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Effective Local Exhaust Ventilation on Cooking Fumes of Seasoned Meats

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This study identified the fumes produced from the cooking of the seasoned meats containing various condiments such as garlic, onion, pepper, soy sauce, and sesame oil. Concentrations, at the breathing zone of the cook, of volatile organic compounds (VOCs) and aldehydes included in the cooking fumes of seasoned meats were identified. Many chloro- and fluoro-aliphatic hydrocarbons, aromatic hydrocarbons, ketones, and aldehydes, which could be carcinogen suspecting chemicals, were producing from the cooking fumes of the seasoned meats. This study also identified the ventilation efficiencies of the cooking fumes of the six exhaust ventilation systems, which were widely being used in the general apartments, houses, and small-food factories. For a comparison of the ventilation efficiencies of the systems, acetaldehyde was chosen as a marker pollutant and its concentrations at the breathing zone of the cook were identified. The laboratory fume hood showed the best ventilation efficiency of the six ventilation systems studied, and then the lateral hood ventilation and the down draft ventilation followed the laboratory fume hood. Finally, this study identified that both a wall factor nearby pollutant sources and a distance factor between the hood face and pollutant sources should be also considered for an effective local exhaust ventilation system design.

Key words: Cooking fumes, VOCs, aldehydes, ventilation, and hood

1. Introduction

Many workers and people have been exposed to various indoor air pollutants. There are many sources of indoor air pollutants: tobacco smoking, building materials, gas stoves, wood stoves and fire places, furnishing and household products, gas and kerosene fueled space heaters, copying machines, and air conditioning systems (Samet, 1987). Cooking is also one of important sources of indoor air pollution (Hollowell, 1981). Especially, cooking of meats and fats can produce very toxic chemicals such as formaldehyde and naphthalene. Therefore, cooking fumes produced from the cooking of meats and fats could be potentially health hazards and might present a risk to exposed workers (Vainiotalo, 1993; Daniels, 1985).

A cooking of seasoned meats containing various condiments, such as garlic, onion, pepper, soy sauce, and sesame oil, has been popular due to their unique taste and flavor. However, unfortunately, many people who work for the food processing at food industries, restaurant, and even homes have been exposed to various cooking fumes, vapors, and dusts produced from cooking of various condiments, meats, fats, and other ingredients. Therefore, these workers have showed a variety of symptoms consistent with respiratory difficulties (Montanaro, 1992), hyperkeratotic, scaly, chapped lesions on the palm surface of cooking hands (Campolmi, 1992), severe asthmatic attacks (Lybarger, 1982), hypersensitivity pneumonitis (Tsuchiya, 1993), skin irritation (Meding, 1993), and coughs (Blanc, 1991).

In spite of many symptoms associated with processing of foods or meats or fats containing seasoning, there is a lack of information available of components and amounts of pollutants which could be emitted from the cooking of seasoned meats. Due to the simultaneous cooking of meats and condiments, the cooking fumes of the seasoned meats may have higher concentrations of various pollutants than the cooking fumes of just raw meats and fats.

Therefore, this study identified air pollutants such as volatile organic compounds (VOCs) and aldehydes emitted from the cooking of the seasoned meats. Another purpose of this study was to find an effective local exhaust ventilation system for the cooking of the seasoned meats. We compared concentrations of a marker compound, acetaldehyde, depending on the six different exhaust ventilation situations, which were widely being used in the general apartments, houses, and small-food factories.

2. Materials and Methods

2.1. Seasoned Meat Preparation

Meat was the top roast beef boneless purchased from the Market Basket, which was one of famous grocery stores in the New England area in U.S.A, and it was sliced as 5 × 10 × 0.5 cm. Components of seasoned meat were as follows; meat of 3,000g, onion of 300g, soy sauce of 352g, garlic of 100g, hot pepper of 100g, sesame oil of 22g, and black pepper of 10g. Seasoned meat was prepared by mixing these materials well with hands and stored at the refrigerator before the cooking.

2.2. Sample Collection and Analysis

Cook of seasoned meat using the electric grill, a contact multi grill made from Tefal, was performed for 30 min at about 230℃, which was measured before the experiments. Cooking fumes containing air pollutants produced from the cook of seasoned meats were collected using adsorption sorbent tubes. Air samples of aldehydes and VOCs in the breathing zone of the cook were obtained using a calibrated Gillian Model (SN type) personal air sampling pump for 30 min. The average sampling pump flow-rate was about 200 ml/min, which was obtained by measuring flow-rates before and after sampling.

As a specific sampling tube for aldehyde collection, the Sep-Pak Cartridge (Waters, Inc.), contained silica gel pre-coated with acidified 2,4-dinitrophenylhydrazine (DNPH), was used. Samples were kept under refrigeration (3℃) while awaiting analysis. Collected aldehydes were converted into DNPH-aldehyde derivatives in the tubes and extracted with 6ml acetonitrile. The eluates were diluted with a known volume of acetonitrile. The chemical analysis of DNPH-aldehyde derivatives was performed a High Performance Liquid Chromatography (HPLC) equipped with a Zorbax ODS column (46 mm ID × 225 cm) and ultraviolet (UV) absorption detector operating at 360 nm in accordance with ASTM D 5197-92 (ASTM, 1992) and US EPA Method To-11 (U.S. EPA, 1988).

The Supelco thermal desorption tube (TDS-3) was used as the air sampling collection device to capture VOCs of the cooking fumes. Samples were kept under refrigeration (3℃) while awaiting analysis. The TDS-3 was desorbed ballistically (from 35℃ to 335℃ in 16 seconds) in a Thermal Desorption Unit (Supelco TDU). The effluent was rapidly transferred to the Gas Chromatography (GC) column (Supelco Wax 10 Capillary) for separation. For identification and quantification of the VOCs in the sample, the effluent was passed through a Mass Spectrometer Detector (MSD) immediately after the GC separation. The MS quantification of the VOCs in the sample was made by comparison with calibrating substances. The calibrating substances contained 1,2-dichloroethane-d_4, tolune-d_8, and bromofluorobenzene as surrogate spikes, and also contained 1,4-difluorobenzene and chlorobenzene as internal spikes.

2.3. Ventilation Systems Studied

Table 1 describes the experimental conditions of the six different ventilation systems studied. First, the hood face ventilation velocities of the used ventilation systems were measured by use of the Rotating Vaneometer. Then, in order to identify the components of aldehydes and VOCs produced from the cooking of seasoned meats, air samples in the breathing zone of the cook were collected under the condition which was not equipped with any ventilation (closed windows without ventilation). Finally, in order to find an effective local exhaust ventilation system for seasoned meat cooking, we compared the ventilation capacities of the six different ventilation systems which were widely being used in the general apartments and houses in U.S. (Table 1). For this comparison study, we analyzed the concentration of acetaldehyde, a marker compound, of the cooking fumes in the breathing zone of the cook during an operation of each ventilation system.

3. Results and Discussion

3.1. Identification of Aldehydes

Table 2 shows components and their concentrations, in the breathing zone of the cook, of aldehydes and ketones produced from the cooking of seasoned meats. Acetaldehyde, formaldehyde, acrolein, acetone, and 2-butanone were identified through HPLC analysis of the DNPH-aldehyde- and DNPH-ketone- derivatives. Although their

Table 1. Experimental conditions during a period of air sampling (30 min).

Sampling Conditions	Cooking/Room Temperatures (℃)	Ventilation Hood Face Velocity (ft/min)	Types of Samples	Comments
Closed windows without ventilation	213 / 21	No hood No fan	Aldehydes VOCs	University APT
Open windows with electric fan and hood	213 / 22	Forced fan : 367 Overhead hood : 73	Aldehydes	University APT No duct connection
Lateral hood ventilation	213 / 24	Lateral wall hood : 221	Aldehydes	Civil APT Wall fan with duct connection
Overhead hood ventilation	213 / 17	Overhead hood : 337	Aldehydes	House Sampling nearby wall Lateral wall fan
Down draft ventilation	213 / 20	Down draft : 283	Aldehydes	House Duct connection
Laboratory fume hood	213 / 12	Fume hood : 183	Aldehydes	University Laboratory Sash Opening : 23cm

Table 2. Typical air emissions of aldehydes and ketones from cooking of seasoned meat.

Aldehyde and Ketone	Concentration (ppm)	NIOSH RELs[a] (ppm)	Concentration (mg/m^3)	NIOSH RELs[a] (mg/m^3)
Acetaldehyde	0.520	100[b]	0.952	180[b]
Acetone	0.161	250	0.390	590
Acrolein	< 0.003	0.1	0.007	0.25
Formaldehyde	0.052	0.016[b]	0.065	0.02[b]
Butyaldehyde	N/D	NA	N/D	NA
2-Butanonec	0.080	200	0.235	590
2-Hexanonec	0.019	1	0.079	4
Crotonaldehyde	Trace	2	Trace	6
Propionaldehyde	N/D	NA	N/D	NA
Valeraldehyde	N/D	50	N/D	175
Isovaleraldehyde	N/D	NA	N/D	NA
Total (Aldehyde + Ketone)	0.816		1.728	

Note : [a]NIOSH RELs stands for National Institute for Occupational Safety and Health Recommended Exposure Limits.
[b]8-hour Time Weighted Average (TWA) in Korea.
[c]Concentrations obtained through the VOC Analysis.
NA stands for not available.

concentrations identified don't exceed their 8-hour time weighted average (8hr-TWA) concentrations, many of these compounds are considered potential carcinogens in conformance with the Occupational Safety and Heath Administration (OSHA) carcinogen policy. Especially, the identified concentrations of formaldehyde are exceeding the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL), 0.016ppm. Therefore, the cook exposed to the cooking fumes of the seasoned meats during a long period of time could have a potential risk of health hazards.

3.2. Identification of Volatile Organic Compounds

Figure 1 shows a gas chromatogram of many chemicals (VOCs) identified through GC-MS analysis of air samples collected from cooking fumes of seasoned meats. Also, table 3 represents air concentrations and components of the VOCs identified from the cooking fumes. The identified VOCs could be classified as three major categories: (1) chloro- or fluoro- hydrocarbons such as chloromethane, chloroform, dichloromethane, trichlorofluoromethane, and tetrachloroethylene, (2) aromatic hydrocarbons such as benzene, toluene, xylene, ethylbenzenes, and styrenes, and (3) ketones such as acetone, 2-butanone, and 3-hexanone. Although their concentrations are not exceeded their 8hr-TWA, many of these compounds are also considered potential carcinogens in conformance with the OSHA carcinogen policy. Therefore, the cooking fumes of the seasoned meats could produce significant amounts of carcinogen suspecting compounds.

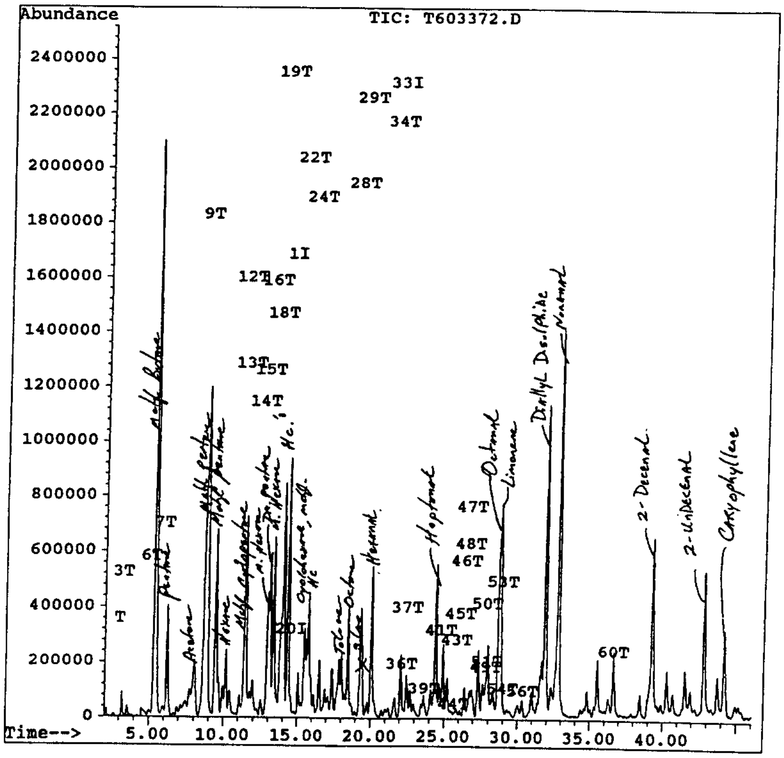

Fig. 1. A gas chromatogram of volatile organic compounds of the cooking fumes.

Table 3. Typical air emissions of volatile organic compounds (VOCs) from cooking of seasoned meat.

Name of VOCs	Concentration (ppb)	NIOSH RELs[a] (ppb)	Concentration ($\mu g/m^3$)	NIOSH RELs[a] ($\mu g/m^3$)
Chloroform	3.85	10,000	18.79	50,000
Chloromethane	40.07	50,000[b]	82.77	105,000[b]
Dichlofluromethane	2.26	10,000[b]	11.18	40,000[b]
Tetrachloroethylene	1.58	100,000	10.69	689,000
1,1,1-Trichloroethane	0.30	10,000	1.62	45,000
Trichlofluromethane	4.21	NA	23.65	NA
Benzene	6.34	100	20.25	325
Ethylbenzene	1.39	100,000	6.32	435,000
Toluene	13.80	100,000	51.99	375,000
Acetone	365.34	250,000	868.16	590,000
Carbondisufide	9.37	1,000	29.15	3,000
2-Butanone (MEK)	79.64	200,000	234.86	590,000
2-Hexanone (MBK)	19.37	1,000	79.37	4,000
Styrene	1.94	50,000	8.26	215,000
Xylenes (total)	8.58	100,000	37.25	435,000

Note : [a]NIOSH RELs stands for National Institute for Occupational Safety and Health Recommended Exposure Limits.
[b]8-hour Time Weighted Average (TWA) in Korea.
NA stands for not available.

3.3. Comparison of Ventilation Systems

Table 4 represents concentrations of a marker compound in order to compare the ventilation efficiencies of the six different exhaust ventilation systems which were widely being used in the general apartment, houses, and small-food factories in U.S. Since acetaldehyde was detected as the highest concentration of air pollutants produced from the cooking of the seasoned meats, its high concentration could make relatively small errors in evaluating the ventilation efficiency. Therefore, acetaldehyde was used as a marker compound and its concentrations in the breathing zone of the cook, depending on each ventilation system, were identified.

Because the studied ventilation systems had different configurations and different experimental conditions, it was very difficult to compare the direct ventilation efficiencies of the systems. However, the purpose of this study was to give a help in selecting ventilation system for the public use. Therefore, through a comparison of acetaldehyde concentrations, the relative ventilation efficiency of each ventilation system studied was identified.

In spite of the lowest ventilation hood face velocity, the ventilation by the laboratory fume hood was the best effective local exhaust ventilation system. This was due to a good ventilation configuration (a type of enclosures) of the laboratory fume hood compared to other systems studied. That is, since all sides, which were nearby pollutant sources, of the ventilation system were blocked except for the small hood-sash opening for the experimental side, the polluted air by the cooking fumes was effectively vented. Therefore, this kind of ventilation system would be good for the use of food factories which should be dealt with a lot of cooking.

The lateral hood system with a wall fan and a duct connection represented a better ventilation capacity compared to the overhead hood system, even though the former system had relatively small hood face velocity compared to the latter system. This was probably due to the difference in the configuration of air flow nearby a sampling point and a hood (face) location. That is, the lateral wall hood ventilation system had another wall which could make an effective air flow towards the hood face. If the pollutants produced were beyond a distance, a range in which the

Table 4. Variation of concentrations in the breathing zone of acetaldehyde, a marker compound, for a comparison of the exhaust ventilation capacity of the six different ventilation systems during the cooking of seasoned meat.

Sampling Conditions	Ventilation Hood Face Velocity (ft/min)	Concentration (ppm)	Concentration (mg/m^3)
Closed windows without ventilation (APT)	No hood No fan	0.520	0.952
Open windows with forced fan and overhead hood (APT)	Forced fan : 367 Overhead hood : 73	0.260	0.476
Lateral hood ventilation (APT)	Lateral wall hood : 221	0.038	0.070
Overhead hood ventilation (House)	Overhead hood : 337	0.046	0.085
Down draft ventilation (House)	Down draft : 283	0.043	0.078
Laboratory fume hood (University)	Fume hood : 183	0.004	0.007

local exhaust ventilation could work effectively, those pollutants could not be vented by the local ventilation system. Therefore, an additional wall located nearby the hood face and pollutant sources in the local exhaust ventilation system could block the pollutant dispersion and then concentrate pollutants, and finally would be effectively vented. In addition, since there was a strong wind the outside of the house during the experiment using the overhead hood, the overhead hood system had a count-current wind towards the hood inside from the outside air. Therefore, it could be difficult to maintain the optimum function of the overhead hood.

In a comparison of a ventilation capacity between the overhead hood and the downdraft ventilations, the downdraft system showed a better ventilation capacity than that of the overhead hood system. That is, even though the ventilation face velocity of the down draft system was slightly lower than that of the overhead hood ventilation at the houses, the former system showed more effective local exhaust ventilation. This was due to a much shorter distance between the hood face and pollutant sources in the downdraft system compared with the overhead hood system.

4. Conclusions

Significant amounts of VOCs such as many chloro- or fluoro-hydrocarbons, aromatic hydro-carbons, ketones, and aldehydes, which could be carcinogen suspecting chemicals, were producing from cooking fumes of seasoned meats.

The ventilation system by the laboratory fume hood, in spite of the lowest ventilation hood face velocity, was the best effective local exhaust ventilation of the six different ventilation systems studied. The local exhaust ventilation capacity of the lateral hood with a duct connection was better than that of the overhead hood without any duct connection. Also, the down draft ventilation system showed more effective local exhaust ventilation capacity than that of the overhead hood ventilation system at the houses.

Both additional walls, which could help in the venting of pollutants, and hood location factors, such as the distance between ventilation systems and pollutant sources, should be considered for effective local exhaust ventilation.

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