lateral canthi, cheeks	II and III	<i>Lateral canthi 85 g:</i> Deep wrinkle severity: ↓ ^g <i>Lateral canthi 250 g:</i> Emerging wrinkle severity: ↑ ^h Average wrinkle severity: Average wrinkle length: ↑ Fine wrinkle severity: ↑ <i>Cheeks:</i> Erythema: ↑ 85 g, ↔ ⁱ 250g MED: ↑
Melon	France / Egoumenides (2018) ³⁴	RCT ^a , double-blind, parallel arm—34 d	44 White adult men (15.9%) and women (84.1%)	Not specified	Not specified	All range: 18-50 (mean 37.2)	(1) 20 mg dried melon concentrate; (2) control pill	Extract in a capsule, 20 mg/d	Buttock, back, or arms	II and III	
Orange	Italy / Puglia (2014) ³⁹	Crossover—15 d	20 White adults	Excluded	Not specified	UV irradiation: 26-47; sunlamp exposure: 45-70	Blood orange (Moro, Tarocco, and Sanguinello) extract, per capsule: ANC ^c 2.8%-3.2%, hydroxycinnamic acids (caffeic, cumaric, ferulic, sinapic acid) 1.8%-2.2%, flavone glycosides (naringin, hesperidin) 8.5%-9.5%, ascorbic acid 5.5%-6.5%	Extract in a capsule, 100 mg/d	Forearm and dorsal hand	UV irradiation: II and III; sunlamp exposure: II and IV	<i>Forearm:</i> Skin erythema index: ↓ <i>Dorsal hand:</i> Melanin index: ↓

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Table 1. Overview of dietary clinical studies examining the effects of plant-based foods and extracts on skin parameters (*continued*)

Plant-based item	Country / first author (year)	Study design	Subjects	Smokers	BMI ^b	Age (y)	Intervention	Form and intake of product	Location of skin	Fitzpatrick skin phototype	Effects ^f
Tomato	Germany / Groten (2019) ⁵²	RCT, double-blind, parallel arm, multicenter—12 wk	145 adult men (23%) and women (77%)	8 smokers (5.5%)	≤30	All range: 20-50; (1) mean 40.9; (2) mean 40.9	(1) Tomato nutrient complex, per capsule: tomato—7.5 mg lycopene, 2.9 mg phytoene and phytofluene, 0.4 mg beta-carotene, 2.8 mg tocopherols; rosemary—2 mg carnosic acid; (2) control: medium-chain triglycerides	Extract, 2 capsules/d	Buttock	I and II	MED: ↔ a*: ↓ L*: ↔
	UK / Rizwan (2011) ⁵¹	RCT, single-blind, parallel arm—12 wk	17 White women	Excluded	Not specified	All range: 21-47 (median 33)	(1) Tomato paste with olive oil, 55 g; per serving: 16 mg lycopene; (2) control: olive oil, 10g	Paste, daily	Upper buttock	I and II	MED: ↑ Erythema index: ↑ Procollagen I: ↑ Fibrillin-1: ↓
	Germany / Stahl (2001) ⁵⁰	RCT, parallel arm—10 wk	22 adult men (36%) and women (64%)	Included with a limit of ≤3 cigarettes/d	Not specified	All range: 26-67	(1) Tomato paste (40 g) with olive oil (10 g); per serving: 16 mg lycopene, 0.5 mg β-carotene, 0.1 mg lutein; (2) control: olive oil, 10g	Paste, daily	Scapular region	II	a*: ↓
Kale	Germany / Meinke (2017) ⁵⁶	RCT, parallel arm—10 mo	29 women	10 smokers (34.5%)	Not specified	All range: 40-56 (mean 49.2)	(1) Curly kale extract, per capsule: total 550 μg carotenoids: 430 μg lutein, 70 μg beta-carotene, 30 μg lycopene, 20 μg zeaxanthin; (2) control: olive oil	Extract, 3 capsules/d	Inner forearm, II and cheeks		Collagen I/elastin ratio: ↑

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Table 1. Overview of dietary clinical studies examining the effects of plant-based foods and extracts on skin parameters (*continued*)

Plant-based item	Country / first author (year)	Study design	Subjects	Smokers	BMI ^b	Age (y)	Intervention	Form and intake of product	Location of skin	Fitzpatrick phototype	Effects ^f
Pomegranate	USA / Henning (2019) ⁶⁰	RCT, parallel, 3-arm, open-label—12 wk	74 women	Not specified	(1) 26.6 ± 5.0; (2) 27.1 ± 5.1; (3) 29.9 ± 6.7	All range: (30-40); (1) 35.1 ± 4.3; (2) 35.9 ± 4.1; (3) 37.9 ± 4.2	(1) Pomegranate juice, per cup: 100 mg punicalagin, 23 mg ellagic acid; (1) pomegranate extract, per capsule: 100 mg punicalagin, 44 mg ellagic acid; (3) control: dextran	Juice, 8 oz/d or extract in a capsule, 1,000 mg/d	Inner arm	II, III, and IV	MED: ↑ Melanin index: ↓
Passion fruit	Japan / Maruki-Uchida (2018) ⁶⁴	RCT, double-blind, parallel arm—8 wk	32 women with dry skin	Not specified	Not specified	All range: 35-54	(1) Passion fruit seed extract containing per capsule: 5 mg piceatannol; (2) control: dextrin	Extract, 2 capsules/d	Cheeks	Not specified	Moisture content: ↑ TEWL ^m : ↓ Skin elasticity: ↓ L* a* b* ⁿ : ↓
Grape	Japan / Yamakoshi (2004) ⁷¹	Open-label—Total 11 mo; 1st period, 6 mo; 1-mo break; 2nd period, 5 mo	12 Japanese women with chloasma	Not specified	Not specified	All range: 34-58 (45.4 ± 6.1)	Grape seed extract, per capsule: 81%, 54 mg PAC ^d	Extract in a capsule, 67 mg, 3 times/d	Cheeks	Not specified	L*: ↑ Diameter of chloasma: ↓ Melanin index: ↓
	Japan / Tsuchiya (2020) ⁷³	RCT, double-blind, parallel arm—12 wk	97 women with lentigo spots on cheeks	Not specified	(1) 21.07 ± 1.78; (2) 21.08 ± 2.59	All range: 30-60; (1) 44.28 ± 6.50; (2) 44.66 ± 5.93	(1) 200 mg dealcoholized red wine oligomeric PACs, per bottle: 208 mg	Extract in beverage, 200 mL/d	Cheeks	Not specified	Lentigo scores: ↓ SC ^o water content: ↑
Nuts and legumes											
Almond	USA / Foolad (2019) ⁸³	RCT, parallel arm—16 wk	28 postmenopausal women	Excluded	(1) 30.7 ± 7.31; (2) 29.7 ± 7.66	All range: 53-80; (1) 63.63 ± 7.09; (2) 58.93 ± 6.10	(1) 20% of daily kcals consumed as almonds; average 2.1 oz/d; (2) control: 20% of daily kcal consumed as calorie-matched nut-free snack	Whole raw almonds, daily	Lateral canthi	I and II	Overall wrinkle severity: ↓ Overall wrinkle width: ↓ TEWL: ↔ Sebum production: ↔

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Table 1. Overview of dietary clinical studies examining the effects of plant-based foods and extracts on skin parameters (*continued*)

Plant-based item	Country / first author (year)	Study design	Subjects	Smokers	BMI ^b	Age (y)	Intervention	Form and intake of product	Location of skin	Fitzpatrick skin phototype	Effects ^f
	USA / Rybak (2021) ⁸⁴	RCT, single-blind, parallel arm—24 wk	49 postmenopausal women	Excluded	Not specified	(1) Range: 51-77; 61.72 ± 8.76; (2) range: 47-84; 65.14 ± 8.14	(1) 20% of daily kcals consumed as almonds; (2) control: 20% of daily kcal consumed as calorie-matched nut-free snack	Whole raw almonds, daily	Lateral canthi, cheeks, forehead	I and II	<i>Lateral canthi:</i> Average wrinkle severity: ↓ <i>Cheeks and forehead:</i> Average pigment intensity: ↓ Hydration: ↑ TEWL: ↔ Sebum: ↔
Soybean	Japan / Izumi (2006) ⁹⁴	RCT, double-blind, parallel arm—12 wk	26 women	Not specified	Not specified	All range: 35-48; (1) 40.1 ± 1; (2) 40.5 ± 0.95	(1) 25 mg fermented soybean extract containing 10 mg (40%) isoflavone aglycones; (2) control: color-matched, no extract	Extract in a 250-mg capsule, 4 capsules/d	Lateral canthi, cheeks	Not specified	<i>Lateral canthi:</i> Fine wrinkles: ↓ Linear wrinkles: ↔ Skin microrelief: ↑ <i>Cheeks:</i> Skin elasticity: ↑
	Korea / Lee (2015) ⁹⁵	RCT, parallel arm—8 wk	65 women with dry and dark skin	Not specified	(1) 21.99 ± 1.7; (2) 21.43 ± 1.95	All range: 25-60; (1) 42.58 ± 4.60; (2) 43.41 ± 4.68	(1) Barley and soybean formula, per 100 mL: 3 g; (2) control: no formula	Extract in beverage, 100 mL/d	Forearm and front cheeks	Not specified	Skin hydration: ↑ SC thickness: ↓
Polyphenol-rich beverages											
Cocoa	South Korea / Yoon (2015) ¹⁰¹	RCT, double-blind, parallel arm—24 wk	64 women with visible wrinkles ≥ grade 2	Not specified	Not specified	All range: 48-86; (1) 63.3 ± 13.9; (2) 60.0 ± 12.6	(1) Cocoa powder, per day: 320 mg total cocoa flavanols; (2) control: nutrient-matched cocoa-flavored beverage without flavanols	Cocoa powder dissolved in 150-200 mL hot water, 4 g/d	Lateral canthi, cheeks, buttock	Not specified	<i>Lateral canthi:</i> Wrinkle depth: ↓ <i>Cheek:</i> Skin elasticity: ↑ Skin hydration: ↔ <i>Buttock:</i> MED: ↑

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Table 1. Overview of dietary clinical studies examining the effects of plant-based foods and extracts on skin parameters (*continued*)

Plant-based item	Country / first author (year)	Study design	Subjects	Smokers	BMI ^b	Age (y)	Intervention	Form and intake of product	Location of skin	Fitzpatrick skin phototype	Effects ^f
	Germany / Heinrich (2006) ¹⁰²	RCT, double-blind, parallel arm—12 wk	24 women	Excluded	Not specified	All range: 18-65	(1) High flavanol, per day: 329 mg total cocoa flavanols (61.1 mg epicatechin, 20.4 mg catechin); (2) low flavanol, per day: 27 mg total cocoa flavanols (6.6 mg epicatechin, 1.6 mg catechin)	Cocoa powder dissolved in 100 mL hot water, 18 g/d	Dorsal skin (back and scapular region)	II	a*: ↓ Cutaneous blood flow: ↑ Skin density: ↑ Skin thickness: ↑ Skin roughness: ↓ Scaling: ↓ Skin hydration: ↑ TEWL: ↓
Coffee	Japan / Ueda (2017) ¹⁰⁷	RCT, double-blind, parallel arm—4 wk	31 women with reported skin dryness	Excluded	(1) 20.7 ± 2.1; (2) 21.3 ± 1.7	All range: 25-35; (1) 31.3 ± 3.7; (2) 29.9 ± 3.4	(1) CPPs ^g , caffeine-free, per 100 mL: 297.8 mg CPP; (2) control: taste-matched, no CPP	Extract in beverage, 100 mL/d	Cheeks, perioral	Not specified	Skin scaliness: ↓
	Japan / Fukagawa (2017) ¹⁰⁸	RCT, double-blind, parallel arm—8 wk	49 women with xerotic skin	Excluded	Range: 18.5-25.0	All range: 25-40	(1) CPP, caffeine-free, per 100mL: 270 mg CPP; (2) control: taste-matched, no CPP	Extract in beverage, 100 mL/ d	Lower cheeks, hands	Not specified	<i>Lower cheek:</i> Skin dryness: ↓ TEWL: ↓ SC hydration: ↑ Skin surface pH: ↓ SC lipids: ↑ SC lactic acid: ↑ <i>Hands:</i> Skin dryness: ↓ TEWL: ↓ SC hydration: ↑ Skin surface pH: ↓

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Table 1. Overview of dietary clinical studies examining the effects of plant-based foods and extracts on skin parameters (*continued*)

Plant-based item	Country / first author (year)	Study design	Subjects	Smokers	BMI ^b	Age (y)	Intervention	Form and intake of product	Location of skin	Fitzpatrick skin phototype	Effects ^f
Green tea	Germany / Heinrich (2011) ¹¹⁵	RCT, double-blind, parallel arm—12 wk	60 women	Excluded	Range: (18-25)	All range: 40-65 (1)	Green tea beverage, per 1L: 1402 mg total tea catechins; (2) control: taste-matched, no catechins	Extract in beverage, 1 L/d	Back scapular region, inner forearm	II	<i>Back and scapular region:</i> a*: ↓ <i>Inner forearm:</i> Viscoelasticity: ↓ Biological elasticity: ↑ Skin density: ↑ Skin thickness: ↔ Skin roughness: ↓ TEWL: ↓ Skin volume: ↓ Skin scaling: ↓ Skin hydration: ↑

^aRCT = randomized controlled trial.

^bBMI = body mass index (measured as kg/m²).

^cANC = anthocyanin.

^dPAC =

^eCPP = coffee polyphenol.

^fSignificant changes (*P* < .05) are bolded.

^g↓ = decrease.

^h↑ = increase.

ⁱ↔ = no changes.

^jMED = minimal erythema dose.

^ka* = skin redness.

^lL* = skin lightness.

^mTEWL = transepidermal water loss.

ⁿb* = skin pigment.

^oSC = stratum corneum.

Melons. Melons (*Cucumis melo* L) are rich in VitC and beta carotene, with cantaloupes containing higher amounts than honeydews.³³ In 44 White subjects aged 18 to 50 with FSPT II or III, consumption of dried melon pulp juice concentrate (MPJC) was associated with decreased UVR-induced damage. Participants consumed the MPJC or a color-matched control capsule daily along with a control topical cream for 30 days.³⁴ Participants' buttocks were irradiated at baseline and after supplementation, and a significant increase in the minimal erythema dose (MED) was observed in the MPJC group compared with controls. The MED represents the lowest amount of UVR required to produce mild sunburn or redness. A higher MED is thought to correlate with decreased susceptibility to UVR damage.³⁵ In another study, examining women aged 40 to 70 with FSPT II to IV, participants consumed a capsule containing the MPJC along with grape seed extract, VitC, and zinc for 8 weeks. Significant improvements in skin color, luminosity, dark circles under the eyes, erythema, and overall subjective satisfaction was noted.³⁶ The authors of both studies suggested that superoxide dismutase was a primary driver contributing to the observed effects of MPJC; however, this mechanism seems unlikely since superoxide dismutase is a protein that is catabolized during digestion and not absorbed intact.³⁷ Regrettably, the studies did not provide information to estimate the equivalent amount of melons consumed. One cup of cantaloupe melon cubes (USDA FDC #169092) provides about 58.7 mg of VitC (65%-90% of RDA for adults) and 3230 μ g beta carotene.²⁸

Oranges. Oranges (*Citrus sinensis*) are widely recognized as being rich in VitC. The nutrient and polyphenolic profiles differ depending on the variety and environmental factors during the growing season.³⁸ The most common flavonoids found in citrus include quercetin, hesperidin, and narirutin. Another flavonoid subclass, the anthocyanins, are found in blood oranges, which give the pulp and juice its red color. Inhibition of UV-induced erythema was observed in 20 White participants aged 26 to 47 years with FSPT II and III when supplemented with 100 mg/d of a powdered extract, derived from a combination of blood orange varieties containing 2.8% to 3.2% anthocyanins, 1.8% to 2.2% hydroxycinnamic acids, 8.5% to 9.5% flavone glycosides, and 5.5% to 6.5% VitC, all on a weight-to-weight basis.³⁹ The same study found a significant inhibition of UV-induced melanogenesis in 25 participants with FSPT II and IV, aged 40 to 70 years. Melanogenesis was assessed in 3 areas containing solar lentigos as well as in 1 lentigo-free area on each hand. Melanin is an important essential molecule for skin photoprotection, absorbing a broad range of UV rays, dissipating energy as heat to protect the skin from DNA damage.⁴⁰ However, chronic UV exposure, particularly to UVB radiation, could exceed the melanin absorbance threshold, resulting in increased ROS generation. Increased melanogenesis can disrupt the equilibrium within melanocytes and may be observed as darkening of the skin or hyperpigmentation.⁴¹

Blood orange juice provides about 6.65 mg of total anthocyanins per 100 mL serving (USDA flavonoid database 3.3, 2018).⁴² A reduction in DNA damage and an increase in the concentrations of plasma anthocyanin cyanidin 3-glucoside, VitC, and carotenoids were noted in adults aged 20 to 27

years old who consumed 600 mL of blood orange juice for 21 days.⁴³ In mice, the intake of a citrus extract rich in hesperidin and narirutin for 7 weeks resulted in a significant inhibition of UV-induced transepidermal water loss (TEWL). This is an important measure of skin barrier function that assesses water diffused from the dermis and epidermis through the stratum corneum to the skin surface.⁴⁴ The study also reported improved skin hydration and reduced epidermal thickening.⁴⁵ Consumption of unripened Jeju mandarin orange extract (50, 100, and 200 mg/kg body weight) for 10 weeks in mice reduced UV-induced TEWL, wrinkle depth, epidermal thickness, and collagen degradation.⁴⁶ The amount of anthocyanins and VitC in the extract in the human study mentioned earlier³⁹ can be met through 300 mL or 1.3 cups of blood orange juice, containing 225 mg VitC and 10.5 mg cyanidin-3-glucoside.⁴³

Tomatoes. Tomatoes (*Lycopersicon esculentum*) are rich in lycopene, a carotenoid with strong oxidant defense capabilities.^{47,48} Human skin and plasma contain the highest amounts of lycopene compared with other body tissues.⁴⁹ Among men and women aged 26 to 67 with FSPT II, a significant decrease in UV-induced erythema, along with an increase in serum lycopene levels, was observed after 10 weeks of daily intake of 40 g of tomato paste, providing approximately 16 mg lycopene, compared with an olive oil control group.⁵⁰ In women aged 21 to 74 with FSPT I or II, consumption of 55 g of tomato paste containing 16 mg of lycopene along with olive oil daily for 12 weeks significantly increased the erythema threshold compared with the intake of olive oil alone.⁵¹ Additionally, those consuming the tomato paste showed a significant increase in procollagen I and inhibition of collagenase metalloproteinase-1 expression, mitochondrial DNA damage, and a reduction in fibrillin-1 in response to UVR-induced tissue injury. Twelve-week supplementation with a carotenoid-rich tomato nutrient complex that included rosemary extract significantly decreased UV-induced erythema in adults aged 20 to 50 with FSPT I or II compared with a control containing medium-chain triglycerides.⁵² A significant increase in serum lycopene was also observed in the tomato nutrient complex group, but not the control group. In the studies mentioned here, 40 to 55 g of tomato paste provided 16 mg of lycopene. Raw tomatoes contain less bioavailable form of lycopene compared with processed tomatoes.⁵³ Therefore, an estimate of 390 g or 2.5 cups of raw tomatoes (USDA FDC #321360) may be needed to provide the same level of lycopene as the studies.²⁸ Due to seasonal availability of local tomatoes, processed tomato products may be a suitable alternative due to consistent availability, longer shelf life, and concentration of bioavailable bioactive compounds.

Kale. Kale (*Brassica oleracea*) is rich in carotenoids, VitC, and glucoraphanin, a glucosinolate that is converted to sulforaphane, which can decrease inflammation and oxidative stress mediated by the Nrf2 signaling pathway.^{54,55} Consumption of carotenoid-rich curly kale extract (2200 μ g lutein, 1000 μ g beta carotene, 50 μ g alpha carotene, 400 μ g lycopene, 700 μ g zeaxanthin, 100 μ g cryptoxanthin) daily for 10 months improved collagen I and elastin levels in 29 women aged 40 to 56 with FSPT II compared with an olive oil control.⁵⁶ In addition, a significant increase in epidermal and

dermal thickness was observed when mice prone to accelerated skin aging consumed spray-dried kale or a glucoraphanin-enriched kale extract daily for 43 weeks, compared with controls.⁵⁷ The beneficial effects were prominent in the glucoraphanin-enriched group compared with those who consumed spray-dried kale. The amount of carotenoids in the extract closely matches 1 cup (118 g) of boiled kale (USDA FDC #169238), which contains about 5880 μg lutein and zeaxanthin, 2040 μg beta carotene, 11.8 μg alpha carotene, and 30.7 μg cryptoxanthin.²⁸ Stir-frying and steaming were reported to preserve more glucosinolates compared with boiling.⁵⁸

Pomegranates. Pomegranates (*Punica granatum* L) are rich in anthocyanins, the ellagitannin punicalagin, and ellagic acid.⁵⁹ A significant increase in MED was observed with daily intake of 8 oz (237 mL) of pomegranate juice or its extract for 12 weeks in 74 women aged 30 to 40 with FSPT II to IV.⁶⁰ The pomegranate juice and extract provided similar amounts of punicalagin and ellagic acid. The intake of pomegranate juice concentrate powder significantly decreased wrinkle formation, inhibited reduction in collagen type I and hyaluronan concentrations, and increased skin water content in UVB-treated mice compared with the group not receiving the powder.⁶¹ Supplementation also inhibited pro-inflammatory cytokine interleukin- β and myeloperoxidase activity that promotes the formation of ROS, while increasing the anti-inflammatory cytokine interleukin-10. One cup of pomegranate juice is equivalent to a serving of fruit and counts toward the daily recommendation.

Passion Fruits. Passion fruits (*Passiflora edulis*) contain edible seeds that provide polyphenols that can benefit the skin.⁶² The seeds have more polyphenols than the pulp or rind, with piceatannol only present in the seeds.⁶³ Improved skin barrier function, as evidenced by a significantly increased moisture content and decreased TEWL, was observed in 32 Japanese women aged 35 to 55 with dry skin complaints who consumed passion fruit seed extract containing 5 mg piceatannol for 8 weeks compared with controls.⁶⁴ Increased facial water content and viscoelasticity were also observed in adults who consumed piceatannol-rich beverages for 8 weeks.⁶⁵ Piceatannol, a polyphenolic compound, has been shown to increase oxidant defense, as evidenced by a reduction in amine-induced hydrogen peroxide generation in rats after 6 weeks of daily supplementation.⁶⁶ Approximately 2.3 g of raw passion fruit seeds are needed to obtain 5 mg (2.2 mg/g) piceatannol,⁶³ an amount that may be obtained from 1 fruit.

Grapes. Grapes (*Vitis vinifera*) contain significant amounts of polyphenols, including anthocyanins,⁶⁷ flavan-3-ols, resveratrol,⁶⁸ and proanthocyanidins⁶⁹ as well as VitC.⁷⁰ Six months of daily supplementation with a grape seed extract providing 162 mg of proanthocyanidins to 12 Japanese women who had melasma (brown skin patches) significantly reduced the melanin index and melasma size and improved skin lightening.⁷¹ The same research group had previously supplemented guinea pigs with the grape seed extract for 8 weeks and observed an inhibition in melanin synthesis and increased lightening of the skin.⁷² Another study observed a significant decrease in lentigos on the cheeks of women aged

30 to 60 years who consumed 200 mL of a beverage containing 200 mg of dealcoholized red wine oligomeric proanthocyanidins compared with a calorie-matched control drink for 12 weeks.⁷³ Stratum corneum water content was significantly increased in the test group and significantly decreased in the controls. Taken together, the studies suggest reduced melanogenesis and skin lightening from the proanthocyanidins-rich grape extracts. Improved cellular oxidant and anti-inflammatory defenses, as seen with an inhibition of Nrf2-dependent antioxidant enzymes in the skin, along with a reduction in epidermal thickness, were observed with 14 days of grape seed extract supplementation (2 mg/kg body weight) in UV-irradiated mice.⁷⁴ The previously mentioned studies provided about 3 to 4 times higher proanthocyanidins than the estimated mean daily intake of 57.7 mg in the United States.⁷⁵ Generally, grapes are a good dietary source of proanthocyanidins, and their juice contains about 524 mg/L.⁷⁵ To obtain 162 to 200 mg of proanthocyanidins provided in the studies, approximately 300 to 382 mL or 1.3 to 1.6 cups of grape juice should be consumed.

The DGAs recommend 2 cups of fruits, especially whole, and 2.5 cups of vegetables with specific suggested amounts for dark-green, red, and orange ones.⁷⁶ Although the studies mentioned illustrate that the estimated amount of select fruits and vegetables generally aligns with the guidelines, different plant foods have different phytochemical profiles, so specificity is needed when making dietary recommendations for different skin conditions.

Nuts and Legumes

Nuts and legumes have an abundance of beneficial fats and are a good source of plant-based protein as well as other micronutrients. A lower risk of severe photoaging, assessed by a physician using a 6-grade ordinal scale, has been associated with a higher intake of n-3 polyunsaturated fatty acids (n-3 PUFA) from plant-based sources⁷⁷ and monounsaturated fatty acids (MUFA) from vegetable oils but not dairy products and meats.⁷⁸ Furthermore, women with the highest intake of n-3 PUFA, especially eicosapentaenoic acid, were less prone to severe photoaging.⁷⁷ Although plant-based foods are not significant sources of eicosapentaenoic acid, it can be metabolized from alpha linolenic acid that is commonly found in vegetable and flax seeds, walnuts, and oils. The 2020-2025 DGAs recommend an intake of 5 oz per week of nuts, seeds, and soy products.⁷⁶ However, higher amounts may be required to promote specific skin health benefits.

Almonds. Almonds (*Prunus dulcis*) are rich in alpha tocopherol, MUFA, and polyphenols, all of which provide oxidant defense.^{79,80} One ounce of almonds (USDA FDC #170567) contains 8.94 g of MUFA, 3.5 g of PUFA, 6 g of protein, and 7.27 mg of alpha tocopherol.²⁸ Alpha tocopherol is the most abundant form of vitamin E in human tissues and functions in part by quenching lipid peroxidation⁸¹ and increasing the levels of plasma glutathione (GSH), an endogenous antioxidant.⁸² A significant decrease in overall wrinkle severity and width was observed in postmenopausal women aged 55 to 80 with FSPT I or II who consumed almonds providing 20% of total calories for 16 weeks, compared with energy-matched nut-free snacks.⁸³ A follow-up study using the same dietary intervention found a significant

decrease in average wrinkle severity in postmenopausal women aged 47 to 84 with FSPT I or II after 24 weeks of daily nut intake. In addition, facial pigment intensity decreased significantly with almond intake, and no changes were observed in the nut-free snack group.⁸⁴

The beneficial effects of almonds on skin esthetics are thought to be due in part to their oxidant defense capability. At 10% or 20% of total daily calories, almonds have been found to increase both plasma and red blood cell alpha tocopherol⁸⁵ and decrease pro-inflammatory high-sensitivity C-reactive protein.⁸⁶ An increase in glutathione peroxidase activity has also been noted from daily intake of 0.7 oz (20 g) of almonds for 8 weeks in overweight and obese women.⁸⁷ Additionally, the consumption of almond skin powder decreased oxidized glutathione, increased plasma glutathione and the plasma glutathione-to-oxidized glutathione ratio, and upregulated glutathione peroxidase activity in healthy adults.⁸⁸ Glutathione neutralizes free radicals and is a cosubstrate for glutathione peroxidase, an important enzyme that quenches hydrogen peroxide and lipid hydroperoxides.⁸⁹ Based on a 2000 kcal diet, 20% of calories from almonds estimates to 400 kcal, which can be obtained from approximately 2.4 oz (68 g), providing 21.5 g of MUFA (9.7% of 2000 kcal), 8.4 g of PUFA (3.8% of 2000 kcal), and 17.5 mg of alpha tocopherol (117% of RDA). However, it is likely that the amount of calories metabolized and absorbed from almonds is less than the estimated amount. A study has shown that the energy content of almonds determined primarily by Atwater factors overestimates the actual amount of metabolizable energy.⁹⁰ The only current PUFA and MUFA recommendations are from the American Heart Association, which are based on heart health outcomes and recommend a daily intake of 10% and 15%, respectively from total calories.⁹¹ Although daily intake of 2.4 oz of almonds is higher than the current American Heart Association guidelines of 1.75 oz of nuts 4 times per week, the previously mentioned study focused on the benefits on skin. The results are of interest and should be repeated at lower intakes, possibly for longer periods of time.

Soybeans. Soybeans (*Glycine max*) are rich in the isoflavones genistein and daidzein that have structures similar to estrogen and may interact with this hormone's receptors.⁹² The reduction in estrogen during menopause has been associated with changes in the dermal layers that increase skin conditions such as wrinkling, dryness, and poor wound healing.⁹³ One ounce of mature raw soybeans (USDA FDC #174270) contains 1.2 g of MUFA, 3.2 g of PUFA, and 10.3 g protein. A significant decrease in fine wrinkles and increased skin microrelief (a network of furrows and ridges) at the lateral canthi and elasticity in the cheeks was observed in Japanese women aged 35 to 48 who consumed an isoflavone-rich soybean extract (40 mg soy isoflavone aglycones) for 12 weeks compared with a control.⁹⁴ Additionally, a significant increase in hydration and a decrease in stratum corneum thickness was observed in adults aged 25 to 60 who consumed a soybean and barley beverage for 8 weeks compared with controls.⁹⁵ An increase in hyaluronan levels in dermal fibroblasts and a decrease in hyaluronidase-2 (an enzyme that degrades hyaluronan) mRNA and protein levels were seen only in the soy/barley group, further supporting the improvement seen in skin hydration. The amount of 40 mg of isoflavones is similar to data from current

epidemiological and clinical studies suggesting an intake of 50 to 90 mg of isoflavones or 15 to 25 g of soy protein per day for women for general health.⁹⁶

Polyphenol-Rich Beverages

Coffee, green tea, and cocoa are widely consumed beverages rich in polyphenols. These beverages typically contain the methylxanthines caffeine and theobromine, with caffeine a possible concern for some consumers. The US Food and Drug Administration has cited 400 mg of caffeine a day as an amount not typically associated with negative effects.⁹⁷ Importantly, decaffeination has little to no effect on polyphenol content,^{98,99} thus it may be a suitable alternative form of coffee and tea.

Cocoa. Cocoa (*Theobroma cacao*) is a rich source of flavan-3-ols (flavanols), a flavonoid-subclass that can inhibit lipid peroxidation, neutralize ROS, and chelate metals that enhance the production of ROS.¹⁰⁰ Furthermore, cocoa flavanols can inhibit enzymes involved in ROS production and upregulate protective genes involved in cellular stress responses. Cocoa is particularly rich in theobromine and is relatively lower in caffeine (~10 mg) per serving compared with tea and coffee. Among Korean women aged 43 to 86, daily consumption of a cocoa beverage containing 320 mg of flavanols for 24 weeks significantly improved measures of elasticity and the MED, as well as skin roughness, suggesting an improvement in wrinkle depth compared with a nutrient-matched control drink.¹⁰¹ In addition, intake of a cocoa beverage containing 329 mg of flavanols for 12 weeks significantly decreased UV-induced erythema, skin roughness, scaling, and TEWL and increased skin density, thickness, hydration, and blood flow to the cutaneous and subcutaneous tissues in women aged 18 to 65 with FSPT II compared with a drink containing low flavanol at 27 mg.¹⁰² The cocoa beverages used in the studies were powders mixed with water. It is important to note that most processing of natural cocoa powders reduces the amount of flavanols.¹⁰³ Therefore, depending on the source of cocoa powder, the amount needed to obtain ~300 mg of flavanol can vary substantially.

Coffee. Coffee (*Coffea L*) is rich in polyphenols, particularly chlorogenic acid.^{104,105} An observational study assessed the amount of chlorogenic acid consumed from coffee by 131 Japanese women aged 30 to 60 and noted a significant association between higher consumption of coffee (≥ 450 mL/d) or coffee polyphenols (≥ 900 mg/d) with lower hyperpigmentation.¹⁰⁶ Daily consumption of a decaffeinated beverage containing 297 mg of coffee polyphenols for 4 weeks significantly improved scaly skin in the cheeks and around the mouth in Japanese women aged 25 to 35 compared with a control drink.¹⁰⁷ In another study, the daily intake for 8 weeks of a 100 mL decaffeinated beverage with 270 mg coffee polyphenols containing mainly chlorogenic acid significantly improved skin permeability barrier function, as evidenced by a decrease in dryness, TEWL, and pH, as well as an increase in stratum corneum lipids, lactic acid, and hydration, in 49 women with dry, itchy, and cracked skin compared with controls.¹⁰⁸ Roasted coffee beans contain 7.95 to 8.75 mg/g of total polyphenols that could decrease to 1.17 to 1.58 mg/g after 12 months of storage.¹⁰⁹ The Specialty

Fruits & Vegetables				Nuts & Legumes	Polyphenolic-rich beverages	
Grape Extract  Proanthocyanins ↑ hydration ↑ brightness ↓ hyper-pigmentation	Mango Whole  β-carotene, Vit C, flavonoids, mangiferin ↓ wrinkles	Melon Extract  Vit C, β-carotene ↓ sunburn ↓ erythema	Tomato Paste or Extract  Lycopene ↑ collagen ↓ erythema	Almond Whole  α-tocopherol, unsaturated fatty acids ↓ wrinkles ↓ hyper-pigmentation	Green tea Extract  Catechins ↑ hydration ↑ elasticity ↑ density ↓ roughness ↓ erythema	Cocoa Beverage  Cocoa flavanols, catechins ↑ blood flow ↑ hydration ↑ density ↑ elasticity ↓ sunburn ↓ roughness ↓ wrinkles ↓ erythema
Orange Extract  Vit C, flavonoids ↓ erythema ↓ hyper-pigmentation	Passion fruit Extract  Piceatannol ↑ hydration	Pomegranate Juice  Punicalagin, ellagic acid ↓ sunburn	Kale Extract  Carotenoids ↑ collagen ↑ elastin	Soybean Extract  Isoflavones ↑ elasticity ↑ hydration ↓ wrinkles	Coffee Extract  Coffee polyphenols ↑ blood flow ↑ hydration ↓ scaliness	

Figure 1. Reported effects of plant-based foods and extracts on the skin. Vit C = vitamin C.

Coffee Association recommends brewing coffee at a ratio of 1.63 g of beans per fluid ounce of water.¹¹⁰ Considering that 29% and 36% of American adults drink 2 and 3 or more cups per day, respectively, this would equate to a daily intake of 270 to 300 mg coffee polyphenols when one uses an estimate of 8 mg total polyphenols per gram of beans.¹¹¹

Green Tea. Green tea (GT; *Camellia sinensis*) provides a number of flavanols,¹¹² particularly epigallocatechin gallate (EGCG).¹¹³ A review of studies on tea flavanols reports protection against UVR and anti-allergenic properties that may be beneficial to the skin.¹¹⁴ Daily consumption of 1 L of a GT drink providing 1402 mg total of tea flavanols (980 mg EGCG) for 12 weeks in 60 women aged 40 to 60 with FSPT II significantly decreased UV-induced erythema, roughness, TEWL, and viscoelasticity (resistance toward an applied vacuum) compared with a control beverage devoid of polyphenols.¹¹⁵ Increased serum flavanol levels, skin density, and biological elasticity (ability to return to original position) were also observed. In both groups, skin volume, scaling, and hydration significantly increased, which likely reflected the large amount of fluid consumed. However, the GT group showed a greater increase in hydration compared with the controls. In another study, supplementation with GT extracts containing 540 mg total flavanols for 12 weeks significantly decreased UV-induced erythema in 14 adults with FSPT I or II when given the maximum UVR dose.¹¹⁶ However, no significant changes were seen when the same adults were given lower levels of radiation. In humans, flavanol metabolites have been found in the skin after daily intake of GT extract containing 450 to 540 mg of tea flavanols for 12 weeks.^{116,117}

An increase in the expression of genes related to skin moisturizing factors in response to EGCG was also observed in vitro.¹¹⁸ Typically, 1.8 to 3 g of leaves are used to brew a cup of tea, but the amount of EGCG varies drastically from 0.07 to 6.1 mg/3 g of leaves.¹¹⁹ Therefore, depending on the quality and processing of the tea leaves, as little as 1 or more than 10 cups of green tea may be needed to achieve an intake of at least 500 mg of tea flavanols. The European Food Safety Authority has found that modest amounts of green tea infusions and similar beverages are safe, but caution against taking more than 800 mg/d EGCG through extracts, because rare cases of liver injury have been reported.¹¹⁹

CONCLUSION

The studies mentioned here collectively provide evidence of the potential benefits of plant-based foods for skin health and esthetics (Figure). In an era of personalized nutrition, this review can help dietitians provide better dietary recommendations of certain plant-based foods to compliment a well-balanced diet. Many of the foods and extracts discussed are rich in bioactive compounds such as VitC, alpha tocopherol, beta carotene, polyphenols, and phenolic acids that provide oxidant defense, support mechanisms to lower inflammation, or promote structural support and UV protection in the skin.¹²⁰ Some of the clinical studies above explored the role of whole and minimally processed foods (juice, beverage, paste), and others used extracts. When possible, we equated the intake of bioactives from extracts to the amounts present in whole food and beverages to evaluate the feasibility of bioactivity from dietary intake; however, further studies are clearly warranted to confirm these

speculations. The food items discussed were added to the participants' habitual diet, mostly on a daily basis, with some at higher amounts than the currently recommended daily amounts. Overall, we found that the consumption of colorful fruits and vegetables abundant in vitamins, carotenoids, anthocyanins, and polyphenols is indicated for skin health and esthetics. In general, yellow, orange, and red fruits such as mangos, melons, citrus, tomatoes, and vegetables such as red bell peppers and dark-green leafy kale are good sources of carotenoids. Fruits with deep red or purple colors such as grapes, pomegranate, and passion fruit are rich in anthocyanins and polyphenols. Nuts and legumes are also encouraged, along with cocoa, coffee, and tea that are rich in polyphenols. Decaffeinated options do not appear to dilute benefits and should be considered for caffeine-sensitive individuals. Although intake of an abundance of plant-based foods is desirable, overconsumption of a single food or extract can be of concern, as illustrated previously by the intake of a large amount of mangos.²⁹

In conclusion, clinical studies in the field of nutrition and skin research support growing evidence to help dietitians make targeted dietary recommendations. More investigations on whole foods and beverages, as well as those fortified with plant-based extracts, are needed to extend current findings.

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AUTHOR INFORMATION

V. W. Fam is a clinical dietitian scientist, Zen Dermatology, Sacramento, CA. P. Charoenwoodhipong is a PhD candidate, Department of Nutrition, University of California, Davis. R. K. Sivamani is a board-certified dermatologist, Pacific Skin Institute, Sacramento, CA. R. R. Holt is an assistant project scientist, Department of Nutrition, University of California, Davis. C. L. Keen is a professor, Department of Nutrition, University of California, Davis. R. M. Hackman is a research nutritionist, Department of Nutrition, University of California, Davis.

Address correspondence to: Vivien W. Fam, PhD, RDN, Zen Dermatology, 4801 J St, Sacramento, CA 95819. E-mail: vivien@integrativeskinresearch.com

STATEMENT OF POTENTIAL CONFLICT OF INTEREST

K. Sivamani serves as a scientific advisor for LearnHealth and Arbonne and as a consultant to Burt's Bees, Novozymes, Nutrafol, Abbvie, Leo, UCB, Sun and Regeneron Pharmaceuticals.

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V. W. Fam and P. Charoenwoodhipong collected the data. V. W. Fam created the table and figure. V. W. Fam wrote the first draft with contributions from P. Charoenwoodhipong and R. M. Hackman. V. W. Fam, R. R. Holt, C. L. Keen, R. M. Hackman, P. Charoenwoodhipong, and R. K. Sivamani reviewed, commented on, and provided further contributions on subsequent drafts of the manuscript.