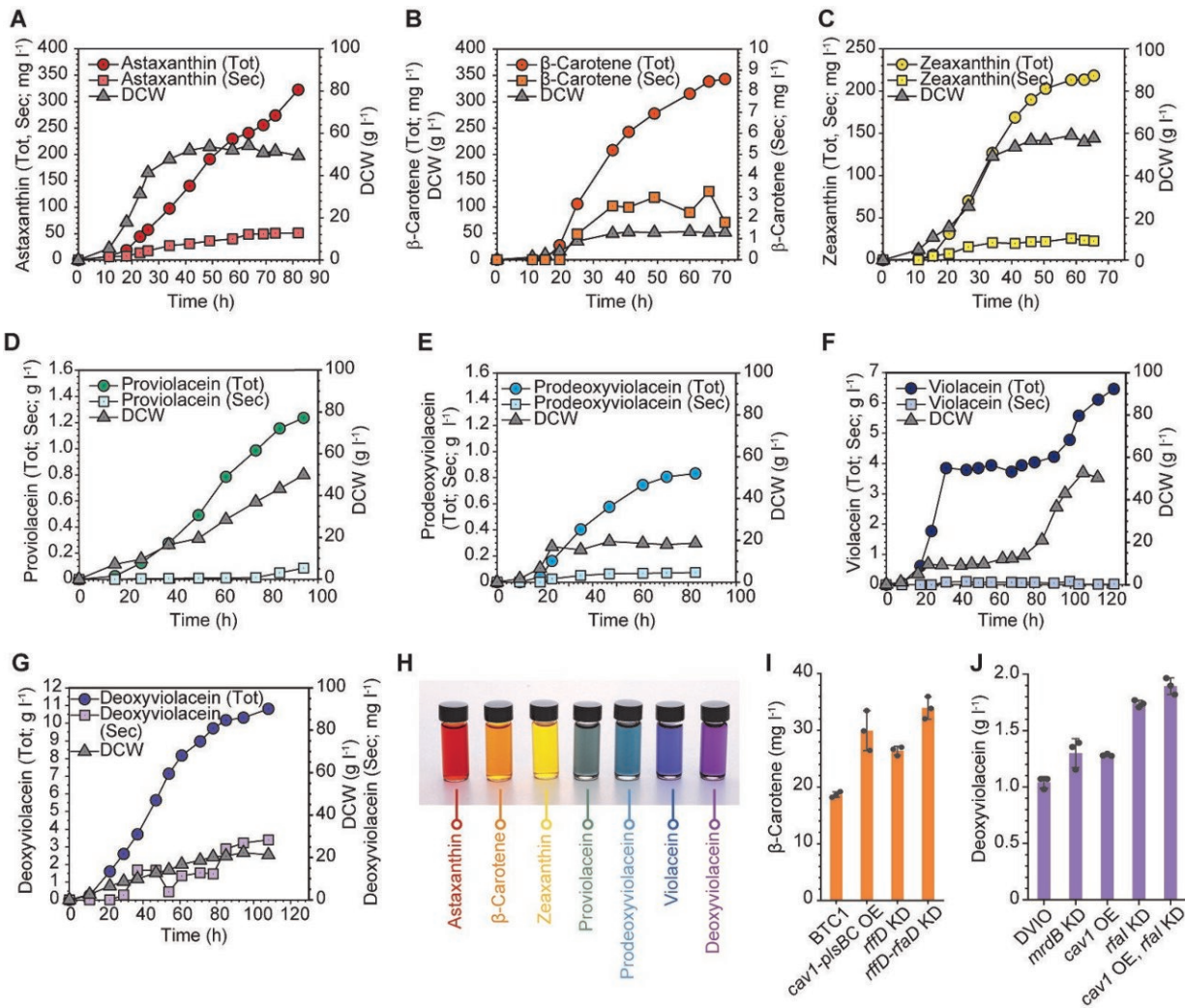


Natural rainbow colorants microbially produced

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Systems metabolic engineering was employed to construct and optimize the metabolic pathways and membrane engineering was employed to increase the production of the target colorants, successfully producing the seven natural

colorants covering the complete rainbow spectrum. Credit: *Advanced Science*, 2100743.

A research group at KAIST has engineered bacterial strains capable of producing three carotenoids and four violacein derivatives, completing the seven colors in the rainbow spectrum. The research team integrated systems metabolic engineering and membrane engineering strategies for the production of seven natural rainbow colorants in engineered *Escherichia coli* strains. The strategies will be also useful for the efficient production of other industrially important natural products used in the food, pharmaceutical, and cosmetic industries.

Colorants are widely used in our lives and are directly related to [human health](#) when we eat food additives and wear cosmetics. However, most of these colorants are made from petroleum, causing unexpected side effects and health problems. Furthermore, they raise environmental concerns such as water pollution from dyeing fabric in the textiles industry. For these reasons, the demand for the production of natural colorants using microorganisms has increased, but could not be readily realized due to the high cost and low yield of the bioprocesses.

These challenges inspired the metabolic engineers at KAIST including researchers Dr. Dongsoo Yang and Dr. Seon Young Park, and Distinguished Professor Sang Yup Lee from the Department of Chemical and Biomolecular Engineering. The team reported the study entitled "Production of [rainbow](#) colorants by metabolically engineered *Escherichia coli*" in *Advanced Science* online on May 5. It was selected as the journal cover of the July 7 issue.

This research reports for the first time the production of rainbow colorants comprising three carotenoids and four violacein derivatives

from glucose or glycerol via systems metabolic engineering and membrane engineering. The research group focused on the production of hydrophobic natural colorants useful for lipophilic food and dyeing garments. First, using systems metabolic engineering, which is an integrated technology to engineer the metabolism of a microorganism, three carotenoids comprising astaxanthin (red), β -carotene (orange), and zeaxanthin (yellow), and four violacein derivatives comprising proviolacein (green), prodeoxyviolacein (blue), violacein (navy), and deoxyviolacein (purple) could be produced. Thus, the production of natural colorants covering the complete rainbow spectrum was achieved.

When hydrophobic colorants are produced from microorganisms, the colorants are accumulated inside the cell. As the accumulation capacity is limited, the hydrophobic colorants could not be produced with concentrations higher than the limit. In this regard, the researchers engineered the cell morphology and generated inner-membrane vesicles (spherical membranous structures) to increase the intracellular capacity for accumulating the natural colorants. To further promote production, the researchers generated outer-membrane vesicles to secrete the natural colorants, thus succeeding in efficiently producing all of seven rainbow colorants. It was even more impressive that the production of natural green and navy colorants was achieved for the first time.

"The production of the seven natural rainbow colorants that can replace the current petroleum-based synthetic colorants was achieved for the first time," said Dr. Dongsoo Yang. He explained that another important point of the research is that integrated [metabolic engineering](#) strategies developed from this study can be generally applicable for the efficient production of other natural products useful as pharmaceuticals or nutraceuticals. "As maintaining [good health](#) in an aging society is becoming increasingly important, we expect that the technology and strategies developed here will play pivotal roles in producing other valuable natural products of medical or nutritional importance,"

explained Distinguished Professor Sang Yup Lee.

More information: Dongsoo Yang, Seon Young Park, and Sang Yup Lee. Production of rainbow colorants by metabolically engineered *Escherichia coli*. *Advanced Science*, 2100743.

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