

Introduction

What Foods are Good for Energy?

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Discussion

You may think you expend energy only when doing exercise, or when awake and moving around, but you are using energy all the time, even when you are asleep or lying still and relaxing. Energy is the basis of life. For example, your ability to maintain a healthy body temperature and support your breathing is called your *basal metabolic rate*, and you use more energy for these functions than for any other. Your body also uses energy to build new tissue, repair damaged tissue, and generate new, healthy cells. Even a simple eye movement requires energy.

How does my body keep energy flowing through my system all of the time?

You get all the energy you use from the food you eat, so sometimes we hear food talked about as if it were gas for a car engine. This is really not the best analogy, though, since

gas is in a form that can be directly burned in the car engine, resulting in immediate energy. Food contains energy in the bonds that hold it together, but your body has the challenge of getting this energy released and then recapturing it, so it can be stored to be used later when and where it's most needed.

Producing energy in the form your body can use requires many steps, and food plays a number of roles. Some of the food you eat is broken down, and the energy in its bonds is stripped and transferred to molecules in your body that can immediately use the energy. Some of the foods you eat contain key nutrients -- vitamins and minerals -- that are necessary to support the energy transfer process. Some foods provide phytonutrients that protect your cells from incorrect or unbalanced energy production, which can cause damage to your cells and tissues. Still, other foods provide the building blocks for keeping your cells healthy, and since energy is produced within your cells, your cells need to have enough of the proteins involved in energy transfer and strong lipid membranes to competently transfer energy.

How does my body make energy from food?

The main types of food used to provide energy - that is, the foods that are stripped of their energy, so it can be used by your body - are carbohydrates and fats. Sometimes amino acids from proteins are used for this as well, but only when your body doesn't have enough of the carbohydrates and fats available. We often call this "burning" foods for energy, but it is really a process of breaking these molecules down piece by piece and transferring the energy that is released during this breakdown. The carbohydrate or fat is destroyed in the process. This breakdown of foods and transfer of energy requires oxygen, which you get from breathing, and results in carbon dioxide and water as waste products.

Carbohydrates and the glycemic index

Consumption of unhealthy high glycemic index foods is a common culprit in fatigue and energy problems; therefore, learning about the glycemic index so that you can make better food choices can make a major contribution towards resolving these problems. The glycemic index is a measure of how fast the carbohydrate in food is broken down to the simple sugar, glucose, which is then absorbed and quickly transported through your bloodstream to your cells. The glycemic index is determined by monitoring the blood sugar of several individuals after they eat a specific food, and foods are categorized from

high to low glycemic index foods. The measure of high to low glycemic index, then, is a way to compare how quickly energy is released in your body from specific foods.

Foods that lead to a strong, fast blood sugar peak after consumption are called high glycemic index foods. These foods may give a quick burst of energy for the first hour or so after eating them, but research shows that this energy burst often goes down just as quickly, resulting in a slump or low energy feeling within a couple of hours after the meal. Foods that are high in simple carbohydrates, like sugar, are often high glycemic index foods. Examples of these foods are soft drinks, candy, pasta and pastries made from refined flour (white flour), and sweetened fruit juices.

The problem is that these foods often leave you with a slump after that quick energy burst is over, and a feeling of energy peaks and valleys may be experienced. These are the foods that can zap energy levels! High glycemic index foods are difficult to handle for people with insulin sensitivities, such as diabetics, and excessive intake of high-glycemic index foods is a major dietary contributor to fatigue.

Low-glycemic index foods are foods that release energy more slowly, resulting in a smaller change in the blood sugar level and a steadier, longer lasting feeling of energy. Chief among these foods are legumes, nuts, and seeds, but also included are root vegetables like celery root and rutabagas; leafy green vegetables; asparagus; artichokes; gourd family vegetables like pumpkin and cucumber; mustard family vegetables like broccoli and cabbage; and onion family vegetables like leeks and scallions.

It is not possible to indicate exactly which foods fall into each category for every individual by looking at the components of the food alone. This is because the glycemic index is not just a factor of the type and amount of carbohydrate, but is also influenced by how the carbohydrate is packaged; that is, the other components in the food. For example, refined flour is almost totally bare carbohydrate since most of its other components have been removed, whereas a whole grain product has protein and fats and other nutrients packaged with the carbohydrates. Research shows that this affects the way your body uses the carbohydrate and how well you can make and sustain energy after eating these foods. This one of the reasons foods made from whole grains, such as whole grain bread or pasta, are so much better for you.

Fats and energy?

Glycemic index is a measure of how quickly energy is released from a food, but since it

measures blood sugar, it is presumed to be more indicative of carbohydrates (sugars) than other food components. Fats in a food lower the glycemic index, but they also provide energy on their own. Fats can be stored in the body for later energy production, which is one of the reasons our bodies accumulate fat.

Because excess dietary fat is so common among Americans, trimming excess fats from your diet has a good chance of helping you find more energy, regardless of your specific health condition. Strangely enough, even though we get plenty of fat in our diets, we usually come up short on the only fats we actually need—the essential fats called the **omega-3 fatty acids**. Sources of essential fats include cold-water fish (like salmon, cod, herring, sardines, sole, pike, perch, flounder, halibut, mackerel, and pollock) and all nuts and seeds.

Fiber and energy

Fiber is an indigestible part of many foods, so one might be inclined to downplay its importance in the creation and maintenance of energy. However, **fiber** is indispensable for the "energy economy" of the body. Fiber (especially soluble fiber, like those in legumes, grains, nuts, and seeds) provides fuel for the friendly intestinal bacteria and supports healthy digestion, healthy fat metabolism and blood lipid levels.

More importantly for energy production, fiber can help slow the breakdown and absorption of sugar from high carbohydrate containing foods. Research has shown that the amount and type of fiber in a food can change its glycemic index and even make a high glycemic index food into a low glycemic index food. Sources of dietary fiber include legumes, grains, nuts, seeds, many root vegetables, fibrous fruits like berries, and leafy green vegetables. You may notice that these foods fall under the category of low-glycemic index foods, and it's no accident!

Nutrients that support energy transfer and storage

Because energy is so essential to life, it is probably not surprising that there are many enzymes and cellular components functioning together to maintain healthy energy levels in the body. These cellular components require a wide range of nutrients to function, and therefore, most essential vitamins and minerals play a role in the transfer and storage of energy. However, some nutrients are more central to maintaining healthy energy in your body.

After you eat food with carbohydrates or fats, these components are digested and absorbed into your body as fat or glucose (sugars). For more on how these foods are absorbed, see the FAQ [How Does Digestion Work and How Can I Improve Mine?](#). Once in your body, the food molecules are taken to your cells where they will be stripped of their energy. The place where your cells get energy from food molecules is called the *mitochondria*. Mitochondria are like cells within your cells; they have a membrane made of fats and proteins like your cell's membrane and their own DNA. Mitochondria use oxygen and the nutrients in the food you eat to capture the food's energy.

The FAQ [How Healthy Nutrition Builds Health, Starting with the Cells](#) provides more information on how mitochondria capture energy from food to provide for your body to use. This energy transfer process uses a variety of enzymes to actually do the work of breaking down the food, and these enzymes require many vital nutrients to function. A multitude of vitamins is required for this process, in particular the B-vitamins: vitamins [B1](#), [B2](#), [B3](#), [B5](#) and [B6](#). Their role in the functioning of the mitochondria is one reason the B-vitamins are considered the energy vitamins. Other nutrients, like [coenzyme Q10](#) and L-carnitine, are also important in this process, as are many minerals like [magnesium](#), [iron](#) and sulfur.

Good sources of the B-vitamins include whole grains since the B vitamins are concentrated in the bran of grains. Whole grains are an excellent source of the entire complement of energy-related B-vitamins. Iron is present in whole grains, and good food sources of sulfur are the cruciferous vegetables, like broccoli. Supplementation of Coenzyme Q10 in humans and animals has been shown to beneficially affect the efficiency of mitochondrial energy production and to protect mitochondrial DNA from free radical damage. Good dietary sources of Coenzyme Q10 include oils from nuts, fish and meat.

[Phytonutrients that protect cells from imbalanced energy production](#)

While it's not surprising that something as important as the generation of energy requires so many nutrients, it is a little surprising that the production of energy can also result in the offshoot production of dangerous molecules with potential to damage your cells. This is because the breakdown of foods and stripping and transferring of energy requires oxygen. During the production of energy, about 2% of the oxygen used escapes in the form of reactive oxygen species (ROS), a type of free radicals. Free radicals are oxidants, which are very reactive molecules that bind to and break DNA chains, directly

causing mutations. They can also bind to and destroy proteins and fats in cell membranes.

When you are in good health, have low toxin exposure, and are eating a nutritious diet, your cells can protect against these ROS free radicals. With poor nutrition, or in the presence of toxins that inhibit or damage the energy transfer mechanics in your cells causing inadequate energy production, the amount of ROS free radicals generated in your cells exceeds the cells' ability to protect themselves against damage. When these damaging free radical by-products are not kept in check, which occurs, for example, when key nutrients are missing from your diet, ROS can bind to and destroy DNA, proteins, and the fats in your cells' membranes.

Over the past four decades, research has been continually showing that these damaging free radical by-products of energy production cause many of the fundamental alterations seen in aging and in chronic degenerative disease. Excess free radicals results in increased risk of premature aging, cataracts, and chronic degenerative diseases such as osteoarthritis, cardiovascular disease, diabetes, and cancer. Proper nutrition plays a critical role in neutralizing these damaging free radicals and protecting the health of your cells.

Research studies have shown an association between DNA mutations and defective energy transfer in cells with low levels of protective antioxidants; therefore, inadequate intake of protective antioxidants in food, such as phytonutrients like the *catechins* and *anthocyanidins* in green tea and fruits, and the *oryzanol* and *ferulic acid* in brown rice; **vitamin C** in citrus foods; **vitamin E** and tocopherols in whole grain oils and legumes; and **carotenoids** in carrots, cantaloupe, sweet potatoes and squash may result in a higher level of DNA mutation, predisposing you to conditions like cancer, as well as promoting fatigue and energy-deficit.

Research on animals suggests that **lipoic acid** supplementation increases mitochondrial membrane function and metabolic activity, and reduces the potential for oxidative damage. In addition, lipoic acid functions directly as an antioxidant and serves as a cofactor for maintaining the active states of coenzyme Q10 and vitamin E, both of which are important to the integrity of the mitochondria. Dietary sources of lipoic acid include **potatoes**, **carrots**, **beets**, and kohlrabi. Although not recommended since it is also loaded with cholesterol, red meat also contains alpha-lipoic acid.

For more on Reactive Oxygen Species and the World's Healthiest Foods see the section

on mitochondria in the [FAQ How Healthy Nutrition Builds Health, Starting with the Cells](#).

Supporting healthy cells for generating energy

Since energy is transferred and stored within your cells, it is no surprise that maintaining healthy levels of energy requires healthy cells. And, energy production from food also requires many factors other than just the machinery involved in the energy transfer process. As an example, think about what happens when you eat a meal. The sugar (glucose) is released and taken into your body through the digestion process, during which it enters your bloodstream. Your body responds to the glucose in your blood by secreting insulin from your pancreas into your bloodstream. When the insulin gets to one of your cells that needs glucose, it attaches to a protein (receptor) on the cell's surface, which then activates, or opens, a gate in the cell to let the glucose enter that cell. This glucose is then either used by the cell to produce energy or is stored for future energy production.

Much of the work of energy transfer in your body is performed by a variety of enzymes, which are proteins. Insulin is a peptide, made of the amino acids from the proteins in your diet. The insulin receptor on your cells is also a protein. The quality of protein in your body, and in these important energy support factors, is reflective of the quality of protein in your diet.

One key factor determining the quality of protein in foods is how well that food supplies the amino acids (building blocks of protein) you need in order to transform the food protein into yourself. All protein-containing foods provide a different profile of the essential amino acids as well as others that may be valuable. Another important consideration is eating protein-containing foods when your body can most efficiently use them to provide the energy you need when you need that energy. High-quality protein is found in foods such as fish, (preferably wild-caught, cold water fish, since they are also an excellent source of beneficial omega 3 fatty acids), organic eggs, legumes, grains, nuts and seeds, and vegetables.

The example above also shows how important healthy cell membranes are in supporting energy generation within your cells. Cell membranes are primarily made of fats, and these fats come from the food you eat. Research has shown that the fats you eat in food are reflective of the fats in your cell membranes. Poor nutrition, such as low intakes of the health-promoting [omega-3 fatty acids](#) and high intake of saturated fats may result in

brittle, broken (leaky) cell membranes that can't function appropriately. Fats that support healthy cell membranes can be provided by cold-water fish oils (especially salmon), many nuts and seeds and their oils (especially flax, canola, pumpkin, borage, black currant, and evening primrose oils), and the oils of marine algae. The menus in the World's Healthiest Foods provide healthy fats for support of cellular health.

What is fatigue?

The creation of energy requires that you receive all the substances necessary and in about the right proportions (food, air, and water). These substances are broken down (digested), and absorbed in your intestinal tract, lungs and sometimes through your skin. The nutrients and substances necessary for your body's energy then need to be transported efficiently (through the actions of your heart, blood vessels, and cell membranes) to your cells, which receive them and then make energy from them. A feeling of health and vitality is also dependent on your body being able to remove all of the waste products that result from the energy production process. A problem in any of these areas can decrease your feeling of energy and lead to a feeling of fatigue.

Fatigue is a symptom rather than a disease, even if it is experienced all of the time. Fatigue is a symptom associated with many conditions and diseases and is not just related to the Chronic Fatigue Syndrome, which is a condition that is defined as a significant drop in overall energy for at least six months. Many people experience substantial fatigue, which can lead to other problems, without being diagnosed with Chronic Fatigue Syndrome, and this fatigue is not necessarily associated with physical or mental exertion. Fatigue may signal a need for modification of some everyday lifestyle habits in order to improve the body's "energy economy" and decrease the likelihood of disease.

What can I do to improve my energy and promote my health and vitality?

Potential dietary causes and contributions to fatigue are as numerous as they are common. Dietary causes of fatigue can include consuming high glycemic foods or drinks that zap your energy, eating particular foods at the wrong time, or eating in a way that contributes to poor digestion. Foods that affect the body adversely, such as stimulants and alcohol, or food to which you are intolerant or allergic can also result in feelings of fatigue. Some of the contributors to fatigue are discussed below:

Stimulants and alcohol

Stimulants (especially coffee, espresso, and other strongly caffeinated beverages) and alcohol can contribute to fatigue because they represent a "metabolic distraction" to a tired-out body already doing its best to cope with energetic challenges. The quick feeling of energy is usually generated out of a neurochemical (brain) message (stimulus) from these foods, but these foods do not support the increased need for energy from the stimulation that is felt after eating them. Instead, the body uses energy reserves, and then a slump or low energy feeling follows. Furthermore, caffeinated beverages have a diuretic (dehydrating) effect, which adds further stress to the body.

Alcohol places an extra burden of detoxification on the liver, a vital organ that may already be very busy processing other toxins (from foods, the environment, chemicals you may be exposed to at home, at work, or in traffic) as well as all of the fats you consume. Additionally, alcohol is also dehydrating to the body and can appear to your body much like a very high-glycemic index carbohydrate, which is a bane to an energetically-challenged body. Stimulants and alcohol can produce feelings of being on an energy rollercoaster and should be avoided or only used in moderation.

Food sensitivities

Food intolerance or allergic reactions are often ignored as causes of fatigue, but they can result in fatigue nonetheless. This is because they cause a stress to the body and result in responses like low-grade inflammatory reactions throughout the body. Some food intolerances can be more obvious and interfere with healthy digestion and absorption of nutrients, resulting in a state of malnutrition in the body even when you are consuming foods containing the key vitamins and minerals you need. Examples of some of the more common food sensitivities include wheat, dairy products, soy products, and eggs. Symptoms of food sensitivities are sometimes vague and can occur many hours after eating the culprit food, which can make them difficult to track down. Eliminating the food for at least a month is one way to investigate if food intolerance is resulting in fatigue or other symptoms.

Toxins and pesticides

Research has shown that diet can support healthy cellular energy production, DNA and membranes, and when the diet is nutrient deficient, these structures and functions

become compromised. Pollution, certain artificial colors and preservatives, pesticides and other toxins also result in increasing free radicals in your body, which can further damage your cells' membranes and cause mutations in your cellular DNA. Furthermore, excess free radicals can also inhibit and even destroy the energy production machinery in the mitochondria, resulting in fatigue and a higher risk of chronic diseases. Therefore, support for healthy energy production includes decreasing this toxic exposure as much as possible. One way to decrease exposure to toxins is to select organically grown foods whenever possible.

Hydrogenated fats and saturated fats

Consumption of hydrogenated fats and a high intake of saturated fats have been shown to result in leaky, ineffective cell membranes. Leaky cell membranes can lead to a higher amount of free radicals, resulting in a decrease in effective energy production and a higher rate of DNA mutations. Avoiding hydrogenated fats and saturated fats, and using fat sources such as [olive oil](#) and [flaxseed oil](#) is one way to support healthy membranes. Also including sources of the essential fats, such as nuts, grains, and cold-water fish also help support healthy membranes.

Keys to support healthy energy

- *Support healthy digestion.* Healthy energy production begins with healthy digestion. Support healthy digestion by eating lightly and stopping as soon as you begin to feel satisfied. If you eat this way, you will need to eat more frequently. This places less burden on your digestion; you will feel lighter and more energetic. Eat slowly and deliberately. Include foods high in fiber in your meals. Enjoy herbs and spices that support digestion as well, such as [ginger](#), [pepper](#), [cinnamon](#), [fennel](#), [rosemary](#), [garlic](#), [curry spices](#), [chili spices](#). There is truly a world of variety!
- *Eat low-glycemic index foods as much as possible.* Low glycemic index foods provide your body with sources of longer lasting energy, and help you avoid the feeling of energy peaks and valleys. Good examples of low-glycemic index foods include root vegetables (e.g., [yams](#), [sweet potatoes](#), turnips, Jerusalem artichokes, [celery](#)), and whole-grain products. Limit foods or drinks that have a high glycemic index.
- *Eat whole grains whenever possible.* Whole grains are one of the best sources for the full spectrum of the key vitamins for energy generation, especially the B-vitamins.

- *Include a good source of protein with each meal, especially during the first half of the day.* Good dietary sources of protein include fish, eggs, and venison. Researchers have found that eating a varied diet featuring whole grains, legumes, and vegetables provides all of the important amino acid building blocks to provide healthy proteins in the cells as well. In addition, some plant-based foods, such as soy, feature an essential amino acid protein profile similar to animal-based foods and can directly substitute for animal protein.
- *Provide a source of essential fatty acids or monounsaturated fats with each meal.* These fats support healthy cell membranes. Good sources for healthy fats include whole raw [almonds](#), [walnuts](#), pecans, [flaxseed](#), [sesame seeds](#), [sunflower seeds](#), or [pumpkin seeds](#) or their oils; [salmon](#), sardines, [cod](#), [halibut](#), sole, perch, turbot, or orange roughy or cold-water fish oils; and [olive oil](#). In addition to these fats, inositol is a component of membrane phospholipids that are involved in various functions including cellular signaling. Increases in dietary inositol and choline have been found to significantly influence the concentration of membrane phospholipids and support healthy membranes. Good dietary sources of inositol include whole grains; [choline](#) is also present in high amounts in [egg yolks](#).
- *Provide your body with foods rich in protective phytonutrients like the antioxidants.* The [vitamin E](#) family, the tocopherols, contains powerful antioxidants that are able to protect both the lipid and protein components in your cell membranes from damage caused by free radicals and other oxidative compounds. Research has suggested that through their powerful antioxidant activity, the tocopherols may be able to protect DNA from the damage caused by oxidative stress. The antioxidant vitamin E can also protect the mitochondria from the effects of the free radicals produced during ATP manufacture. In addition, supplemental vitamin E seems to support tissue retention of supplemental [coenzyme Q10](#), a critical nutrient for energy production. Good dietary sources of the vitamin E family include wheat germ and wheat germ oil, as well as oils from other grains and legumes, like soy oil.
- *Eat foods rich in antioxidants.* The body's premier water-soluble antioxidant, [vitamin C](#) is critical to cellular membrane health since it plays an integral role in recycling [vitamin E](#) back to its active form. By regenerating vitamin E back to its active form, vitamin C also plays a role in protecting the mitochondria from potential damage by reactive oxygen species, like free radicals. Excellent dietary sources of vitamin C include [chili peppers](#), [parsley](#), [broccoli](#), [bell pepper](#), [strawberries](#), [oranges](#), [lemon juice](#), [[papaya](#), [cauliflower](#), [kale](#), [mustard greens](#), and

Brussels sprouts.

- *Limit your alcohol intake, avoid foods or drinks to which you are sensitive or intolerant, and avoid the temptations of stimulants and sweet snacks, especially soft drinks, coffee, and candy.*
- *Select organic food whenever possible and avoid food cultivated with pesticides.* Several of the agricultural chemicals used in the conventional growing of foods have also been shown to have a negative effect upon mitochondrial function. These chemicals include paraquat, parathion, dinoseb and 2,4-D, all of which have been found to affect the mitochondria and cellular energy production in a variety of ways, including increasing membrane permeability (which exposes the mitochondria to damaging free radicals), and inhibiting the protein that creates ATP, the energy currency of the body. Avoid foods containing preservatives, additives and colorants when possible as well, since many of these compounds have been associated with membrane damage, DNA mutations, or altered energy production.

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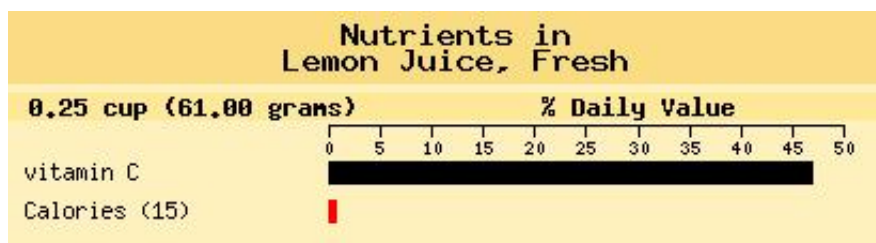
Lemon/Limes

Although lemons and limes may not be what you would choose for an afternoon snack, we consider them as powerhouses when we want to bring out the flavor of other foods. While both are available throughout the year, lemons are in the peak of their season around May, June and August while limes are at their peak from May through

October.

Lemons are oval in shape and feature a yellow, texturized outer peel. Like other citrus fruits, their inner flesh is encased in eight to ten segments.

Usually smaller than lemons, limes are oval or round in shape having a diameter of one to two inches with green flesh and skin. They can be either sour or sweet depending on the variety; however, sweet limes are not readily available in the United States. Sour limes contain citric acid giving them an acidic and tart taste, while sweet limes lack citric acid and are sweeter in flavor.



This chart graphically details the %DV that a serving of Lemon/Limes provides for each of the nutrients of which it is a good, very good, or excellent source according to our Food Rating System. Additional information about the amount of these nutrients provided by Lemon/Limes can be found in the Food Rating System Chart. A link that takes you to the In-Depth Nutritional Profile for Lemon/Limes, featuring information over 80 nutrients, can be found under the Food Rating System Chart.

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Health Benefits

Phytonutrients with Antioxidant and Antibiotic Effects

Like many of the fruits and vegetables featured on our website, lemons and limes contain unique flavonoid compounds that have antioxidant and anti-cancer properties.

Of special interest in limes have been flavonoids called *flavonol glycosides*, including many *kaempferol*-related molecules. While these flavonoids have been shown to stop cell division in many cancer cell lines, they are perhaps most interesting for their antibiotic effects. In several villages in West Africa where cholera epidemics had occurred, the inclusion of lime juice during the main meal of the day was determined to have been protective against the contraction of cholera. (Cholera is a disease triggered by activity of the bacteria called *Vibrio cholera*). Researchers quickly began to experiment with the addition of lime juice to the sauce eaten with rice, and in this role, lime juice was also found to have a strong protective effect against cholera.

Several other fascinating research studies on the healing properties of lemons and limes have shown that cell cycles-including the decision a cell makes about whether to divide (called *mitosis*) or die (*apoptosis*-are altered by lime juice, as are the activities of special immune cells called *monocytes*.

In addition to their unique phytonutrient properties, lemons and limes are an excellent source of **vitamin C**, one of the most important antioxidants in nature. Vitamin C is one of the main antioxidants found in food and the primary water-soluble antioxidant in the body. Vitamin C travels through the body neutralizing any free radicals with which it comes into contact in the aqueous environments in the body both inside and outside cells. Free radicals can interact with the healthy cells of the body, damaging them and their membranes, and also cause a lot of inflammation, or painful swelling, in the body. This is one of the reasons that vitamin C has been shown to be helpful for reducing some of the symptoms of osteoarthritis and rheumatoid arthritis.

Since free radicals can damage blood vessels and can change cholesterol to make it more likely to build up in artery walls, vitamin C can be helpful for preventing the development and progression of atherosclerosis and diabetic heart disease.

Vitamin C is also vital to the function of a strong immune system. The immune system's main goal is to protect you from illness, so a little extra vitamin C may be useful in conditions like colds, flu's, and recurrent ear infections.

Owing to the multitude of vitamin C's health benefits, it is not surprising that research has shown that consumption of vegetables and fruits high in this nutrient is associated with a reduced risk of death from all causes including heart disease, stroke and cancer.

Limonins Support Optimal Health

In animal studies and laboratory tests with human cells, compounds in citrus fruits, including lemons and limes, called limonoids have been shown to help fight cancers of the mouth, skin, lung, breast, stomach and colon. Now, scientists from the US Agricultural Research Service (ARS) have shown that our bodies can readily absorb and utilize a very long-acting limonoid called limonin that is present in citrus fruits in about the same amount as vitamin C.

In citrus fruits, limonin is present in the form of limonin glucoside, in which limonin is attached to a sugar (glucose) molecule. Our bodies easily digest this compound, cleaving off the sugar and releasing limonin.

In the ARS study, 16 volunteers were given a dose of limonin glucoside in amounts ranging from those that would be found in from 1 to 7 glasses of orange juice. Blood tests showed that limonin was present in the plasma of all except one of the subjects, with concentrations highest within 6 hours after consumption. Traces of limonin were still present in 5 of the volunteers 24 hours after consumption!

Limonin's bioavailability and persistence may help explain why citrus limonoids are potent anti-carcinogens that may prevent cancerous cells from proliferating. Other natural anti-carcinogens are available for much less time; for example, the phenols in green tea and chocolate remain active in the body for just 4 to 6 hours.

The ARS team are now investigating the potential cholesterol-lowering effects of limonin. Lab tests indicate that human liver cells produce less apo B when exposed to limonin. Apo B is a structural protein that is part of the LDL cholesterol molecule and is needed for LDL production, transport and binding, so higher levels of apo B translate to higher levels of LDL cholesterol.

Protection against Rheumatoid Arthritis

While one study suggests that high doses of supplemental vitamin C makes osteoarthritis, a type of degenerative arthritis that occurs with aging, worse in laboratory animals, another indicates that vitamin C-rich foods, such as lemons and limes, provide humans with protection against inflammatory polyarthritis, a form of rheumatoid arthritis involving two or more joints.

The findings, presented in the *Annals of the Rheumatic Diseases* were drawn from a study of more than 20,000 subjects who kept diet diaries and were arthritis-free when

the study began, and focused on subjects who developed inflammatory polyarthritis and similar subjects who remained arthritis-free during the follow-up period. Subjects who consumed the lowest amounts of vitamin C-rich foods were more than three times more likely to develop arthritis than those who consumed the highest amounts.

Description

Lemons

Lemons, scientifically known as *Citrus limon*, are more commonly known as the fruit that evokes images of sunshine and the sweet smiles of children standing roadside at their homemade lemonade stands.

Lemons are oval in shape and feature a yellow, texturized outer peel. Like other citrus fruits, their inner flesh is encased in segments, with the average lemon having eight to ten.

While most lemons are tart, acidic and astringent, they are also surprisingly refreshing. The two main types of sour lemons are the Eureka and the Lisbon. The Eureka generally has more texturized skin, a short neck at one end and a few seeds, while the Lisbon has smoother skin, no neck and is generally seedless. In addition to these sour lemons, there are also some varieties that are sweet in flavor. One notable example is the Meyer lemon that is becoming more popular in both markets and restaurants.

Limes

Limes are a small citrus fruit, *Citrus aurantifolia*, whose skin and flesh are green in color and which have an oval or round shape with a diameter between one to two inches. Limes can either be sour or sweet, with the latter not readily available in the United States. Sour limes possess a greater sugar and citric acid content than lemons and feature an acidic and tart taste, while sweet limes lack citric acid content and are sweet in flavor.

There are two general varieties of sour limes available, the Tahitian and the Key. Among Tahitian limes are the egg-shaped Persian and the smaller, seedless Bearss. Key limes, famous for the pie bearing their name, are smaller and more acidic than the Tahitian variety.

History

Lemons

Lemons were originally developed as a cross between the lime and the citron and are thought to have originated in China or India, having been cultivated in these regions for about 2,500 years. Their first introduction to Europe was by Arabs who brought them to Spain in the 11th century around the same time that they were introduced into Northern Africa. The Crusaders, who found the fruit growing in Palestine, are credited with bringing the lemon to other countries across Europe. Like many other fruits and vegetables, lemons were brought to the Americas by Christopher Columbus in his second voyage to the New World in 1493, and have been grown in Florida since the 16th century.

Lemons, like other vitamin-C rich fruits, were highly prized by the miners and developers during the California Gold Rush in the mid-19th century, since they were used to protect against the development of scurvy. They were in such demand that people were willing to pay up to \$1 per lemon, a price that would still be considered costly today and was extremely expensive back in 1849. The major producers of lemons today are the United States, Italy, Spain, Greece, Israel and Turkey.

Limes

Limes are grown on trees that flourish in tropical and subtropical climates. They were thought to originate in Southeast Asia. Arab traders brought lime trees back from their journey to Asia and introduced them into Egypt and Northern Africa around the 10th century. The Arabian Moors brought them to Spain in the 13th century and then, like many fruits, they were spread throughout southern Europe during the Crusades.

Limes made their way to the New World with Columbus on his second voyage in 1493, and were subsequently planted in many Caribbean countries whose hot, humid climates supported the cultivation of this fruit. Centuries later, British explorers and traders, who were readily using the vitamin C-rich limes that grew in their West Indies colonies to prevent scurvy, earned the nickname "limey," a word that is often still used colloquially for persons of British descent.

The introduction of limes to the United States began in the 16th century when Spanish Explorers brought the West Indies lime to the Florida Keys, beginning the advent of Key limes. In the following century, Spanish missionaries attempted to plant lime trees in California, but the climate did not support their growth. In great demand by the miners

and explorers during the California Gold Rush as a fruit that was known to prevent scurvy, limes began to be imported from Tahiti and Mexico at this time in the mid-19th century. Today, Brazil, Mexico and the United States are among the leading commercial producers of limes.

How to Select and Store

For the most antioxidants, choose fully ripened lemons and limes:

Research conducted at the University of Innsbruck in Austria suggests that as fruits fully ripen, almost to the point of spoilage, their antioxidant levels actually increase.

Key to the process is the change in color that occurs as fruits ripen, a similar process to that seen in the fall when leaves turn from green to red to yellow to brown- a color change caused by the breakdown and disappearance of chlorophyll, which gives leaves and fruits their green color.

Until now, no one really knew what happened to chlorophyll during this process, but lead researcher, Bernard Kräutler, and his team, working together with botanists over the past several years, has identified the first decomposition products in leaves: colorless, polar NCCs (nonfluorescing chlorophyll catabolytes), that contain four pyrrole rings - like chlorophyll and heme.

After examining apples and pears, the scientists discovered that NCCs replace the chlorophyll not only in the leaves of fruit trees, but in their very ripe fruits, especially in the peel and flesh immediately below it.

"When chlorophyll is released from its protein complexes in the decomposition process, it has a phototoxic effect: when irradiated with light, it absorbs energy and can transfer it to other substances. For example, it can transform oxygen into a highly reactive, destructive form," report the researchers. However, NCCs have just the opposite effect. Extremely powerful antioxidants, they play an important protective role for the plant, and when consumed as part of the human diet, NCCs deliver the same potent antioxidant protection within our bodies. . [Angew Chem Int Ed Engl. 2007 Nov 19;46\(45\):8699-8702.](#)

Lemons

One of the tricks to finding a good quality lemon is to find one that is rather thin-

skinned since those with thicker peels will have less flesh and therefore be less juicy. Therefore, choose lemons that are heavy for their size and that feature peels that have a finely grained texture. They should be fully yellow in color as those that have green tinges will be more acidic due to the fact that they have not fully ripened. Signs of overmature fruit include wrinkling, soft or hard patches and dull coloring. Fresh lemons are available all year round.

Lemons will stay fresh kept at room temperature, away from exposure to sunlight, for about one week. If you will not be using them within this time period, you can store the lemons in the refrigerator crisper where they will keep for about four weeks.

Lemon juice and zest can also be stored for later use. Place freshly squeezed lemon juice in ice cube trays until frozen, subsequently storing them in plastic bags in the freezer. Dried lemon zest should be stored in a cool and dry place in an airtight glass container.

Limes

Choose limes that are firm and heavy for their size, free of decay and mold. They should have a glossy skin that is deep green in color; although limes turn more yellow as they ripen, they are at the height of their lively, tart flavor when they are green in color. While brown spots on the skin of limes may not affect their color, limes that are mostly brownish in color should be avoided since this may be an indication that they have "scald" which may cause them to have an undesirable moldy taste. Limes are available in the marketplace throughout the year, although they are usually in greater supply from mid-spring through mid-fall.

Limes can be kept out at room temperature where they will stay fresh for up to one week. Make sure to keep them away from sunlight exposure since it will cause them to turn yellow and will alter their flavor. Limes can be stored in the refrigerator crisper, wrapped in a loosely sealed plastic bag, where they will keep fresh for about 10-14 days. While they can be kept longer than that, for another several weeks, they will begin to lose their characteristic flavor.

Lime juice and zest can also be stored for later use. Place freshly squeezed lime juice in ice cube trays until frozen, subsequently storing them in plastic bags in the freezer. Dried lime zest should be stored in a cool and dry place in an airtight glass container.

How to Enjoy

For some of our favorite recipes, click [Recipes](#).

Tips for Preparing Lemon and Limes:

Lemons and limes are often called for in recipes in the form of juice. As they will produce more juice when warmer, always juice them when they are at room temperature or place them in a bowl of warm water for several minutes. Rolling them under the palm of your hand on a flat surface will also help to extract more juice.

Before cutting the lemon or lime in half horizontally through the center, wash the skin so that any dirt or bacteria residing on the surface will not be transferred to the fruit's interior. While you could remove any visible seeds before juicing the halves, you could also wait until after the process is complete, since there are bound to be some seeds that reside deeper and are not visible from the surface. The juice can then be extracted in a variety of ways. You can either use a juicer, reamer or do it the old fashioned way, squeezing by hand.

If your recipe calls for lemon or lime zest, make sure that you use fruit that is organically grown since most conventionally grown fruits will have pesticide residues on their skin. After washing and drying the lemon or lime, use a zester, paring knife or vegetable peeler to remove the zest, which is the colored part of the peel. Make sure not to remove too much of the peel as the white pith underneath is bitter and should not be used. The zest can then be more finely chopped or diced if necessary.

A Few Quick Serving Ideas:

Place thinly sliced lemons, peel and all, underneath and around fish before cooking. Baking or broiling will soften the slices so that they can be eaten along with the fish.

Combine lemon juice with olive or flax oil, freshly crushed garlic and pepper to make a light and refreshing salad dressing.

If you are watching your salt intake (and even if you are not), serve lemon wedges with meals as their tartness makes a great salt substitute.

Combine freshly squeezed lime juice, evaporated cane juice and either plain or sparkling water to make limeade.

Add an-easy-to-prepare zing to dinner tonight by tossing seasoned cooked brown rice

with garden peas, chicken pieces, scallions, pumpkin seeds, lime juice and lime zest.

Squeeze some lime juice onto an avocado quarter and eat as is.

Individual Concerns

Lemon and Lime Peels and Oxalates

The peels of lemons and limes are among a small number of foods that contain measurable amounts of oxalates, naturally-occurring substances found in plants, animals, and human beings. When oxalates become too concentrated in body fluids, they can crystallize and cause health problems. For this reason, individuals with already existing and untreated kidney or gallbladder problems may want to avoid eating lemon or lime peels. Laboratory studies have shown that oxalates may also interfere with absorption of calcium from the body. Yet, in every peer-reviewed research study we've seen, the ability of oxalates to lower calcium absorption is relatively small and definitely does not outweigh the ability of oxalate-containing foods to contribute calcium to the meal plan. If your digestive tract is healthy, and you do a good job of chewing and relaxing while you enjoy your meals, you will get significant benefits - including absorption of calcium - from calcium-rich foods plant foods that also contain oxalic acid. Ordinarily, a healthcare practitioner would not discourage a person focused on ensuring that they are meeting their calcium requirements from eating these nutrient-rich foods because of their oxalate content. For more on this subject, please see "[Can you tell me what oxalates are and in which foods they can be found?](#)"

Lemons and Limes and Wax Coatings

Conventionally grown lemons and limes may be waxed to protect them from bruising during shipping. Plant, insect, animal or petroleum-based waxes may be used. Carnauba palm is the most common plant-source wax. Other compounds, such as ethyl alcohol or ethanol, are added to the waxes for consistency, milk casein (a protein linked to milk allergy) for "film formers" and soaps for flowing agents. Since you may not be able to determine the source of these waxes, this is another good reason to choose organically grown lemons and limes.

Nutritional Profile

Lemons and limes are excellent sources of vitamin C.

For an in-depth nutritional profile click here: [Lemons](#).

In-Depth Nutritional Profile

In addition to the nutrients highlighted in our ratings chart, an in-depth nutritional profile for [Lemon/Limes](#) is also available. This profile includes information on a full array of nutrients, including carbohydrates, sugar, soluble and insoluble fiber, sodium, vitamins, minerals, fatty acids, amino acids and more.

Introduction to Food Rating System Chart

In order to better help you identify foods that feature a high concentration of nutrients for the calories they contain, we created a Food Rating System. This system allows us to highlight the foods that are especially rich in particular nutrients. The following chart shows the nutrients for which this food is either an excellent, very good, or good source (below the chart you will find a table that explains these qualifications). If a nutrient is not listed in the chart, it does not necessarily mean that the food doesn't contain it. It simply means that the nutrient is not provided in a sufficient amount or concentration to meet our rating criteria. (To view this food's in-depth nutritional profile that includes values for dozens of nutrients - not just the ones rated as excellent, very good, or good - please use the link below the chart.) To read this chart accurately, you'll need to glance up in the top left corner where you will find the name of the food and the serving size we used to calculate the food's nutrient composition. This serving size will tell you how much of the food you need to eat to obtain the amount of nutrients found in the chart. Now, returning to the chart itself, you can look next to the nutrient name in order to find the nutrient amount it offers, the percent Daily Value (DV%) that this amount represents, the nutrient density that we calculated for this food and nutrient, and the rating we established in our rating system. For most of our nutrient ratings, we adopted the government standards for food labeling that are found in the U.S. Food and Drug Administration's "Reference Values for Nutrition Labeling." [Read more background information and details of our rating system.](#)

Lemon juice, fresh				
0.25 cup				
61.00 grams				
15.25 calories				
Nutrient	Amount	DV (%)	Nutrient Density	World's Healthiest Foods Rating
vitamin C	28.06 mg	46.8	55.2	excellent

World's Healthiest Foods Rating	Rule				
excellent	DV>=75%	OR	Density>=7.6	AND	DV>=10%
very good	DV>=50%	OR	Density>=3.4	AND	DV>=5%
good	DV>=25%	OR	Density>=1.5	AND	DV>=2.5%

In-Depth Nutritional Profile for [Lemon/Limes](#)

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