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Short Communication

Phytochrome-mediated Carotenoids Biosynthesis in Ripening Tomatoes[1]

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RONNIE L. THOMAS AND JOSEPH J. JEN
Departments of Food Science and Biochemistry, Clemson University, Clemson, South Carolina 29631

ABSTRACT

Red light induced and far red light inhibited carotenoid biosynthesis in ripening tomatoes (*Lycopersicon esculentum* Mill.) when compared to controls kept in the dark. Red illumination following far red illumination reversed the inhibitory action of far red light on carotenoid biosynthesis, suggesting a phytochrome-mediated process. Quantitation of individual carotenoids favored the hypothesis of two separate carotenoid biosynthetic pathways in tomatoes.

Piringer and Heinze (9) have shown that the synthesis of a flavonoid pigment was promoted by red illumination and inhibited by far red illumination in the cuticle of tomatoes. Khudairi and Aboleda (7) proposed that lycopene biosynthesis in tomatoes was phytochrome-mediated and was related to plant hormones. Jen (6) used spectral lights and showed that red light enhanced carotenoid formation in tomatoes more than white or green lights. Thomas and Jen (12) demonstrated that the amount of carotenoids synthesized in ripening tomatoes was proportional to the logarithm of red light intensity up to a saturation point, a phenomenon associated with the phytochrome-mediated response in plants (8).

In this communication, the effects on carotenoid biosynthesis in tomatoes by red and far red illumination were investigated, and the carotenoid composition of the treated fruit was analyzed.

EXPERIMENTAL

Mature green tomatoes (*Lycopersicon esculentum* Mill. cv. 'Homestead') were obtained from a local market and sorted for uniform breaker stage of maturity and ripened under controlled conditions as described previously (6). The growth chambers used for light treatments were described in previous studies (6, 12). For each light treatment, 30 breaker tomatoes were used. Red light treatment was 243 mw/cm² for 14 hr/day. Far red light treatment was one application of 488 mw/cm² for 30 min followed by darkness throughout the ripening period (12). Temperatures inside of the tomatoes were controlled at 25 ± 0.5 C as described previously (6). At 2-day intervals, three tomatoes were removed at random and homogenized, extracted, and analyzed spectrophotometrically for total carotenoids by the method of Zscheile and Porter (14). The extracts were then used for separation, identification, and quantitation of individual carotenoid as described by Jen (5).

RESULTS AND DISCUSSION

Figure 1 shows that carotenoid biosynthesis in ripening tomatoes was inhibited by far red illumination and promoted by red illumination. The inhibition of carotenoid biosynthesis by far red illumination was reversed by subsequent red illumination. The rate of pigment biosynthesis appeared to be the same throughout the ripening period, judging from the slope of the red illumination reversal of the far red light treatment. The results were in agreement with Khudairi and Aboleda (7) who reported that carotenoid biosynthesis was stimulated by red light irradia

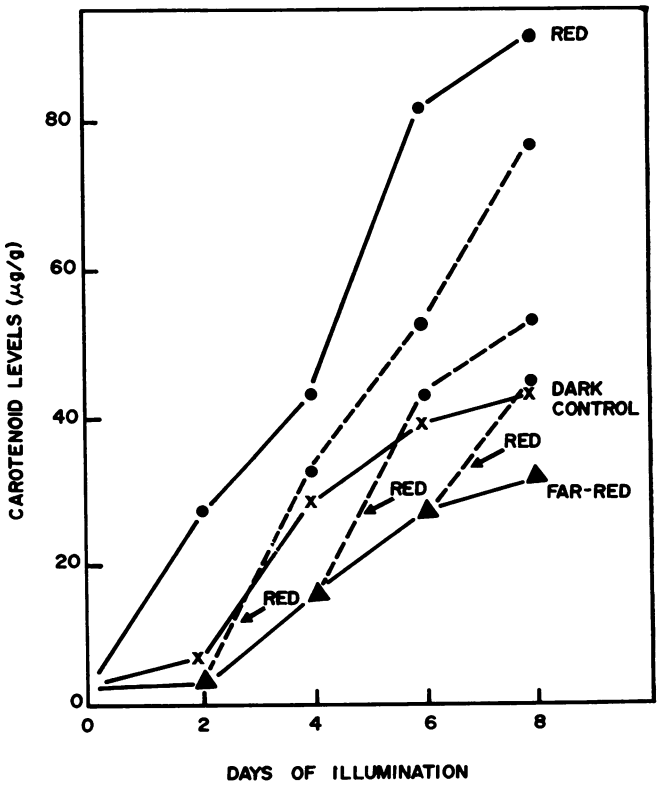

FIG. 1. Effects of red and far red light on carotenoid biosynthesis in ripening tomatoes.

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Table I. *Carotenoid Analysis of Tomatoes Treated with Red or Far Red Light or Kept in Darkness*

Carotenoids	Light Treatment		
	Red[1]	Dark control	Far red[2]
	μg/g dry wt		
Phytoene	89.2	100.9	49.4
Phytofluene	92.6	67.6	36.3
ζ-Carotene	26.9	38	16.6
Neurosporene	8.1	4.9	0
Lycopene	692.5	345.6	180.8
γ-Carotene	6.6	7.8	9.8
β-Carotene	55.1	51.6	49.5
Total	971	616.4	342.4

[1] Six Gro-Lux lamps served as the source of red light. The photoperiod was 14 hr/day for 8 days.

[2] Far red treatment was for one 30-min period followed by darkness for the remainder of the ripening period.

tion. They reported that far red illumination did not enhance or inhibit lycopene biosynthesis in detached tomato fruits. The dark reversion of Pfr to Pr is well known (2). The rate of the reversion is probably slow in tomatoes because carotenoid synthesis leveled off in the dark, whereas synthesis under illumination continued into senescence (12), indicating a gradual dark reversion of Pfr. The reversion of Pfr to Pr is instantaneous upon illumination with far red light (3); thus, tomatoes illuminated with far red light would be expected to produce less carotenoids than tomatoes kept in the dark.

Table I shows the carotenoid content of treated fruit and the dark control after an 8-day ripening period. The amount of β-carotene was the same in all samples, whereas the amount of lycopene and the total carotenoids were greatly affected by light treatments. The more saturated acyclic carotenes, phytoene, phytofluene, ζ-carotene, and neurosporene showed different responses to red light but were all suppressed in far red light-treated fruit in comparison to the dark control. On the other hand, the only other cyclic carotene detected, γ-carotene, was not affected by light treatments. Several reports have proposed that in ripening tomato fruit a physically separated pathway of carotenoid biosynthesis exists which is superimposed on the chloroplast pathway (4). These reports include the inhibition of lycopene but not β-carotene in tomatoes held above 30 C (13) and in tomatoes treated with dimethylsulphoxide (10). Electron microscope studies also indicated that accumulation of β-carotene was ahead of lycopene in tomatoes (1). Raymundo *et al.* (11) and Jen (5) both observed that β-carotene was synthesized first and quickly reached a plateau before mass lycopene accumulation in normal red and red lutescent tomatoes, respectively. If two pathways do exist, phytochrome is probably mediating only one of them. Probably, the enzymes of one of the pathways were established early in the life of the fruit and were not affected by far red light at the mature green stage. On the other hand, the carotenoid biosynthetic pathway developed during fruit ripening was stimulated by red light but repressed by far red treatment.

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