

Raman Measurement of Carotenoids in Living Tissues

A validated method for determining meaningful aspects of human health

Over 50 full-length peer-review articles validate the use of Raman spectroscopy for the measurement of carotenoids in living tissues. An additional 14 abstracts presented at scientific symposiums further confirm the validity of this method as a meaningful health parameter.

The Pharmanex BioPhotonic Scanner uses resonant Raman light to detect concentrations carotenoids in *intact* human skin as an indicator of nutritional intake and *in vivo* antioxidant status. Prior to being adapted for measurements in human skin, Raman resonance was validated for detection of carotenoid concentrations in *intact* human retinas (an indicator of macular health). Well over a dozen peer-reviewed articles have been published on the use of Raman spectroscopy to detect macular carotenoids *in vivo*⁴⁵⁻⁶⁰. Raman spectroscopy has also been validated as an accurate measurement of skin carotenoid concentrations. Pharmanex has published two full-length studies in English^{1,2}, and an additional two full-length studies in Chinese^{3,4} (Chinese publications presented data that is entirely unique from data published in English journals; the Chinese papers are not simply translations of the English publications).

In addition to research conducted by Pharmanex scientists, seven independent research groups have used the Pharmanex BioPhotonic Scanner to conduct their own studies—which has led to the publication of at least six peer-review, full-length scientific articles⁶⁻¹¹, and three scientific abstracts^{61, 69, 73}. The Pharmanex BioPhotonic Scanner is highlighted in the highly respected textbook: *Krause's Food, Nutrition and Diet Therapy* (12th Edition)¹³. It has also been given a complete chapter in the book *Carotenoids and Retinoids: Molecular Aspects and Health Issues*¹², which was edited by the distinguished Dr. Lester Packer (Father of the Antioxidant Theory). At least 14 additional abstracts of studies which used the Pharmanex BioPhotonic Scanner have been presented in scientific meetings around the world⁶¹⁻⁷⁴.

Pharmanex is not the only research group that has used and validated Raman spectroscopy for the measurement of skin carotenoid concentrations as a meaningful biological parameter. At least five other research groups (all disinterested in Pharmanex, Nu Skin, or the sale of dietary supplements) have designed their own Raman spectrometers to measure skin carotenoids. From these five research groups at least 31 full-length peer-reviewed articles have been published¹⁴⁻⁴⁴.

The following full-length studies are co-authored by at least one in-house Pharmanex scientist, and each of the following four studies used the Pharmanex BioPhotonic Scanner:

1. Zidichouski JA, Mastaloudis A, Poole SJ, Reading JC, Smidt CR. Clinical validation of a noninvasive, Raman spectroscopic method to assess carotenoid nutritional status in humans. *J Am Coll Nutr.* 2009 Dec;28(6):687-93. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/20516269>
2. Bergeson SD, Peatross JB, Eyring NJ, Fralick JF, Stevenson DN, Ferguson SB. Resonance Raman measurements of carotenoids using light-emitting diodes. *J Biomed Opt.* 2008 Jul-Aug;13(4):044026. *Full-length article available at:* <http://arxiv.org/pdf/0801.1697v1.pdf>

3. Li CL, Bi SX, Zhu JS, Zhu ZG. New functions of carotenoids and clinical assessments. *Shanghai Journal of Preventive Medicine* 2006;6:261-264. [Article in Chinese] *No online abstract available.*
4. Li CL, Bi SX, Poole S, Smidt C, Zhu JS. Human Skin Carotenoids in 88,611 subjects measured by Biophotonic Scanner. *Chinese Journal of Clinical Pharmacy* 2006;15(2):124-125. [Article in Chinese] *No online abstract available.*

One review paper authored by Pharmanex scientists published as a full-length article:

5. Smidt, C.R., Burke, D.S. Nutritional Significance and Measurement of Carotenoids. *Current Topics in Nutraceutical Research*. 2004, Vol. 2, No. 2, pp. 79-91. Review
Abstract available at: http://ctnr.newcenturyhealthpublishers.com/about/issue_2_2.php#2
Full-length article of the above available at same website with paid subscription.

The following five publications are full-length studies conducted by third party research groups. Each of the five studies used the Pharmanex BioPhotonic Scanner to measure skin carotenoids. Full-length versions can be purchased at the PubMed links provided below (abstracts available free of charge):

6. Ramírez-Vélez R, González-Ruiz K, García S, López-Alban CA, Escudero N, Agredo-Zúñiga RA. Non-invasive assessment of β -carotene levels in the skin of colombian adults. *Endocrinol Nutr*. 2012 Apr 13. <http://www.ncbi.nlm.nih.gov/pubmed/22503818>
7. Rerksuppaphol S, Rerksuppaphol L. Carotenoid intake and asthma prevalence in Thai children. *Pediatr Rep*. 2012 Jan 2;4(1):e12. *Full-length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3357611/pdf/pr-2012-1-e12.pdf>
8. Richer SP, Stiles W, Graham-Hoffman K, Levin M, Ruskin D, Wrobel J, Park DW, Thomas C. Randomized, double-blind, placebo-controlled study of zeaxanthin and visual function in patients with atrophic age-related macular degeneration: The Zeaxanthin and Visual Function Study (ZVF) FDA IND #78, 973. *Optometry*. Nov 2011; 82(11) 667-680. <http://www.ncbi.nlm.nih.gov/pubmed/22027699>
9. Lima XT, Kimball AB. Skin carotenoid levels in adult patients with psoriasis. *J Eur Acad Dermatol Venereol*. 2011 Aug;25(8):945-9. <http://www.ncbi.nlm.nih.gov/pubmed/21054574>
10. Harpenau LA, Cheema AT, Zingale JA, Chambers DW, Lundergan WP. Effects of nutritional supplementation on periodontal parameters, carotenoid antioxidant levels, and serum C-reactive protein. *J Calif Dent Assoc*. 2011 May;39(5):309-12, 314-8. <http://www.ncbi.nlm.nih.gov/pubmed/21721475>

11. Rerksuppaphol S, Rerksuppaphol L. Effect of fruit and vegetable intake on skin carotenoid detected by non-invasive Raman spectroscopy. *J Med Assoc Thai*. 2006 Aug;89(8):1206-12. *Full-length article available free of charge at:* http://www.mat.or.th/journal/readpdf.php?link=files/Vol89_No8_1206.pdf

Book chapters or sections that discuss the Pharmanex BioPhotonic Scanner and related research:

12. *Carotenoids and Retinoids: Molecular Aspects and Health Issues*. Gellermann W, Zidichouski JA, Smidt CR, Bernstein PS. Raman Detection of Carotenoids in Human Tissue. In: Packer L, Obermueller-Jevic U, Kraemer K, and Sies H, eds. Champaign, IL: AOCS Press, 2005: Ch. 6, 86-114.
13. Mahan LK and Escott-Stump S. (Eds.). *Krause's Food, Nutrition and Diet Therapy*, 12th Ed. Philadelphia, PA: Saunders 2007; Ch. 15, 427-428.

Krause's Food & Nutrition Therapy has been considered one of the most authoritative nutrition texts for over 50 years worldwide. It provides a basic overview of nutrition as well as in-depth information on up-to-date nutrition therapies for medical conditions. Krause's is a text used by students in many allied health programs as well as other disciplines interested in the theoretical and clinical knowledge of the nutrition care process. It is commonly used as a reference for dietitians, nurses, doctors, dentists, life coaches, health educators and child development specialists.

Although Pharmanex (Nu Skin) owns exclusive rights for use of Raman spectroscopy in *for profit* settings, other research groups are permitted to develop their own Raman skin carotenoid devices for research purposes. The following 29 studies use Raman spectroscopy to measure skin carotenoid concentrations as a meaningful parameter of human health. The Raman devices used in these studies were not the Pharmanex BioPhotonic Scanner. The fact that research groups other than Pharmanex (Nu Skin) have validated Raman measurement of skin carotenoids as a meaningful health parameter further confirms the legitimacy of this method. Full-length versions of the following studies can be purchased at the PubMed links provided below (abstracts available free of charge):

14. Mayne ST, Cartmel B, Scarmo S, Jahns L, Ermakov IV, Gellermann W. Resonance Raman spectroscopic evaluation of skin carotenoids as a biomarker of carotenoid status for human studies. *Arch Biochem Biophys*. 2013 Jun 30. <http://www.ncbi.nlm.nih.gov/pubmed/23823930>
15. Scarmo S, Cartmel B, Lin H, Leffell DJ, Ermakov IV, Gellermann W, Bernstein PS, Mayne ST. Single v. multiple measures of skin carotenoids by resonance Raman spectroscopy as a biomarker of usual carotenoid status. *Br J Nutr*. 2013 Sep;110(5):911-7. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3696054/>

16. Darvin ME, Sandhagen C, Koecher W, Sterry W, Lademann J, Meinke MC. Comparison of two methods for noninvasive determination of carotenoids in human and animal skin: Raman spectroscopy versus reflection spectroscopy. *J Biophotonics*. 2012 Jan 23. <http://www.ncbi.nlm.nih.gov/pubmed/22271669>
17. Fluhr JW, Sassning S, Lademann O, Darvin ME, Schanzer S, Kramer A, Richter H, Sterry W, Lademann J. In vivo skin treatment with tissue-tolerable plasma influences skin physiology and antioxidant profile in human stratum corneum. *Exp Dermatol*. 2012 Feb;21(2):130-4. <http://www.ncbi.nlm.nih.gov/pubmed/22142271>
18. Scarmo S, Henebery K, Peracchio H, Cartmel B, Lin H, Ermakov IV, Gellermann W, Bernstein PS, Duffy VB, Mayne ST. Skin carotenoid status measured by resonance Raman spectroscopy as a biomarker of fruit and vegetable intake in preschool children. *Eur J Clin Nutr*. 2012 May;66(5):555-60. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3380427/pdf/nihms381137.pdf>
19. Vierck HB, Darvin ME, Lademann J, Reißhauer A, Baack A, Sterry W, Patzelt A. The influence of endurance exercise on the antioxidative status of human skin. *Eur J Appl Physiol*. 2012 Jan 22. <http://www.ncbi.nlm.nih.gov/pubmed/22270481>
20. Darvin ME, Fluhr JW, Meinke MC, Zastrow L, Sterry W, Lademann J. Topical beta-carotene protects against infra-red-light-induced free radicals. *Exp Dermatol*. 2011 Feb;20(2):125-9. <http://www.ncbi.nlm.nih.gov/pubmed/21255091>
21. Darvin ME, Fluhr JW, Schanzer S, Richter H, Patzelt A, Meinke MC, Zastrow L, Golz K, Doucet O, Sterry W, Lademann J. Dermal carotenoid level and kinetics after topical and systemic administration of antioxidants: enrichment strategies in a controlled in vivo study. *J Dermatol Sci*. 2011 Oct;64(1):53-8. <http://www.ncbi.nlm.nih.gov/pubmed/21763110>
22. Darvin ME, Haag SF, Meinke MC, Sterry W, Lademann J. Determination of the influence of IR radiation on the antioxidative network of the human skin. *J Biophotonics*. 2011 Jan;4(1-2):21-9. <http://www.ncbi.nlm.nih.gov/pubmed/20151398>
23. Dayan SH, Arkins JP, Sharma V, Paterson E, Barnes D. A phase 2, double-blind, randomized, placebo-controlled trial of a novel nutritional supplement product to promote healthy skin. *J Drugs Dermatol*. 2011 Oct;10(10):1106-14. <http://www.ncbi.nlm.nih.gov/pubmed/21968660>
24. Fluhr JW, Caspers P, van der Pol JA, Richter H, Sterry W, Lademann J, Darvin ME. Kinetics of carotenoid distribution in human skin in vivo after exogenous stress: disinfectant and wIRA-induced carotenoid depletion recovers from outside to inside. *J Biomed Opt*. 2011 Mar;16(3):035002. <http://www.ncbi.nlm.nih.gov/pubmed/21456863>

25. Haag SF, Taskoparan B, Darvin ME, Groth N, Lademann J, Sterry W, Meinke MC. Determination of the antioxidative capacity of the skin in vivo using resonance Raman and electron paramagnetic resonance spectroscopy. *Exp Dermatol*. 2011 Jun;20(6):483-7. <http://www.ncbi.nlm.nih.gov/pubmed/21366704>
26. Lademann J, Meinke MC, Sterry W, Darvin ME. Carotenoids in human skin. *Exp Dermatol*. 2011 May;20(5):377-82. <http://www.ncbi.nlm.nih.gov/pubmed/21366698>
27. Lademann J, Schanzer S, Meinke M, Sterry W, Darvin ME. Interaction between carotenoids and free radicals in human skin. *Skin Pharmacol Physiol*. 2011;24(5):238-44. <http://www.ncbi.nlm.nih.gov/pubmed/21447993>
28. Darvin ME, Haag S, Meinke M, Zastrow L, Sterry W, Lademann J. Radical production by infrared A irradiation in human tissue. *Skin Pharmacol Physiol*. 2010;23(1):40-6.. <http://www.ncbi.nlm.nih.gov/pubmed/20090407>
29. Ermakov IV, Gellermann W. Validation model for Raman based skin carotenoid detection. *Arch Biochem Biophys*. 2010 Dec 1;504(1):40-9. <http://www.ncbi.nlm.nih.gov/pubmed/20678465>
30. Meinke MC, Darvin ME, Vollert H, Lademann J. Bioavailability of natural carotenoids in human skin compared to blood. *Eur J Pharm Biopharm*. 2010 Oct;76(2):269-74. <http://www.ncbi.nlm.nih.gov/pubmed/20558286>
31. Scarmo S, Cartmel B, Lin H, Leffell DJ, Welch E, Bhosale P, Bernstein PS, Mayne ST. Significant correlations of dermal total carotenoids and dermal lycopene with their respective plasma levels in healthy adults. *Arch Biochem Biophys*. 2010 Dec 1;504(1):34-9. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2957565/pdf/nihms229903.pdf>
32. Mayne ST, Cartmel B, Scarmo S, Lin H, Leffell DJ, Welch E, Ermakov I, Bhosale P, Bernstein PS, Gellermann W. Noninvasive assessment of dermal carotenoids as a biomarker of fruit and vegetable intake. *Am J Clin Nutr*. 2010 Oct;92(4):794-800. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3133234/pdf/ajcn9240794.pdf>
33. Blume-Peytavi U, Rolland A, Darvin ME, Constable A, Pineau I, Voit C, Zappel K, Schäfer-Hesterberg G, Meinke M, Clavez RL, Sterry W, Lademann J. Cutaneous lycopene and beta-carotene levels measured by resonance Raman spectroscopy: high reliability and sensitivity to oral lactolycopene deprivation and supplementation. *Eur J Pharm Biopharm*. 2009 Sep;73(1):187-94. <http://www.ncbi.nlm.nih.gov/pubmed/19442725>

34. Darvin ME, Fluhr JW, Caspers P, van der Pool A, Richter H, Patzelt A, Sterry W, Lademann J. In vivo distribution of carotenoids in different anatomical locations of human skin: comparative assessment with two different Raman spectroscopy methods. *Exp Dermatol*. 2009 Dec;18(12):1060-3. <http://www.ncbi.nlm.nih.gov/pubmed/19650865>
35. Hesterberg K, Lademann J, Patzelt A, Sterry W, Darvin ME. Raman spectroscopic analysis of the increase of the carotenoid antioxidant concentration in human skin after a 1-week diet with ecological eggs. *J Biomed Opt*. 2009 Mar-Apr;14(2):024039. <http://www.ncbi.nlm.nih.gov/pubmed/19405767>
36. Darvin M, Patzelt A, Gehse S, Schanzer S, Benderoth C, Sterry W, Lademann J. Cutaneous concentration of lycopene correlates significantly with the roughness of the skin. *Eur J Pharm Biopharm*. 2008 Aug;69(3):943-7. <http://www.ncbi.nlm.nih.gov/pubmed/18411044>
37. Darvin ME, Patzelt A, Knorr F, Blume-Peytavi U, Sterry W, Lademann J. One-year study on the variation of carotenoid antioxidant substances in living human skin: influence of dietary supplementation and stress factors. *J Biomed Opt*. 2008 Jul-Aug;13(4):044028. <http://www.ncbi.nlm.nih.gov/pubmed/19021355>
38. Shao YH, He YH, Ma H, Nan N, Qian LS, Wang SX. [Carotenoid levels measured by resonance Raman in vivo]. *Guang Pu Xue Yu Guang Pu Fen Xi*. 2007 Nov;27(11):2258-61. Chinese. <http://www.ncbi.nlm.nih.gov/pubmed/18260408>
39. Darvin M, Schanzer S, Teichmann A, Blume-Peytavi U, Sterry W, Lademann J. [Functional food and bioavailability in the target organ skin]. *Hautarzt*. 2006 Apr;57(4):286, 288-90. German. <http://www.ncbi.nlm.nih.gov/pubmed/16485123>
40. Ermakov IV, Sharifzadeh M, Ermakova M, Gellermann W. Resonance Raman detection of carotenoid antioxidants in living human tissue. *J Biomed Opt*. 2005 Nov-Dec;10(6):064028. Review. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3086339/pdf/nihms277219.pdf>
41. Ermakov, I.V. Ermakova, M.R., Gellermann, W., Lademann, J. Noninvasive selective detection of lycopene and beta-carotene in human skin using Raman spectroscopy. *J Biomed Opt*. 2004 Mar;9(2):332-8. <http://www.ncbi.nlm.nih.gov/pubmed/15065899>
42. Gellermann, W., Ermakov, I.V., Scholz, T.A. and Bernstein, P. S. Noninvasive laser Raman detection of carotenoid antioxidants in skin. *Cosmetic Dermatology* 2002;15(9):65-68. [no online abstract available]
43. Ermakov IV, Ermakova MR, McClane RW, Gellermann W. et al. Resonance Raman detection of carotenoid antioxidants in living human tissues. *Optics Letters* 2001;26:1179-1181. <http://www.ncbi.nlm.nih.gov/pubmed/18049555>

44. Hata TR, Scholz TA, Ermakov IV, McClane RW, Khachik F, Gellermann W, Pershing LK. Non-invasive raman spectroscopic detection of carotenoids in human skin. *J Invest Dermatol*. 2000 Sep;115(3):441-8. *Full length article available free of charge at:* <http://www.nature.com/jid/journal/v115/n3/pdf/5600819a.pdf>

Raman spectroscopy in the Eye

Prior to being adapted for measurements in human skin, Raman resonance was validated for detection of carotenoid concentrations in intact human retinas (an indicator of macular health). Well over a dozen full-length peer-reviewed articles have been published on the use of Raman spectroscopy to detect macular carotenoids. Many of the following full-length articles are available free of charge; all other links provide PubMed abstracts from which full-length articles may be purchased:

45. Bernstein PS, Ahmed F, Liu A, Allman S, Sheng X, Sharifzadeh M, Ermakov I, Gellermann W. Macular Pigment Imaging in AREDS2 Participants: An Ancillary Study of AREDS2 Subjects Enrolled at the Moran Eye Center. *Invest Ophthalmol Vis Sci*. 2012 Sep 14;53(10):6178-86. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/22879423>
46. Ward MS, Zhao da Y, Bernstein PS. Macular and serum carotenoid concentrations in patients with malabsorption syndromes. *J Ocul Biol Dis Infor*. 2008 Mar;1(1):12-8. *Full length article available free of charge at:* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2600549/pdf/12177_2008_Article_9008.pdf
47. Sharifzadeh M, Zhao DY, Bernstein PS, Gellermann W. Resonance Raman imaging of macular pigment distributions in the human retina. *J Opt Soc Am A Opt Image Sci Vis*. 2008 Apr;25(4):947-57. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3079576/pdf/nihms277266.pdf>
48. Ermakov IV, Ermakova MR, Gellermann W. Simple Raman instrument for in vivo detection of macular pigments. *Appl Spectrosc*. 2005 Jul;59(7):861-7. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3079574/pdf/nihms277046.pdf>
49. Neelam, K.; O'Gorman, N.; Nolan, J.; O'Donovan, O.; Wong, H.B.; Au Eong, K.G. and Beatty, S. Measurement of Macular Pigment: Raman Spectroscopy versus Heterochromatic Flicker Photometry. *Invest Ophthalmol Vis Sci* 2005;46(3):1023-1032. *Full length article available free of charge at:* <http://www.iovs.org/cgi/reprint/46/3/1023>
50. Ermakov I, Ermakova M, Gellermann W, Bernstein PS. Macular pigment Raman detector for clinical applications. *J Biomed Opt* 2004; 9(1):139-48. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3086335/pdf/nihms277261.pdf>

51. Bernstein PS, Zhao DY, Sharifzadeh M, Ermakov IV, Gellermann W. Resonance Raman measurement of macular carotenoids in the living human eye. Arch Biochem Biophys 2004;15;430(2):163-9. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/15369814>
52. Gellermann, W., Bernstein PS. Noninvasive detection of macular pigments in the human eye. J Biomed Opt. 2004 Jan-Feb;9(1):75-85. Review. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/14715058>
53. Zhao DY, Wintch SW, Ermakov IV, Gellermann W, Bernstein PS. Resonance Raman measurement of macular carotenoids in retinal, choroidal, and macular dystrophies. Arch Ophthalmol 2003;121(7):967-72. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/12860799>
54. Gellermann, W., Ermakov, I.V., McClane, R.W. Raman imaging of human macular pigments. Optics Letters 2002; 27(1):833–835. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/18007943>
55. Gellermann W, Ermakov IV, Ermakova MR, McClane RW, Zhao DY, Bernstein PS. *In vivo* resonant Raman measurement of macular carotenoid pigments in the young and the aging human retina. J Opt Soc Am A Opt Image Sci Vis. 2002;19(6):1172-86. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/12049355>
56. Bernstein PS, Zhao DY, Wintch SW, Ermakov IV, McClane RW, Gellermann W. Resonance Raman measurement of macular carotenoids in normal subjects and in age-related macular degeneration patients. Ophthalmology 2002;109(10):1780-7. *Full length article available free of charge at:* <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3079575/pdf/nihms277255.pdf>
57. Bernstein, P.S., Gellermann W. Measurement of carotenoids in the living primate eye using resonance Raman spectroscopy. Methods Mol Biol. 2002;196:321-9. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/12152212>
58. Bernstein, P.S. New insights into the role of the macular carotenoids in age-related macular degeneration. Resonance Raman studies. Pure and Applied Chemistry 2002;74(8):1419-1425. *Full length article available free of charge at:* <http://www.iupac.org/publications/pac/2002/pdf/7408x1419.pdf>
59. Ermakov IG, McClane RW, Gellermann W. Resonant Raman detection of macular pigments in the living human retina. Optics Letters 2001;26(4):202–204. *Abstract available at:* <http://www.ncbi.nlm.nih.gov/pubmed/18033547>
60. Bernstein PS, Yoshida MD, Katz NB, McClane RW, Gellermann W. Raman detection of macular carotenoid pigments in intact human retina. Invest Ophthalmol Vis Sci 1998;39(11):2003-11. *Full length article available free of charge at:* <http://www.iovs.org/cgi/reprint/39/11/2003>

The following 14 abstracts are available as abstracts only (with the exception of Wengreen 2010 which is available as a poster); **all were presented at scientific symposiums. The tool used to measure skin carotenoids was the Pharmanex BioPhotonic Scanner. All but three of the following were co-authored by at least one Pharmanex scientist:**

61. Wengreen H, Aguilar S, Lefevre M. Skin Carotenoids as a Biomarker of Fruit and Vegetable Intake in Children. Presented at American Dietetic Association's Food & Nutrition Conference & Expo. Boston, Ma. November 6-9, 2010. *[no online abstract available]*
62. Duan L, Lu J, Li G, Zhu JS. Improvement of Skin Carotenoids Antioxidant Scores with G3 Drink and LifePak is affected by Endurance Training Intensity in Young Athletes. FASEB J. 2009 23:1007.3. *Abstract available at:*
http://www.fasebj.org/cgi/content/meeting_abstract/23/1_MeetingAbstracts/1007.3
63. Wood SM, Mastaloudis A, Carlson J, Zidichouski JA, Holubkov R, Reading J, Stavens S, Askew EW, Morrow JD, Milne GL, Poole SL, Bartlett M. Consistency of correlations of serum and skin carotenoids as measured by high performance liquid chromatography and Raman spectroscopy. Presented at 15th International Symposium on Carotenoids, Okinawa Japan, June 2008. *[no online abstract available]*
64. Bi SX, Li CL, Guo HW, Poole SL, Zhu JS. The effects of life styles and LifePak on human skin carotenoids scores measured by resonance Raman spectroscopy BioPhotonic Scanner. FASEB Journal 2007;21(4):A709. *Abstract available at:*
http://www.fasebj.org/cgi/content/meeting_abstract/21/5/A709
65. Carlson J, Stavens S, Holubkav R, Zidichouski J, Mastaloudis A, Smidt CR. and Askew, E. Associations of Antioxidant Status, Oxidative Stress, with Skin Carotenoids Assessed by Raman Spectroscopy (RS). Experimental Biology meeting abstracts. FASEB Journal 20: A824.3; 2006. *Abstract available at:*
http://www.fasebj.org/cgi/content/meeting_abstract/20/5/A1318-c
66. Li CL, Guo HW, Bi SX, Zhu, ZG, Zhu JS. Skin Carotenoids Measured by Resonance Raman Spectroscopy BioPhotonic Scanner and the Effects of Life Styles and LifePak on Human Carotenoids Nutritional Status and Skin Scores. Asian Pacific Journal of Clinical Nutrition 2006;15(Suppl.):S79. *Abstract available at:*
http://apjcn.nhri.org.tw/server/APJCN/Volume15/vol15apcns/IUNS-APCNS2006_HEC.pdf (see page 92 out of 207 of the PDF at previous link)
67. Stavens S, Carlson J, Holubkav R, Zidichouski J, Mastaloudis A, Smidt CR. and Askew, E. Associations of Fruit and Vegetable Intake with Serum Carotenoids and Skin Carotenoids Measured with Raman Spectroscopy (RS). FASEB Journal 20: A669.4;2006. *Abstract available at:* http://www.fasebj.org/cgi/content/meeting_abstract/20/5/A1058-d

68. Zukley LM, Nguyen V, Lowndes J, Smidt C, Angelopoulos TJ, Rippe JM, Effects of antioxidant supplementation on skin and serum carotenoids, FASEB Journal 2006;20:A145. *Abstract available at:*
http://www.fasebj.org/cgi/content/meeting_abstract/20/4/A145-a
69. Zukley LM, Lowndes J, Greenstone CL, Melton R, Nguyen V, TJ Angelopoulos, Rippe JM. Assessment of The Relationship Between Oxidative Stress, Antioxidant Status, Inflammation And Cardiorespiratory Fitness In The Obese. *Medicine & Science in Sports & Exercise*: May 2005. 37(5); pS385. *[no online abstract available]*
70. Fiutem J, Zukley L, Geise T, Legowski P, Nguyen V, Dube T, Yount B, Smidt C, Angelopoulos T, Rippe J. Adiposity Negatively Influences Carotenoids and Antioxidant Status in Overweight Individuals. *Medicine and Science in Sports and Exercise*. 36 (5) Supplement S302, 2004. *[no online abstract available]*
71. Smidt, C.R., Gellermann, W., Zidichouski, J.A. Non-invasive Raman spectroscopy measurement of human carotenoid status. Pharmanex Research Institute. FASEB 18(4):A480, 2004. *[no online abstract available]*
72. Zidichouski, J.A., Poole, S.L., Gellermann, W. Smidt, C.R. (2004) Clinical validation of a novel Raman spectroscopic technology to non-invasively assess carotenoid status in humans. *Journal of Am. Coll. Nutr.* 23 (5): p.468. *[no online abstract available]*
73. Zukley L, Legowski P, Nguyen V, Geise T, Lowndes J, Melanson K, Angelopoulos T, Rippe J. The Effect of Weight Loss on Dietary Carotenoid and Skin Carotenoid Levels in Subjects Participating in a Weight Loss Study. *Obesity Research Suppl* 2004;12:A57. *[no online abstract available]*
74. Smidt C.R. and Shieh D. Non-invasive biophotonic assessment of skin carotenoids as a biomarker of human antioxidant status. *FASEB J* 2003, 17 (5): A1115. *[no online abstract available]*

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