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Mom always said, "eat your vegetables and good things will happen."

Turns out that she knew what she was talking about, according to Franklin & Marshall biologist Dan Ardia and his Arizona State University research partner Kevin McGraw.

In a new physiological study of birds, recently published in *Biology Letters*, a journal of the Royal Society of London, Ardia and McGraw have found that carotenoids – the pigments that give carrots and corn their distinctive colors – have even greater health benefits than previously thought.

"The results of our study indicate that carotenoids appear to offset the potentially negative effects that testosterone can have on health," said Ardia.

In the study, titled "Do carotenoids buffer testosterone-induced immunosuppression: An experimental test in a colourful songbird," Ardia and McGraw studied zebra finches, a species native to Australia that is now a popular pet. What made the zebra finches prime candidates for their research was the male bird's distinctive red bill.

"Zebra finches use carotenoid pigment to make their bills red," explained Ardia. "Previous research has shown that males vary in their redness and that females prefer males with red bills."

The carotenoids that cause the redness also contribute to brightly colored plumage in other birds, which in turn, also act as signals to attract potential mates.

Ardia explained that it is believed that one of the reasons that all males don't have bright bills, whether it be bills in zebra finches, or feathers in cardinals, is that there is a cost to producing and maintaining these displays, specifically having a high level of testosterone.

While high levels of testosterone can produce positive effects, such as aggression and showy displays like red bills, things that aid them in survival and reproduction, these same high levels are believed to suppress the immune system, said Ardia.

What makes his and McGraw's results interesting is that they report a mechanism by which high-quality birds can both have a good display as well as buffer the potential costs of high testosterone. "The mechanism is that some birds are using these carotenoid pigments in order to set off the negative effects of testosterone and enhance plumage, while also using them as anti-oxidants to scavenge free radicals from the bloodstream," Ardia said.

According to Ardia, animals cannot create these carotenoid pigments on their own, and must find them in the wild. "Some are going to be better than others at getting carotenoids," he said. Those that do can use them to both produce good displays and offset the high costs of testosterone."

The researchers experimentally examined the relationship between testosterone, carotenoids and immune state in 35 male and female zebra finches. They found that when they administered testosterone implants to the birds, the implants acted as a stimulant to the finches' immune

systems.

They went on to show that carotenoids acquired from food and circulating through the blood were changing in ways that were linked to testosterone levels. Birds that were given additional testosterone depleted their carotenoid levels and became healthier, as if they were combating testosterone directly with antioxidants.

"Our findings show that there are ways for animals to counteract the costs of high levels of testosterone and still maintain their high-quality displays," said Ardia.

The implications for human nutrition are not lost on Ardia. "There has been a big push among members of the medical community to get people to take anti-oxidants, he said. "Carotenoids are one of many forms of anti-oxidants and I think this suggests that there are benefits to eating foods that are rich in carotenoids that can help scour free radicals (by-products of metabolism that have the potential to damage cellular processes) from the system."

Ardia plans to continue his research in his lab at the new Barshinger Life Sciences and Philosophy Building. Sometime this fall, he hopes to have a colony of zebra finches established in the vivarium, and already has students at the ready to continue his work. The hope is that the humble zebra finch can continue to provide insights into issues of evolutionary tradeoffs and human health.

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