Cooking Fumes and Relative Diseases

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***Abstract*—Cooking fumes are mixture of various toxic components such as aldehydes, heterocyclic amines (HCAs), polycyclic aromatic hydrocarbons (PAHs), fat aerosols and particulate matters (PM), which are mainly produced during or after cooking. Due to the toxic contents of CFs, CFs might cause lung toxicity, immune toxicity, hereditary toxicity, potential carcinogenicity and so on to organism. There were several studies investigated the toxicity impact of CFs. However, comprehensive review about the production, composition harm to the contacts and reduction methods of CFs is still lacking. In this review, the production, composition and effects on the contacts of cooking fumes were presented. In addition, reduction methods of cooking fumes were also presented. This review would provide references for the avoidance of CFs relative disease and the comprehensive disposal of CFs.**

Keywords-cooking fumes; toxic contents; toxicity; reduction method

I. INTRODUCTION

Cooking fumes (CFs) are mainly produced through complex chemical reaction during or after cooking [1], which were recognized as a source of negative impacts on air quality and human health [2]. Though the components of CFs may be vary depend on the kinds of food, the kinds of cooking oil and the cooking method [3], it contains many kinds of toxic components such as aldehydes, heterocyclic amines (HCAs), polycyclic aromatic hydrocarbons (PAHs), fat aerosols and particulate matters (PM)[1, 4-6] . Many studies have demonstrated that exposed to COFs may increase risk of respiratory tract cancer and many other diseases [2, 7-9]. However, systematic review about the production, composition, effect to the contacts and reduction methods of cooking fume is still lacking.

In this review, the production, composition and effects on the contacts of cooking fumes were reviewed. In addition, reduction methods of cooking fumes were also presented. This review would provide references for the avoidance of CFs relative disease and the comprehensive disposal of CFs.

II. THE PRODUCTION AND COMPOSITION OF COOKING FUMES

A. Production of CFs

Cooking fuels burning, cooking oil volatilization and reaction during heating process, the reaction between food and cooking oil are the main sources for the production of cooking oil fume, which will also affect the composition of CFs [6, 10, 11]. According to the study of To et al. [12] the emissions of extractable organic material depended significantly on the cooking fuel and the cooking process in domestic kitchens and commercial kitchens. Nowadays, natural gas is the mainly cooking fuel in urban while there are still some agricultural stalks and coals using in countryside. Natural gas is mainly composed by CH4, which will only produced CO2, H2O during burning. Less amount of CO might also produce during the burning of natural gas under incomplete combustion condition. Relatively, due to the complex components of agricultural stalks and coals, there are much more resultants producing during burning. In addition, electrical heating is also a main cooking method, which is cleaner compared with natural gas, agricultural stalks and coals. Animal and vegetable oils are the most used cooking oil. During the cooking process, oils repeatedly reacted with oxygen from atmosphere at high temperature, which will lead to the oxidation and degradation of cooking oils [13]. Oils would convert to volatile chain scission products, non-volatile oxidized derivatives, and dimeric, polymeric or cyclic substances [14]. Harmful degradation products also may be formed from food at high temperature, which due to the degradation of sugars, pyrolysis of proteins and amino acids and the degradation of fats [15-17].

B. Composition of CFs

Due to the different cooking oil used, food or cooking method, the composition of CFs may be different. CFs at least contained 200 kinds of compounds, which could be divided into aldehydes, heterocyclic amines (HCAs), polycyclic aromatic hydrocarbons (PAHs), fat aerosols and particulate matters (PM) [6, 7, 18-20]. Shields et al. [21] investigated the effects of various appliances such as ovens, broilers and griddles on the production and composition of CFs. The CFs emissions from fatty foods were associated with the cooking appliances; the highest CFs emissions were obtained over open flames. According to Lin et al.[22], the types and quantities of volatile aliphatic aldehydes were depended on the temperature of cooking oil. Francis and Lipinski [23] also demonstrated during barbecue, temperature is important, there were more pollutions producing at higher temperature. Yao et al.[1] examined the effects of deep-frying and frying methods using rapeseed, soybean, peanut, and olive oil on the characteristic of PAHs, results showed deep-frying methods generate more PAHs and benzo[a]pyrene (B[a]P), rapeseed oil produced more PAH emission than the other three oil varieties. Ontanón et al. [24] studied volatile compounds released during heating olive and sunflower oil. Results showed the stability of oils during heating process was different, the concentration of alkenes had no significant variation as the temperature changed, and however it was higher in the olive oil. The concentration of alkenes was higher in sunflower oil. According to Gao et al.[25], particulate matters emissions were associated with the heating temperature and had little dependence on the types of vegetable oil used. Differently, Gao [26] found source strengths of particulate matters were highly sensitive to the oil type. Kabir and Kim [5] studied the emission characteristics of various pollutants in relation to 3 food types (including cabbage, clam, and coffee seeds) and 2 cooking methods (between mild and harsh treatments), which found odorant emissions prevailed by roasting coffee seeds followed by brewing coffee, frying cabbage, and grilled clam. The concentrations of the pollutants released from roasting coffee seeds were significantly high relative to other sample types obtained during the cooking periods.

III. THE EFFECTS OF COOKING FUMES ON THE CONTACTS

According to World Health Organization (WHO), there are approximately 1.6 million excess deaths annually among human-based combustion activities such as cooking and heating, which account for nearly 3 % of the global burden of diseases [27]. Due to the complex toxic compounds of CFs, CFs might caused lung toxicity, immune toxicity, hereditary toxicity, potential carcinogenicity and so on to organism. Occupational exposure to CFs led to increased oxidative damage [4]. A complex mixture of particulates, metals, volatile organic compounds, polycyclic aromatic hydrocarbons (PAHs), benzene, quinines, and carbonyl compounds will produces during oil heating process, which were related to the formation of reactive oxygen species (ROS) and the induction of cellular events resulting in cell death[27]. Especially polycyclic aromatic hydrocarbons (PAHs) of CFs have carcinogenic properties on mucosal and endothelial lining of upper aero digestive tract [28]. In addition, particularly fine particulate matter (PM2.5) of CFs could penetrate into the lungs readily, which would increase the incidence of respiratory and cardiovascular diseases [29]. Summary of the potential effects of CFs were shown in table I.

TABLE I. COMPONENTS OF CFS AND DAMAGE

Component	Damage	Reference
PAHs	carcinogenic properties on mucosal and endothelial lining of upper aero digestive tract, oxidative damage, induction of cellular events resulting in cell death	[1] [27] [28] [30]
Aldehydes	Mucosa congestion, respiratory inflammation, damage to the macromolecules, adduct producing protein carbonyl compounds, inhibiting the synthesis of protein and DNA	[9] [31] [32][33]
Particulate matter, especially PM 2.5	penetrate into the lungs, increase the incidence of respiratory and lung cancer	[25] [29][34]
Heterocyclic amines (HCAs)	carcinogenic risk	[35] [36][37][38]

A. *Cooking Fumes Effects on the Gene*

When studying the interaction of XRCC1 and XPD Gene Polymorphisms with Lifestyle and Environmental Factors Regarding Susceptibility to Lung Cancer, Saikia et al. [39] found Interaction of XRCC1Gln/Gln genotype with exposure of cooking oil fumes (OR=3.45, CI=1.39-8.58; p=0.008) were significantly associated with increased risk of lung cancer. In addition, Gln/Gln alleles of both XRCC1 and XPD genes showed to amplify the effects of household exposure, smoking and betel quid chewing on lung cancer risk. The hOGG1 Ser326Cys polymorphism might be associated with the risk of lung adenocarcinoma and significant gene-environment association between cooking oil fumes and hOGG1 326 Cys/Cys genotype in lung adenocarcinoma among female non-smokers was reported by Xue et al. [40].

B. *Cooking Fumes Effects on the Cell*

Transforming growth factor-β (TGF-β) mainly functioned in regulating cellular functions and has been proven to play an important role in various cancer, the study composed by Ren et al. [41] showed TGF-β1 gene C509T polymorphism might be associated with decreased risk of lung adenocarcinoma in Chinese females exposed to cooking oil fumes, but no association was observed TGFBR2 gene

G875A polymorphism. Che et al. [42] also demonstrated exposure to CFs might lead to mitochondrial and death receptor pathways in AEC II cells, which would finally lead to apoptosis. Exposure to cooking oil fumes might increase the risk of lung adenocarcinoma in Chinese nonsmoking females (adjusted OR=1.58, 95%CI=1.11-2.25, P=0.011). However, significant interaction of cooking oil fumes and TP63 polymorphisms was not observed[43]. Cao et al. [44] demonstrated decreased cell viability, increased malondialdehyde (MDA) level, decreased superoxide dismutase (SOD) and glutathione (GSH) activities in a dose- and time-dependent manner of CFs, which proved CFs may lead to toxicity in AEC II cells at a very low dose.

C. Cooking Fumes Effects on the Blood Circulation System

According to the study carried out by Hecht et al. [45], exposed to CFs has statistically significant effects on the levels of 3-hydroxy propylmercapturic acid and 3-hydroxy-1-methylpropylmercapturic acid, but not S-phenylmercapturic acid. The level of creatinine 3-hydroxypropylmercapturic acid of women cooking more 7 times a week was 36.8% higher than that of women who cooking less than once a week. When studying the association between inflammatory markers concentration in blood and exposure to cooking fumes, Svedahl et al. [46] found only small changes in the levels of inflammatory markers in exhaled air and in blood after short-term exposure to moderate concentrations of cooking fumes. The concentration of the d-dimer in blood increased from 0.27 to 0.28 mg ml–1 after exposure to cooking fumes (P-value = 0.004). A trend of an increase in interleukin (IL)-6 in blood, ethane in exhaled air, and IL-1β in EBC after exposure to cooking fumes was also observed.

D. Cooking Fumes And Lung Cancer

In the study of Yu et al. [47], who investigated the relationship between cooking fumes exposures and lung cancer among Chinese nonsmoking women found the risk of lung cancer in Hong Kong nonsmoking women could be increased when cumulative exposed to cooking by means of any form of frying. Similarly, Phukan et al. [48] also reported exposure of cooking oil fumes ($p<0.003$), wood as heating source for cooking ($p=0.004$), kitchen inside living room ($p=0.001$), improper ventilated house ($p=0.003$), roasting of soda in kitchen ($p=0.001$), current smokers of tobacco ($p=0.043$), intake of smoked fish ($p=0.006$), smoked meat ($p=0.001$), Soda ($p<0.001$) and GSTM1 null genotype ($p=0.003$) could significantly increase the risk of lung cancer among women in Mizoram. Intake of bamboo shoots (p=<0.001) and egg ($p<0.001$) had significantly protective effect. Kim et al. [11] investigated the association among Home kitchen ventilation, cooking fuels, and lung cancer risk of never smoking women in Shanghai,China. Their research showed poor ventilation increased lung cancer risk (HR: 1.49; 95% CI: 1.15–1.95) for 49%. The use of coal and cooking oil had no significantly impact on lung cancer risk. However, ever coal use with poor ventilation increased the lung cancer risk significantly. According to Metayer et al. [49], exposed to cooking fumes could increase the risk of lung cancer among women. In addition, the risk of lung cancer risks increased along with total number of years cooking (trend, $P<0.09$). Differently, Study carried out by Seow et al. [50] showed, cooking practices did not increase lung cancer risk among nonsmokers but increase the risk of lung cancer among smokers.

IV. Reduction of Cooking Fume

Due to the high toxic content of CFs and the hazards of CFs to contacts, reasonable disposal of CFs is essential. There are several CFs reduction methods: local ventilation, filtration, catalytic/thermal oxidation, non-thermal plasma technique and biological method [10].

A. Local Ventilation Method

Among all the reduction method of CFs, local ventilation method is most used. Local ventilation method means using some mechanical means to transfer CFs. Rim et al.[51] investigated the removal efficiency of ultrafine particles produced by coking stoves with kitchen exhaust hoods. Results showed the removal efficiency of ultrafine particles was affected by range hood flow rate and burner position. The removal efficiency of ultrafine particles improved as the increase in the range of hood flow rate.

B. Filtration Method

Filtration method means using some mediums to absorb the toxic contents in CFs. The removal efficiency of CFs by filtration method is depending on the adsorbing material. However, the adsorbing materials are easily blocked, which will affect the removal efficiency of CFs seriously. In addition, the renewal of adsorbing material also need large amount of capital input, which is not economic.

C. Catalytic/Thermal Oxidation Method

Catalytic/thermal oxidation means using catalytic/thermal method to change the toxic contents in CFs to harmless substance. According to Yang et al. [52], who adopted a novel catalyst, based on MnO_2/CuO treating CFs at a low temperature. Most organics in CFs could be mineralized by this catalyst at the temperature range of 200-300℃under the contact time of less than 1 s. 96% removal efficiency could be achieved if the contact time prolonged to 3.18 s.

D. Biological Method

Biological method means using the ability of microorganisms to removal the toxic contents in CFs. In the study of Liao et al. [3], activated sludge was used to decompose pollutants from CFs. Microorganisms showed higher capacity to decompose pollutants; the degradation rate could be 0.15 mg (oil)/mg (biomass) under optimum conditions. Within 28 h, the pollutants concentration of CFs could decrease from 56.9 to 0.78 mg/L.

E. Summary

Although different reduction methods of CFs have been studied, there are still many limitations during the adoption of these reduction methods. Filtration method need high energy input and equipment needs large area for installation, also the pollutions were just transferred not eliminated, which is easily to produce secondary pollution [10, 53]. The activity of catalyst is easily lost during the application of catalyst in decomposing pollutants from CFs and usually the catalyst is expensive. As to biological method, though the removal efficiency seems high, the removal efficiency is unstable and the reactor of biological method also needs large area for installation. In general, several reduction methods of CFs have been developed; however, there are many limitations during the application of these methods. An efficient reduction method of CFs is till need to develop.

V. Prospect

CFs is mixture of complex toxic compounds, which might caused lung toxicity, immune toxicity, hereditary toxicity, potential carcinogenicity and so on to organism. Several reduction methods of CFs have been studied. However, there are more or less shortages in these reduction methods. Due to the toxicity of CFs, more research about CFs should be carried out. Meanwhile, comprehensive disposal methods to relieve or eliminate the toxicity of CFs need developing.

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