

Chemicals in Meat Cooked at High Temperatures and Cancer Risk

Key Points

- Heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs) are chemicals formed when muscle meat, including beef, pork, fish, and poultry, is cooked using high-temperature methods, such as pan frying or grilling directly over an open flame (see Question 1).
- The formation of HCAs and PAHs is influenced by the type of meat, the cooking time, the cooking temperature, and the cooking method (see Question 2).
- Exposure to high levels of HCAs and PAHs can cause cancer in animals; however, whether such exposure causes cancer in humans is unclear (see Question 3).
- Currently, no Federal guidelines address consumption levels of HCAs and PAHs formed in meat (see Question 4).
- HCA and PAH formation can be reduced by avoiding direct exposure of meat to an open flame or a hot metal surface, reducing the cooking time, and using a microwave oven to partially cook meat before exposing it to high temperatures (see Question 5).
- Ongoing studies are investigating the associations between meat intake, meat cooking methods, and cancer risk (see Question 6).

1. What are heterocyclic amines and polycyclic aromatic hydrocarbons, and how are they formed in cooked meats?

Heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs) are chemicals formed when muscle meat, including beef, pork, fish, or poultry, is cooked using high-temperature methods, such as pan frying or grilling directly over an open flame (1). In laboratory experiments, HCAs and PAHs have been found to be mutagenic—that is, they cause changes in DNA that may increase the risk of cancer.

HCAs are formed when amino acids (the building blocks of proteins), sugars, and creatine (a substance found in muscle) react at high temperatures. PAHs are formed when fat and juices from meat grilled directly over an open fire drip onto the fire, causing flames. These flames contain PAHs that then adhere to the surface of the meat. PAHs can also be formed during other food preparation processes, such as smoking of meats (1).

HCAs are not found in significant amounts in foods other than meat cooked at high temperatures. PAHs can be found in other charred foods, as well as in cigarette smoke and car exhaust fumes.

2. What factors influence the formation of HCA and PAH in cooked meats?

The formation of HCAs and PAHs varies by meat type, cooking method, and “doneness” level (rare, medium, or well done). Whatever the type of meat, however, meats cooked at high temperatures, especially above 300°F (as in grilling or pan frying), or that are cooked for a long time tend to form more HCAs. For example, well done, grilled, or barbecued chicken and steak all have high concentrations of HCAs. Cooking methods that expose meat to smoke or charring contribute to PAH formation (2).

HCAs and PAHs become capable of damaging DNA only after they are metabolized by specific enzymes in the body, a process called “bioactivation.” Studies have found that the activity of these enzymes,



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which can differ among people, may be relevant to cancer risks associated with exposure to these compounds (3–5).

3. What evidence is there that HCAs and PAHs in cooked meats may increase cancer risk?

Studies have shown that exposure to HCAs and PAHs can cause cancer in animal models (6). In many experiments, rodents fed a diet supplemented with HCAs developed tumors of the breast, colon, liver, skin, lung, prostate, and other organs (7–12). Rodents fed PAHs also developed cancers, including leukemia and tumors of the gastrointestinal tract and lungs (13). However, the doses of HCAs and PAHs used in these studies were very high—equivalent to thousands of times the doses that a person would consume in a normal diet.

Population studies have not established a definitive link between HCA and PAH exposure from cooked meats and cancer in humans. One difficulty with conducting such studies is that it can be difficult to determine the exact level of HCA and/or PAH exposure a person gets from cooked meats. Although dietary questionnaires can provide good estimates, they may not capture all the detail about cooking techniques that is necessary to determine HCA and PAH exposure levels. In addition, individual variation in the activity of enzymes that metabolize HCAs and PAHs may result in exposure differences, even among people who ingest (take in) the same amount of these compounds. Also, people may have been exposed to PAHs from other environmental sources, such as pollution and tobacco smoke.

Nevertheless, numerous epidemiologic studies have used detailed questionnaires to examine participants' meat consumption and meat cooking methods to estimate HCA and PAH exposures. Researchers found that high consumption of well-done, fried, or barbecued meats was associated with increased risks of colorectal (14), pancreatic (15, 16), and prostate (17, 18) cancer.

4. Do guidelines exist for the consumption of food containing HCAs and PAHs?

Currently, no Federal guidelines address the consumption of foods containing HCAs and PAHs. The World Cancer Research Fund/American Institute for Cancer Research issued a report in 2007 with dietary guidelines that recommended limiting the consumption of red and processed (including smoked) meats; however, no recommendations were provided for HCA and PAH levels in meat (19).

5. Are there ways to reduce HCA and PAH formation in cooked meats?

Even though no specific guidelines for HCA/PAH consumption exist, concerned individuals can reduce their exposure by using several cooking methods:

- Avoiding direct exposure of meat to an open flame or a hot metal surface and avoiding prolonged cooking times (especially at high temperatures) can help reduce HCA and PAH formation (20).
- Using a microwave oven to cook meat prior to exposure to high temperatures can also substantially reduce HCA formation by reducing the time that meat must be in contact with high heat to finish cooking (20).
- Continuously turning meat over on a high heat source can substantially reduce HCA formation compared with just leaving the meat on the heat source without flipping it often (20).
- Removing charred portions of meat and refraining from using gravy made from meat drippings can also reduce HCA and PAH exposure (20).

6. What research is being conducted on the relationship between the consumption of HCAs and PAHs and cancer risk in humans?

Researchers in the United States are currently investigating the association between meat intake, meat cooking methods, and cancer risk. Ongoing studies include the NIH-AARP Diet and Health Study (14, 21), the American Cancer Society's Cancer Prevention Study II (22), the Multiethnic Cohort (23), and studies from Harvard University (24). Similar research in a European population is being conducted in the European Prospective Investigation into Cancer and Nutrition (EPIC) study (25).

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