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COVER STORY

Protecting Your DNA from Lethal Mutations

By Dave Tuttle



“Cancer results from the accumulation of mutations in genes that regulate cellular proliferation.”

Source: Haber D. Roads leading to breast cancer. N Engl J Med. 2000 Nov 23;343(21):1566-8.

Even doctors have a hard time understanding that most cancers are caused by mutations in genes that regulate cell division.

Mutagens come from a variety of sources, including tobacco smoke and environmental pollutants. The number-one cancer-causing mutagen, however, is our diet.

Fortunately, scientists have identified new methods to detoxify and minimize the impact of these mutagens on our genes.

Every day, we are surrounded by environmental toxins ranging from automobile exhaust to poisons released during the dry cleaning of clothes and estrogen-like chemicals in the plastic wrap covering our food. These chemicals can have dangerous effects on the very makeup of our DNA.

Barbequing food produces mutagenic heterocyclic amines. The frying, baking, and roasting of carbohydrate-rich foods such as potatoes create acrylamide, which is a known cancer-causing agent in animals. Just breathing the air exposes us to a constant barrage of chemical by-products from industrial processes.

Because of these influences, it is critical to take preventive measures to boost your body's defenses against the continuous assault of the mutagens that surround us.

DETOXIFICATION ENZYME SYSTEMS

The human body has several systems for detoxifying the wide array of synthetic chemicals known as xenobiotics—such as pesticides and other foreign compounds—that are found in our environment.¹ These detoxifying systems are also able to eliminate the toxic end products of naturally occurring metabolic processes, as well as bacterial endotoxins produced within the body. The two main systems used by the body are known as Phase I and Phase II. This two-phase system is necessary because many xenobiotics are fat soluble, and must be converted to a water-soluble molecule that can then be excreted in the urine or bile.



While these detoxification systems are quite complex, their general characteristics are fairly easy to understand.

The molecules produced during Phase I may be more toxic than the original molecules. This is because the reactive groups that are added to the original molecules enable these intermediate molecules to function like free radicals in the liver, with all of their potential damage. Provided that the Phase II system is functioning well, the conversion process will occur quickly and without undue damage to the body. However, as with many bodily processes, the efficiency of these detoxification systems may be diminished as we age. In addition, genetics

affects detoxification, with some people being “rapid” metabolizers and others “slow” metabolizers. This highlights the need to maximize the effectiveness of Phases I and II through nutritional supplementation, and reinforces the necessity of maintaining ample supplies of antioxidants and other liver-protective nutrients in the body.

One of the reasons that agricultural chemicals are so harmful to humans is that they can wreak havoc on the body's detoxification system. For example, the popular herbicide Roundup® contains gly-phosate, a compound that depresses the

function of cytochrome P450 and two other enzymes that are vital for detoxification.² Other chemicals used to raise food have similar impacts, and it is hard to avoid exposure to these common mutagens.

While a variety of nutrients act as essential cofactors in detoxification, four have been found to directly enhance Phase I or Phase II: curcumin, chlorophyllin, wasabi, and broccoli extract.

CURCUMIN PREVENTS MUTATION DAMAGE

One of the most effective anti-mutagens is curcumin, a phytonutrient derived from the Indian spice turmeric, the main ingredient in curry. The general term curcumin actually refers to a group of polyphenolic plant pigments that are responsible for turmeric's characteristic canary-yellow color and virtually all of its beneficial properties.

Turmeric has played an important role in the Ayurvedic system of holistic medicine for centuries. A member of the ginger family, it has a reputation for quelling inflammation and healing various maladies ranging from ulcers to arthritis. Turmeric is a popular remedy for upset stomach throughout Asia, and has been shown to have numerous cardiovascular benefits, in part because it reduces total cholesterol levels and inhibits LDL (low-density lipoprotein) oxidation.



In the last decade, scientists have discovered that curcumin can also help protect against the multitude of mutagens in our environment. Study after study has shown that these environmental toxins are often a direct link to cancer development in humans. For example, heterocyclic amines are potent mutagens generated during the cooking of meat and fish. Several of these compounds have produced tumors when given to experimental animals at dosages that humans could obtain from their diets.³ A study at India's Panjab University explored the benefits of curcumin and two of its analogs, demethoxycurcumin and bis-demethoxycurcumin, in counteracting the effects of seven of these heterocyclic amines. The researchers found that curcumin inhibited mutagenicity by as much as 80% against all of the tested mutagens in cooked food.⁴

Several studies have found that curcumin supplementation can reduce the likelihood of colon cancer. In a year-long study of rats at the American Health Foundation, scientists induced carcinogenesis in the colon with the mutagenic drug azoxymethane.⁵ At five weeks of age, the rats were divided into groups that were fed diets with or without curcumin. Two weeks later, drug administration began. After 52 weeks, the rats were sacrificed and their colonic tumors evaluated. The results indicated that dietary administration of curcumin significantly inhibited the incidence of all colon carcinomas (both invasive and noninvasive). The curcumin regimen also suppressed average colon tumor volume by 57% compared to the control diet. Also found were reduced levels of certain prostaglandins, indicating that curcumin had partially blocked the metabolism of arachidonic acid, which would normally produce inflammation.



Turmeric (*Curcuma longa*)

Additional studies by this same research group revealed that curcumin is also effective at reducing colon carcinogenesis even when given only during the promotion/progression phase of the disease.⁶ This is a significant finding, as it is one thing to reduce an experimentally induced cancer when curcumin is in the body to begin with, and quite another if it proves effective when supplementation begins after the cancer has already developed. This experiment's design was similar to the earlier one, except that curcumin was added to the control diet 14 weeks later in order to give the azoxymethane time to produce a more advanced cancer. Despite the drug's 14-week head start, the percentage of animals with tumors and the number of tumors per animal both decreased significantly in the curcumin-supplemented group compared to the control group.

In addition, the scientists found evidence of increased apoptosis, which is the programmed death of abnormal cells. Cancer cells often are able to trick the body's immune system into allowing them to stay alive despite their malignant nature. Curcumin was able to promote apoptosis at a dosage of just 0.2% of the diet. In fact, when compared to the control group, the percentage of cells exhibiting apoptosis nearly doubled (9.2% vs. 5.3%) in the animals that started taking curcumin before drug administration began. Those that needed to catch up with the drug still had a respectable rate of apoptosis (7.6%, or 43% higher than the controls). The authors concluded that apoptosis is one of the mechanisms by which curcumin does its job, though the herb's ability to inhibit arachidonic acid metabolism and reduce cell proliferation are also important factors. Still, the observed difference in rates of apoptosis underlines the importance of taking preventive action by beginning curcumin use before mutagens have a chance to promote cancer in the body.

Curcumin has proven its effectiveness against other cancers as well. Two studies at Thailand's Chiang Mai University found that dietary curcumin reduced skin tumor formation in mice after the application of a mutagenic chemical.^{7,8} More of the mice ingesting curcumin remained free of tumors than mice in the control group, and those that did develop tumors had fewer and smaller ones than the controls. Curcumin intake also significantly decreased the expression of cancerous oncogenes. In-vitro experiments demonstrate that the herb boosts the effectiveness of the anti-cancer drug vinblastine against a multidrug-resistant

human cervical cancer cell line,⁹ and inhibits the growth of hormone-dependent, hormone-independent, and multi-drug-resistant breast cancer cells.¹⁰ With positive results such as these, more long-term human studies are clearly warranted to confirm curcumin's benefits in cancer treatment.

CURCUMIN'S MECHANISM OF ACTION

Curcumin has many different mechanisms of action. It boosts the activity of glutathione S-transferase, an important Phase II enzyme.¹¹ A Japanese study in mice found that oral supplementation (2% of diet) enhanced the activity of this enzyme by 170% in the liver and 110% in the kidney.¹² Curcumin also inhibits the production of nitric oxide synthase and is a potent scavenger of free radicals.¹³ Studies have specifically confirmed its action against the superoxide radical and singlet oxygen.^{14,15} Both of these reactive oxygen species have considerable mutagenic properties. In fact, curcumin's protective effect against singlet oxygen was greater than that of well-known antioxidants such as lipoic acid, alpha tocopherol, and beta-carotene. Curcumin also down-regulates various growth factor receptors and transcription factors, in addition to having anti-inflammatory properties.¹⁶ Given these numerous mechanisms of action, it is no surprise that curcumin is such an effective anti-mutagen.



Curcumin

CHLOROPHYLLIN INHIBITS MUTAGENICITY

Chlorophyll is the green pigment in plants that acts as a receptor in photosynthesis, the light-driven process by which carbon dioxide is converted to carbohydrates and water, enabling the plant to live. Chlorophyllin, a sodium/copper derivative of chlorophyll, has the benefit of being water soluble, allowing it to be transported easily in the blood. It also has anti-carcinogenic properties.

Several studies have demonstrated chlorophyllin's effectiveness. In an experiment with bacteria, the nutrient was added to petri dishes containing substances that normally produce mutations, such as fried beef, fried pork, cigarette smoke, coal dust, and diesel emission particles.¹⁷ Chlorophyllin inhibited mutagenicity by a minimum of 75% and by as much as 100%. The experiment also revealed that chlorophyllin is heat-stable. While the nutrient's precise mechanism of action is unknown, the authors note that it is an antioxidant, and suggest that the scavenging of free radicals or its interaction with the active group of mutagenic compounds is responsible for its anti-mutagenic activity.

Several studies in rodents confirm these results. One European experiment with rats found that chlorophyllin significantly decreased the number of colon tumors produced by a mutagenic chemical when added to the drinking water at a 1% concentration.¹⁸ Even better, chlorophyllin proved effective when started five weeks after cancer-causing chemicals were given to the rats at this same concentration, resulting in a dose-related reduction in liver tumors.¹⁹ A study in murine bone marrow cells revealed that the nutrient produced an 80% decline in cell proliferation kinetics within 24 hours when given simultaneously with the mutagen.²⁰

A study at Oregon State University found that chlorophyllin promotes apoptosis in human colon cancer cells.²¹ These cells underwent growth arrest and apoptosis after just 24 hours of exposure to the nutrient. The scientists noted an attenuation of mitochondrial membrane potential, leading to a release of apoptosis-inducing factor from the mitochondria and activation of subsequent downstream events leading to the destruction of the cells. According to the researchers, chlorophyllin also is able to form molecular complexes, which may contribute to its powerful anti-mutagenic properties.

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WASABI BATTLES CARCINOGENS

Wasabi japonica is a member of the Brassica, or cruciferous, family of vegetables, which includes cabbage, broccoli, cauliflower, bok choy, horseradish, and 10 other plants. These vegetables add crunch and flavor to meals, and have long been recognized as important parts of a healthy diet because of their fiber content. Recent research has revealed, however, that there is much more to these vegetables than mere fiber. They contain high levels of glucosinolates, a group of compounds that are converted to isothiocyanates by the enzyme myrosinase when the plant cells are damaged by harvesting, cutting, or chewing. It is the isothiocyanates that give these vegetables their sharp flavors. Wasabi, the green, pungent horseradish usually served with sushi, is one of the most potent sources of isothiocyanates among all plant species.

The isothiocyanates do more than add flavor to a meal. A Japanese study found that allyl isothiocyanate has significant antioxidant actions, particularly against the superoxide radical.²² According to the authors, this phytochemical also has an inhibitory effect on the growth of food poisoning bacteria and fungi, and showed anti-mutagenic activity against a common carcinogen found in broiled fish and meat.

Three other Japanese studies discovered dramatic benefits from 6-methylsulfinylhexyl isothiocyanate, or 6-MITC. Researchers at Japan's Nagoya University found 6-MITC to be a potent inducer of glutathione S-transferase, one of the most important Phase II detoxification enzymes, due to its high reactivity.²³ 6-MITC has also been shown to inhibit cell proliferation in human leukemia and stomach cancer cells in vitro by promoting apoptosis within 24 hours.^{24,25} This may suppress the growth of pre-clinical tumors and contribute to a decreased incidence of cancer. Scientists at Japan's Kanazawa Gakuin College learned that 6-MITC has similar properties against breast cancer and melanoma cells, influencing not only cell growth but also the cells' survival.²⁶ The authors concluded that because of the low dosages required, 6-MITC has the potential to control cancer cells of all types.

The importance of 6-MITC has also been demonstrated in experiments with rats and mice. Japanese researchers discovered that oral 6-MITC is easily absorbed and rapidly enters the circulatory system, reaching a maximum level within 30 minutes.²⁷ Blood levels then decrease relatively slowly, allowing it to stimulate higher glutathione S-transferase levels for extended periods. Additional experiments have found that isothiocyanates inhibit rat lung, esophagus, mammary gland, liver, small intestine, colon, and bladder tumorigenesis.²⁸⁻³⁰ These results have led researchers to consider isothiocyanates to be readily available cancer chemopreventive agents.

Because cultivating wasabi is complex and time consuming, and fresh Wasabi japonica rhizomes (roots) are very expensive, most restaurants substitute less expensive European horseradish, adding green color and a touch of real wasabi for flavor. European horseradish, however, does not contain wasabi's diversity of isothiocyanates. While it shares many of the short-chain isothiocyanates, European horseradish lacks longer-chain isothiocyanates, including 6-MITC. Most other vegetables in the Brassica family are also deficient in these longer-chain isothiocyanates, so it is hard to attain all the potential benefits of these phytochemicals from dietary sources. In addition, cooking these vegetables results in substantial degradation of the myrosinase conversion enzyme. This makes wasabi supplementation an attractive option.

BROCCOLI EXTRACT: RICH IN ANTI-MUTAGENS

Broccoli is a plentiful source of glucosinolates, which are converted enzymatically into isothiocyanates. In the body, the isothiocyanates in broccoli boost production of several Phase II detoxification enzymes, enhance antioxidant status, and protect animals against chemically induced cancer.³¹ As a result, nutritionists recommend consuming broccoli and similar vegetables at least three times a week. Concentrated extracts of broccoli enable you to boost your intake of these beneficial compounds even more.

One of the primary isothiocyanates in broccoli is sulforaphane. In numerous studies, this plant chemical has demonstrated anti-carcinogenic actions. In an in-vitro experiment with mouse liver cancer cells, sulforaphane raised levels of two Phase II detoxification enzymes, glutathione S-transferase and quinone reductase.³² The authors concluded that sulforaphane's ability to elevate these enzymes may be a significant component of broccoli's anti-cancer action.

A study at Johns Hopkins University examined oral sulforaphane's effects on chemically induced mammary cancers in rats.³³ When given around the time of exposure to the carcinogen, sulforaphane significantly reduced the incidence, multiplicity, and weight of mammary tumors, and their development was delayed. An in-vitro experiment shows that sulforaphane can also help fight prostate cancer,³⁴ a disease characterized by early and near-universal loss of expression of the glutathione S-transferase enzyme. However, when sulforaphane was added to several human prostate cancer cell lines in vitro, Phase II enzyme expression increased dramatically, bolstering cell defenses. This finding helps to explain the observed correlation between increased consumption of cruciferous vegetables and reduced risk of prostate cancer.



Broccoli's benefits do not end there. A study of vegetables found that broccoli produced the greatest protective effect against several mutagenic chemicals,³⁵ and also stimulated the proliferation of non-cancerous cells. Another experiment at Johns Hopkins found that the sulforaphane in broccoli is a potent agent against three reference strains and 45 clinical isolates of the *H. pylori* bacterium.³⁶ A study performed at the same time showed that sulforaphane also blocked stomach tumors in mice exposed to mutagenic chemicals. According to the researchers, these multiple benefits resulted from increased production of Phase II detoxification and antioxidant enzymes.

MAXIMIZING PROTECTION AGAINST MUTAGENS

It has become increasingly difficult to protect our health from the encroachment of carcinogenic chemicals, including pesticides, that are part of the air we breathe, the water we drink, and the food we eat. Providing the body with defensive agents such as curcumin, chlorophyllin, wasabi, and broccoli extract can maximize protection against DNA damage, thus making an important contribution to optimal health and longevity.

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