

Eating chocolate can significantly protect the skin from UV light

Stefanie Williams, MD,^{1,2} Slobodanka Tamburic, PhD,¹ & Carmel Lally, BSc (Hons)¹

¹Cosmetic Science Group, School of Management and Science, London University of the Arts, London, UK

²European Dermatology London, London, UK

Summary

Background Cocoa beans fresh from the tree are exceptionally rich in flavanols. Unfortunately, during conventional chocolate making, this high antioxidant capacity is greatly reduced due to manufacturing processes.

Aim To evaluate the photoprotective potential of chocolate consumption, comparing a conventional dark chocolate to a specially produced chocolate with preserved high flavanol (HF) levels.

Methods A double-blind *in vivo* study in 30 healthy subjects was conducted. Fifteen subjects each were randomly assigned to either a HF or low flavanol (LF) chocolate group and consumed a 20 g portion of their allocated chocolate daily. The minimal erythema dose (MED) was assessed at baseline and after 12 weeks under standardized conditions.

Results In the HF chocolate group the mean MED more than doubled after 12 weeks of chocolate consumption, while in the LF chocolate group, the MED remained without significant change.

Conclusions Our study demonstrated that regular consumption of a chocolate rich in flavanols confers significant photoprotection and can thus be effective at protecting human skin from harmful UV effects. Conventional chocolate has no such effect.

Keywords: cocoa, MED, photoprotection, polyphenols, flavanols, food supplement

Introduction

In recent years the beneficial effects of dietary cocoa polyphenols have received increasing attention from both nutritionists and scientists.^{1–12} However, evidence-based evaluation of dietary factors influencing parameters of skin physiology remains scarce and is a subject of controversy within dermatology. Cocoa beans fresh from the tree are exceptionally rich in polyphenols and have a higher antioxidant capacity (measured as ORAC value) than all other known food items, including so-called “super foods” such as green tea, pomegranate, goji berry, and blueberry. The main phenolic phytochemicals

in cocoa beans are flavanol monomers epicatechin and catechin, along with the procyanidins (oligomers of the monomeric flavanol base units). The final flavanol concentration and thus antioxidant capacity of finished food products derived from cocoa depend on type and origin of the cocoa bean, growing conditions, post-harvest handling, and manufacturing process. Unfortunately, during conventional chocolate making, the high antioxidant capacity of fresh cocoa beans is greatly reduced.^{13,14}

Chronic UV exposure is the main course for premature skin aging and also plays an important role in cutaneous carcinogenesis. UV exposure generates free radicals in the skin and depletes the skin's endogenous antioxidant system. Topical and systemic administration of different antioxidants including vitamin E and C and a multitude of phytochemicals has been shown to be of

Correspondence: Stefanie Williams, 10 Harley Street, London W1G 9PF, UK.
E-mail: dr.williams@eudelo.com

Accepted for publication April 10, 2009

varying benefit with regard to protection of the skin against ultraviolet's harmful effects.

The aim of our study was to evaluate the photoprotective potential of chocolate consumption, comparing a conventional dark chocolate to a specially produced chocolate with preserved high flavanol (HF) levels. The study hypothesis was that ingestion of HF chocolate is photoprotective and thus can contribute to nutritional protection against skin damage from sunlight.

Materials and methods

We conducted a controlled, double-blind, *in vivo* study in 30 healthy subjects (22 female, 8 male) aged 42.7 ± 10 (SD) years. Subjects with skin phototypes II and III following the Fitzpatrick classification were included. The study was approved by a local ethics committee and all volunteers gave informed consent. Fifteen subjects each were randomly assigned to either a HF or low flavanol (LF) chocolate group. The HF chocolate was manufactured by Barry Callebaut (Lebbeke-Wieze, Belgium), using a particularly gentle method (Acticoa™ method), which preserves the naturally high level of cocoa bean flavanols. The 70% cocoa solids chocolate was also sugar reduced and contained added fiber (see Table 1 for details). The LF chocolate in our study was of identical recipe, the only difference being that the LF chocolate was produced through means of a conventional manufacturing method, involving the usual, higher temperatures. The HF chocolate contained a minimum of 3% flavanols (>600 mg flavanols and >10 000 ORAC units per 20 g portion), while the LF chocolate contained <30 mg of flavanols per 20 g portion.

All subjects were instructed to eat one pre-packed 20 g portion of chocolate droplets each day as a mid-morning

snack for 12 weeks. At baseline (before start of the study) and after 12 weeks, the minimal UVB erythema dose (MED, 280–320 nm) was assessed using the automated Durham Erythema Tester® (Hospital Lamp Supplies Ltd., Leicester, UK). Increasing UV doses (exact dosages depending on the individual's skin phototype following the Fitzpatrick classification) were applied on a randomly assigned volar forearm through means of 10 small round apertures within the MED tester. Testing was performed under standardized conditions after an acclimatization period of 30 min. No application of skin care products on the arm 12 h before and 24 h after UV application was allowed. Participating volunteers were also asked not to change their routinely used skin care regime on the test side during the entire study period. Furthermore, subjects were advised to continue their normal dietary habits. Additional dietary supplements were not to be taken during the 12-week intervention trial. Sunbathing and use of tanning machines were not allowed during the study period. MED readings were taken 24 h after application of UV, with the MED being defined as the lowest dose of UV resulting in visible erythema of the skin.

Results

Twenty-eight subjects completed the study. In the LF chocolate group the average MED remained without significant change (mean $0.124 \text{ J/cm}^2 \pm \text{SEM } 0.071$ at baseline vs. $0.132 \text{ J/cm}^2 \pm 0.015$ at week 12, $P = 0.477$, Wilcoxon test). However, in the HF chocolate group, the mean MED more than doubled from $0.109 \text{ J/cm}^2 \pm 0.011$ (mean \pm SEM) before intervention to $0.223 \text{ J/cm}^2 \pm 0.019$ after 12 weeks of chocolate consumption (see Fig. 1 and Table 2). This improvement was statistically significant ($P = 0.005$, Wilcoxon test).

Table 1 Nutritional value of the high flavanol chocolate

	Nutritional value per 100 g	Comments
Energy	502 kcal	Approx. 100 kcal per 20 g portion
Sugars	23.3 g	Mono and di. No polyols or other sweeteners used
Fiber	19.1 g	Based on a combination of inulin, fructooligosaccharides and resistant dextrin
Fat	38.1 g	7.62 g fat per 20 g portion
Flavanols	Min. 3%	Min. 600 mg flavanols per 20 g portion
ORAC (analyt.)	50 900 (509/g)	Min. 10 000 ORAC units per 20 g portion

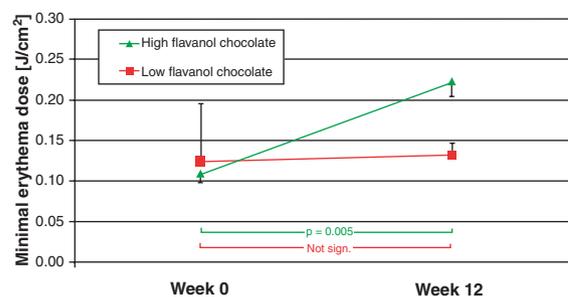


Figure 1 Minimal erythema dose (MED, mean \pm SEM) at baseline and after 12 week consumption of high flavanol or low flavanol chocolate: Significant photoprotection after high flavanol chocolate ingestion, no significant change after low flavanol chocolate.

Table 2 Details of cutaneous sensitivity to broadband UVB irradiation: minimal erythema doses at baseline (week 0) and after 12 week consumption of high flavanol or low flavanol chocolate (randomized assignment to group)

	High flavanol chocolate	Low flavanol chocolate
Week 0 (baseline)	0.109 ± 0.011	0.124 ± 0.071
Week 12	0.223 ± 0.019	0.132 ± 0.015
P-value (Wilcoxon test: week 0 vs. week 12)	0.005*	0.477

Values are mean ± standard error of mean.

*Statistically significant change ($P \leq 0.05$).

Discussion

In summary, our controlled, double-blind, randomized *in vivo* study demonstrated, for the first time to our knowledge, that regular consumption of a chocolate rich in flavanols confers substantial photoprotection and can thus be effective at protecting human skin from harmful UV effects. Conventional chocolate had no such effect. The main underlying mechanism of action is likely to be the anti-inflammatory and antioxidant activity of cocoa flavanols.^{15–17} The acute inflammatory response in UV-induced erythema is thought to be mediated by a variety of factors including generation of reactive free radicals and inflammatory mediators such as prostaglandins, nitric oxide, leukotrienes, and histamine. It has been shown that cocoa flavanols can modify the production of pro-inflammatory cytokines, nitric oxide-mediated mechanisms, the synthesis of eicosanoids, the activation of platelets, and a number of other signaling pathways.^{16–18}

While there are a growing number of studies supporting the beneficial effects of cocoa flavanols, they have so far not been in the scientific limelight to the same extent as green tea polyphenols. Green tea has been shown to not only offer significant anti-inflammatory and antioxidant effects, but also to have anticarcinogenic, cytoprotective and immunomodulatory properties.¹⁹ However, it has recently been revealed that cocoa flavanols may also offer significant anticancer properties.^{9,20} Cocoa flavanols are now also being investigated with regard to potential anti-aging effects and interestingly have been demonstrated in animal models to improve cognitive performance in aged individuals and increase lifespan.^{1,3} In human subjects flavanol-rich chocolate improved cardiovascular risk factors including total and LDL cholesterol, blood pressure, flow-mediated dilation, insulin sensitivity, and beta cell function.^{2,7,8} There is now also increasing evidence that cocoa flavanols exert biological effects independent of their

antioxidant properties such as vasodilatation and improvement in endothelial function.

With regard to skin health, cocoa consumption has been shown to improve cutaneous microcirculation,²¹ which in turn influences thermoregulation, and nutrient and oxygen delivery to the skin. Our pilot study on chocolate is in line with recent investigations on a HF cocoa drink, which confirmed a photoprotective effect in human skin.²² In this study Heinrich *et al.* measured the erythema response after exposure with 1.25 times of the individual MED. Consumption of a HF cocoa beverage resulted in significantly less pronounced erythema compared to baseline, while a LF cocoa drink had no significant effect.²² There have also been reports of nutritional photoprotection with other “functional foods” or supplements such as various vitamins, beta-carotene, green tea, and lycopene.^{23–28} A combined intake of 2 mg ascorbic acid and 1000 IU α -tocopherol for 8 days for example, was shown to increase the MED from 0.080 to 0.0965 J/cm².²³ This is an MED increase of approximately 20% with a vitamin C–vitamin E combination. Fuchs *et al.* demonstrated an MED increase of approximately 60% after 50 days of 2 g α -tocopherol plus 3 g ascorbic acid intake per day.²⁴ There was no significant change in MED after either vitamin taken alone in the Fuchs *et al.* study. Compared to these studies, the photoprotective effect of HF chocolate consumption in our study was much more powerful with an MED increase of more than 100% (from 0.109 to 0.223 J/cm²).

Concerning the effect of cocoa on parameters of skin physiology, a study by Heinrich *et al.* revealed improvements in skin density and thickness, stratum corneum hydration, transepidermal water loss, and skin surface roughness after long-term ingestion of a flavanol-rich cocoa drink in healthy women.²² Neither of these variables was affected in the control group, who consumed a LF cocoa drink instead.²² In a later study the German researchers found that HF cocoa drink consumption acutely increases dermal blood flow and oxygen saturation, while LF cocoa had no such effect.²¹ The lack of effectiveness of LF cocoa described in these studies was mirrored by our own finding that a conventional dark chocolate did not offer any significant photoprotection. In conventional chocolate the HF level of fresh cocoa beans is greatly reduced by the routinely used higher production temperatures, whereas our HF chocolate was made using more gentle methods in all stages of the chocolate making process.

With regard to topical application of HF cocoa extracts, there is not much scientific data available in

the literature yet. However, a recent study using *ex vivo* human skin explants showed that topical application of cocoa polyphenols increased glycosaminoglycans in the skin and improved collagen I, III, and IV content.²⁹

In summary, our study revealed that HF chocolate protects the skin from harmful UV effects. The physiological relevance of the measured MED increase as demonstrated in our study is not only a reduced sunburn risk, but might also indicate a consequently reduced risk for later sequelae of UV-induced skin damage such as extrinsic skin aging and skin cancer. Further studies are warranted to look into the long-term effects.

Conflict of interest and source of funding

The study was funded by the University of the Arts, London. There was no external source of funding for the study.

Acknowledgments

We thank Barry Callebaut, Belgium, for kindly supplying the study products and ongoing support of our research. We also thank our volunteers for taking part in this study.

References

- 1 Bisson JF, Nejd A, Rozan P, Hidalgo S, Lalonde R, Messaoudi M. Effects of long-term administration of a cocoa polyphenolic extract (Acticoa powder) on cognitive performances in aged rats. *Br J Nutr* 2008; **100**: 94–101.
- 2 Vlachopoulos C, Alexopoulos N, Stefanadis C. Effect of dark chocolate on arterial function in healthy individuals: cocoa instead of ambrosia? *Curr Hypertens Rep* 2006; **8**: 205–11.
- 3 Rozan P, Hidalgo S, Nejd A, Bisson JF, Lalonde R, Messaoudi M. Preventive antioxidant effects of cocoa polyphenolic extract on free radical production and cognitive performances after heat exposure in Wistar rats. *J Food Sci* 2007; **72**: S203–6.
- 4 Bisson JF, Hidalgo S, Rozan P, Messaoudi M. Preventive effects of ACTICOA powder, a cocoa polyphenolic extract, on experimentally induced prostate hyperplasia in Wistar-Unilever rats. *J Med Food* 2007; **10**: 622–7.
- 5 Bisson JF, Hidalgo S, Rozan P, Messaoudi M. Therapeutic effect of ACTICOA powder, a cocoa polyphenolic extract, on experimentally induced prostate hyperplasia in Wistar-Unilever rats. *J Med Food* 2007; **10**: 628–35.
- 6 Stevenson DE, Hurst RD. Polyphenolic phytochemicals – just antioxidants or much more? *Cell Mol Life Sci* 2007; **64**: 2900–16.
- 7 Faridi Z, Njike VY, Dutta S, Ali A, Katz DL. Acute dark chocolate and cocoa ingestion and endothelial function: a randomized controlled crossover trial. *Am J Clin Nutr* 2008; **88**: 58–63.
- 8 Grassi D, Desideri G, Necozione S, Lippi C, Casale R, Properzi G, Blumberg JB, Ferri C. Blood pressure is reduced and insulin sensitivity increased in glucose-intolerant, hypertensive subjects after 15 days of consuming high-polyphenol dark chocolate. *J Nutr* 2008; **138**: 1671–6.
- 9 Bisson JF, Guardia-Llorens MA, Hidalgo S, Rozan P, Messaoudi M. Protective effect of Acticoa powder, a cocoa polyphenolic extract, on prostate carcinogenesis in Wistar-Unilever rats. *Eur J Cancer Prev* 2008; **17**: 54–61.
- 10 Mehrinfar R, Frishman WH. Flavanol-rich cocoa: a cardioprotective nutraceutical. *Cardiol Rev* 2008; **16**: 109–15.
- 11 Messaoudi M, Bisson JF, Nejd A, Rozan P, Javelot H. Antidepressant-like effects of a cocoa polyphenolic extract in Wistar-Unilever rats. *Nutr Neurosci* 2008; **11**: 269–76.
- 12 Jalil AM, Ismail A. Polyphenols in cocoa and cocoa products: is there a link between antioxidant properties and health? *Molecules* 2008; **13**: 2190–219.
- 13 Miller KB, Hurst WJ, Payne MJ *et al*. Impact of alkalization on the antioxidant and flavanol content of commercial cocoa powders. *J Agric Food Chem* 2008; **24**: 56.
- 14 Andres-Lacueva C, Monagas M, Khan N, Izquierdo-Pulido M, Urpi-Sarda M, Permanyer J, Lamuela-Raventos RM. Flavanol and flavonol contents of cocoa powder products: influence of the manufacturing process. *J Agric Food Chem* 2008; **14**: 56.
- 15 di Giuseppe R, Di Castelnuovo A, Centritto F *et al*. Regular consumption of dark chocolate is associated with low serum concentrations of C-reactive protein in a healthy Italian population. *J Nutr* 2008; **138**: 1939–45.
- 16 Lee KW, Kundu JK, Kim SO, Chun KS, Lee HJ, Surh YJ. Cocoa polyphenols inhibit phorbol ester-induced superoxide anion formation in cultured HL-60 cells and expression of cyclooxygenase-2 and activation of NF-kappaB and MAPKs in mouse skin in vivo. *J Nutr* 2006; **136**: 1150–5.
- 17 Selmi C, Mao TK, Keen CL, Schmitz H, Gershwin ME. The anti-inflammatory properties of cocoa flavanols. *J Cardiovasc Pharmacol* 2006; **47**(Suppl. 2): S163–71.
- 18 Selmi C, Cocchi CA, Lanfredini M, Keen CL, Gershwin ME. Chocolate at heart: the anti-inflammatory impact of cocoa flavanols. *Mol Nutr Food Res* 2008; **52**: 1340–8.
- 19 Yusuf N, Irby C, Katiyar SK, Elmets CA. Photoprotective effects of green tea polyphenols. *Photodermatol Photoimmunol Photomed* 2007; **23**: 48–56.
- 20 Kim M, Wu X, Song I *et al*. Selective cytotoxicity of synthesized procyanidin 3-O-galloylprocatechin-4b, 8-3-O-galloylprocatechin to human cancer cells. *Cell Cycle* 2008; **7**: 1648–57.
- 21 Neukam K, Stahl W, Tronnier H, Sies H, Heinrich U. Consumption of flavanol-rich cocoa acutely increases

- microcirculation in human skin. *Eur J Nutr* 2007; **46**: 53–6.
- 22 Heinrich U, Neukam K, Tronnier H, Sies H, Stahl W. Long-term ingestion of high flavanol cocoa provides photoprotection against UV-induced erythema and improves skin condition in women. *J Nutr* 2006; **136**: 1565–9.
 - 23 Eberlein-König B, Placzek M, Przybilla B. Protective effect against sunburn of combined systemic ascorbic acid (vitamin C) and d-alpha-tocopherol (vitamin E). *J Am Acad Dermatol* 1998; **38**: 45–8.
 - 24 Fuchs J, Kern H. Modulation of UV-light-induced skin inflammation by D-alpha-tocopherol and L-ascorbic acid: a clinical study using solar simulated radiation. *Free Radic Biol Med* 1998; **25**: 1006–12.
 - 25 González S, Pathak MA, Cuevas J, Villarrubia VG, Fitzpatrick TB. Topical or oral administration with an extract of *Polypodium leucotomos* prevents acute sunburn and psoralen-induced phototoxic reactions as well as depletion of Langerhans cells in human skin. *Photodermatol Photoimmunol Photomed* 1997; **13**: 50–60.
 - 26 Jeon HY, Kim JK, Kim WG, Lee SJ. Effects of oral epigallocatechin gallate supplementation on the minimal erythema dose and UV-induced skin damage. *Skin Pharmacol Physiol* 2009; **22**: 137–41.
 - 27 Stahl W, Sies H. Carotenoids and flavonoids contribute to nutritional protection against skin damage from sunlight. *Mol Biotechnol* 2007; **37**: 26–30.
 - 28 Stahl W, Heinrich U, Aust O, Tronnier H, Sies H. Lycopene-rich products and dietary photoprotection. *Photochem Photobiol Sci* 2006; **5**: 238–42.
 - 29 Gasser P, Lati E, Peno-Mazzarino L, Bouzoud D, Allegaert L, Bernaert H. Cocoa polyphenols and their influence on parameters involved in ex vivo skin restructuring. *Int J Cosmet Sci* 2008; **30**: 339–45.