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REVIEW ARTICLE

Effects of Fumes Inhaled from Cooked Meat

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Abstract

Since 2015, the World Health Organization has regarded the ingestion of processed meat as a definite carcinogen and red meat as a probable carcinogen, basing their recommendations on studies showing an increased risk of colorectal cancer. The findings have led many to limit their ingestion of red and processed meat. Over the past several decades, a growing body of literature has formed regarding the possible harmful, if not carcinogenic, effects of fumes emanating from cooked meat on humans. In this article, we discuss the evidence available on the subject.

Keywords

Fumes, Cooked meat, Cancer

Introduction

Since 2015, the World Health Organization has regarded the ingestion of processed meat as a definite carcinogen and red meat as a probable carcinogen, basing their recommendations on studies showing an increased risk of colorectal cancer [1]. The findings have led many to limit their ingestion of red and processed meat. Over the past several decades, a growing body of literature has formed regarding the possible harmful, if not carcinogenic, effects of fumes emanating from cooked meat on humans. In this article, we discuss the evidence available on the subject.

Carcinogenicity of Ingested Meat

The strongest evidence for the carcinogenicity of ingested meat is with colorectal cancer. Colorectal cancer is the third most prevalent cancer globally, accounting for 10% of all global cancer diagnoses [2]. Colorectal cancer is considered to be a lifestyle cancer, with only 5% of diagnoses being attributed to inherited genetic mutations while 80% are secondary to diet [3,4]. In 2015, a group, the International Agency for Research on Cancer (a cancer-specific agency of the WHO), of 22 experts from 10 countries reviewed more than 800 epidemiologic studies to find evidence that processed meat causes colorectal cancer [1]. The same group labeled red meat as "probably carcinogenic". A meta-analysis of cohort studies revealed an 18% increased risk for colorectal cancer for every 50 g of processed meat ingested and a 17% increase for every 100 g of red meat ingested per day.

The postulated mechanisms for carcinogenicity of red and processed meat are numerous and may be related to the presence of heme, heterocyclic amines (HCAs), polycyclic aromatic hydrocarbons (PAHs), N-glycolylneuraminic acid, and N-nitroso compounds [5]. We limit our discussion to HCAs and PAHS as these are also the best studied compounds in fumes of cooked meat.

HCAs are organic molecules with at least one heterocyclic ring- a ring comprised of at least two different elements-and one amine group. HCAs are known mutagens, or agents capable of causing DNA damage, that form in meat cooked at high temperatures, especially above 150 °C, by pyrolysis of creatine with specific amino acids [6,7]. Although other factors are necessary in the production of HCAs, they are commonly created in large quantities when meat is grilled, fried, broiled, or barbecued above this temperature [8]. The most abundant HCAs found in cooked meat are amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP) and 2-amino-3,8-dimethyl imidazo[4,5-f]quinoxaline (MeIQx), and both have been classified as "possibly carcinogenic" [9,10]. Another compound, known as 2-amino-3-methylimidazo[4,5-f]quinoline, has been

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classified as "probably carcinogenic" [10]. Altogether, over 25 HCAs have been found in meat cooked at high temperatures in contrast to nearly negligible amounts in other foods [9].

PAHs, hydrocarbons forming two or more aromatic rings, are also formed at high temperatures during the incomplete combustion of organic substances [11]. They can be found in the fumes during the incomplete burning of fossil fuels, garbage, tobacco, and wood [12]. During cooking, PAHs attach to the surface of the meat and are then ingested. PAHs also form when meat is exposed to smoke or is charred [11]. The main sources for PAHs for humans are from cooked (grilled, roasted, or fried) or smoked meat and fish, especially when barbecued, and tobacco smoke [13,14]. When meat is barbecued, PAH levels can reach 130-13,000 times as high as uncooked foods [15]. The best studied PAH in meat is benzo[a]pyrene, which is classified as a known carcinogen, whereas 15 other PAHs have been classified as "probable" or "possible carcinogens" [10,16].

Carcinogenicity of Fumes Inhaled from Cooked Meat

Workers exposed to industrial airborne PAHs have been reported to have an increased risk of lung, skin, and bladder cancer [12]. Workers most vulnerable are those exposed to diesel exhaust, iron and steel foundries, fossil fuel processing, road paving, chimney sweeping, and carbon black production. Even though these workers are exposed to other chemicals with the PAHs, the increases risk of cancer "is not likely to be due to other carcinogenic exposure present in the same industries" [12].

The carcinogens in cooked meat, like HCAs and PAHs, are also found in the fumes emanating from the cooking process [17,18]. These fumes can persist in the air and deposit on adjacent surfaces, like kitchen walls and fans, ultimately affecting indoor air quality and the health of those inhaling these substances [17]. Aerosol emissions from cooked meat have been measured at 40 g per kg of cooked meat, creating the opportunity for significant exposure [19].

The presence of PAHs and HCAs in cooked meat fumes may be why cooks have an increased risk of certain cancers, including those of the lung and bladder [20-22]. Other studies using different populations have shown a similar association between cooks and respiratory cancers [23]. As such, researchers have been concerned about airborne carcinogens from the cooking of meat since at early as 1995 [18].

HCAs and PAHs have been found in the smoke condensates of beef, pork, chicken, and fish [18,24-26]. By comparison, the fumes produced from cooking soy-based products did not have any mutagenic properties [18]. Those most at risk are workers who are cooking meat indoors, which can increase the amount of carcinogenic particles deposited into the lung by 10 times compared to those cooking meat outdoors [27]. However, those outside are also exposed to significant quantities of PAHs. In one study, researchers measured the particulate matter in the surrounding air from exhaust pipes of restaurants cooking meat in Taiwan and the United States [28]. Higher levels of PAHs were detected in the air surrounding the restaurants. Using a probabilistic risk model, researchers showed that those living in these areas were at increased risk of cancer over a lifetime and that those with more exposure had a higher risk.

Taiwanese and Chinese researchers have been interested in fumes from meat due to the high rates of lung cancer in their countries, which is incompletely attributed to smoking based on epidemiologic studies. In one study, Taiwanese researchers took fumes from fried fish and exposed them to human lung cells *in vitro* and were able to show the formation of DNA adducts, which are the product of carcinogens bound to DNA, an initial step in cancer progression [29]. In another study, researchers conducted a case-control study of 303 Chinese women with lung cancer and 765 controls to examine the association between exposure to meat cooking and lung cancer risk [30]. Among those who smoked, women who reported that they stir-fried daily had a higher risk of cancer, which was increased further if they stir fried meat. The highest risk was seen in women who stir fried meat daily and reported that their kitchen was filled with oily fumes during cooking. These cooking practices did not increase risk among nonsmokers in this study, however.

Harmful (Non-Carcinogenic) Effects of Fumes Inhaled from Cooked Meat

The effects of PAHs have been studied in other fields. We know from industrial experience that short-term exposure to PAHs can worsen lung function in asthmatics and even thrombosis in those with coronary artery disease, although it is not known which PAHs are responsible for these effects [31]. Mixtures of PAHs have also been shown to cause skin irritation and inflammation [32]. Another adverse effect is hemolytic anemia [33].

Fumes from cooked meat containing airborne PAHs are likely hazardous in other ways. In a prospective cohort of 432 pregnant Polish women, researchers measured the exposure to airborne PAHs during barbecuing by personal air monitoring in the second trimester of pregnancy along with birth outcomes [34]. Those exposed to airborne PAHs from grilled meat were associated with having babies with a birth weight deficit of 165 g, reduced head circumference, and reduced length of the baby. All of these factors may explain why airborne PAH exposure may affect future cognitive development of children [35].

Conclusion

Chronic exposure to inhaled PAHs and HCAs may play a role in the development of cancer and other health problems. Further research should be done to investigate the roles and risk of these compounds among those with chronic inhalational exposure.

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