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Editorial

Carotenoids in Fresh and Processed Food: Between Biosynthesis and Degradation

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1. Introduction

Currently, there is a general trend in food science to link food and health in line with consumers' concern about what is in their food and how what they eat can promote well-being. Thus, food is considered today not only a source of energy but also an affordable way to prevent future diseases. In this context, studying carotenoids content in food is very relevant. Indeed, epidemiological studies have demonstrated that the consumption of diets rich in carotenoids is associated with a lower incidence of cancer, cardiovascular diseases, and age-related macular degeneration, mainly due to their antioxidant and provitamin A activity [1]. Although many works have been conducted concerning the presence and properties of carotenoids in food [2], some challenges must be still faced in this research field: The role of carotenoids as antioxidants and its mechanism of action need to be investigated further; detailed qualitative and quantitative composition of carotenoids in underutilized fruits and vegetables is required in order to contribute significant information to select nutrient rich plants for food formulation; how emerging packaging and processing techniques (i.e., high electric field pulse, high-pressure CO_2, etc.) can preserve the content of carotenoids in processed food products needs to be understood; the complete understanding of carotenoid biosynthesis, regulation, and roles of various carotenoid derivatives for edible plants and animals is still not well established; and detailed studies for identifying the pre- and post-harvesting favorable factors (i.e., elicitors, cooking methods, etc.), which improve the bioavailability and bioaccessibility of carotenoids from different foods, are necessary.

The Special Issue "Carotenoids in Fresh and Processed Food: Between Biosynthesis and Degradation" was aimed to invite worldwide scholars (particularly experts in the sector of food science and food chemistry) to submit their most interesting communications, reviews, and original articles that can improve the knowledge in the field of carotenoids in food.

Potential topics included, but were not restricted to, carotenoids and apocarotenoids chemistry and biosynthesis, structural isomerization and degradation, content in vegetable and non-vegetable foods, and bioavailability and bioaccesibility methods of analysis.

2. Carotenoids in Fresh and Processed Food: Between Biosynthesis and Degradation

The aim of this Special Issue was to group the most recent and relevant research in relation to the aforementioned topics regarding carotenoids in food into a single document. Subsequently, the possibility of publishing a book with the contributions of all authors has been assessed. There were six papers submitted to this Special Issue, and five of them were accepted. In the following paragraphs, a summary of these papers with their most relevant findings is presented.

The first paper [3] deals with the protection of β-Carotene from photodegradation. The authors of this work showed how β-Carotene degrades rapidly in a 2% oil-in-water emulsion, made from food-grade soy oil with 7.4 mg β-carotene/mL oil, during storage and when exposed to light. However, the addition of clove oil (2.0, 4.0, or 8.0 μL/mL of emulsion) prevented the photodegradation of β-carotene, regardless of the ratio between clove oil and β-carotene in the concentration range studied. Since plant phenols have been demonstrated to efficiently regenerate carotenoids from their initial photooxidation products, the authors concluded that the observed regeneration of β-carotene was due to eugenol, the main plant phenol of clove oil to occur in the oil-water interface. Therefore, clove oil in low concentrations may find use as a natural protectant of provitamin A in enriched foods during retail display.

The second paper [4] presented how two typical plant hormones, namely salicylic acid (SA) and methyl jasmonate (MeJA), were able to regulate the accumulation of flavonoids (i.e., eriocitrin, narirutin, and poncirin) and carotenoids (i.e., β-cryptoxanthin) in the juice sacs of Satsuma mandarin in vitro. The results showed that SA treatment was effective in enhancing the contents of eriocitrin, narirutin, poncirin, and β-cryptoxanthin, whilst MeJA treatment inhibited these compounds accumulation in the juice sacs ($p < 0.05$). Moreover, gene expression analysis confirmed that the changes of flavonoid and carotenoid contents were highly regulated at the transcriptional level. In particular, a transcriptional factor CitWRKY70 was identified in the microarray analysis, which was induced by the SA treatment while being suppressed by the MeJA treatment. Since the change in the expression of CitWRKY70 was consistent with that of flavonoid and carotenoid biosynthetic key genes, this finding indicated that CitWRKY70 might be involved in the regulation of the investigated compounds content in the juice sacs of citrus fruit in response to SA and MeJA treatments.

In the third article, Gałązka-Czarnecka et al. [5] studied the influence of light at different wavelengths (white light at 380–780 nm, UVA at 340 nm, blue light at 440 nm, and red light at 630 nm) and pulsed electric field (PEF) at different strength (1, 2.5 and 5 kV/cm) on the content of carotenoids (i.e., lutein, zeaxanthin, and β-carotene) in red clover sprouts. The experiment was carried out in a climatic chamber with phytotron system under seven growing conditions differing in light-emitting diode (LED) wavelengths and PEF strength applied before sowing. Lutein was found as the dominant carotenoid in germinating red clover seeds, with content varying from 743 mg/kg in sprouts grown in red light to 888 mg/kg in sprouts grown in blue light. Blue light treatment during the red clover sprouts growing had the most beneficial effect in enhancing carotenoids content up to 42% in β-carotene, 19% in lutein, and 14% in zeaxanthin. An increase of β-carotene (8.5%) and lutein (6%) amount was also obtained with white light without PEF pre-treatment; conversely zeaxanthin decreased by about 3.3%. Therefore, the authors concluded that PEF pre-treatment may increase mainly the content of β-carotene in red clover sprouts.

The presence of carotenoids in grape berries is well documented [6]; the grape variety and viticulture practices, but also climate conditions and geographic origin, can influence their qualitative and quantitative profile as well as their degradation during grape ripening from véraison to harvest [7]. The last two works, belonging to this SI, treated about effective practices for conditioning carotenoids degradation in grapes. In particular, Asproudi et al. [8] investigated the impact of bunch microclimate on the evolution of some relevant carotenoids (i.e., neoxanthin, luteinin, and β-carotene) in Nebbiolo grapes, collected from green phase up to harvest, during two consecutive seasons. Overall, higher temperature in the less vigorous and south facing vineyards led to lower amounts of carotenoids, both during ripening and at harvest. Lutein and neoxanthin contents (µg/berry) varied similarly in both seasons and achieved a maximum after veraison, especially in the cooler plots. Therefore, a variety effect on the lutein seasonal trend was hypothesized. Conversely, b-carotene content remained generally constant during ripening, with the exception of the south plots showing dissimilar evolution between the seasons. This observation allowed the authors to conclude that bunch zone temperature and light condition may affect both synthesis and degradation of grape carotenoids determining their amount and profile at harvest.

Crupi et al. [9] aimed to study the effect of the foliar application of yeast extracts (YE) to Negro Amaro and Primitivo grapevines on the carotenoid content during grape ripening and the difference between the resulting véraison and maturity (ΔC). The results showed that β-carotene and (allE)-lutein were the most abundant carotenoids in all samples, ranging from 60% to 70% of total compounds. Their levels, as well as those of violaxanthin, (9-Z)-neoxanthin, and 5,6-epoxylutein, decreased during ripening. This was especially observed in treated grapes, with ΔC values from 2.6 to 4.2-fold higher than in untreated grapes. Thereby, the YE treatment has proved to be effective in improving the C_{13}-norisoprenoid aroma potentiality of Negro Amaro and Primitivo, which are fundamental cultivars in the context of Italian wine production.

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References

1. Eggersdorfer, M.; Wyss, A. Carotenoids in human nutrition and health. *Arch. Biochem. Biophys.* **2018**, *652*, 18–26. [CrossRef] [PubMed]
2. Meléndez-Martínez, A.J.; Mandić, A.I.; Bantis, F.; Böhm, V.; Borge, G.I.A.; Brnčić, M.; Bysted, A.; Cano, M.P.; Dias, M.G.; Elgersma, A.; et al. A comprehensive review on carotenoids in foods and feeds: Status quo, applications, patents, and research needs. *Crit. Rev. Food Sci. Nutr.* **2021**, *5*, 1–51. [CrossRef] [PubMed]
3. Zhou, Y.-M.; Chang, H.-T.; Zhang, J.-P.; Skibsted, L.H. Clove Oil Protects β-Carotene in Oil-in-Water Emulsion against Photodegradation. *Appl. Sci.* **2021**, *11*, 2667. [CrossRef]
4. Yamamoto, R.; Ma, G.; Zhang, L.; Hirai, M.; Yahata, M.; Yamawaki, K.; Shimada, T.; Fujii, H.; Endo, T.; Kato, M. Effects of Salicylic Acid and Methyl Jasmonate Treatments on Flavonoid and Carotenoid Accumulation in the Juice Sacs of Satsuma Mandarin In Vitro. *Appl. Sci.* **2020**, *10*, 8916. [CrossRef]
5. Gałązka-Czarnecka, I.; Korzeniewska, E.; Czarnecki, A.; Kiełbasa, P.; Dróżdż, T. Modelling of Carotenoids Content in Red Clover Sprouts Using Light of Different Wavelength and Pulsed Electric Field. *Appl. Sci.* **2020**, *10*, 4143. [CrossRef]
6. Crupi, P.; Coletta, A.; Milella, R.A.; Palmisano, G.; Baiano, A.; La Notte, E.; Antonacci, D. Carotenoid and Chlorophyll derived compounds in some wine grapes grown in Apulian region. *J. Food Sci.* **2010**, *75*, S191–S198. [CrossRef] [PubMed]
7. Crupi, P.; Coletta, A.; Antonacci, D. Analysis of carotenoids in grapes to predict norisoprenoid varietal aroma of wines from Apulia. *J. Agric. Food Chem.* **2010**, *58*, 9647–9656. [CrossRef] [PubMed]
8. Asproudi, A.; Petrozziello, M.; Cavalletto, S.; Ferrandino, A.; Mania, E.; Guidoni, S. Bunch Microclimate Affects Carotenoids Evolution in cv. Nebbiolo (*V. vinifera* L.). *Appl. Sci.* **2020**, *10*, 3846. [CrossRef]
9. Crupi, P.; Santamaria, M.; Vallejo, F.; Tomás-Barberán, F.A.; Masi, G.; Caputo, A.R.; Battista, F.; Tarricone, L. How Pre-Harvest Inactivated Yeast Treatment May Influence the Norisoprenoid Aroma Potential in Wine Grapes. *Appl. Sci.* **2020**, *10*, 3369. [CrossRef]