CHEMICAL ENGINEERING TRANSACTIONS
VOL. 68, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; **ISSN** 2283-9216
DOI: 10.3303/CET1868070

Analysis for Improvement of Kitchen Odour by Oil Fume Purification Technology

Rui Yan, Miaomiao Li*, Yao Wang, Yao Fu

Donlinks School of Economic and Management, University of Science and Technology Beijing, 00083, China
limiaomiao@ustb.edu.cn

The purpose of this study is to improve the kitchen odour. To this end, the comparative experiments were conducted in the methods such as mechanical purification, electrostatic purification, adsorption cleansing, filtration purification, washing purification, composite purification, and catalytic combustion etc. The experimental results show that there is a clear correlation between the purification effect and cost, that is, the method with better purification effect has higher purification cost. Through the comprehensive comparison, it's found that the catalytic combustion method has the best cost performance. Thus, it's suitable for large-scale promotion.

1. Introduction

There are fewer frying treatments in foreign diets, so the oil fume concentration emitted in the kitchen is relatively low. In large-scale restaurants, thermal oxidation incineration is mainly used, that is, thermal oxidation, to convert the oil fume into CO_2 and H_2O; small and medium-sized hotels mainly use catalyst purification method, which converts oil droplets into CO_2 and H_2O by catalytic oxidation combustion, thus eliminating the pollution and odour (Zhang et al., 2010). At present, for the range hood widely used in domestic kitchens, its operating principle is to firstly use the mechanical filtration method to remove large particles of water droplets and oil droplets, and then through the rotation of the impeller, to generate inertial separation for centrifugal force and purify the oil fume by filtration (Yao et al., 2015). However, the purification effect of this method is limited, since the obvious smoke can still be seen in the discharge outlet of the range hood, polluting the atmospheric environment (Mcdonald et al., 2003). Nowadays, the main purification technologies for the cooking fume include: mechanical purification, electrostatic purification, adsorption purification, filtration purification, washing purification, composite purification and catalytic combustion method (Xia and Yuan, 2008).

2. Oil fume purification technology

2.1 Formation of cooking oil fume

Cooking oil starts to break down when cooking temperature reaches 170 ℃, began to form small oil droplets, the diameter of over 10 ~ 3 cm; Cook begins when the temperature reaches above 270 ℃ evaporation, forming small oil droplets, the diameter of the 10-7-10-3 cm. When food is added to oil, water in food first expands to form fog, which is mixed with oil mist formed by oil fume and smoke formed by fuel thermal decomposition, forming oil smoke visible to the naked eye. When food materials are added to hot oil, milad reaction occurs between cooking oil and carbohydrate, protein, fat and amino acids in the food materials, and secondary reaction occurs between the reaction products and intermediates of the above substances (Chang et al., 1978). The water in the food material quickly vaporizes and expands and mixes with the soot and the smoke produced by the fuel to form the oil smoke, which spreads from the cooker to the air, collides with the air molecules and forms an aerosol containing the condensate. Finally, the oil produced in each stage forms the cooking fume together with the thermophilic decomposition of the food material, the oil smoke, the water gas, the aerosol containing the condensate, and the smoke from the fuel decomposition. Therefore, in general, the soot we refer to is mainly composed of tiny oil droplets with diameters of 10-3cm or more (Buonanno et al., 2009).

Please cite this article as: Yan R., Li M., Wang Y., Fu Y., 2018, Analysis for improvement of kitchen odour by oil fume purification technology, Chemical Engineering Transactions, 68, 415-420 DOI: 10.3303/CET1868070

2.2 The main components of cooking oil fume

From the formation process of lampblack, it can be seen that lampblack is a kind of aerosol with three phases of gas, liquid and solid. Its composition is very complex, and it changes with different cooking conditions and food materials. Due to the differences in dietary habits, there are few reports on the composition of lampblack abroad. In recent years, domestic research on this aspect has attracted great attention. Knowing the ingredients of cooking oil fume can help to develop targeted oil fume purification technology and equipment. In addition, understanding the main components of cooking fume also has important guiding significance for the design of smoke simulation and detection device in the experimental research scheme.
Liu et al. (2002) performed gc-ms analysis on organic components in repeatedly heated cooking oil smoke, and detected a total of 196 components, including aldehyde, ketone, hydrocarbon, ester, acid, alcohol, aromatic and heterocyclic compounds. As can be seen from Table 1, the main components are alkanes and olefin, followed by organic acids, aldehydes and polycyclic aromatic hydrocarbons.

Table 1: Organics in cooking oil smoke are classified and distributed

Classification	Smoke particles	Volatile organic compound
Aliphatic hydrocarbon	54	24
Mononuclear aromatics	2	5
Polyaromatic hydrocarbon	10	4
Aldehyde	10	15
Phenol	5	2
Alcohol	5	3
Acid	15	8
ester	12	6
Ketone	8	1
heterocycle	5	2

Li et al. (1992) used gas chromatography-mass spectrometer to analyze the total chemical composition of the condensate in kitchen oil-absorbing tobacco machine cup. The study showed that there were 74 compounds in total, and after removing 15 isomers, the remaining 59 organic compounds were divided into 8 categories, including hydrocarbons, alcohol phenols, aldosterone, carboxylic acids, thick-ring heterocyclic rings, and polyols.
According to the components of lampblack, the main components of lampblack contain alkanes and olefin, followed by organic acids, aldehydes, ketones and polycyclic aromatic hydrocarbons. Ingredients are very complex and include many toxic and harmful ingredients. Zhu (1985) pointed out that although aliphatic hydrocarbons, the main component of oil fume, are not carcinogens, but eleven alkanes, dodecane, octadecane and eicosane are important carcinogenic substances. The detection of formaldehyde, acetaldehyde, propanal, glutaraldehyde and heptanal, as well as dimethyl acrolein, dimethyl octenaldehyde, 9,17-octadecanoaldehyde and so on, has been proved to be mutagenic and closely related to the occurrence of lung cancer. The phenolic compounds detected, such as phenol and methylphenol, are important oncogenic compounds. Detect many kinds of polycyclic aromatic hydrocarbons (such as naphthalene, fluorene, fluoranthene, pyrene, benzopyrene, etc.) is recognized as an important strong carcinogen, it can raise the risk of damage to the reproductive system, lead to skin cancer, lung cancer, upper gastrointestinal tumor, hardening of the arteries, infertility, polycyclic aromatic hydrocarbons as the impact of environmental contaminants in food cannot be underestimated (Zhou, 1997; Chen et al., 1999), in the process of smoked and roasted food often produce a large number of polycyclic aromatic hydrocarbons, is very dangerous to the health of human body.

2.3 Mechanical purification

Mechanical purification method mainly includes inertial separation, cyclone separation and filtration etc. Its main advantages are simple equipment, low operating cost and low pressure drop; however, the removal rate of small particles is very low (Xia and Yuan, 2008). It is generally suitable for cleaning in the case of pretreatment or in combination with other methods. Figure 1 shows the basic process flow of this method.

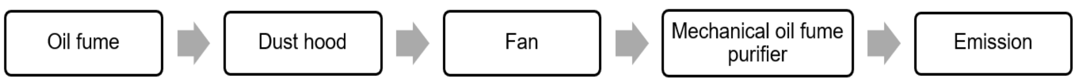

Figure 1: Process flow of mechanical purification method

2.4 Electrostatic purification

The electrostatic purification device utilizes the collision of electrons and smoke particles under the action of high-voltage electric field to charge the smoke particles, so that the charged particles are captured in the dust-removing area by the electric field force, so as to achieve the purpose of purifying and separating. It has the advantages of small occupied area and high purification efficiency, but its application is subject to certain restrictions due to secondary pollution caused by daily maintenance and cleaning. Figure.2 shows the basic process flow of this method.

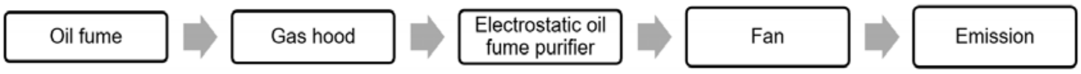

Figure 2: Process flow of electrostatic purification method

Tang (2015) designed a new cooking fume separation device using the principle of high voltage static electricity. The device consists of three parts: the insulating shell, and first and second electrostatic devices; the first electrostatic device is disposed below the second electrostatic device. It's characterized by easy assembly and good insulation performance since all the live parts are enclosed in the insulating shell. The device is applied to a range hood, and the high-voltage electrostatic fume separation device can be easily disassembled, greatly expanding the application range.

2.5 Adsorption purification

The adsorption purification method mainly utilizes the adsorption characteristics of the porous material to adsorb and remove most of the particulate matter and VOCS. The main advantage is that the removal rate of the aerosol is high, and the purification effect on the odor is obvious; however, the adsorption capacity of the adsorption material is gradually reduced with the adhesion of the smoke, so the adsorption material must be frequently replaced, so the maintenance cost is higher, and the replaced adsorbent material will also be subjected to secondary pollution due to the proliferation of bacteria and mould (Zheng et al., 2015). Therefore, this method has not been widely used.

2.6 Filtration purification

The main principle of the filtration purification is that the fume particles are filtered through the filtering layer made of the lipophilic polymer filter fabric (fibre, filter cloth, etc.), and the contaminants are trapped so as to achieve the purpose of filtration. It has the advantages such as high purification efficiency, up to 90%, and the stable operation process, but also has the disadvantages of large pressure drop, high cost and noise pollution (Chen et al., 2006). These all limit the promotion of filter purification.

2.7 Washing purification

The principle of the washing purification is to change the washing liquid (water, chemical agent) into the liquid mist or liquid film by specific devices, so that the pollutants can be transferred from the gas phase to the liquid phase, thereby achieving the purpose of washing and absorbing harmful gases and particulate matter. Liquid washing purification can achieve the absorption of harmful gases and the removal of particulate contaminants in fumes, but the washing waste liquid must be treated before being discharged into the sewer, otherwise it will easily cause secondary pollution (Liang et al., 2011). Therefore, in future, the research should focus on the optimization of washing liquid modification and processing technology so as to reduce pollution (Zeng and Qiu, 2014).

2.8 Composite purification method

Since the composition of the cooking fumes is very complicated, the advantages and disadvantages of various purification methods are quite different, so a combination of various purification technologies are adopted in the purification equipment, that is, the composite purification method. Commonly, inertial separation combined with electrostatic methods has been widely used because of its high efficiency in line with the domestic sustainable development concept.

Mi Junfeng et al. Junfeng Mi et al. (2015) developed a new composite fume treatment device, and its principle is the combination of centrifugal technology, filtration technology, photolysis technology and corona discharge technology. Studies have shown that as working hours continue to increase, the purification efficiency can be maintained at around 95%.

In addition, the high-gravity method integrated with inertial collision, filtration separation, interception effect centrifugal separation, diffusion effect, and liquid washing etc. is used to realize the separation of gas phase, liquid phase and solid phase in the fumes, and then achieve the efficient, economical and environmentally friendly purification (Atik Winarti et al., 2018). However, this method hasn't been widely used because it is still in the small gas test phase (Zhang, 2009).

2.9 Catalytic combustion method

Catalytic combustion is a process in which organic matter is subjected to flameless combustion under the action of the catalyst to generate carbon dioxide and water. Since the entire process can be carried out at lower temperatures, energy consumption is greatly reduced. Compared with the ordinary thermal oxidation method, the catalytic combustion method has higher pollutant removal efficiency to avoid the generation of secondary pollutants. It's an environmentally friendly catalytic purification technology (Lv, 2010).

Catalyst plays a very important role in the catalytic combustion process. It can effectively reduce the activation energy of the reaction, thereby increasing the reaction rate and lowering the reaction temperature. The catalyst performance determines the efficiency of the catalytic combustion reaction. Precious metal catalysts have been widely recognized by many scholars for their high activity, long service life and good heat resistance. However, precious metals are quite expensive and difficult to recycle and recycle, making the cost of precious metal catalysts greatly improved.

3. Experiments for purification technology to improve the kitchen odour

3.1 Experimental design

In this technical experiment, several types of fume purification equipment above were used to verify and compare the air quality purification effect in the kitchen. A 15 square meter enclosed space was used as the kitchen.

3.1.1 Experimental equipment and materials

The common fume purification equipment in line with the standards was selected in the market, one equipment for each purification technology was selected. The specific equipment model corresponding to the purification technology is: Jing Zhicong mechanical catering industry fume purification integrated machine adopts mechanical purification method; Hunzio electrostatic hood adopts electrostatic purification method; Macro range hood adopts adsorption purification method; Robam air purification range hood adopts the filtration type purification method; the Uger SX100 washing machine adopts the washing type purification method; the Oerlikon commercial range hood adopts the composite purification method; the JTWD catalytic combustion environmental protection equipment adopts the catalytic combustion method.

According to the sales of edible oil in shopping malls and supermarkets, this experiment selected the blend oil commonly used in food cooking as the research material. The specific material was: Gold Arowana blend oil.

3.1.2 Purification verification design

(1) Before each experiment, continuously exhaust the experimental kitchen for more than 12 hours, and then stand still for not less than 1 hour;

(2) Close all doors and windows of the experimental kitchen, and only keep the ventilation interface between the purification equipment and the outside;

(3) Heat 200ml of cooking oil (new oil) at the cooking temperature of 200°C in the centre of the experimental kitchen, continue heating for ten minutes, and then make subjective odour evaluation;

(4) Start the fume purification equipment (one device per experiment), and make purification treatment for 0.25h, 0.5h, 1h, 2h, respectively, and carry out the odour evaluation separately.

After each experiment, the residual fumes and oil stains in the experimental kitchen were completely removed to avoid interference with the results of the next experiment.

3.2 Analysis of experimental results

Table 2 lists the purification technology verification results. During the seven experiments, the odour level in the experimental kitchen was 1.5 before the purification treatment. The electrostatic purification, adsorption purification, combined purification and catalytic combustion methods have a better purification effect, and the kitchen odour level can be significantly improved. Among them, the catalytic combustion method has the highest purification efficiency, and the kitchen odour level can be raised to level 4 within 0.5 hours. Filtration purification and washing purification are generally effective, and after 2 hours of treatment, the kitchen odour level can only be raised to 3.5. The worst purification effect is the mechanical purification method, which increases the odour level of the kitchen to 3 after 2 hours of treatment.

Table 2: Kitchen odour evaluation results before and after the treatment of fume purification

Purification technology	Pre-fume treatment	Treating for 0.25h	Treating for 0.5h	Treating for 1h	Treating for 2h
Mechanical purification	1.5	2	2.5	3	3
Electrostatic purification	1.5	3	3.5	4	4
Adsorption purification	1.5	3	3.5	4	4
Filtering purification	1.5	2.5	3	3.5	3.5
Washing purification	1.5	2.5	3	3.5	3.5
Composite purification	1.5	3	3.5	4	4
Catalytic combustion	1.5	3.5	4	4	4

3.3 Comprehensive comparative analysis of fume purification technology

This paper makes a comprehensive comparative analysis of the fume purification technology in terms of technicality and economy. The results are shown in Table 3. The catalytic combustion methods have the best purification effect and the least secondary pollution. The electrostatic purification method, adsorption purification method and composite purification method take second place in terms of purification effect, but with the disadvantage of high cost. The filtration purification method and the washing purification method have a common purification effect and low cost, but with the disadvantage of higher secondary pollution. The mechanical purification method has the worst purification effect and the lowest cost; it's suitable for pre-treatment of the large-scale fume purification.

Through comprehensive analysis, among these purification technologies studied in this paper, the catalytic combustion method is a more economical and direct method for purifying the cooking fumes. From the development trend of the fume pollution control technology in the catering industry, on the one hand, it is necessary to formulate more stringent standards and control the emission of PME and VOCs in the fume as soon as possible; on the other hand, the study on the catalytic purification mechanism of macromolecular oxygen-containing organic compounds should be also carried out urgently according to the characteristics and laws of cooking fumes.

Table 3: Comparison of various types of fume purification technology

Type	Purification efficiency	Secondary pollution	Cost	Operation
Mechanical Purification	Lower	Less	Lower	Make cleanliness every half year for pre-treatment and primary treatment
Electrostatic purification	High	The absorbed and precipitated waste oil needs to be treated	High	Clean the plate (with much grease stain, difficult to be cleaned) every half year
Adsorption purification	High	More	High	Adsorption materials must be replaced frequently
Filtration purification	Common	replaced waste should be properly treated	Common	Filter medium requires frequent replacement
Washing purification	Common	The absorbent needs to be treated before being emitted	Lower	Make cleanliness every half year
Catalytic combustion	Higher	Less	Higher	Annual replacement of catalyst
Composite purification	High	Common	Higher	Automatic cleaning, monthly replacement of cleaning agent

4. Conclusions

In this paper, kitchen purification experiments were performed on seven types of fume purification technologies such as mechanical purification, electrostatic purification, adsorption purification, filtration purification, washing purification, composite purification, and catalytic combustion. It's found that all these seven purification technologies have good kitchen odour purification effect. Among them, the catalytic combustion method has the best odour enhancement effect and less secondary pollution, which is suitable for wide-scale promotion.

References

Atik Winarti, Nanung A. Fitriyanto, Jamhari, Ambar Pertiwiningrum, Zaenal Bachruddin, Yudi Pranoto, Yuny Erwanto, 2018, Optimizing of protease purification from bacillus cereus td5b by ammonium sulfate precipitation, Chemical Engineering Transactions, 63, 709-714, DOI: 10.3303/CET1863119

Buonanno G., Morawska L., Stabile L., 2009, Particle emission factors during cooking activities, Atmospheric Environment, 43(20),3235-3242, DOI: 10.1016/j.atmosenv.2009.03.044

Chang S.S., Peterson R.J., Ho C.T., 1978, Chemical reactions involved in the deep-fat frying of foods, Journal of the American Oil Chemists' Society, 55(10),718-727, DOI: 10.1007/bf02665369

Chen X.S., Liang X.C., Li W., Xuan K.Y., 2006, Experiment on Purifying Oily Smoke of Restaurants Using Filtration and Rinsing Method, Environmental Science and Technology, 29(11), 71-73, DOI: 10.3969/j.issn.1003-6504.2006.11.029

Chen Y.L., Wang X.R., 1999, Research progress on toxicity of cooking oil fume, Journal of environment and health, 16(2), 120-122, DOI: 10.16241/j.cnki.1001-5914.1999.02.036

Li S.G., Pan D.G., Wang G.X., 1992, Analysis of polycyclic aromatic hydrocarbons in some edible oils and their heating products, Journal of environment and health, (5), 217-219, DOI: 10.16241/j.cnki.1001-5914.1992.05.008

Liang B., Wang Y.E., Jin J.J., Wang J.M., Xie G.J., 2011, Review of Studies on Harm and Treatment Technology of the Fumes from Restaurant Industry, Anhui Chemical Industry, 37(3), 59-61, DOI: 10.3969/j.issn.1008-553X.2011.03.020

Liu Z.W., Sun Y.M., 2002, Analysis of organic components in cooking oil smoke, Chinese public health, 18(9), 1046-1048.

Lu L., 2010, Research on kitchen fume purification catalyst, Jilin University, TQ426.

Meloni E., Caldera M., Palma V., Pignatelli V., Gerardi V., 2018, Open cell foams filters for soot abatement from biomass boilers, Chemical Engineering Transactions, 65, 799-804, DOI: 10.3303/CET1865134

Mcdonald J.D., Zielinska B., Fujita E.M., Sagebiel J.C., Chow J.C., Watson J.G., 2003, Emissions from charbroiling and grilling of chicken and beef, Journal of the Air & Waste Management Association, 53(2), 185-94, DOI: 10.1080/10473289.2003.10466141

Mi J.F., Yan D.M., Du S.N., 2015, Elimination of soot and deodorization experiment in compound lampblack purifier, Chemical Industry and Engineering Progress, 34(12), 4403-4406, DOI: 10.16085/j.issn.1000-6613.2015.12.045

Tang L.J., 2015, A high-voltage electrostatic fume separation device: CN204122234U.

Xia Z.B., Yuan H., 2008, Research on Swirl Tube Kitchen Fume Purification Technology, Chemical Industry Equipment Technology, 29(2), 13-16, DOI: 10.16759/j.cnki.issn.1007-7251.2008.02.010

Yao X., Chen M., Fan Z.Y., 2015, Research Progress in Cooking Fume Pollution and Its Control Technology, Chemical Industry and Engineering, 32(3), 53-58, DOI: 10.13353/j.issn.1004.9533.2015.03.007

Zeng P., Zhang Z.B., Ji H.C., 2015, Analysis of oil fume purification technology and development trend, Green Science, (8), 247-248.

Zeng X.F., Qiu H.H., 2014, Comparison of Food Fume Purification Treatment Technology, Environment, (S1), 58-59.

Zhang X.D., 2009, Research on Purification of Catering Fume by High Gravity Method, North University of China, X701

Zhang X.D., Liu Y.Z., Fan G.Y., 2010, Development and Research Status of Fume Purification Technology in Catering Industry, Industrial Safety and Environmental Protection, 36(4), 32-33, X701.

Zhou Y.M., 1997, Effects of edible oil fume on health, Shanghai environmental science, (2), 35-36.

Zhu H.G., Yu S.Z., 1985, Cancer and mutagenesis in drinking water, Environmental protection, (4), 21-23, DOI: 10.14026/j.cnki.0253-9705.1985.04.008