

# Highlights of the 15<sup>th</sup> International Symposium on Carotenoids

**George Britton**

University of Liverpool, United Kingdom

Correspondence: George Britton, University of Liverpool, Life Sciences Building, Crown Street, Liverpool L69 7ZB, United Kingdom  
Email: g.britton@liv.ac.uk



The end of the Symposium. The Symposium Chair, Wataru Miki hands over the Symposium Banner to Fred Khachik, new President of the International Carotenoid Society.

All the ingredients were there. The four 'S' words: Sun, Sea, Sand and Science. This was Okinawa Island. This was the 15<sup>th</sup> International Symposium on Carotenoids, held in Japan for only the second time. Amidst the normal bustle of the Moon Beach Hotel, the 'Hashimoto Army' of young researchers was working hard to get every detail into place for the Symposium. Throughout the week, these smiling, friendly young people worked tirelessly to make sure that everything ran smoothly.

The program followed the pattern that has become tradition in this international symposia series. Sunday afternoon registration was fol-

lowed by an informal mixer reception at which, over drinks and snacks, old friends could catch up on gossip and newcomers could experience the unique friendly and relaxed atmosphere of a carotenoid meeting. We also had our first taste of local culture – music with drummers and dancers weaving their way under the palms between the hotel and the beach. This put us all in the right frame of mind and eager for the main business of the Symposium to begin on Monday morning.

After the Opening Ceremony, with words of welcome from Symposium Secretary Hideki Hashimoto, Chairman Wataru Miki, and the President of the International Carotenoid Society, Richard Cogdell, the Symposium began fittingly with a plenary lecture by Masayoshi Ito (Japan), one of the great names of carotenoid chemistry, who treated us to a survey of his lifetime's work synthesizing the most challenging carotenoid structures. This was followed by a sec-

ond plenary lecture on the High Performance Liquid Chromatography (HPLC) analysis of carotenoids, given by Fred Khachik (USA), President Elect of the International Carotenoid Society. This was followed by a number of sessions with the customary mix of plenary lectures, and invited and contributed talks, supported by poster presentations. The range of topics covered reflects the great diversity of the carotenoid field.

As always, the presentations on the photochemistry and photophysics of carotenoids, led by the plenary lecture of Hideki Hashimoto (Japan), were remarkable, and even non-specialists could not fail to be impressed by the intricate structural details now revealed by X-ray crystallography of the photosynthetic pigment-protein complexes, and by studies of transient species and energy transfer on a femtosecond (10–15 sec) timescale.

Advances in the industrial synthesis of carotenoids were described in the plenary lecture by Hansgeorg Ernst (Germany), who gave us food for thought by proposing that, when all factors are considered, including use of land, effects on natural ecosystems and resources,

clean technology and waste disposal, the production of pure nature-identical carotenoids by chemical synthesis is at least as environmentally friendly as the natural production that is usually considered 'green.'

Takashi Maoka (Japan) gave a progress report on structural studies of carotenoids in plants and animals, adding to the ever-increasing list of new carotenoid structures, and Peter Molnar described more than 30 years of research on the (*E/Z*)-isomerization of carotenoids. Geir Kildahl-Andersen (Norway) described the formation, characterization and properties of blue forms of carotenoids, and revealed the mechanism behind the blue color formed in the Carr-Price reaction, which has been used for many years for the quantitative analysis of retinol. Methods for the total and partial synthesis of specific optical isomers of lutein and zeaxanthin, peridinin analogues, carotenoid glycosides and stable anionic carotenoid radicals, and the preparation and properties of various unusual and novel carotenoid derivatives were described in poster presentations.

Progress in the study of carotenoid biosynthesis from the first isolation of the bacterial genes to the current development of transgenic plants was surveyed in a plenary lecture by Gerhard Sandmann (Germany), and recent work with food sources, especially tomato and maize, and with oil seed crop plants (linseed, rapeseed) to produce natural oils containing nutritionally important carotenoids was reported by a series of other speakers. The cleavage reactions, enzymes and genes by which carotenoids are broken down were also discussed. Many such 'nor-isoprenoids' make important contributions to flavour, aroma and perfume. This was

exemplified in a talk by Manuela Mendes-Pinto (Portugal/Australia) about their contribution to wine aroma, illustrated by a selection of wines provided for sampling at an informal wine party. Other presen-

play of aquatic life, especially marine life indigenous to the Pacific waters around the Okinawa Islands. This stunning spectacle, which was also seen by some as a living menu or a treasure store of



Members of the Lycocard group in the poster room

tations discussed the role of these compounds in Japanese green tea and tobacco aroma, and in the perfume of rose flowers. Research on the carotenoid cleavage reactions, enzymes and genes was included in the biosynthesis sessions.

It is common practice to include a source of carotenoids in the feed used for aquaculture of invertebrate animals and fish. The use of astaxanthin to color the muscle flesh of salmon and trout was included in Wataru Miki's lecture. A talk and several posters reported feeding and metabolic studies with anemone fish, the red devil and other ornamental fish, the food fish 'Red Porgy', sea urchins, and the brine shrimp *Artemia*.

A lively Wednesday morning of poster viewing and discussion led on to the Symposium Excursion to the famous Okinawa Churaumi ('Beautiful Ocean') Aquarium which is home to a spectacular dis-

new sources of carotenoids for analysis, was a reminder of the beauty, fragility and special ecological importance of the oceans in their great diversity.

Back at the hotel and changed into the recommended informal dress, preferably the Symposium 'kariyushi' shirt, we were ready for the Conference Dinner, a buffet banquet with whole roasted piglets and many local and other delicacies, so that everyone could meet and mingle and enjoy the special entertainment – music, dance and displays of martial arts. The skills of our Symposium Secretary Hideki were most impressive – no one would step out of line for the rest of the meeting. This was also an occasion for short speeches and for the awards presentation, graced by the presence of Miss Okinawa (in duplicate), and led by the President of the International Carotenoid Society, Richard Cogdell. The Otto Isler Award for long and distin-

guished research in Carotenoid Chemistry was presented to Masayoshi Ito. Unfortunately, Johannes von Lintig (Germany/USA) was not present to receive his Trevor Goodwin Award for distinguished research in carotenoid biochemistry/biology. Three prizes for young scientist poster presentations went to Yoshiro Iinuma (Japan), Christer Øpstad (Norway) and Emiko Shibata (Japan).



Synnøve Liaaen-Jensen with two young admirers

As expected, there was broad coverage of carotenoids in human nutrition and health. This generally followed familiar themes – anti-cancer, anti-AMD, antioxidant – with effects demonstrated in cell cultures, animal experiments and some human studies, though with some new angles and insights.

Accurate, reliable and sensitive analysis is an essential requirement for all carotenoid work, not least in nutrition and health studies. In his plenary lecture, Fred Khachik gave an overview of the reversed-phase and normal phase HPLC procedures he has used successfully for a number of years to analyze carotenoid profiles in food, tissues and serum, including the separation of *cis-trans* isomers and of xanthophyll esters. Daniele Giuffrida (Italy) described LC-LC methods employing serial coupling of normal phase/reversed phase,  $C_{18}/C_{30}$ , and  $C_{30}/C_{30}$  columns to achieve improved resolution. Takashi Nakajima (Japan) assessed the use of Ultra-performance LC (UPLC) with stationary phases of very small particle sizes ( $< 2 \mu\text{m}$ ) to analyze carotenoids of human serum. The much shorter run times, excellent resolution and high reproducibility make this procedure ideal for routine screening of a

large number of samples. Susan Mayne (USA) reported on the validation of a non-invasive resonance Raman (RR) method for the determination of dermal carotenoids. Comparison with HPLC analysis showed the RR method to be reproducible and reliable for use in large-scale human studies.

Few presentations were directly devoted to the distribution of carotenoids in food sources, though the distribution of  $\beta$ -carotene, lycopene and lutein in fruit and vegetables commonly consumed in India, and the provitamin A quality of orange-fleshed sweet potatoes in Bangladesh and loquat fruit in China were reported in posters, as were analyzes of carotenoids in pumpkins, sweet pepper mutants, apples and some indigenous Panamanian fruits. The search for new microbial sources of carotenoids continues, and surveys of isolates from around the corals reefs of Okinawa and of marine bacteria isolated in Thailand were presented.

There is great variability among individuals in the efficiency of  $\beta$ -carotene absorption and conversion into vitamin A, with a substantial proportion of ‘low responders’. Franck Tourniare (UK) showed that single nucleotide polymor-

phism (SNP) variability in the genes coding for the central and excentric cleavage influences not only vitamin A formation but also lipid metabolism. Jayant Deshpande (India) described novel coated-beadlet formulations from which  $\beta$ -carotene, lycopene and lutein are released sequentially at specific time

intervals, to avoid competition for absorption.

Poster presentations reported that, in a healthy aged population, smoking and drinking were associated with decreased carotenoid levels, cigarette smoke affects the concentration of lycopene and other carotenoids in human plasma, and soluble fibres influence the bioavailability of  $\beta$ -carotene and lutein. The accumulation of  $\beta$ -cryptoxanthin in tissues of ferrets was dose-dependent and tissue-specific



Discussions outside



Masayoshi Ito speaking after receiving the Otto Isler Award

changes in the central and excentric cleavage enzymes were reported. Retinal pigment epithelium cells take up lutein and zeaxanthin in preference to  $\beta$ -carotene. Supplementation led to increased lutein and zeaxanthin concentrations in plasma within hours, but it was four weeks before an increase was detected in macular optical density.

A poster by Wolfgang Schalch (Switzerland) gave an overview of the literature on the role of lutein and *meso*-zeaxanthin in the human macula and in protection against age-related macular degeneration. Paul Bernstein (USA) described a lutein-binding protein in human retinal tissues, enriched in the macula, and suggested that, besides absorbing excess blue light and attenuating oxidative damage, the macular pigment may inhibit the formation of the lipofuscin component A2E. Richard Bone (USA) reported the application of an eye-tracking method to confirm that light and important images were

focused mainly on the fovea/macula region of the retina. John Landrum (USA) presented evidence for the active uptake and metabolism of lutein and zeaxanthin, and showed how major differences in the topology of xanthophyll end groups help to explain why *meso*-zeaxanthin rather than lutein plays a key role in the macula. A poster by Karol Subczynski (Poland/USA) showed that, in model membrane bilayers, dihydroxyxanthophylls, notably lutein, can form raft domains similar to the 'cholesterol rafts' that are known to influence membrane dynamics and functions. This could be significant for the physiological roles of xanthophylls.

Helmut Sies (Germany) assessed the role of lycopene and other carotenoids in photoprotection of skin, and Hirono Sasaki (Japan) described work with human skin fibroblasts and suggested that lycopene may have potential anti-wrinkle benefits against skin aging, through affecting collagen production. Mechanisms for photoprotection of skin by carotenoids were summarized by Wolfgang Schalch (Switzerland).

In his plenary lecture on carotenoids and cancer, Hoyoku Nishino (Japan) reported that  $\beta$ -cryptoxanthin, alone or in combination with lycopene, showed promise as a preventive/protective agent against cancers of skin, lung and liver. The efficient large-scale synthesis of (3*R*)- $\beta$ -cryptoxanthin described by Hansgeorg Ernst, makes this compound available for biological studies.  $\beta$ -Cryptoxanthin-enriched extracts of satsuma mandarin fruit were reported to have health-promoting effects in relation to post-menopausal osteoporosis, fatigue and obesity.

John Erdman (USA), in his plenary lecture, asked the question "Are health attributes of lycopene related to antioxidant function?" He concluded that, in general, they are not; the lycopene concentration in LDL, for example, is much too low for any significant antioxidant protection. He considered it most likely that reported effects on cellular and molecular processes are due to 'lycopenoids', i.e. apolycopenals and apolycopenoic acids that are metabolites/breakdown products of lycopene itself. This was supported by other presentations describing work with cell cultures, which showed the effects of lycopene breakdown products on RAR/RXR pathways, expression of detoxifying and antioxidant enzymes, activation of PPAR $\gamma$  and inhibition of liver cell growth *in vivo* and *in vitro*, and suppression of proliferation of human colon cancer cells. These effects were all related to the anti-cancer action of lycopene.

In mice, dietary lutein inhibited DSS-induced colitis (a risk factor for colon cancer) and the associated development of colorectal carcinoma. In cancer cell lines, fucoxanthin and fucoxanthin-rich seaweed products showed effects on molecular processes including apoptosis, and had anti-obesity and anti-diabetic effects in mice and rats.

An 'Astaxanthin Symposium' concentrated mostly on specific aspects of astaxanthin and health. Astaxanthin is generally not detected in blood and tissues of individuals consuming a 'normal diet' but numerous presentations reported effects of supplements of astaxanthin or astaxanthin-rich extracts in humans and animals and effects of astaxanthin on molecular processes in cells in culture. A session on Carotenoids and Sports Nutrition – a topic not covered previously in these meet-



The Symposium Secretary Hideki Hashimoto receiving a present from Miss Okinawa

ings – also dealt mainly with astaxanthin. A plenary lecture by Stefan Branth (Sweden) was followed by several talks describing the beneficial effects of astaxanthin on physical performance and endurance. Further information on these topics was presented in posters.

Research on astaxanthin in relation to human health and well-being is at an early stage, but beneficial effects of astaxanthin were described on eye fatigue, brain function and senile dementia, and photoaging of skin as well as anti-diabetic, anti-inflammatory and anti-tumour activity. An interesting new area suggests that astaxanthin, given as supplements, can influence mitochondrial energy metabolism, stimulating lipid catabolism and reducing lactate accumulation, and thus help to sustain exercise performance, reduce fatigue and improve recovery, and aid weight management against obesity. If any of these effects are substantiated, astaxanthin could become a carotenoid of major importance in relation to human health.

The abstracts of all presentations are published in an edition of *Carotenoid Science* (Volume 12, June 2008), and the texts of plenary and invited lectures will be published in *Archives of Biochemistry and Biophysics*.

What began in 1966 as a small satellite meeting has now become the major event in the calendar of the International Carotenoid Society; the 15<sup>th</sup> Symposium was attended by 293 people from more than 30 countries. After a stimulating and successful week in Okinawa, the Symposium next returns to Europe. The International Carotenoid Society and the Symposium Organiser Kazimierz Strzałka cordially invite all with interest in any area of carotenoid science, academic and commercial, to Poland in July 2011 for the 16<sup>th</sup> International Symposium on Carotenoids, which will be held in the historic city of Krakow, a UNESCO World Heritage Site. Information about this meeting will be given on the website of the International Carotenoid Society ([www.carotenoidsociety.org](http://www.carotenoidsociety.org)).



The sun going down over Moon Beach