From synthetic to natural and high performing colorants

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Colorants, and red colorant in particular, are widely used by industry to increase the appearance of beverage and foodstuff making both visually more attractive.
A few examples include baked goods, dry grocery goods such as extruded cereals, strawberry yogurts and other dairy products.

Industry, historically, relied on approved synthetic dyes such as Red 40, a red azo dye derived from coal tars, which has been associated, along with other synthetic colorants, to child hyperactivity (1).

Driven by ever increasing health consciousness of consumers across the world, the demand for natural food colors has grown significantly in the last decade, accounting for $1.31 billion in 2015. The market is expected to grow at over 5% annual rate between 2016 and 2021, with several new suppliers likely to enter the marketplace (2).

Betalains are still a small fraction of this market, but their utilization potential is very significant (3). The use of purple-red betanin (E162) extracted from red beet juice, for example, already widely used in coloring (*inter alia*) ice creams, soft drink beverages and soups has the potential to transform a debated health issue into an opportunity for enhancing public health, exactly as it would happen when replacing synthetic food antioxidants with olive biophenols (4).

Water-soluble betanin, for instance, has an exceptionally high free radical scavenging activity being 1.5-2 times more active than anthocyanins considered excellent free radical scavengers (5).

Similar arguments hold true for lipophilic lycopene, the red carotenoid pigment of tomatoes and other red fruits (6). Indeed, companies formulating ingredients based on natural products, have lately started to offer formulations in which betanin and lycopene are formulated together to attain a natural red colorant mixture of enhanced performance for food, beverage and cosmetic applications (7).

As it happens with organic foods, consumers are prone to pay an higher price for foodstuff colored with health beneficial colorants. The main issue that remains to be addressed to satisfy the broad and increasing consumer demand for natural colorants has to do with supply rather than with demand.

To increase the supply of contaminant-free, standardized natural colorant extracts yielding consistent results, suppliers are switching to new production technologies beyond conventional solvent extraction; whereas to scale production levels new abundant sources such as agricultural or food processing waste are actively being investigated.

Opuntia ficus-indica derived betanin

Accommodating 88 wt% water in the cladodes, the cactus pear (*Opuntia ficus-indica*) is a water and livestock feed reserve that will play an important role to combat desertification. Though containing a lesser dye amount (50 mg/kg for *Opuntia* vs. 300-600 mg/kg for red beet) sourcing betanin from *Opuntia* in addition to current industrial practice to extract the pigment from red beet (*Beta vulgaris L.*), would provide significant advantages. As stated by Brazilian scholar Azeredo, "the commercial exploitation of cactus fruits as alternative sources of food colourants may not only provide a wider colour spectrum than the red beet without its negative sensory impacts, but also contribute to the sustainable development of the usually underdeveloped semi-arid regions which could supply markets with cactus fruits" (3).

Figure 1. Red aqueous extracts from the peel of white and red Opuntia ficus-indica fruits, obtained with microwaves only (Reproduced from Ref.10)

Using an entirely clean process requiring microwaves only, the peel of the cactus pear *Opuntia ficus-indica* could shortly become an important source of pectin and betanin, namely the most important natural hydrocolloid and a valued red natural colorant for both of which a consistent shortage in the last few years has led to rapid price increases and delays in product delivery.

Indeed, the integral extraction via microwave-assisted hydrodiffusion and hydrodistillation of water-soluble bioproducts contained in the peel of *Opuntia ficus-indica* white and red cultivars, affords red and stable aqueous extracts mostly containing valued betanin, pectin and biophenols (10).

Potentially useful as nutraceutical products, these aqueous extracts are a source of valued ingredients in high demand for a number of important food, cosmetic, beverage and nutraceutical applications.

This is a rapidly developing field of today's chemical and biotechnology research in which several today's students and young researchers will work in the near future, making the foundation of new bioeconomy research and educational initiatives an important policy aim (8), especially in those countries hosting large agricultural and food industries such as Brazil, Russia, India, South Africa, Argentina, the US, and several south east Asian countries.

For example, using chemistry and biotechnology tools, chemists and food technologists are becoming increasingly able to formulate stable natural colorant mixtures in which the color, its intensity and other chromatic qualities are purposefully modulated, and color stabilized also against heat, so as to provide food and beverage manufacturers with a natural alternative to synthetic dyes.

Furthermore, aiming to stabilize coloring strength and lack of flavor -- and thus extend the application range of foodstuffs colored with betalains - scientists started to investigate their decomposition pathways (9).

Like most natural substances, natural colorants are chemically and physically much less stable compared to synthetic dyes, being sensitive to thermal and photochemical degradation induced by light, as well as being prone to oxidation induced by air's oxygen. Yet, very often the same biological matrix embedding the natural colorants, contains also powerful natural antioxidants such as biophenols which act as stabilizers.

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