

## **Can you tell me more about chlorophyll, including what foods it can be found in and the effect that cooking has upon it?**

Although it's not very well known in the world of nutrition, chlorophyll couldn't be more important in the world of biology and plants. All green plants contain at least one type of chlorophyll (chlorophyll a). Plants that evolved at a later point in history ("higher plants") also contain a second type of chlorophyll (chlorophyll b). There are also forms of chlorophyll called chlorophyll c1, c2, and c3, as well as a chlorophyll d, but these forms are much less widely distributed in the plant world. Chlorophyll is the single most critical substance in plants that allows them to absorb light from the sun and convert that light into usable energy. (In biochemistry, it's called the primary photoreceptor pigment).

In many vegetables, there is slightly more chlorophyll a than chlorophyll b, and this slight edge in favour of chlorophyll a tends to decrease as the plant ages. However, research studies have yet to clarify what the exact health significance is of this chlorophyll a-to-chlorophyll b ratio.

### **The colour of chlorophyll**

It's usually easy to tell when a food has significant amounts of chlorophyll, because chlorophyll provides the green colour that is found in grasses, leaves, and many of the vegetables that we eat. These plants and foods would not be green without their chlorophyll, since chlorophyll pigments reflect sunlight at exact appropriate wavelengths for our eyes to detect them as green. The chlorophyll a molecule actually reflects light in a blue-green range (about 685 nanometer wavelengths), while chlorophyll b reflects light in a more yellow-green colour (about 735 nanometer wavelengths). The overall affect, however, is for us to see varying shades of a colour we would simply call "green."

### **Foods that contain chlorophyll**

While all green plants contain chlorophyll a, and most vegetables that we eat contain both chlorophyll a and chlorophyll b, some vegetables contain particularly high amounts of total chlorophyll. Best studied of all the vegetables is spinach (*Spinacia oleracea* in the Latin scientific name), with this vegetable containing about 300-600 milligrams per ounce.

To understand how high in chlorophyll this amount turns out to be, compare the chlorophyll content of spinach to another of the World's Healthiest Foods - olives. Chlorophyll is one of the primary pigments in olives, but olives contain only 30-300 micrograms per ounce (about 1/1000th as much as spinach). Some olive oil producers deliberately allow leaves to be placed in the olive presses to increase the chlorophyll and "grassiness" of the olive oil.

All of the green vegetables in the World's Healthiest Foods - asparagus, bell peppers, broccoli, Brussels sprouts, green cabbage, celery, collard greens, green beans, green peas, kale, leeks, green olives, parsley, romaine lettuce, sea vegetables, spinach, Swiss chard, and turnip greens are concentrated sources of chlorophyll.

## **Chlorophyll and health**

Research on the health benefits of chlorophyll has focused on the area of cancer (including treatment and prevention). This research got underway when damage to genes (or more precisely, to the genes' DNA) by carcinogenic substances called aflatoxins (or more precisely aflatoxin B1, or AFB1), was found to be prevented by chlorophyllin. Chlorophyllin is a derivative of chlorophyll in which the magnesium in its centre is removed (usually by placing it in an acid bath in a science lab) and replaced with copper.

Research studies in humans have found that damage to DNA by aflatoxin can be decreased as much as 55% through supplementation with chlorophyllin at 100 milligrams, three times a day, for four months. This amount of chlorophyllin, 300 milligrams per day, is the same amount of chlorophyll found in one weighted ounce of spinach (a little over 1/2 cup of chopped raw spinach). Although research is still in the early stage, prevention and treatment of liver cancer, skin cancer, and colon cancer are all being investigated in relationship to intake of chlorophyll-containing vegetables and supplementation with chlorophyllin.

## **The effect of cooking on chlorophyll**

One of the primary reasons for the change in colour when green vegetables are cooked is the change in chlorophyll. What happens during this process is actually quite interesting.

## **The chemical perspective**

Chlorophyll has a chemical structure that is quite similar to a chemical structure found within our red blood cells. A basic difference is the fact that this structure (called a porphyrin ring) contains an atom of iron at its centre when it is found in our red blood cells, but when it is found in plants, it contains an atom of magnesium at the centre. When plants are heated and/or exposed to acid (and when green vegetables are cooked and/or exposed to acid), the magnesium gets removed from the centre of this ring structure and replaced by an atom of hydrogen. (In biochemistry, the chlorophyll a gets turned into a molecule called pheophytin a, and the chlorophyll b gets turned into pheophytin b). With this one simple change, the colour of the vegetable changes from bright green to olive-grey. (The pheophytin provides a green-grey colour, and the pheophytin b provides an olive-green colour).

## **The practical perspective**

The jury is definitely still out on the impact of cooking on chlorophyll. At one end of the spectrum, it's totally clear that dramatic loss of chlorophyll occurs after prolonged cooking. In studies on broccoli, for example, about two thirds of the chlorophyll was removed after 20 minutes of boiling. Researchers have also determined that there are steadily increasing losses of both chlorophyll a and chlorophyll b when the boiling time for broccoli is increased from 5 to 20 minutes. However, at cooking times less than five minutes, the research is not as clear, and some studies suggest that brief steaming of vegetables like spinach actually increases the amount of chlorophyll that can be absorbed into our body.

Whenever a vegetable is cooked long enough to cause a change in colour from bright green to olive-grey, we know that some of the chlorophyll a and chlorophyll b in the vegetable have been changed to pheophytins a and b. This colour change is one of the reasons we have established the relatively short steaming times for green vegetables in the World's Healthiest Cooking techniques! Our cooking methods are designed to preserve the unique concentrations of chlorophyll found in these magnificent vegetables.

## Practical tips

Overcooking is particularly important to avoid when it comes to chlorophyll, but with very short steaming times, the chlorophyll content of these foods is preserved, and absorption of chlorophyll from these foods may actually be increased. Consumption of these green vegetables in raw form is also an excellent way to obtain the health benefits of chlorophyll.

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