Can Food Processing Enhance Cancer Protection?

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Food processing can be defined as the transformation of raw ingredients into food or of food into other forms. This review summarizes an American Institute for Cancer Research symposium that addressed the question of what is known about food processing in relation to cancer risk. To approach this question, it is valuable to understand something about the evolutionary history of food processing as well as the broad range of commonly utilized industrial/home processing technologies. Nutr Today. 2014;49(5):230–234

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On the surface, one might think that food processing is a modern application of technology to preserve food. Whereas our ancestors had little knowledge about microbial contamination and spoilage of food, they figured out the utility of sun drying, fermentation, and preservation with salt to extend their food supply to periods of need. For most of our forbearers, hunger was a daily challenge to overcome. In their classic textbook, *Food Technology*, Prescott and Proctor[1] noted that "the growth of towns and cities involved larger need (for food) and new difficulties in storage and transportation… gradually transforming food production from an occupation to a business." The foundations of the canning industry were developed by Appert in France in the early 19th century even before Pasteur began to elucidate the bases of microbiological spoilage of foods. With electricity came refrigeration and extension of shelf-life for perishable foods, followed by further shelf-life extension with development of frozen foods.

Does processing destroy nutrients or preserve them? Some nutrients, such as vitamin C, are known to be significantly lost during cooking, whereas absorption of others, such as the pro–vitamin A carotenoids, are enhanced by heating with oil. Some foods, including many meats, form unhealthy or even carcinogenic products with high heat or fermentation. Many more are rendered safe from bacterial contamination during processing. Nutritionists and food scientists are working together to provide safe processed foods with optimized nutritional value.

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Today, modern food processing operations include some of the older technologies plus some newer ones. These include fermentation (with and without salt), dehydration (sun, spray drying, freeze drying, hot air, etc), freezing and cooling, many forms of thermal processing, and various separation techniques (milling, membrane, centrifugation, etc). There are many benefits from these techniques including protection from microbial and chemical hazards, availability of an array of foods year around, reduction of spoilage, and of course convenience. Could there be drawbacks? Yes, of course, as one considers the components of those foods (excess calories, salt, fat, or sugar) or use of excess heat, whether the food is purchased from the manufacturer, a foodservice establishment or overheated on the grill at home, for example. On the other hand, some nutrients and health-promoting compounds may be more available after processing. This review article investigates both the potential benefits and the drawbacks to use of some types of food processing, specifically related to potential impact on cancer risk.

RETENTION AND BIOACCESSIBILITY OF BIOACTIVE FOOD COMPONENTS

Different processing procedures are used to convert raw materials into final food products that are acceptable for consumption and are easily digestible. For example, heating of vegetables can soften plant tissue and destroy naturally occurring degradation enzymes, but at the same time, excess heat can thermally degrade some important micronutrients. It is of crucial importance that micronutrients and bioactives (eg, vitamin C, folates, carotenoids, anthocyanins, etc) are both maximally retained during processing and storage and are maximally accessible during digestion (bioaccessible). The goal is to optimize nutrient uptake by the human body (bioavailability). The concern is the stability, and in some cases the chemical form, of highly bioaccessible water-soluble micronutrients (eg, vitamin C) or the stability, chemical form, and accessibility to lipid-soluble micronutrients (eg, vitamin A).[2]

Water-Soluble (Hydrophilic) Micronutrients. For water-soluble micronutrients, there are well-documented examples of both positive and negative roles of processing: (i) the influence of processing conditions on maintaining vitamin C (eg, protection against enzymatic degradation due to the presence of ascorbate oxidase, or oxidative and nonoxidative breakdown) highlighting the importance of processing—and even the sequence of processing steps (eg, thermal processing prior to or after mechanical disintegration) and the presence of oxygen during processing; (ii) the enzymatic conversion of folates (from nonabsorbed polyglutamate to bioavailable monoglutamate) during processing due to the action of γ-conjugase[3] and (iii) maintaining conversion of glucosinolates to bioactive isothiocyanates during processing, due to protection of the active enzyme myrosinase in broccoli and other *Brassica*.

Lipid-Soluble (Lipophilic) Micronutrients. Carotenoids represent an interesting category of lipid-soluble micronutrients. Nutritional studies have shown that the mechanism of uptake follows the same digestive route as lipids and that carotenoids need to be incorporated into micelles within the gastrointestinal tract to facilitate absorption. This means that the processing of carotenoid-containing raw materials into foods for final incorporation of carotenoids into micelles during digestion should be designed to minimize barriers limiting this transfer.

The choice of raw materials and subsequent processing steps plays a key role in both the carotenoid profile at the moment of intake and the bioaccessibility later, during digestion. The raw materials create the starting point in terms of amount, physical state, and type of carotenoids and their isomers. Mechanical processing (eg, blending, high-pressure homogenization[4]) will have an effect on the natural barriers to accessibility related to the chromoplast structure and the cell wall properties.[5] Thermal processing may lead to possible carotenoid breakdown and isomerization[6] as well as changes in cell wall polysaccharides, in particular pectin changes. These concerted changes will lead to an overall balance of bioaccessible carotenoids.[7] The addition of certain food ingredients, in particular lipids, during processing and/or digestion[8] can strongly influence the location of the carotenoids in the food matrix (eg, transfer of carotenoids to the lipid phase and finally incorporation into micelles during digestion, which is necessary for optimal bioavailability). From these examples, it is clear that the interplay of raw materials, food ingredients, and processing becomes a crucial factor influencing the amount, profile, and bioaccessibility of carotenoids and therefore the final health-promoting effects of carotenoid-containing foods as part of our diet.[9]

The available information is far from complete, but there is sufficient foundational knowledge for food technologists to fine tune processing parameters, maximizing the health benefit of carotenoid-containing food systems.[10] This requires continuous dialogue between food technologists and nutritionists to deliver food systems with optimal health characteristics. Improved integration of these fields of expertise will allow targeted processing of foods for specific health-related functional properties.

PROCESSING OF CRUCIFERS TO RETAIN OPTIMAL BIOACTIVITY

Epidemiologic studies show that eating 3 to 5 servings of cruciferous vegetables per week can decrease risk for many different cancers, by 30% to 50%.[11] Cruciferous vegetables contain a family of uniquely effective cancer preventive compounds termed *glucosinolates*. Although glucosinolates have no direct health effects, upon crushing or chewing cruciferous vegetables, such as broccoli, the glucosinolates come into contact with the plant enzyme myrosinase and release bioactive isothiocyanates, including sulforaphane. Heat processing, through industrial blanching before freezing or through home cooking, can destroy the myrosinase, so that we must rely on bacterial enzymes in the gut to release sulforaphane, but for most people, the gut releases only about 10% of the potential sulforaphane.[12] If broccoli is steamed for 3 to 5 minutes, rather than boiled or microwaved, the enzyme is protected, and sulforaphane is released for absorption.[13]

An alternative option for ensuring that the enzyme is present in your meal is to include in the meal a second, uncooked, source of the enzyme such as stone-ground mustard, whole mustard seeds, coleslaw, red radish, or arugula salad. Only a small amount of the raw vegetable is needed: Dosz and Jeffery[14] added 0.25% by weight dried daikon radish to frozen broccoli that had been cooked in the microwave, and 100% of the available sulforaphane was released. They carried out a small study showing that if men ate a processed broccoli product similar to a broccoli supplement, which had no myrosinase, very little sulforaphane was absorbed into their blood. In contrast, if they ate fresh broccoli sprouts, a substantial amount of sulforaphane was absorbed. Furthermore, when they ate the 2 products at the same meal, myrosinase from the sprouts was able to release sulforaphane from the powder that contained glucosinolates but no myrosinase.[12]

If garlic is not crushed before cooking, heat processing inactivates alliinase enzymes, changing the flavor, limiting the production of bioactives and limiting the health benefits.[15] We have grown accustomed to crushing garlic before cooking, which overcomes this. Until processors develop a way to protect myrosinase during cooking of broccoli, we need to learn to steam broccoli for only 3 or 4 minutes to protect the myrosinase enzyme until we crush/chew the cooked broccoli. Alternatively, we can add another source of the enzyme, an uncooked brassica, to the meal for full benefit of this cancer-fighting vegetable.

PROCESSING OF MEAT TO MINIMIZE FORMATION OF CARCINOGENS

Meat intake has been associated with an elevated risk of several chronic diseases, including cancers of the colorectum, stomach, esophagus, prostate, breast, and pancreas,[16] as well as all-cause mortality.[17] There are several plausible biological mechanisms potentially underlying an association between meat consumption and cancer, including components of meat or mutagens associated with meat preservation or preparation.

Meat Preservation—Processed Meats. Curing meat by adding salt, nitrate, or nitrite or by smoking has been a method of preservation, or processing, for many years. Nitrate or nitrite is added to some processed meats as antibacterial agents and to produce the characteristic red-pink color of cured meats; however, they are also known precursors of *N*-nitroso compounds (NOCs), which can be formed within meat treated with nitrate or nitrite.[18] *N*-nitroso compounds are powerful chemical carcinogens, and therefore even small amounts in the human body could be important. In addition, meat that is smoked is known to contain polycyclic aromatic hydrocarbons (PAHs), some of which are carcinogenic in animal models.

An extensive review of the epidemiologic literature indicates that the evidence is "convincing" for a positive association between processed meat and colorectal cancer and "probable" for salted fish and nasopharyngeal cancer.[16] Although there is limited evidence for a similar consensus for other cancers, numerous individual studies have identified positive associations between processed meat and cancers of the brain, oral cavity, larynx, pancreas, and prostate, for example. For specific processing procedures, the evidence is limited, but studies have also implicated salted meats and smoked meats in gastric cancer, as well as NOC intake from processed meats in colorectal cancer. Reducing any risks associated with processed meat involves limiting the consumption of this meat type. However, the formation of NOCs also can be reduced by the addition of ascorbic acid to the processing procedure, which is common practice in the United States.

Meat Preparation

In addition to processing procedures carried out before the meat reaches the consumer, the way meat is prepared at home may influence the associated risks. Meat that is cooked well done by high-temperature cooking methods contains both heterocyclic amines (HCAs) and PAHs,[19] both of which have shown carcinogenicity in animal models. Meat cooked well done or by high-temperature cooking methods has been associated with an increased risk of cancers of the colorectum, lung, bladder, pancreas, and prostate.

Some epidemiologic studies have estimated individual HCA and PAH intake by linking detailed questionnaires with cooking information to a HCA and PAH database developed by the US National Cancer Institute. Using these data, specific HCAs have been positively associated with cancer at several sites, including the colorectum, pancreas, and prostate. The formation of HCAs can be reduced by decreasing the heat and the length of cooking, or by preheating meat in the microwave, which removes the creatine needed for formation of HCAs to occur. In addition to being found in smoked foods, PAHs are formed in grilled/barbecued meat as the meat juices drip onto the hot fire, yielding flames containing a number of PAHs, which adhere to the surface of the meat. Epidemiologic studies of PAHs from meat in relation to cancer have reported increased risks of colorectal adenoma and pancreatic cancer.

In conclusion, meat can be a source of several carcinogens, depending on processing and preparation methods. Nevertheless, the intake of potential carcinogens from meat can be minimized if processed meat intake is limited and if meat is not cooked very well done or by high-temperature cooking methods.

EFFECTS OF FERMENTATION OF FOODS

Fermentation is one of the oldest methods of food preservation, and fermented foods are an important part of the diets of many populations worldwide. Nutritionally, fermentation can improve digestibility by hydrolyzing inedible components and can make inedible foods edible by metabolizing/destroying antinutritional factors and toxins. Some fermented foods are also sources of live microbes introduced during the fermentation process.

Pickling (ie, fermenting in water with or without salt) is widely used to preserve vegetables. Several meta-analyses of studies in populations habitually consuming large amounts of pickled vegetables (eg, Japan, Korea, China) suggest that high intakes of pickled vegetables may increase risk of esophageal and gastric cancer,[20,21] and fermented soy foods may increase gastric cancer risk.[22] Cantonese-style salted fish, dried outdoors under lower than usual salt conditions and subject to fermentation, is a probable cause of nasopharyngeal cancer,[23] although fish preserved by other pickling methods have not been associated with risk of this cancer. The association between pickled foods and risk of cancer has been attributed in part to the high levels of nitrate and nitrosamines generated during fermentation. These react to form carcinogenic NOCs, but formation can be slowed with vitamins C and E. Experimental studies in nonhuman primates suggest that *Helicobacter pylori* infection and NOCs in pickled foods may synergistically induce gastric cancer. Fermented dairy products containing live microbes (eg, yogurt or cheeses such as camembert with a bloomy rind) may impart additional benefit beyond milk in relation to bladder cancer, at least in part due to the presence of lactic acid bacteria.[24,25]

Identifying the contribution of fermented foods in general or particular fermented foods specifically to cancer risk is challenging. Fermented foods as a group include a wide variety of foods. They are not consumed in isolation, and cuisines high in some types of fermented foods also include other foods that may be considered healthy or less healthy. Future observational studies might benefit from distinguishing more explicitly between different types of fermented foods, and more mechanistic studies are needed to follow up on epidemiologic findings.

CONCLUSIONS

This symposium addressed what is currently known about the benefits and drawbacks to some food processing procedures, specifically as processing techniques potentially impact cancer risk. There are many benefits to food processing, including protection from microbial and chemical hazards, availability of an array of foods year around, reduction of spoilage, improved digestibility, and of course convenience. Heating of foods is critical for protection against microbiological hazards such as pathogens and for enhancing the digestibility, bioaccessibility, and bioavailability of nutrients and anticarcinogens from foods. However, excessive heating may destroy some vitamins and bioactives particularly in fruits and vegetables or create carcinogens in meats. In order to reduce cancer risk, it is recommended, for example, that meats not be cooked well done or with very high temperatures.

To maximize the health benefits of certain foods, and to reduce the health risk of other foods, it is imperative that we continue to study the effects of processing and cooking procedures whether the foods are processed by the food industry or prepared at home or in foodservice establishments. We have discussed the effects of heat processing on plant enzymes and the effect of high temperatures when cooking meat. In addition, preservation by some forms of fermentation or by the use of some additives, such as nitrate or nitrite, can lead to the formation of potentially carcinogenic compounds, whereas addition of other live bacteria to fermented products such as yogurt may support the gut in providing anticarcinogens to the body. Continuous dialogue between food technologists and nutritionists is necessary to deliver foods processed for optimal health.

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ROOM FOR IMPROVEMENT IN ELEMENTARY SCHOOLCHILDREN'S LUNCHES AND SNACKS FROM HOME

Open a child's lunch box and you're likely to find that the lunches and snacks inside fall short of federal guidelines. The researchers used digital photography to document the lunches and snacks of more than 600 Massachusetts third and fourth graders in 12 schools in 6 public school districts. They compared student's lunch and snack items to federal National School Lunch Program (NSLP) and Child and Adult Food Care Program (CAFCP) standards, respectively. They found that only 27% of the lunches met at least 3 of the 5 NSLP standards, and only 4% of snacks met at least 2 of the 4 CAFCP standards, both of which emphasize fruits, vegetables, whole grains, and low-fat or nonfat dairy. The findings highlight the challenges families face that are associated with packing healthful items to send to school. The researchers found the few existing studies on packed lunches report that children who bring their lunch tend to consume fewer fruits and vegetables, less fiber, and more total calories at lunch than do those who participate in the National School Lunch Program. The researchers also found considerable room for improvement in school snacks. Hubbard and colleagues found that a typical snack consisted of 1 or more sugar-sweetened beverages paired with a packaged snack food or dessert. The current study evaluated 1 day's worth of lunches and snacks in 12 schools. The researchers acknowledge the need for larger studies of more diverse groups of students over an extended period. This study points to the need to help parents find ways to build nutrition into the packed-lunch routine. The researchers acknowledge that this is a challenge that will require creative approaches to packing lunch boxes with affordable, easy-to-prepare, and healthy options while creating a demand for these options among children.

Source: Hubbard KL, Must A, Eliasziw M, Folta SC, Goldberg J. What's in children's backpacks? Foods brought from home. J Acad Nutr Diet. In press, corrected proof. July 17, 2014. doi: 10.1016/j.jand.2014.05.010.

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