



A Comprehensive Review on the Formation of Carcinogens from Food Products with Respect to Different Cooking Methods

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ABSTRACT

It has been seen that the majority of carcinogens are formed depending upon the cooking and processing conditions employed which influences their magnitude to adversely affect the food products. High heat, marination, roasting, frying, grilling etc. can significantly affect the household food products. The most frequently occurring carcinogens are Heterocyclic aromatic amines (HAA), Polycyclic aromatic hydrocarbons (PAH), N-Nitrosamines (NA), Acrylamide (AA) and aflatoxins. These agents are found in variety of food sources due to unhealthy processing conditions such as marinated pork dishes, chicken drumsticks, grilled chicken, smoked chicken and fish preparations, potato chips, sausages, soy sauce etc. Apart from these, marketed cooking oils of various grades, synthetic antioxidants and regular high consumption of coffee can remarkably increase the risk of causing cancer. Therefore, an appropriate knowledge and awareness in context to some harmful

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processing conditions must be taken into consideration before consuming the final food product. This review aims to summarize the major carcinogens from food with evidences, the mechanism of formation, carcinogenic action and ways to reduce the level of these carcinogens from food.

Keywords: Carcinogens; heterocyclic aromatic amines; polycyclic aromatic hydrocarbons; cooking; cancer.

1. INTRODUCTION

Cancer is the world's most common cause of death where food and food borne chemicals are assumed to play a significant role in its etiology [1]. A lot of laboratory and epidemiologic research have been done by several governmental and international agencies to find out beneficial and harmful impacts of various diets, dietary components, food pollutants and their role in causing cancer [1]. Human body is unceasingly exposed to a myriad number of chemical substances, present in food, which possess significant carcinogenic or mutagenic potentials. Exposure to food-borne carcinogens contribute significantly in the development of a majority of human cancers [1]. Proinflammatory carcinogens or anticancer immune responses have a qualitative and quantitative relationship with environmental carcinogens (such as food, tobacco, etc.). A direct relationship between UV light and melanoma, or tobacco use and lung cancer can be sharply constructed whereas dietary materials and cancer is not as linear as those [2]. Carcinogens in food can occur naturally, such as derivatives of hydrazine, and found in both wild and cultivated mushrooms [3]. A well-validated biomarker confirmed the causative relationship with the mold generated carcinogenic contaminant, aflatoxin, upon exposure through food in Asia and Africa [4]. Again, carcinogens may arise due to microbial contamination or other man-made causes. Aflatoxin which is a toxic metabolite produced from mold i.e., *Aspergillus* species are found in many food substances like maize, rice, nuts, dried spices. Aflatoxin is even found in contaminated milk from animal fed foods [5]. In elevating liver cancer risk, aflatoxin and hepatitis B displayed a conspicuous synergistic interaction [6,7].

Cooking is considered as the easiest and safest process to make the raw foods bacteriologically safe and free from possible harmful contaminants. However, a large number of genotoxic agents or "cooking toxicants" can be produced because of cooking at high temperature. Nowadays, the impact of cooking

toxicants on human health is a serious concern [8]. In parallel, heterocyclic amines (acrylamide, heterocyclic amines, nitrosamines and polyaromatic hydrocarbons), are the most important class of mutagens and carcinogens, found in diet and responsible for cancer development at numerous organ sites [9]. When meats are heated over 180°C for prolonged period, heterocyclic amines are produced. Epidemiology studies estimated that consumption of over cooked meats is related to the development of cancer in colon [10]. Most recently, acrylamide has been identified as a deleterious food toxicant produced during food processing by heat [11,12]. Again, food additives such as coloring agents, preservative and sweeteners may also serve as source of carcinogenic exposure from food [13]. Food toxicants can cause various types of DNA damage, most common being the damages of nucleotide alterations, chromosomal aberrations and formation of carcinogen-DNA adducts, which result from covalent binding [14–16].

The major methods of studying carcinogenesis or mutagenesis from food includes *in vitro* cell culture and DNA assays, bioassay on animal models and different epidemiological studies like cohort, case-control studies. There have been numerous studies to find the relationship of carcinogens from food source to specific type of cancer. More than 20 different type of HCAs have been identified and these have been found to cause cancer of different organs including colon, breast, prostate, skin and liver in animal models [17]. Increased incidence of stomach cancer has been reported with consumption of smoked food which contain PAHs along with nitrite and nitrosamines [18]. Acrylamide formed from sugars and amino acids due to high heat processing of food were found to cause tumors of lungs and skin in mice [19].

2. NEED FOR STUDYING THE ROLE OF CARCINOGENS IN FOOD PRODUCTS

A lot of chemicals that may appear in food as natural constituents, contaminants, or additives are proved to be carcinogens. Coming in contact

with a carcinogen does not mean that someone will develop cancer. It depends on how much, how long, how often, and when they are exposed to these chemicals. Usually, the more the exposure of risk factors, the higher the risk of developing cancer [20]. So, reducing the exposure to harmful carcinogens, reduces the risk of developing cancer. Therefore, if we can identify carcinogen-containing food products, we can limit our consumption of those particular food stuffs. Rigorous risk assessment studies have been done to find out the major dietary pollutants and their role in causing cancer. There are four primary types of potentially carcinogenic compounds that have been examined to determine if they act as carcinogens in humans. The first are natural products that may be present in food and are unavoidable. For example, the process of creating salted fish produces carcinogens which cannot be easily avoided. Secondly, natural products that may be avoided such as the contamination of grain with the carcinogenic fungal metabolite aflatoxin, which can be reduced or eliminated using best practices for grain storage. Third, the anthropogenic chemicals that, are present in food. For instance, 2,3,7,8-tetrachlorodibenzo-p-dioxin has been inadvertently produced during the manufacture of chlorinated hydrocarbons, but it contaminates the environment, resists degradation, and accumulates in certain foodstuffs. A fourth category of concern is anthropogenic chemicals intentionally added to foods, such as saccharin or food coloring, but this particular category has not been addressed as they are beyond the scope of this review [1].

3. CARCINOGENS FROM FOOD PRODUCTS

Traditionally, foods consumed in India are classified into 3 categories which are Satvika, Tamasika and Rajsika. Satvika foods include cooked vegetables, milk, honey and fresh fruits. Tamasika includes meat, garlic, liquor, spicy and sour foods. However, Rajsika foods are considered as highly energetic, since the energy required for carrying out daily activities is accomplished by these categories of foods such as grains, pulses, oils and fats. Grains based traditional foods include idli, ambali, ragi, sel roti which are prepared by fermentation process [21]. The naturally occurring substances or chemicals which are present in our food supply can be broadly classified into 5 categories: constitutive chemicals, derived chemicals, acquired chemicals, pass through chemicals and added

chemicals. By chemicals, we mean the naturally occurring substances present in our food [22].

Constitutive chemicals: Those substances that are synthesized through biochemical and physiological processes present in food organisms themselves. e.g.- Coumarins, isoflavonoids, alkaloids, etc [23].

Derived chemicals: Those substances that are formed by the result of the breakdown of constitutive chemical during storage, stress, preparation and processing of foods. e.g.- heterocyclic amines, pyrazines, hydrocarbons, agents that provide the roasted food flavor such as nuts, coffee, chocolates, etc [23].

Acquired chemicals: Those substances that, are developed as a result of spoilage caused by various bacteria or fungi. e.g.- Aflatoxins [24].

Pass through chemicals: Materials that are already present in animal derived from the food which they eat which in turn is consumed by humans. e.g.- seafood toxins, aflatoxins from cow's milk, etc. [23].

Added chemicals: Chemical agents obtained from plant or animal sources or semi synthesized and added to the food products [22-24].

The major risk factors of carcinogens are associated with their cooking methods primarily high heating, roasting, grilling, frying, deep frying, etc [25].

4. EFFECT OF COOKING METHODS ON FORMATION OF CARCINOGENS

As we know that every substance is a poison, it's only the dose that makes the difference [26]. Thus, the food which we take on a daily basis may contain a huge number of these naturally occurring chemicals which if consumed improperly or unknowingly, can even pose a potential hazard to human health by coming under the umbrella of carcinogenic materials. Cigarette smoking, nutrition and dietary factors and inflammation and infection are one of the major components of human carcinogenesis [24,26]. Chemical carcinogens damage DNA and stimulates proliferations by utilizing hormones such as estrogens, prolactin, etc [27].

Much importance has been given to carcinogenic/mutagenic heterocyclic amines (HAs), they are present mostly in protein rich

foods and are produced as a result of chemical reaction with the several amino acids and monosaccharides [28]. Their formation depends upon various parameters such as cooking temperature, equipment used, cooking time, cooking technique, heat transfer, etc [25]. It has been reported that frying/grilling of chicken and fish preparations can result in the formation of small amounts of Has [29]. The International Agency for Research on Cancer (IARC) identified 8 types of HAAs (Heterocyclic aromatic amines) HAAs which are carcinogenic and includes the derivatives of indole, pyridine, and quinoline nucleus in them. Amino imidazoarenes (AIA) and amino carbolines are two classes of HAAs produced by cooking at 150-300°C [30]. Table 1 shows the types of HAA and the detection techniques used for their estimation [30].

The authors-reported some major functions of food used in the food processing and classified food according to 3 criteria, i.e. food processing design and principles, foods that transformed from basic technology to an advanced- cooking and NOVA classification [31].

Use of NOVA classification: Food processing was developed using tools and technologies for improvement of its availability, ease of digestion,

safety, transport and storage. The tools used were unit operations such as air drying, smoking and fermentation for all edible food sources and the technology used include refrigeration, pasteurization, sterilization and canning for transportation. Table 2 shows the NOVA classification system of food products [31].

The author and co-authors-suggested that cooking methods that uses high heat can increase the risk of prostate cancer. Excessive amount of oil used in deep frying methods can be of particular concern as it can result in the formation of carcinogenic agents such as acrolein, aldehydes, polycyclic aromatic hydrocarbons, aromatic amines, etc. [29]. They reported that marinating chicken before cooking can decrease the formation of 2-amino-1-methyl-6-phenylimidazo[4,5-b] pyridine (PhIP), a heterocyclic amine found in cooked meat. It can also be minimized if the cooking is done for less than 40min [32]. The workers-in their-study suggested that the four major heterocyclic amines found in beef products such as 2-amino-3,8-dimethylimidazo[4,5-f] quinoxaline (MeIQx), 2-amino-3,4,8-trimethylimidazo[4,5-f] quinoxaline (DiMeIQx), 2-amino-1-methyl-6-phenylimidazo [4,5-b] pyridine (PhIP) and 2-amino-3-methylimidazo[4,5-f] quinoline (IQ) along with some other precursors can be

Table 1. Identification of HAAs

S. No.	HAA Types	Method of detection
1	Indole, quinoline derivatives in agricultural products	LC-MS/MS
2	Quinoline derivatives in grilled pork	HPLC
3	Quinoline derivatives	HPLC
4	Pyridine derivatives in roasted coffee	HPLC with Fluorescent detector
5	Pyridine, quinoline, quinoxaline derivatives in meat products	LC-DAD-MS/MS
6	Pyridine, quinoline, quinoxaline derivatives in commercial meat products	HPLC-DAD-ESI-MS/MS
7	Quinoline, pyridine, quinoxaline derivatives in fried chicken nuggets	RP-HPLC
8	Quinoline, quinoxaline derivatives	UHPLC- U.V/Fluorescent detector
9	Pyridine, quinoline, quinoxaline derivatives in coffee products	UHPLC-MS/MS

Table 2. NOVA classification [31]

Ultra-processed foods	Unprocessed/minimally processed food
Breads, Cookies, Biscuits, Cakes, Pastries, Ice creams, Jams, Chocolates, Chips, Sauces, Pizzas, Pre-prepared Meat, Poultry, Fish, Chicken nuggets, Hotdogs, Salted pickles, Smoked Meat and Fish, Baby Food.	Fresh, Chilled, Frozen, Vacuum Packed, Fungi, Vegetables, Fruits, Pulses, Grains, Rhizomes, Tubers, Roots, Pasteurized milk, Eggs, Tea, Coffee.

reduced to a great extent by microwave pretreatment at 200-250°C for 6 min [33]. The fact that flame grilling can result in the formation of both polycyclic aromatic hydrocarbon (PAH) and heterocyclic aromatic amines (HAAs), analyzing their processing conditions can help to minimize their occurrence. With amounts found around 0.1-14 ng/g of HAA and around 1 ng/g of PAH in restaurant and commercial foods it exceeds the detection limits i.e., about 0.1 ng/g [34]. Thus, a proper processing condition must be followed to reduce their formation below detectable limits [35]. The International agency for research on cancer (IARC) proposed that the consumption of red meat is “probably carcinogenic to humans” and the processed meat as “carcinogenic to humans”. It can probably increase the chances of developing colorectal cancer [36]. A study conducted by The investigations on PAH revealed that the primary dietary sources of PAHs are vegetables and cereals, preferably than meat, except when there is a very high consumption of meat cooked in an open high flame. Among these, benzo [a] pyrene is the most common PAH which is produced by the incomplete combustion of organic food [37] REF. Although, PAH are found as a source of environmental contaminants but their exposure from organic food is unavoidable [37]. The amount of HAAs in the pan residues of some common Swedish meat and food products such as meatball, bacon, smoked fish, sausages were found to be higher (around 19ng/g) as compared with their products. These are mostly DiMeIQx and MeIQx [38]. Another group of carcinogens that are known to cause gastro intestinal cancers are N-nitroso compounds which are produced *in vivo* by the dietary intake of nitrates and nitrites [39]. Leafy vegetables and water are the major sources of nitrates, while cured meats are the main sources of nitrites [39]. The Nitroso compounds (nitrates and nitrites) are usually used for improving the quality of food and protect food from microbial contamination [39]. While processing meat nitrosamines are formed which are carcinogenic in nature [39]. Based upon their daily consumption, a regulatory limit has been set by the various food standard agencies. Also, proper method for estimating their contents in dietary food has been developed by them [40]. They also reported that 80% of all cancers in humans are caused due to environmental factors associated with food, air and water [41]. A very interesting study conducted by a group of scientists from Saudi Arabia [42] revealed that the presence of antioxidants in food additives can provide pro-oxidative effects to the home

cooked samples and fast food due to which IQ and MeIQ contents are found in very low concentration in the cooked camel meat burgers and related foods consumed in middle east countries. This suggests that food products and additives having some antioxidant properties can help to prevent harmful chain reactions in body which in turn can also reduce the carcinogenic capacity of the cooked food samples [40]. In contrary to that, laboratory of biotechnology, USA. [42] reported that the formation of acrylamide, a chemical used to make copolymers like polyacrylamide in many industrial processes such as production of plastic and dyes can also be found in many fried and oven cooked foods and their formation had absolutely no affect by the presence of phenolic antioxidants. These indicate that the formation of acrylamide is non-oxidative in nature. The actual formation of acrylamide in cooked food is not very clear till now but some reports say that being a component of tobacco smoke, it can be formed by the heating of biological materials [43]. It is known to produce neuropathy, testicular damage and neurotoxicity in humans and can be found on a variety of fried potato chips and French fries [44]. The authors in their-study found that, acrylamide (AA) is a toxic and carcinogenic substance usually formed in food products containing starch. AA is formed when a food substance is subjected to higher temperatures. The toxic effects of AA seen in animals and humans are hepatotoxicity, neurotoxicity, carcinogenicity, genotoxicity and reproductive toxicity. Presence of higher quantities of acrylamide in diet causes multiple myeloma, lymphoma, oesophageal cancer and breast cancer [45]. Maximum AA consumption per day should be limited to 0.3µg/kg to 5 µg/kg [46]. It was in the year 2010 that they had studied the phenomena of the formation of HAAs in chicken and duck meat with effect from different cooking methods. They found out that chicken dishes prepared by charcoal grilling contains the highest amount of HAAs which can be as high as 112ng/g, followed by that pan fried duck breast contains 53.3ng/g of HAAs. Out of these, the most abundant HAA was reported to be 9H-pyrido-[4,3-b] indole (Norharman). Some other amines that are estimated were 1-methyl-9H-pyrido-[4,3-b] indole (Harman) 2-amino-1-methyl-6-phenylimidazo[4,5-b] pyridine (PhIP). This suggests that the quantity of carcinogenic chemicals in cooked poultry meat preparations can vary with cooking methods adopted and cooking conditions followed [47]. The existence of Polycyclic aromatic hydrocarbons (PAH) can

be detected in both the raw and processed foods, their presence in non-processed food can be due to environmental pollution whereas in the processed foods they may be contaminated due to processing and preservation techniques [48]. Contaminants are also released from packages made up of tin, vessels made up of copper, plastics made from bisphenol and phthalate materials. Phthalates [49,50]. These contaminants are released due to oxidation of fats and oils [51]. Another category of contaminants, which are released from packing materials include dioxin, structurally related to polychlorinated dibenzo para dioxins (PCDDs) [52]. Continuous exposure to dioxins causes different types of cancers [53]. In environment, high concentration of dioxin is found which are accumulated in the fatty tissues of animals [54]. These dioxins are highly toxic not only for cancer but also effect the reproductive system, developmental delays, decreases immune power by interfering with the hormones. Most of the people are exposed to these dioxins through consumption of meat, dairy products and fish [55]. Thus, taking into consideration all the analysis from these studies, These workers had suggested that any material i.e., composed of carbon and hydrogen when heated can result into the thermal degradation of the product and form PAH which can also be formed by the industrial processes of pyrolysis, liquefaction, petroleum treatment and some other metabolic processes of plants and bacteria [48]. After observing anaphylactic shock by consuming a pizza made of wheat flour due to buck wheat present in the dough [56], it was necessary to define few methods to detect the allergens present in food products, starting from 1^o processing until the end product. Even though the percentage fraction of allergens is less but can cause allergic reactions. Therefore, to detect the presence of these allergens in various products like oats, peanuts, soyabeans, tree nuts, sesame seeds, wheat, mustard seeds, milk, eggs, sea food, etc. an ELISA method is proposed [56]. There has been a more comprehensive discussion on the effects of sugar and soya sauce on the formation of HAAs in various food preparation such as egg, marinated pork, bean cakes [57]. The separate food mixtures with water, soya sauce and sugar were heated for around 1h in a closed vessel. The six HAAs such as IQ, MeIQx, MeIQ, DiMeIQx, 2-amino-9H-pyrido [2,3,-b] indole (AaC) and PhIP were detected in the pork samples (marinated), along with five HAAs in bean cakes namely PhIP, MeIQx, DiMeIQx, and

AaC whereas four HAAs, 3-amino-1,4-dimethyl-5H-pyrido[4,3-b]indole (Trp-P-1), MeIQx, DiMeIQx and PhIP were found in eggs. Thus, in all the samples PhIP was produced in large amount as a major HAAs. Also, the presence of sugar and soya sauce can greatly increase the formation of HAAs in marinated samples [54]. The investigations were based on - their research work on different toasting procedures in bread found that several toasting techniques used to prepare bread products could strongly affect the level of PAH being produced in the final product. The ones toasted by flame grilling and charcoal grilling process reported a heavy amount of PAH formation (up to 350mg/kg). This could be due to the deposition from smoke [58]. Thus, it can be concluded from this study that PAH are the incomplete burning products of coal, garbage, oil, wood, gas, tobacco or other organic substances [58].

The nutritional factors associated with carcinogenic capacity are categorized into two types i.e., genotoxic and non-genotoxic agents [59]. Genotoxic agents are basically the micro components of nutrition such as PAH, HAAs, N-nitrosamine, aflatoxins, etc. Non genotoxic agents are the tumor promoters, basically the macro components of nutrition e.g., high fat. Conversely, the nutritional factors are also known to contain elements that can minimize the risk of cancer through detoxification. Thus, cancers that develop from nutritional factors are due to an imbalance between carcinogenic and anti-carcinogenic components [60]. In India, a huge majority of people in rural household utilizes energy source by burning of unprocessed biomass to cook food in traditionally homemade chulhas that generates many airborne particles including PAHs [61]. Their concentration increased significantly during the combustion of biogas during winter season as compared to summer. The individual PAHs that were present are benzo(k)-fluoranthene, chrysene, dibenz(a,h)anthracene & benzo(a)pyrene [62]. Continuous exposure to these by rural women of India can be harmful and result into chronic pulmonary illness [61,62]. It can be said that the potency of undergoing mutation of HAAs are about 100 times more than that of aflatoxins, and 2000 times more than that of benzo[a]pyrene. In a laboratory model studied by The investigation carried out has been seen that products such as chicken drumsticks and chicken wings obtained from fast food restaurants were found to contain more amount of HAAs as compared to household cooking, this is due to uncontrolled

and unhealthy frying conditions in restaurants [63]. In fact, the cooking oils that are used in restaurants and household cooking can produce fumes containing PAHs, exposure to which can potentially result in an increased chance of developing lung cancer. The marketed oils such as olive oil, coconut oil, vegetable oil, sunflower oil, mustard oil, etc. were examined for quantification purposes to analyze the amounts of carcinogens present. The exposure to these carcinogens can be reduced by using fume extractors near the cooking system [64]. A group of researchers from Spain investigated the changes in the amounts of polybrominated diphenyl ethers (PBDEs), various polycyclic aromatic hydrocarbons - and hexachlorobenzene (HCB) in several food stuffs including fish (tuna, hake, sardine), meat (pork, steak, chicken, lamb), rice, potato and olive oil. All the samples were subjected to analysis, before and after cooking (boiled, grilled, roasted, fried). The quantity of PBDEs depends not only on cooking but also on some other parameters such as temperature, specific food item, time of cooking, duration of cooking etc. [65]. The highest concentration of HCB was found in hake after cooking while raw sardine samples had more HCB as compared to cooked ones and a minute difference in tuna (before/after cooking). The highest concentration of PAHs was found in meat samples (after cooking), while potato also revealed some carcinogenic components after cooking [66]. The fish products are also the major source of another group of carcinogens i.e., N-Nitrosamines (NAs), in a fresh fish the level of NAs are undetectable. But on application to different cooking methods, such as smoked, fried, grilled, salted, pickled the level of NAs increase and it can go up to 8.29 mg/kg [67]. The different types of NAs known to affect fish products are N-nitrosodiethylamine, N-nitrosodimethylamine, N-nitrosodibutylamine and N-nitrosopyrrolidine and N-nitrosopiperidine [68]. Based on a cohort study conducted in Netherlands in the late 90s to investigate or establish a link between dietary intake of synthetic antioxidants, Butylated Hydroxytoluene (BHT)/Butylated hydroxyanisole (BHA) and gastric cancer, after 6.3 years of extensive follow up, completed data was studied and suggested that frequent intake of mayonnaise and creamy salad dressings was not found to be associated

with gastric cancer [61, 69]. However, cooking fats, oils and dried soups can very minutely contribute to the same but overall, there is no significant line for stomach cancer was found with usual consumption of low levels of these antioxidants [65]. It is very hard to determine the exact quantity of HAAs consumed in food as it depends upon the type of food and the method of cooking adopted to prepare the final product. But it is mostly formed on thermally treated poultry products [70]. A nephrocarcinogenic/nephrotoxic mycotoxin produced by some very common moulds has been primarily found in cereals and coffee beans from two very important genera *Aspergillus* and *Penicillium* [71]. REF The predominantly occurring mycotoxin, Ochratoxin A (OA) isolated from *Aspergillus ochraceus*, is the substance of concern in coffee beans. Out of 40 coffee samples collected from commercially available shops, 22 of them reported to contain Ochratoxin A up to a range of 7.8 mg OA/kg [71]. It was seen that roasting at a temperature around 250°C for 2.5 min can reduce only a small amount of OA concentration from coffee beans [71]. Therefore, regular consumption of coffee may also contribute to human exposure to OA. Workers from University of China, revealed the differences of PAH content in duck meat with and without skin [68]. They showed that with increase in cooking time, duck meat products with skin contains the more amount of PAH as compared to duck meat products without skin and also suggested that much extensive research is needed to estimate the level of two rare carcinogens benzo[a]anthracene and benzo[b]fluoranthene as they are also present in several preparations of duck meat [72]. Very recently it came into light, that the carbonated beverages as well as the caramel colors are also suspected to contain 4(5)-methylimidazole, a potential carcinogenic chemical formed during the production and manufacturing of beverages [73]. It can be found within the range of 1 to 1000ppm and can cause harmful adverse effects on the consumers. This data was supported by National Toxicology Program (NTP) and confirmed the presence of cancer-causing carcinogen in these food stuffs [74,75]. The different types of malignancy associated with particular carcinogens are enlisted in Fig. 1. GIT-Gastro intestinal Tract.

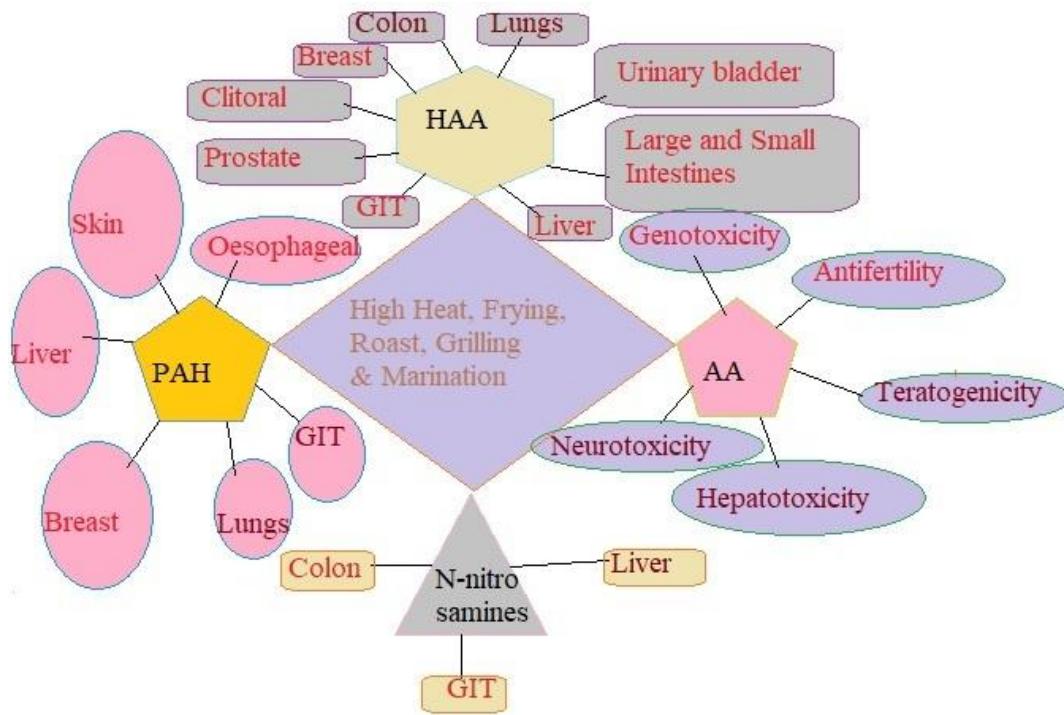


Fig. 1. Different types of cancers associated with chemical carcinogens from food [76,77]

5. SOME ANTI-CARCINOGENIC FOOD PRODUCTS

Apart from these carcinogens present in food products, there are some other chemicals present in several food stuffs that are actually beneficial to the human beings [78]. Some of them have immunomodulatory benefits like taro root (*Colocasia esculanta*) [79], some of them may serve as a functional food for the prevention of cancer like Beetroot (*Beta vulgaris*), or Capsaicin [80]. Various categories of fruits and vegetables containing flavonoids or anthocyanin principles like pomegranate, apples, berries, etc [81-82]. Many other natural substances such as polyphenols, carotenoids, eugenol, antioxidants, etc. can serve as a potential anti carcinogenic factor [80–82].

6. FOOD PRODUCTS WHERE AWARENESS IS NEEDED

As discussed in this review so far, a number of harmful food products and their preparations which are consumed can be a risk factor for developing cancer. Some of these thoroughly studied carcinogenic products are grilled chicken, high temperature cooked meat, smoked fish, potato chips, sausages, duck meat, soy sauce,

marinated pork dishes, bean cakes, coffee beans, marketed cooking oil of various categories, etc [83-89]. This type of food preparations should be cooked by following the safety cooking methods so as to avoid the formation of chemical carcinogens [83-89,90].

7. CONCLUSION

In a nutshell, it can be said that the cooking processes mostly employed in the household environment do not conclusively guarantee the safest consumption of foods. High temperature, choice of equipment, time duration, cooking technique, heat transfer and use of food additives are the crucial parameters that determine their suitability for human intake. The proper understanding of the formation of these carcinogenic substances should be ensured along with the techniques utilized during cooking. In the long run, this can help to minimize the risk of causing cancer related issues from unhygienic food conditions and their final products. The findings reported from this study should trigger additional research on carcinogenic components present in the food before cooking that can further prove to be fatal after heat treatment as well as the antagonistic events associated with

anthropogenic chemicals added to foods such as saccharin, food coloring agents, etc.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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