The Ohio State University, Department of Food Science & Technology

Effect of Light Energy on Anthocyanin Color Expression and Stability

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ABSTRACT

The purpose of this study was to investigate the effect of light treatments on the color expression of acylated anthocyanins (ACN). Using randomized block study-design, this study compares industry-accessible light sources in their production of photoisomerized pigments. All of the light treatments induced the isomerization reaction, but the greatest efficiency was observed when the extract was irradiated for 10 hours with D65 lamp. The produced *cis*-acylated ACN exhibited color at pH 4– a condition that typically bleaches ACN. This expands ACN role in replacing synthetic colorants in food products at diverse pH ranges.

INTRODUCTION

Color is an identifying characteristic of food products. Most consumers would be alarmed if they came across blue tomatoes. Thus, color is an integral part of our eating experience. In the recent years, consumers have been demanding more colorants derived from plant materials, such as fruits and vegetables.[1] Therefore, research efforts on anthocyanins (ACN) have increased.

ACN's diverse color expression, ranging from orange to blue hues, make these pigments suitable sources for their incorporation in food products.[2] However, the use of ACN in food products is challenging due to its degradation in atmospheric conditions. Studies show enhancement of ACN performance via addition of stabilizing compounds (intramolecular copigmentation).[3] Unfortunately, the addition of these compounds could alter the flavor or texture of the pigment.[4]

Applying light treatment to acylated ACN is a novel way to modulate its color expression, without external addition of stabilizing compounds. Specifically, photoisomerization of ACN acylating group from *trans*- to *cis*-configuration leads to an expansion of their color expression (Figure 1).

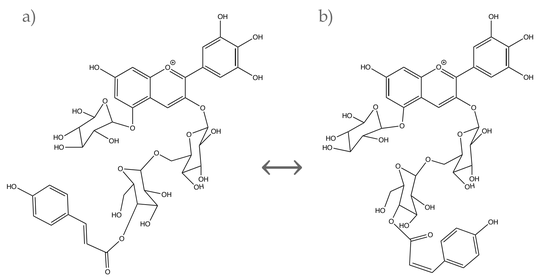


Figure 1. a) chemical structure of delphinidin (a type of anthocyanin) with *trans*-*p*-coumaric acid acylation and b) chemical structure of delphinidin with *cis*-*p*-coumaric acid acylation.

OBJECTIVE

Our objective was to investigate the impact of different light sources on the production of rare ACN pigments with enhanced performance.

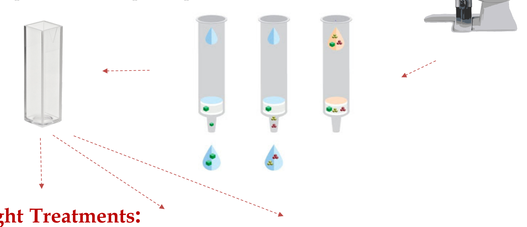
MATERIALS & METHODS

Anthocyanin Extraction:

- Pigment extraction from East Asian eggplants
- Acetone & chloroform phase separation

Sample Purification:

- Solid phase extraction for semi-purification
- Preparation of sample in quartz cuvettes

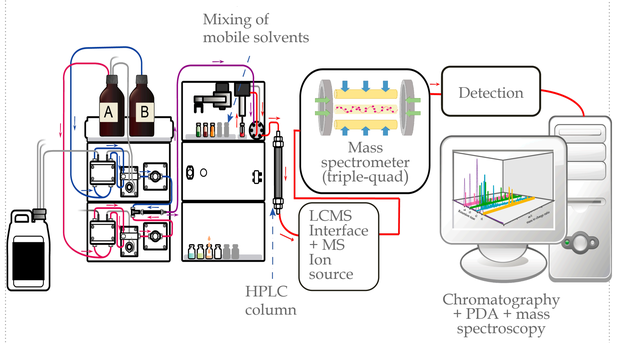


Light Treatments:

- Irradiation with sunlight, D65 lamp, and UV chamber at 365 nm

Sample Analysis:

- uHPLC-PDA-MS/MS



Photoconversion:

$$\frac{(AUC_{530nm}cis-\mathrm{Dp})_{t_n}-(AUC_{530nm}cis-\mathrm{Dp})_{t_0}}{(AUC_{530nm}\mathrm{trans}-\mathrm{Dp})_{t_0}}$$

Pigment Degradation:

$$\frac{(AUC_{530nm}total\ ACN\ pigment)_{t_n}}{(AUC_{530nm}total\ ACN\ pigment)_{t_0}}$$

RESULTS

- **Sunlight**

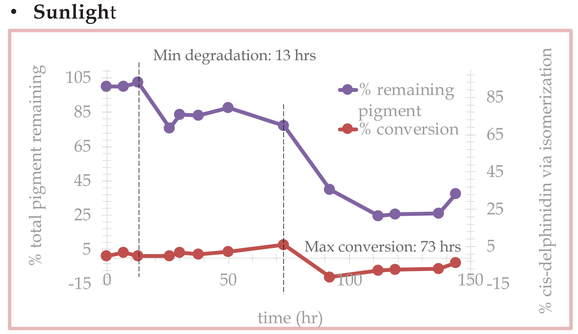


Figure 2. Greatest conversion from *trans* → *cis* was observed after 73 hours when acylated delphinidin was exposed to the sunlight. The duration of irradiation includes day time and night time, which means that there was no light exposure for half of the days. The % total pigment degradation was much greater than the % photoconversion.

- **D65 Lamp**

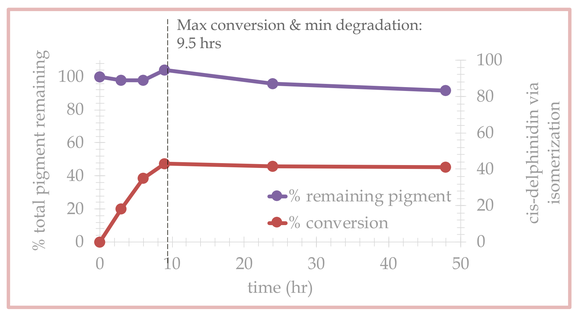


Figure 3. Greatest conversion from *trans* → *cis* was observed after 9.5 hours when acylated delphinidin was exposed to D65 lamp light, resembling sun light. At 9.5 hr, most of the pigment remained present. Additional incubation time only favored degradation, with no more trans-cis conversion. Although D65 lamp is comparable to sunlight, it showed greater photoconversion than sunlight did.

- **UV Chamber (365 nm)**

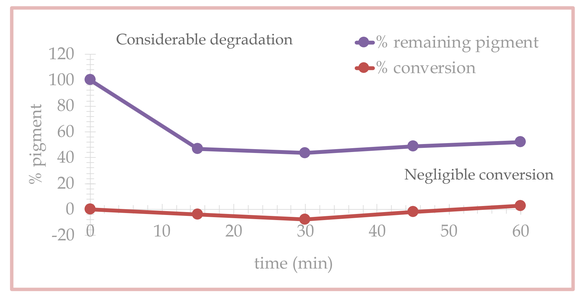
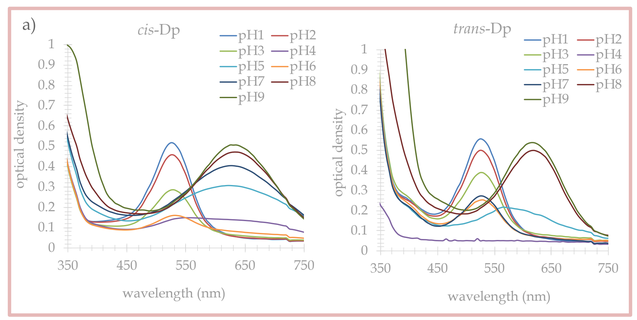


Figure 4. Photoconversion from *trans* → cis-Dp was negligible. The total pigment content decreased immediately with UV treatment at 365 nm. This is attributed to the concentration of light dispersion inside a UV chamber, in comparison to that of sunlight.



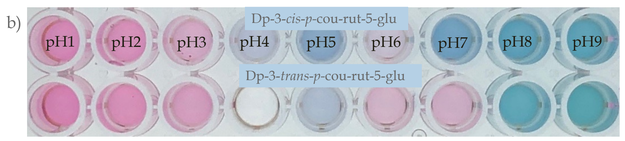


Figure 5. a) spectral distribution of both isomers from pH 1 – pH 9 b) color expression of Dp-3-*cis*-*p*-cou-rut-5-glu and Dp-3-*trans*-*p*-cou-rut-5-glu (top and bottom) from pH 1 – pH 9 (left to right).

CONCLUSIONS & DISCUSSION

- Greatest conversion occurred with minimal total pigment degradation when the extract was irradiated for **9.5 hours with D65 lamp**.
- Sunlight generated **maximal conversion at 73 hrs** with minimal degradation at 13 hrs. Overall, sunlight produced considerable ACN degradation due to its long irradiation time with negligible photoisomerization.
- **UV chamber** irradiation at 365 nm produced **negligible conversion** with pigment degradation by half.
- *Cis*- and *trans*-isomers of delphinidin possess **different color characteristics and pigment stability**.

SIGNIFICANCE

Controlled light exposure produced *cis*-acylated ACN that exhibited a distinct color range from its *trans*-counterpart, and in pH ranges typically challenging for ACNs. Specifically, ACN in *cis*-configuration could be used for products near pH 4, such as yogurt. This contributes to ACN's role in making foods healthier and more visually appealing.

BIBLIOGRAPHY

1. Sigurdson GT, Tang P, Giusti MM (2017) Natural Colorants: Food Colorants from Natural Sources. Annu Rev Food Sci Technol 8:261-280.
2. Ahmadiani N, Robbins RJ, Collins TM, Giusti MM (2016) Molar absorptivity (ε) and spectral characteristics of cyanidin-based anthocyanins from red cabbage. Food Chem 197:900-906.
3. Bakowska-Barczak A (2005) Acylated anthocyanins as stable, natural food colorants: A review. Polish J food Nutr Sci 14:107-116.
4. Boulton R (2001) The copigmentation of anthocyanins and its role in the color of red wine: A critical review. Am J Enol Vitic 52:67-87.

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