proteinspotlight
> ONE MONTH, ONE PROTEIN <

Issue 63, October 2005

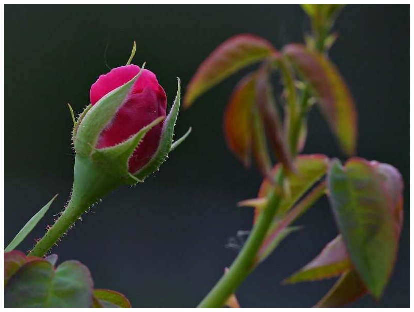
www.proteinspotlight.org

The colour of the rose

Vivienne Baillie Gerritsen

One of the beauties of Autumn is the firework of orange, yellow and red hues it displays. Anthocyanin is a plant pigment involved in this colourful palette. And not only in the autumnal shades but also in the reds, blues and purples of petals and fruit all year round. The array of colours offered to us by Nature has always fascinated scientists who have put a great deal of effort into understanding both the structure of the various pigments but also the pathways leading to their synthesis. The final steps leading to anthocyanin are performed by an enzyme known as anthocyanidin glucosyltransferase. And in roses, this particular enzyme catalyses not one reaction – as is the case in the production of other flower anthocyanins known to date – but two reactions which lead to rose anthocyanin.

Roses have been exhibiting their colours in gardens for thousands of years – the first rose gardens seem to have been Sumerian – and incessant crossbreeding has produced the many tints we know today. In 1840, the horticultural societies of Britain and Belgium offered a 500’000 franc prize to those who could produce a blue flower. Why blue? Simply because blue roses do not exist, yet they seem to have all the necessary ingredients to conjure up such a colour. It was perhaps an event like this that sparked the scientific desire to know what pigments are on a more intimate level.



Rose bud in dusk

Courtesy of Bruce M. Burton.

The German chemist Richard Willstätter (1872-1942) made the first breakthrough. Not towards the growth of blue roses but towards a greater understanding of the chemical structure of plant pigments and how colours could vary from plant to plant. And, as a result, he was rewarded the 1915 Nobel Prize in Chemistry. He demonstrated that anthocyanins are glucosides that can be split into glucose – mainly – and a colour component, cyanidin. He also showed that the colour of a plant is not only dependent on the pigment’s structure but also the plant’s sap – or to be more precise its physiological pH – and the concentration of the pigments themselves.

Surprisingly, despite Willstätter’s clear sightedness, he – amongst others – did not believe that enzymes were biological entities but ‘merely’ chemical substances. And it was only in the 1930s that the notion of an enzyme as something truly biological was agreed upon universally. Willstätter’s work was interrupted by World War I when he was asked to turn his attention to the making of a gas mask… After the war, he pursued his research, which was interrupted a second time by World War II. Of Jewish background, Willstätter decided to leave Germany in 1939 for Switzerland where he died only three years later. In the decades that followed, the different enzymes and chemical entities which are part of anthocyanin biosynthesis were revealed, and today the pathway is known in its molecular detail and entirety.

Anthocyanin glucosyltransferase is present in all plants. Roses, however, have their specific transferase: an anthocyanidin 5,3-O-glucosyltransferase, which catalyses two succeeding glycosylation reactions, as opposed to only one. The enzyme's first substrate is anthocyanidin. Anthocyanidins are low molecular weight phenylbenzopyrones – or flavonoids – of which there are over 4000 compounds. Unglycosylated anthocyanidins are unstable and they are the first substrate to which the rose glucosyltransferase adds a glucoside. Only it adds it in such a way that the novel glucoside is unstable. So the glucosyltransferase adds a further glucoside thus creating a diglucoside. Thus gylcosylated, the anthocyanin is stable in roses, and gives the flower its hue.

Why is it that glycosylation in roses does not proceed in the same way as in other plants? The intricateness of colour – as of smell – evolved in plants for the purpose of pollination. Plants fast needed the aid of insects – and vice versa – not only to survive but also to spread, and the two species have been evolving in unison for millions of years. Besides their role in pollination, anthocyanins also protect plant cells from harmful UV radiation thanks to their antioxidative properties. Both these properties – colouration and protection – are of great practical interest. Anthocyanins can replace harmful dyes which have been banned, and their anti-oxidant properties – revealed by the apparent lower risk of chronic diseases such as cancer and cardiovascular disease associated with the consumption of fruit and vegetables – have been proved. In July 2005, a first account of anthocyanin synthesis via recombinant *Escherichia coli* was reported. Such an adventure should permit the synthesis of anthocyanin compounds on an industrial scale but also the creation of fresh ones with novel catalytic acitivities, singular structures and – who knows – perhaps the colour blue?

Cross-references to Swiss-Prot

Anthocyanidin 5,3-O-glucosyltransferase, *Rosa hybrid cultivar*: Q4R1I9

References

1. Ogata J., Kanno Y., Itoh Y., Tsugawa H., Suzuki M.
   Plant biochemistry: anthocyanin biosynthesis in roses
   Nature 435:757-758(2005)
   PMID: 15944692

2. Yan Y., Chemler J., Huang L., Martens S., Koffas M.A.
   Metabolic engineering of anthocyanin biosynthesis in Escherichia coli
   Appl. Environ. Microbiol. 71:3617-3623(2005)
   PMID: 16000769

Protein Spotlight (ISSN 1424-4721), http://www.proteinspotlight.org, is published by the Swiss-Prot group at the Swiss Institute of Bioinformatics (SIB). Authorization to photocopy or reproduce this article for internal or personal use is granted by the SIB provided its content is not modified. Please enquire at spotlight@isb-sib.ch for redistribution or commercial usage.