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How Cooking Techniques Affect the Nutritional Qualities of Food

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The inherent nutritional properties of food is a topic widely covered in nutrition education journals and media, but there is less awareness about how cooking can affect these nutritional properties. The role of an RD is to help people improve their health through food. This includes influencing the types and portions of foods people eat and how these foods are prepared both to maximize nutritional benefit and minimize potential negative effects that can occur during cooking. Because standard training to become a dietitian does not mandate culinary education, many RDs may have a limited understanding of the cooking techniques used to prepare food and their effect on flavor and the nutritional composition of the ingredients.

This knowledge, however, is imperative for the successful guidance of clients. For example, simply telling a client to eat more vegetables so that they can benefit from their plethora of vitamins may not be enough. RDs also should explain how to cook those vegetables to preserve as much of their vitamin content as possible. Similarly, telling clients to eat lean red meat to increase their iron content may end up hurting them in the long run. Certain methods of cooking red meat can lead to carcinogen buildup, so being able to advise clients about how to avoid those unwanted carcinogens is key to improving their health. As all RDs know, success with clients involves helping them make healthy food palatable. By understanding which cooking techniques are best suited for which food items, RDs will be better equipped to educate clients about how to make healthy foods taste better, thus increasing favorability of these foods.

This continuing education course reviews the various common cooking techniques used to prepare meat and poultry, fish and shellfish, and fruits and vegetables and analyzes their nutritional implications.

Cooking Techniques

Since most food groups are prepared utilizing similar cooking methods, the following section defines all of the cooking methods that will be repeatedly referenced throughout this article.

Most cooking techniques are divided into the following two main categories: moist heat methods and dry heat methods. An exception is microwave cooking.

Moist Heat

Moist heat cooking techniques involve the transfer of heat through water in some form. These techniques include boiling, blanching, poaching, simmering, pressure-cooking, and *sous vide*.

Boiling is the process of cooking food by transferring heat from water that has reached approximately 212° F. Boiling water has large rolling bubbles rising to the surface.[1] Blanching is similar to boiling but is the process of cooking foods briefly in boiling water, typically with the intention of par cooking to be followed by a different cooking method to complete the cooking process. Blanching is also typically followed by "shocking" the food in ice water to stop the cooking process.

Steaming is a cooking method by which food is cooked through vaporized liquid that is the same temperature as boiling water. There are several variations of steaming including pan steaming and *en papillote*. For pan steaming, food is placed in a perforated vessel over another vessel of boiling liquid that has been infused with aromatics. The food is placed close enough to the aromatic liquid that it can impart a flavor through the steam and the top vessel is covered so the steam is kept inside. *En papillote* is the process of encasing food (typically fish or vegetables) in a parchment paper or foil envelope and placing it in an oven. The food cooks through steam created from the natural liquid released from the food during cooking.

Pressure cooking is the process of cooking in a sealed vessel through heat transfer from a combination of boiling water and steam; the water and steam reach 250° F, which is higher than boiling temperature as a result of the trapped steam.[2]

Simmering is the method of cooking food in a hot liquid that is just below boiling point. This may result in small bubbles on the liquid's surface but is much less turbulent than boiling.

Poaching is a cooking method by which food is completely submerged in liquid that is hot but below the boiling point, at approximately 160° to 180° F.[1]

Sous vide is a cooking method not commonly used at home because it requires specific equipment, but it has been gaining popularity in recent years among home cooks. *A* French term for "under vacuum," *sous vide* refers to a method of placing food sealed in an airtight bag (known as reduced oxygen packaging) in hot water. The result is similar to poaching or steaming but allows for the maintenance of a precise and consistent temperature throughout the cooking process.

Dry Heat

Dry heat cooking does not use water as a medium for transferring heat to the food. These techniques are defined in this section.

Grilling is a cooking method whereby the heat is located under the cooking surface. There are various types of grilling methods. With flame grilling, the flame comes into direct contact with the food. With flat top grilling, the flame is separated from the food by a piece of equipment, such as a metal slab on a griddle. And with charcoal grilling, the heat comes from the hot smoke emanating from the coals.

Broiling transmits heat in a manner similar to that of grilling, but instead of heating from below, broiling transmits heat from above. Cooking results vary depending on the intensity of the heat and its proximity to the food.

Baking and roasting involve dry heat in a controlled environment, such as an oven. They essentially are the same technique, but different terms are used for their application with different foods and different temperatures. Roasting is typically done at a higher temperature (400° F and above), and generally applies to food with a solid structure to begin with, such as meat, poultry, vegetables, fruits, and foods that are typically coated with fat on the exterior, either naturally or through the addition of a cooking fat. Baking generally refers to food that may lack structure early on but become solid during the process (eg, casseroles, breads, cakes, and pastries). Baking also can refer to solid food items cooked at a lower temperature (less than 400° F). With baking and roasting, the food remains in the same position. Rotisserie involves the baking and roasting technique, but the food is mechanically rotated for equal distribution of heat throughout.

Barbecuing is a term that has been taken to mean many different things in the culinary world; technically speaking, barbecue is the cooking of food in chambers or pits filled with smoke. Wood chips are used to create the smoke, along with any additional aromatics such as carrots, celery, and onion, and, if desired, herbs or tea leaves to make smoke.[2]

Sautéing is a dry heat method through which food is cooked and turned continuously in a shallow pan over medium to high heat with a little fat so everything is cooked evenly. Dry sautéing is the same process without any the use of added fat.[2]

Searing is a variation of sautéing, but instead of moving the food during cooking, the food is laid to rest so that is browns on all sides to develop a crust. Some fat might be used to prevent the food from sticking.

Frying brings food in contact with a significant amount of oil. With deep frying, the food is completely immersed in hot fat, whereas pan frying uses less fat, which does not completely cover the food during cooking. Stir frying is done in a wok where the food is continuously turned as it cooks.

Additional Methods

Some cooking methods include both dry and moist heat, such as braising and stewing. Braising involves the dry heat method of searing following by the moist heat method of simmering slowly with a liquid. Stewing refers to a similar process used with smaller pieces of meat or vegetables.

Finally, microwave cooking exposes food to electromagnetic radiation. It heats foods quickly and efficiently, and the cooking is fairly uniform, particularly in food items with a high water content.[2]

Meat and Poultry

Meat and poultry can be good sources of protein, vitamins, and minerals, especially when cooked appropriately. Studies have shown that saturated fat can increase risk for cardiovascular disease, obesity, cancer, and type 2 diabetes.[3] Because red meats can be high in saturated fats, it is advisable to choose cuts that are inherently leaner, such as pork or beef tenderloin or bison, or opt for poultry whose fat composition is predominantly unsaturated.

Meat and poultry also have particularly high levels of heme iron. While low intake of iron can cause iron deficiency and anemia, in certain cases iron toxicity can result from too much iron and can lead to increased risk for cardiovascular disease and even cancer.[4]

When deciding how to cook meat and poultry, the cut of the animal should be considered. Generally speaking, tenderer and leaner cuts of meat require less cooking time and therefore are best prepared with dry, quick cooking methods. Tougher pieces need enough cooking time to turn collagen into gelatin. These cuts tend be best prepared using wet, longer cooking methods.[2] However, aside from taste and texture, consideration of nutrition and health is also important when deciding the best way to cook meat and poultry.

Certain methods for cooking meat and poultry have been shown to produce several types of carcinogens. One class of carcinogens called nitrosamines can destroy DNA and ultimately cause cancer.[2] Nitrosamines are formed when nitrite, a metabolite of the naturally occurring chemical nitrate undergoes a chemical transformation during the cooking process. When nitrites interact with the amino acids from the meat under high heat cooking methods (such as deep frying or flame grilling), they turn into nitrosamines. However, while most people may only associate nitrates with processed meats, more than 80% of the nitrates consumed in the average diet come from vegetables.[5] Naturally cured meats get their nitrites from nitrate-containing vegetable derivatives such as celery powder in place of synthetic sodium nitrite. Though “naturally cured meats” may sound more healthful, these nitrates can still produce nitrosamines and the associated ill effects of those meats cured with synthetic sodium nitrate. In fact, when choosing between the two, buying meat that has been cured with synthetic curing salts may be the lesser of two evils; these meats must follow specific guidelines regarding the amount of allowed nitrite whereas naturally cured meats are subject to less scrutiny.[6]

Another class of carcinogens, heterocyclic amines (HCAs), are created when heat comes into contact with animal muscle proteins. The formation of HCAs is largely dependent on the intensity of the cooking temperature. High-heat cooking methods such as charcoal grilling and frying have been documented to produce higher amounts of HCAs. If the meat is cooked for longer amounts of time (for example, a well-done steak), HCAs will also increase.[7] The final class of carcinogens, polycyclic aromatic hydrocarbons (PAHs), form in smoke and settle on the meat’s surface and are higher in items that are smoked or charred.[8]

Dry Cooking Methods

Grilling is a very popular method for cooking meat and poultry and it has both positive and negative implications that should be considered. Leaner cuts of meat are best for grilling because the cooking time is generally very short. With grilling, there isn’t enough time for fattier cuts to render the fat or for the collagen in tougher cuts to be broken down. Because poultry does not have fat marbling or collagen like red meat, all cuts can be cooked on the grill. With minimal added fat, grilling is a good option from an energy-density perspective. However, the high heat of the grill and the smoke that is created lend themselves to carcinogen formation. There are several measures that can be taken to mitigate this. Reducing the fire temperature, placing the meat farther from the fire, and shortening cooking time can all help.[1] For example, grilling on a plancha, or a griddle, creates a barrier between the heat source and the food. Furthermore, bringing the meat to room temperature before grilling helps to reduce necessary

cooking time.[2] PAH formation in particular can be mitigated by grilling meat with less fat so that less fat drips into heat source, thus causing less flare-ups and smoke.[1] Using marinades with antioxidants can help to reduce the number of these carcinogens.[2]

When it comes to frying meat and poultry, heat is transferred via convection currents in the fat medium. This means that the heat particles move from warmer to cooler areas in a fluid or gas medium, ultimately warming the whole thing. It only takes a few seconds for the surface of meat to brown when fried. Because the heat transfer is so quick with frying, it is best for the smaller, more tender cuts that might also be grilled. In general, frying is more commonly used to cook poultry than red meat.[2] The high heat of frying lends itself to shorter cooking time, but, like grilling, it also creates more HCAs.[2] Frying, especially when the food is coated with a batter or breading, also contributes to the energy density of the dish, adding calories without any particular beneficial nutritional content.

Unlike grilling and frying, which are used for smaller cuts of meat, such as a filet of meat or a chicken breast, baking and roasting allow for a wide range of temperatures and can therefore be used for a wide range of cuts. For example, while roasting takes place on the higher end (around 400° F), the low temperatures of baking (250° F) allow for little surface browning and long cooking times. This way, the interior can slowly cook through without losing too much moisture and an even level of doneness can be achieved throughout. Similarly, rotisserie cooking is slow and uses low temperature; it is therefore best for large cuts of meat and even whole animals.[2]

Nitrosamine and HCA formation has been found with roasting and baking cooking methods, as with grilling and frying.[9] While the nitrosamines can be found on the meat itself, the HCAs are generally found in the juices that are rendered from these cooking techniques. It is for this reason that pan drippings should not be reused later on in the cooking process, such as in gravy. As long as pan drippings are not used and the smoke point of the fat being used is not reached, cooking meat or poultry in an oven at a low temperature (below 350° F) is a good way to avoid unwanted carcinogens in a meat dish.[10] Because the juices get reabsorbed during the rotisserie process, cuts that are cooked in this particular fashion tend to be high in HCAs regardless of whether pan drippings are used. This should be a consideration when choosing to use the rotisserie method or to roast in a more conventional fashion.

From a culinary perspective, barbecuing and smoking are similar to rotisserie cooking in that they are dry-heat methods best suited for tough, inexpensive cuts. With hot smoking, wood is burned in one chamber of a smoker and is transferred to the meat in a second connected chamber so that there is no direct heat from the coals as there is with grilling. With cold smoking, the meat is kept in an unheated chamber and smoke passes from an entirely separate chamber. Because of the difference in temperature, cold smoking takes up to seven times longer to deposit its vapor onto the meat. On the one hand, this prolonged time also allows for higher concentrations of phenolic components to form. Phenolic compounds are health-promoting chemicals that come from the wood used in the smoking process. Not only are these compounds antioxidative and antibacterial but they also contain sweet-spicy components that the enhance flavor of the meat. However, this prolonged exposure to smoke also allows for more possible carcinogens (ie, PAH) to accumulate.[2]

Moist Cooking Methods for Meat and Poultry

Generally, moist heat cooking methods such as stewing and poaching, which are done at temperatures lower than 212° F, do not produce as many, if any, carcinogens, as dry heat methods.[1] While boiling meat and poultry is usually only a means to make stock, poaching is a method that is used to cook flatter, more tender cuts of meat. With poaching, most of the cooking takes place at roughly 180° F, but the liquid must first come to a boil to kill any potential bacteria on the meat. This method is not only healthful due to the lack of carcinogen formation but also from an energy-density perspective. The cuts of meat and poultry that are poached, such as beef tenderloin or chicken breast, are lean to begin with and the poaching liquid does not add much, if anything, to the energy density of the dish.[2]

While poached meat and poultry are immersed in the cooking liquid, steamed meat and poultry never come into direct contact with the cooking liquid. Steaming brings the surface temperature of the meat to a boil so quickly that it is best for thin, tender cuts of meat. This is because their interiors will still be able to cook through before their surfaces dry out.[2] Although the temperature is high, the cooking time is so short that there is little to no time for carcinogens to develop.

With a pressure cooker, heat transfers to the meat two or three times as fast as with steaming; this helps turn collagen to gelatin in tougher cuts of meat. However, at the same time, the proteins get very hot and lose a lot of moisture in the process. Thus, meats to be cooked in a pressure cooker must have enough fat and collagen to stay moist.[2] For example, short ribs would cook well in a pressure cooker, whereas a piece of chicken breast might not. Similar to pressure cooking, braising is a technique that's great for breaking down collagen in tougher cuts of meat. The key is to cook the meat slowly at a temperature just hot enough to dissolve the collagen and cool enough to help prevent drying. Once the connective tissue turns to gelatin, the gelatin helps to retain the juices from the meat. Cheaper cuts, such as the shank and shoulder, are rich in collagen and are therefore well suited for braising.[2] Unlike with grilling, where fat that is rendered falls away from the meat and poultry, with both pressure cooking and braising, the fat has nowhere to go. Thus, it's advisable to skim the fat during the cooking process to reduce the fat content of the dish.

Microwave Cooking

Though it's neither a dry nor a moist cooking method, microwaving is another possibility that clients may consider. However, with microwaving, the outside of the meat is cooked quickly with a great amount of moisture loss. Furthermore, microwaves cannot brown meat. As previously mentioned, the browning of meat comes as a result of the surface of the meat coming into contact with hot particles in the air that have been transmitted via convection currents. Since the heat is transmitted via radio waves in a microwave, browning does not occur.[2] As such, while there is little to no concern for carcinogen development, because the results of microwaving meat are undesirable from a culinary standpoint, it's inadvisable.

Seafood

Fish can be a particularly healthy source of protein, especially species rich in omega-3 fats, such as salmon and mackerel. Omega-3 fats have been shown to reduce the risk for cardiovascular disease, so eating fatty fish at least once a week is recommended.[1] Some fish,

however, contain toxic metals and chemical pollutants that do not get destroyed during the cooking process.[11] The only way to avoid them is by sourcing fish that have fewer of them to begin with. Fish that contain a significant amount of these toxins and pollutants are fish that are generally higher on the food chain, such as shark, swordfish, and big-eye tuna, as well as filter-feeding shellfish from contaminated waters.[2] These fish can still be eaten for their other health benefits, as they may be good sources of healthy fats and minerals, but they should be consumed in moderation. Information about mercury and other contamination is available from institutions such as the Monterey Bay Aquarium.

Another concern is the formation of carcinogens through cooking; however, this doesn't occur as commonly with fish as it is does meat and poultry—typically the cooking time is shorter and the temperature is lower.

During cooking, the flesh of fish responds very differently to heat than does that of meat or poultry. Whereas collagen in meat plays a large role in the cooking method and final texture, the collagen in fish gets destroyed too quickly to have any effect on the final product.[2] Fish proteins are more heat sensitive than meat and poultry muscle proteins. Because the protein dries out so quickly, the biggest challenge when cooking fish is to ensure that it does not get too dry too quickly.[2]

Dry Cooking Methods

Grilling is a common cooking method used for fish and is best for fish fillets, steaks, and thin whole fish, such as branzino. When grilling, the distance from the heat should be gauged by the thickness of the fish; to prevent overcooking, the thinner the fish, the farther it should be from the heat.[2] As with meat and poultry, fish is somewhat susceptible to HCAs and PAHs, though to a much lesser extent due to their shorter cooking time with dry heat. Using marinades can actually reduce carcinogen formation when high dry heat is used.[2]

Frying is another dry cooking method used for fish. As with meat and poultry, fish that will be fried is often coated with breading or batter. This buffer helps keep the fish moist while creating a crisp outer layer.[2] However, deep frying battered fish adds energy density without nutritional benefits and is therefore inadvisable from a health perspective.[1] When pan frying, fish is often quickly fried to develop browning on the outside (usually the skin) and then finished in a hot oven to continue cooking the fish evenly throughout.[2] This is a less energy-dense option for frying fish and is preferred to deep frying. However, it is important to note that, as with grilling, the high temperature inherent in frying lends itself to carcinogen formation.

Roasting and baking fish helps prevent drying out because this method cooks the fish slowly due to the inefficient transfer of heat through air. As with meat and poultry, oven cooking allows for temperature control. At a higher temperature, whole fish is roasted with the skin on, while fillets of fish are usually baked at a slightly lower temperature. At even lower temperatures (as low as 200° to 225° F), the fish is warmed by the hot air and cooled by evaporation at the same time, so the fish never gets hotter than 120° to 130° F. This leaves it with a minimally cooked texture and reduces the incidence of carcinogen formation compared with hotter cooking techniques.[2]

While meat and poultry can either be hot or cold smoked, most fish are cold smoked. Fish is first smoked at a cooler temperature (85° F) to create a barrier so that the outside of the fish does not dry out, while allowing some overall moisture to release to create a denser piece of fish without having to actually cook it. The fish is then cold (90° F) or hot (150° to 170° F) smoked. When cold smoked, the fish has a delicate and raw texture, whereas hot smoked fish becomes dry and flaky.[2] Again, as with meat and poultry, smoking leaves unwanted carcinogenic deposits of PAHs on the surface of the fish.

Moist Cooking Methods

Moist cooking methods are more efficient at transferring heat than are dry cooking methods. With these methods there is less formation of carcinogens and vitamin loss but increased risk for drying out the fish too quickly. As such, these techniques are nutritionally desirable but culinarily challenging.[12] Simmering, poaching, and stewing are cooking methods that help control the level of heat transferred to the fish by altering the cooking liquid temperature. These methods usually use aromatics such as herbs, spices, and vegetables to impart flavor into the cooking liquid. However, because water is an extremely efficient way to transfer heat, the fish usually doesn't spend enough time in the cooking liquid to adopt any flavors from it.[2]

Steaming is an even more efficient means of transferring heat as the heat is transferred via steam. The short cooking time calls for thinner fish so that the fish can cook evenly in that small window. If the fish were thicker, the surface would overcook before allowing the rest of the piece to cook through. Fish can be steamed in a conventional steamer over the stove, or wrapped in parchment paper and put in the oven, a method known as *en papillote.* With *en papillote,* the heat creates steam that is captured in the package, thus cooking the fish. Aromatics can be used to flavor the fish by putting them in the steaming water, directly underneath the fish in the steamer, or in the parchment paper along with the fish.[2]

Though not a moist cooking method, microwaving also requires minimal cooking time. Microwaving only penetrates the first inch of the fish, but if the fish is only one or two inches thick, the electromagnetic waves can cook it evenly throughout.[2] Thus, steaming and microwaving are viable options for the right cut of fish, such as white fish. As with simmering, poaching, and stewing, steaming and microwaving don't produce carcinogens. While these cooking methods do not allow for enough time for the fish to absorb and develop flavor before drying out, adding sauces and complementary dish components can enhance their flavor profile.

Produce

There are myriad ways to prepare produce, many of which can have a direct impact on the nutritional profile of the food. Fruits and vegetables contain a variety of vitamins and minerals, both water soluble and fat soluble, as well as different plant pigments, or flavonoids, which provide antioxidant activity.

There are several variables that affect the nutrient content in cooked fruits and vegetables. Cooking time and cooking temperature are two key factors in addition to the inherent nutritional profile of the food. In some cases, the way the vegetable is prepared prior to cooking can also have an impact. Generally, water-soluble vitamins are the most sensitive to processing and cooking, whereas fat-soluble vitamins as well as minerals are more stable.

High cooking temperatures, prolonged cooking time, and exposure to light and oxygen can all negatively affect certain nutrients commonly found in fruits and vegetables. Cooking time and temperature as well as the preparation of the fruit or vegetable prior to cooking will affect the degree of the nutrient loss. For example, cooking techniques that require longer cooking times will result in increased nutrient losses, so the goal should be to keep cooking times as short as possible. This is most significant for foods rich in water-soluble nutrients including vitamin C, vitamin B12, thiamin, niacin, riboflavin, tryptophan, pantothenic acid, biotin, and folic acid.[2] However, it is important to note that while keeping the cooking time short is a priority, it is also best to minimize the surface area of the vegetable that is exposed to oxygen or heat as this will also affect the nutrient loss. For example, blanching diced vegetables for a short duration may result in greater nutrient losses in the cooking liquid than will steaming them whole for a longer duration.[2]

Similarly, peeling or dicing produce far in advance of cooking will result in increased nutrient loss due to increased surface area exposed to light and oxygen. One study documented a significant range of nutrient loss: vitamin C loss in precut fruit stored for six to nine days at 41° F ranged from <5% to 25% (mango, strawberry, and watermelon were at the lower range, whereas diced cantaloupe was at the higher range, followed by kiwi and pineapple). Carotenoid losses ranged from 0% to 25% (kiwi and watermelon were at the lowest range while pineapple was in the highest range, followed by cantaloupe, mango, and strawberries). No significant losses in phenolic compounds over the six days were documented.[13] The same study also concluded that despite these nutrient losses, the precut fruit would visually spoil prior to the onset of significant nutrient loss. Storage time is not just important for precut produce but also for whole produce, since transportation time can often near one week. Local produce harvested and quickly transported at their peak ripeness will generally contain more nutrients than will produce that has been harvested prematurely and held in storage for extended periods. For this reason, frozen vegetables may be preferred for out-of-season produce in some instances since produce is frozen within hours of being picked.

Plant pigments, flavor compounds, and nutrients are sensitive to heat. The goal during cooking is to create optimum texture and flavor without compromising nutritional content. While some nutrients will decrease during cooking, others may be enhanced.[14] One of the most sensitive nutrients to heat is vitamin C. However, cooking vegetables may increase their antioxidant capacity due to the change in chemical structures and better extraction of its compounds.[15] Consuming a variety of both raw and cooked vegetables will maximize nutrient intake.

Vegetables can be prepared using moist heat cooking methods or dry-heat cooking methods. The following section reviews the different cooking methods commonly used to prepare vegetables as well as their impact on nutritional content.

Moist Heat Methods

Boiling is an efficient method for cooking vegetables but can lead to nutrient losses in water-soluble vegetables; water-soluble nutrients are prone to leaching into cooking liquid. This is most frequently documented in regard to vitamin C, B-vitamins such as folate, and highly water-soluble minerals such as potassium. The degree of losses vary considerably for different foods; one study found more than 50% losses in folate for boiled spinach compared with 20%

losses in folate for boiled green beans.[16] Another study that looked at the effect of processing on cauliflower found that the highest loss was observed for water-blanched and water-boiled cauliflower (38.69% and 41.99%, respectively).[17] The loss of water-soluble nutrients is not related to the heat from the cooking process but rather from the direct loss into the water. The degree to which this occurs is dependent on the nutrient's solubility level in addition to the time the food item spends in the aqueous environment. For example, potassium, the most abundant mineral in vegetables, is extremely mobile and easily lost by leaching during boiling and blanching because of its high solubility in water. However minerals such as calcium and magnesium are generally more stable and not readily lost by leaching; they can even be taken up by vegetables during the cooking process.[18]

In contrast to water-soluble nutrients, fat-soluble nutrients such as carotenoids are hydrophobic and much more stable during moist cooking methods; cooking vegetables high in carotenoids may actually increase carotenoid bioavailability. Several studies show increases in carotenoid compounds after boiling as compared with their raw state.[19,20] For example, cooked tomatoes contain greater lycopene than fresh raw tomatoes, but if cooked too long, will start to deteriorate.

One way to mitigate nutrient losses of water-soluble vitamins during boiling is to add salt to the cooking water at about the concentration of seawater (3%, or 2 T per quart). This will speed the softening of the vegetables, decrease cooking time, and minimize the loss of the cell contents into the water.[2] Exercising care to not overcook vegetables is also important; cook vegetables just until tender and serve immediately or cool quickly by shocking in ice water to stop the cooking process.

Unlike green vegetables, starchy vegetables such as potatoes respond better in unsalted water and are best prepared in cold water that is gradually brought to a temperature just below boiling, rather than adding them directly to boiling water.[2] This promotes even cooking of the starchy vegetable and prevents an overcooked exterior and undercooked interior. In general, because some nutrient loss in the cooking liquid is inevitable while boiling, reserve the cooking liquid and use in another application, such as a soup or sauce, so that those nutrients are still consumed.

Steaming and *sous vide* are the ideal moist-cooking methods for cooking vegetables high in water-soluble nutrients. Steaming is an excellent method for cooking vegetables at boiling point but without exposing them directly to turbulent boiling water that can leach out flavor and nutrients.[19] Evenness of cooking can be a challenge unless vegetables are arranged in a single layer or are loose enough that steam can pass between them. Typically, steaming does not enhance flavor; however, it is possible to add aromatics such as herbs, spices, and citrus, into the cooking water so the steam can give off an aroma that is then imparted into the food. Steaming does not allow for any control of the salt content, but it does promote better nutrient preservation overall than does boiling. There will still be some nutrient losses related to the exposure to heat, however, so care should still be taken to not overcook vegetables.

Sous vide is optimal for both infusing flavor and retaining nutrients. The *sous vide* reduced-oxygen packaging prevents the loss of moisture and concentrates flavors. Because of the

concentration effect, this method requires less added salt to achieve the desired flavor, resulting in lower sodium content overall and providing an opportunity to infuse strong flavors through herbs and spices without any adverse health effects.[1] This method also requires little or no added fat. Because with the *sous vide* technique food is cooked at lower temperatures and does not come into contact with water, any sensitive vitamins and minerals are well preserved.[21] It should be noted that using aromatics such as onion, garlic, and celery will not flavor the food as they do in conventional cooking because the temperature is too low to soften the starches and cell walls. *Sous vide* also reduces growth of any aerobic bacteria but does create an environment for anaerobic bacteria such as *Clostridium botulinum*, so safe food handling practices, particularly cooking food to its proper internal temperature, need to be followed at all times.[1]

Pressure cooking can be a useful method because it cooks vegetables very quickly, minimizing the negative effects outlined above from prolonged cooking times; however, it can easily lead to overcooking so should be monitored closely.

Dry Heat Methods

Dry heat cooking methods are ideal for cooking vegetables when browning and deeper flavors are desired.

Baking vegetables can be a good method for concentrating and intensifying flavor, but consideration needs to be given to the cooking time, which is much longer than that of other cooking preparations such as boiling—it takes longer for the heat to penetrate the food. Convection ovens speed cooking by circulating the hot air more rapidly. Coating vegetables with oil can also speed the cooking process because the heat the oil absorbs from the oven gets transferred directly to the vegetable and raises its temperature. Oil also promotes greater browning, which positively influences flavor; browning cannot be achieved through moist cooking methods.[2]

Roasting, which is essentially baking at a higher temperature, will decrease cooking time, result in greater browning, and produce more concentrated flavors, but caution should always be used when heating oil at high temperatures to ensure that the oil does not exceed its smoke point; this can then lead to the formation of potentially harmful free radicals. Free radicals are produced when oils are continuously oxidized by high temperatures such as during deep frying.[1]

Frying is most commonly used for starchy vegetables such as potatoes, but is also used for nonstarchy vegetables, with batter (eg, tempura battered broccoli) or without (eg, deep-fried brussels sprouts). The typical temperature involved in frying ranges between 300° and 375° F. The oil needs to be hot enough to sizzle when the food is added but not hot enough to smoke. If the temperature of the oil is too low, the food will absorb too much oil and become greasy, increasing its energy density. If the oil is too hot, it can smoke and form carcinogenic compounds.[22] Smoke points differ among cooking oils, so it is important to note the smoke point of the oil prior to using it for frying. Furthermore, the phenolic compounds in the oil will start to break down if frying oil is saved and reused multiple times, decreasing any nutritional benefit it had prior to heating.[23] If oil must be reused, carefully monitor temperature, and do not

use more than two or three times. In addition to oil absorption and increased energy density, deep frying can also have an effect on the nutrient content of the item being fried. For example, foods high in heat-sensitive nutrients such as vitamin C will deteriorate and there will be some loss of fat-soluble vitamins into the cooking oil, just as water-soluble nutrients leach into cooking water during boiling.

Stir frying, when done properly, is a quick method of cooking vegetables since it involves high heat. If vegetables are diced to an appropriate size, the cooking oil is hot enough, and the pan is not overcrowded, vegetables should only take about a minute to cook, but this method requires constant stirring to prevent burning. It's essential to preheat the pan prior to adding the oil, then add the vegetables almost immediately after adding the oil to the hot pan; otherwise, the oil can get too hot and start to smoke, potentially forming carcinogens. Because this is such a rapid cooking technique, it is a good method for retaining nutrients and color.[2]

Grilling can be a healthy cooking method for produce. The most important factor is the degree of browning, which depends on how close the food is to the source of heat and the cooking time. As with baking, coating fruits and vegetables in oil will speed the cooking process and browning and also improve flavor. If food becomes charred as a result of flame grilling or flareup, HCAs may form as they do during grilling of meat. Vegetables and fruit, however, appear to bind HCAs in the digestive tract, preventing them from causing damage.[2] PAHs, however, may still be formed from any organic matter that burns and creates smoke, such as wood or fat. Furthermore, the high heat from grilling will decrease the less stable nutrients such as vitamin C. However, the benefits of increased intake of fruits and vegetables as a result of enhanced flavor during grilling may outweigh the potential risks from the grilling process.

Broiling in an oven is almost identical to grilling but the temperature is easier to control and there is less smoke compared with grilling. However, if vegetables are broiled for an extended period of time and fat is heated beyond its smoke point, there is still potential for carcinogens to form.

Lastly, when applying heat to certain foods that contain the amino acid asparagine, there is the potential to form the carcinogen acrylamide. Asparagine is found in a variety of foods but is particularly high in potatoes. Acrylamide is formed when the food is heated above 248° F.[24] Though frequently associated with fried potatoes, acrylamide can also form during baking and roasting as these cooking temperatures exceed 248° F. Longer cooking times also increase acrylamide production.[25] While the National Cancer Institute states that moist heat cooking methods such as boiling and microwaving have shown to be less likely to promote acrylamide formation, one study found the microwaving actually produced more acrylamide compared with roasting or frying.[24,25]

Microwaving

Microwave cooking, although more often used for reheating purposes, is one of the most effective methods of preparing vegetables to minimize nutrient losses. An exception should be noted regarding the concern over acrylamide formation when cooking potatoes; however, microwaving requires minimal added cooking liquid and is highly efficient. For optimum

microwave cooking, enclose vegetables in an almost steam-tight container along with a small amount of water so that the vegetables retain their moisture and nutrients.

Puréeing

Although not one of the traditional cooking methods, making a fruit and vegetable purée is a versatile cooking method that can be incorporated into myriad applications. To create a purée, a fruit or vegetable is cooked until completely soft either by boiling, steaming, or sweating (cooking the fruit or vegetable over low heat in a small amount of fat). The cooked fruit or vegetable is then blended until completely smooth. In this process, the plant's cell walls are broken apart, increasing the bioavailability of their nutrients.[15]

The goal when cooking vegetables is to create optimum texture and flavor without compromising nutritional content. As illustrated in this section, some nutrients will deteriorate during cooking while others may be enhanced. Losses during cooking can be mitigated by minimizing cooking time and the use of excessive amounts of cooking fat or liquid that could promote nutrient leaching. Consuming highly browned or blackened produce does not present the same risk associated with meat; however, it should still be limited due to some formation of carcinogens and potential deterioration of heat-sensitive nutrients. Thus, consuming a variety of both raw and lightly cooked foods will maximize nutrient intake.

Putting It Into Practice

As this paper has shown, the intersection of nutrition and cooking can be a complex topic. There are myriad factors to consider when trying to get the most out of food, both from a flavor and nutrition standpoint. It begins with choosing healthy ingredients and then matching these ingredients with the appropriate preparation and cooking techniques to enhance the food's nutritional value and maximize taste. RDs can impart this information to their clients to empower them with the confidence to nourish themselves in the best way possible. This knowledge is not only useful when preparing food at home but also when dining out at a restaurant. Understanding the nuanced differences between cooking techniques that are being used in various dishes can make a significant impact on personal health. Knowledge is power. Knowing what foods to eat is only half of it; knowing what to do with those foods is the rest.

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Quiz

1. Which of the following has the least impact on nutrient loss in produce prior to cooking?
A. Peeling
B. Freezing
C. Dicing
D. Prolonged storage time

2. Which mineral is most easily lost when boiling or blanching produce?
A. Calcium
B. Magnesium
C. Potassium
D. Iron

3. What concentration should the salt content of the cooking water be to mitigate the loss of water-soluble vitamins during boiling or blanching?
A. 0.5%
B. 3%
C. 5%
D. 10%

4. Which cooking method for vegetables is optimal for flavor and nutrient retention?
A. Sautéing
B. Boiling
C. Steaming
D. *Sous vide*

5. What is the most significant health concern when preparing produce with fat using a high-heat cooking method such as grilling or frying?
A. Increased energy density
B. Accumulation of polycyclic aromatic hydrocarbons (PAHs)
C. Accumulation of heterocyclic amines (HCAs)
D. Loss of fat-soluble nutrients

6. What is the most significant health concern with respect to smoked meats?
A. Increased phytochemical concentration
B. Accumulation of PAHs
C. Accumulation of HCAs
D. Heavy metal contamination

7. Fish that are higher on the food chain or shellfish that are filter feeders from contaminated water tend to have higher concentration of which potentially unhealthy substance?
A. Mercury
B. Carcinogens
C. Fat
D. Sodium

8. Which cooking method helps turn the collagen of tougher cuts of meat into gelatin?
A. Braising
B. Smoking
C. Grilling
D. Microwaving

9. Why is cooking fish in water not ideal for transferring flavor to the fish?
A. Because water transfers heat so quickly, the fish gets cooked too quickly to absorb the aromatics added to the water.
B. Water molecules block the aromatics from imparting their flavors to the fish.
C. The water dilutes the flavor of the aromatics.
D. The flavor of the fish overpowers the flavor of the aromatics.

10. Which of the following cooking combinations produces the least carcinogens?
A. Low heat, low temperature
B. High heat, low temperature
C. Low heat, high temperature
D. High heat, high temperature