Effects of Food Materials on Emission Characteristics of Fine Particulate Matter in Cooking Process

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ABSTRACT
In this paper, the particle emission characteristics of vegetables, meat and vegetables plus meat were studied when stir-frying was used as cooking aspect. The particle size, quantity and distribution of different food materials under the same cooking conditions were analyzed through field tests. The results showed that the food material had a significant effect on the particle size distribution and time evolution of the particles emitted during cooking. Foodmaterials have no significant effect on the vertical distribution characteristics of particulate matter. The effect of exhaust speed of range hood on particulate matter in different cooking process is different.

Keywords: *Foodmaterials; Cooking; Particulate matter; Distributing characteristics*

1. INTRODUCTION

As an important indoor pollution source, cooking fume has a significant negative impact on indoor air quality and residents' health[1,2]. Studies show that the cooking process of the kitchen oil flue gas contains a variety of toxic and harmful substances, including CO2, SO2, CO, NOx, inhalable particulate matter, polycyclic aromatic hydrocarbons and a variety of strong carcinogens[3,4]. Therefore, effective control of cooking fume is an important way to improve indoor air quality.

Particulate matter is an important pollutant produced in cooking process and also the focus of cooking fume pollution research[5-9]. A number of studies have shown that the particulate matter produced in the cooking process is mainly fine particulate matter and ultrafine particulate matter, and its particle size is affected by the oil temperature. However, in the actual cooking process, the characteristics of the food material itself will also have an impact on the emission characteristics of particulate matter, which is rarely considered in existing studies.

In this paper, the particulates emission characteristics of vegetables, meat and vegetables plus meat were studied when stir-frying was used as cooking aspect. The particle size, quantity and distribution of different food ingredients under the same cooking conditions were analyzed through field tests, and then the influence of food material on the emission of fine particles in the cooking process was obtained.

2. FIELD MEASUREMENT METHOD

2.1. Test instrument and measuring point layout

In this paper,weselected typical kitchens in Beijing for testing(see Figure 1). Graywolf PC3016-IAQ particulate matter detector was used to detect indoor particulate matter concentration. The temperature of the oil pan during cooking was measured by infrared thermography. Three measuring points were arranged for particulate matter detection, namely A1, A2 and A3 (see Figure 2). Point A-1 is set directly above the pot, 58cm away from the desktop, the sampling port of dust particle counter is connected with the rubber hose, and the air inlet is placed horizontally perpendicular to the direction of flue gas flow. Sampling point A-2 is set 50cm from the north side of the hearth, 70cm from the desktop, and the air inlet section is vertically downward to simulate the concentration of cooking smoke at the chef's mouth and nose. Sampling point A-3 is set in the center of the kitchen, 220cm above the ground, and the air inlet is vertical upward.

Fig.1 schematic diagram of the kitchen


(a)A-1 and A-2 sampling points


（b）A-3 sampling points

FIG. 2 Sampling point layout

2.2. Test Method

In the test, green pepper and pork were selected as food materials to analyze the effects of single vegetable, single meat and vegetable plus meat on the emission characteristics of particulate matter in cooking. Table 1 shows the amount of food materials, oil and seasoning under different working conditions.

Table 1. Consumption of food materials under different working conditions

Working condition	Food materialsand dosage	Edible oildosage(g)	Edible oildosage(g)
1	100g green pepper	26.0	3.6
2	50g pork	26.0	3.6
3	50g pork +100g green pepper	26.0	3.6

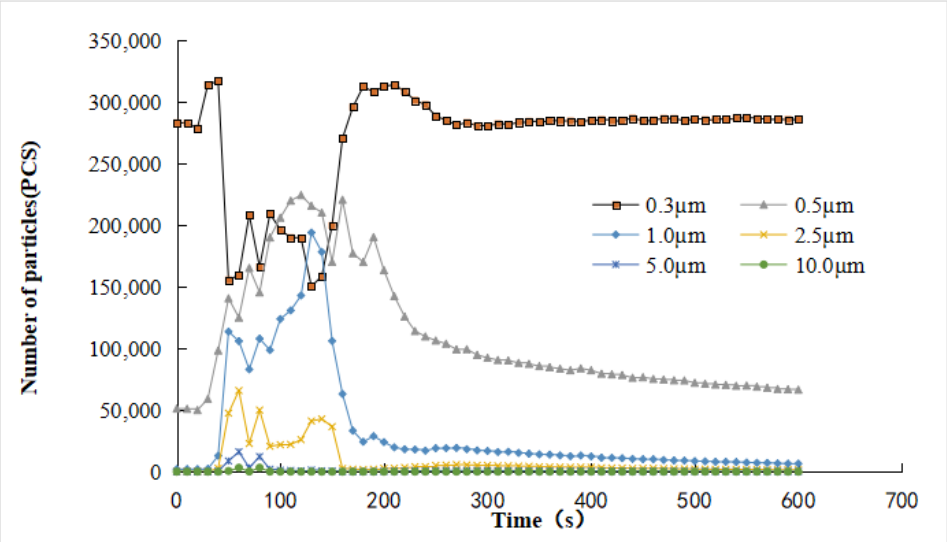
In the measurement, firstly, open the range hood, fire the water in the pot after drying, use the infrared thermometer to observe the temperature of the iron pot, till pot temperature reached 220℃, add cooking oil and open 3 dust particle counters. For working condition 1, heat it on medium heat for 20 seconds, then add sliced green pepper and soy sauce, stir-fry it for 120s, and then remove it from the pot. For working condition 2, heat it on medium heat for 20 seconds, then add sliced meat and soy sauce, stir-fry it for 120s, and then remove it from the pot. For working condition 3, heat it on medium heat for 20 seconds, then add shredded meat and soy sauce, stir-fry it for 60 seconds, then add green pepper, stir-fry it for 60 seconds, and then serve it.

3. ANALYSIS OF MEASURED RESULTS

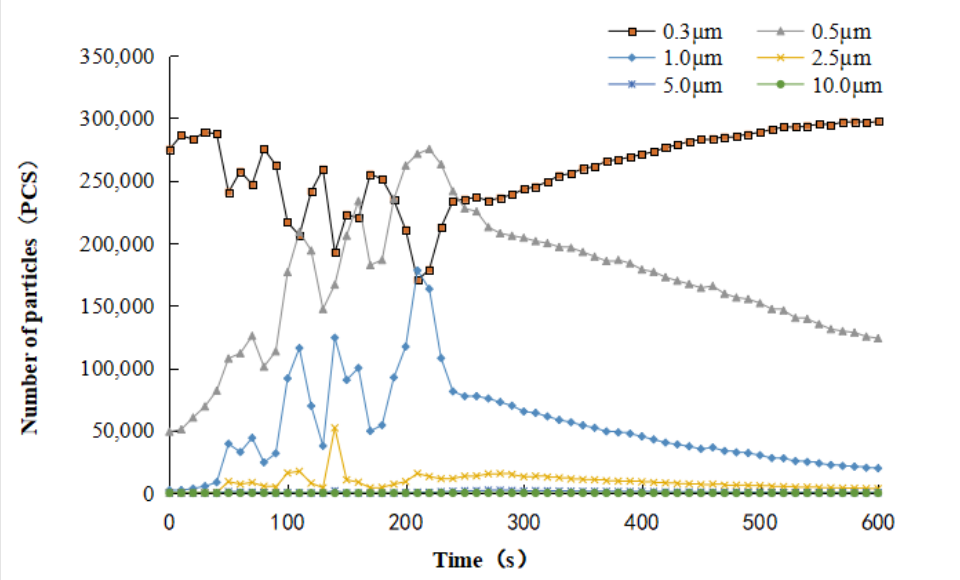
3.1. Particle size distribution

The measured results show that the particles produced in cooking are mainly fine particles with particle size less than 2.5μm under the three working conditions (see Figure 3). However, there are significant differences in the relative proportions of particles with different particle sizes under different working conditions.For condition 3, there is an obvious negative correlation between the number of particles and their particle size during the

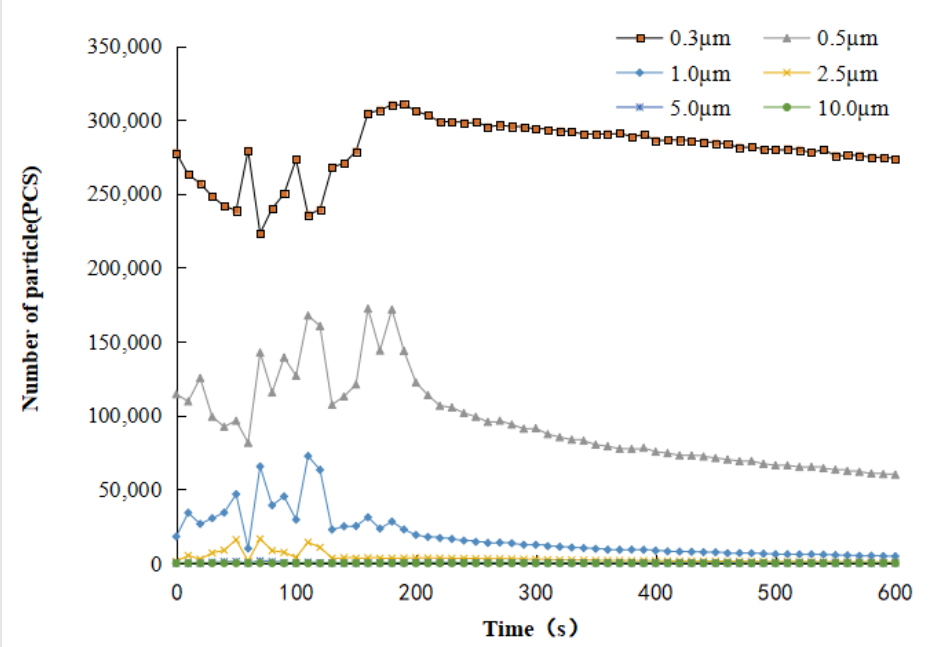
whole cooking process, that is, the smaller the particle size is, the more particles are emitted during the cooking process. In addition, the number of PM0.3 is much larger than other particle sizes. However, for conditions 1 and 2, the relative quantities of PM0.3, PM0.5 and PM1.0 were different throughout the cooking process. In addition, for condition 2, although the number of PM0.3 is still the largest among all particle sizes in the middle and late cooking period, the difference between PM0.3 and other particle sizes is significantly smaller than that in condition 1 and condition 3.



(a) Working condition 1



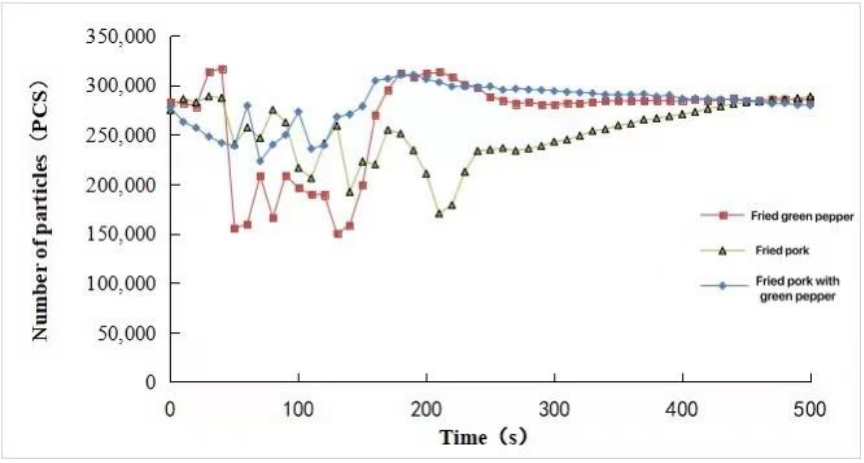
(b) Working condition 2



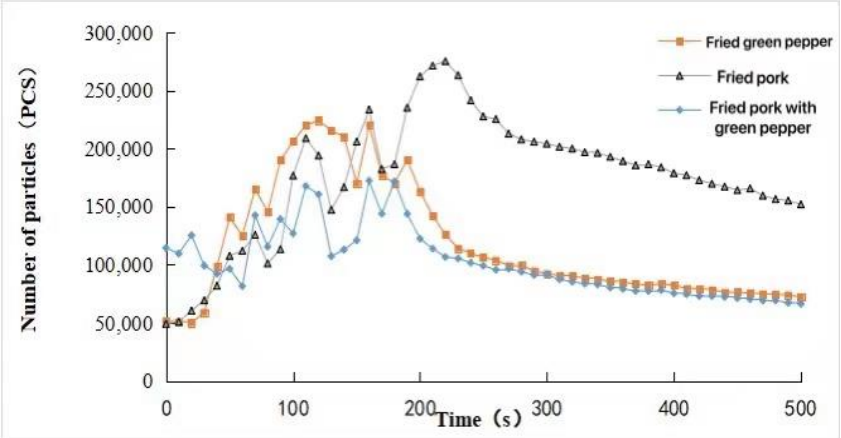
(c) Working condition 3

FIG. 3 Variation of particle concentration above the pot under different working conditions

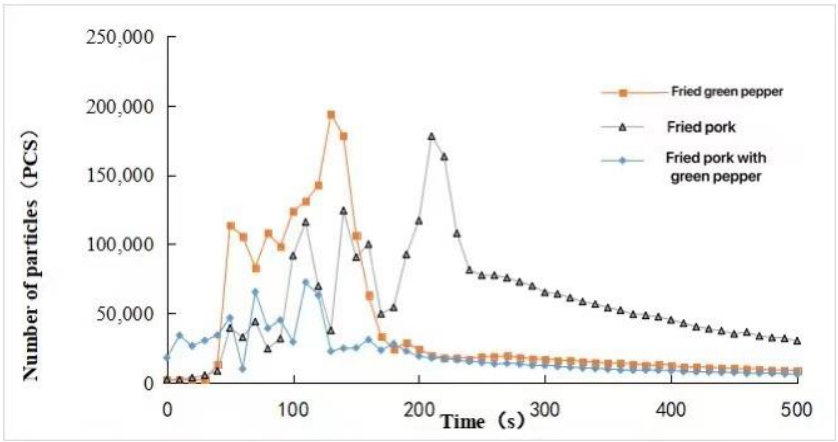
At the same time, the figure 4 shows, besides PM0.3, under the condition 1, particles within the cooking in the early 100seconds reached the peak, and then declinedgradually;and under the condition 2, soot particles in the 150 seconds reached peak after cooking.Investigating its reason is that at the beginning of the cooking ,oil and green pepper frying produced a large number of soot particles, with the release of the green pepper in water, soot particles in edible oil precipitated that reduced the emission of particulate matter;while in the case of fried pork, the cooking oil evaporated the water in the pork at the beginning of cooking. After all the water has evaporated, the oil in the pork began to release soot particles under the action of the cooking oil, so the emission peak time of fried green peppers soot particles was earlier than pork's.Andstir-fried pork with green pepper particles emission peak time was between fried green pepper and friedpork;at the same time, the peak value of particulate matter released was also lower than that of fried green pepper and friedpork, indicating that the moisture generated in the mixed cooking process can inhibit the production of soot particulate matter.



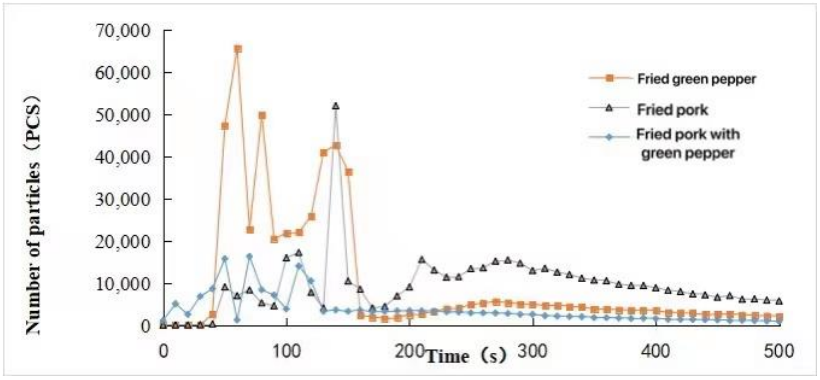
(a)PM0.3 above the pot



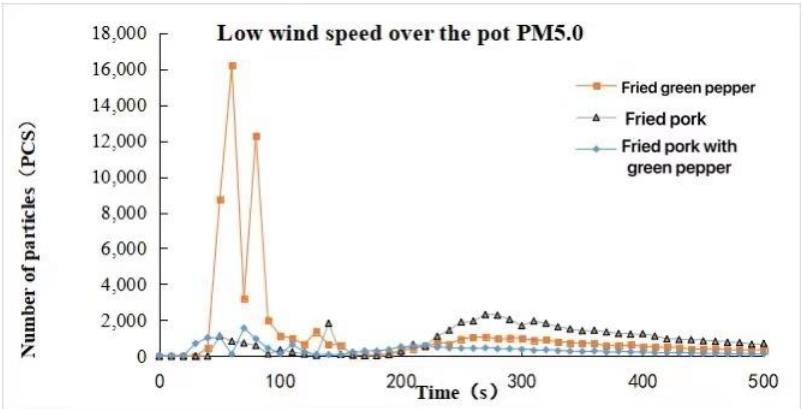
(b)PM0.5 above the pot



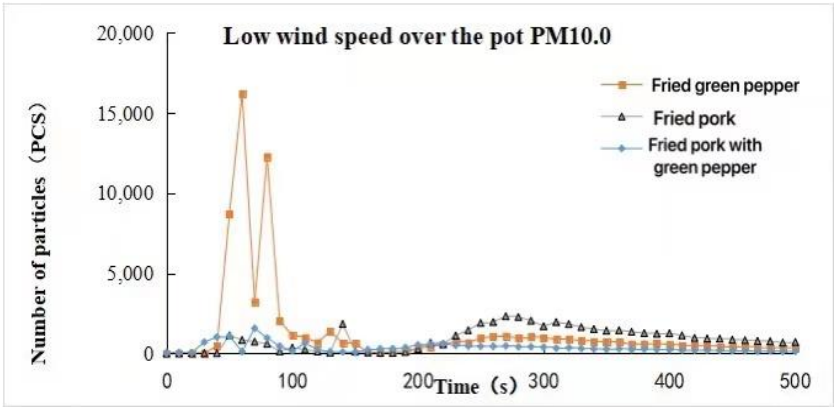
(c)PM1.0 above the pot



(d)PM2.5 above the pot



(e)PM5.0 above the pot

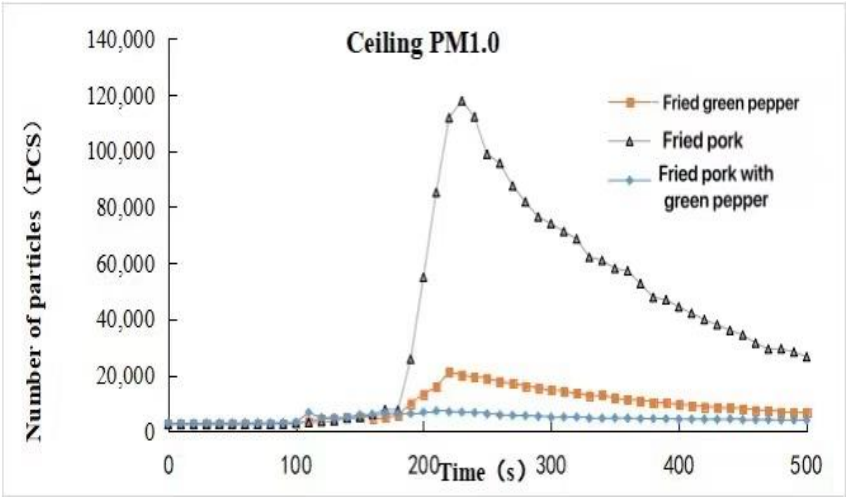


(f)PM10.0 above the pot

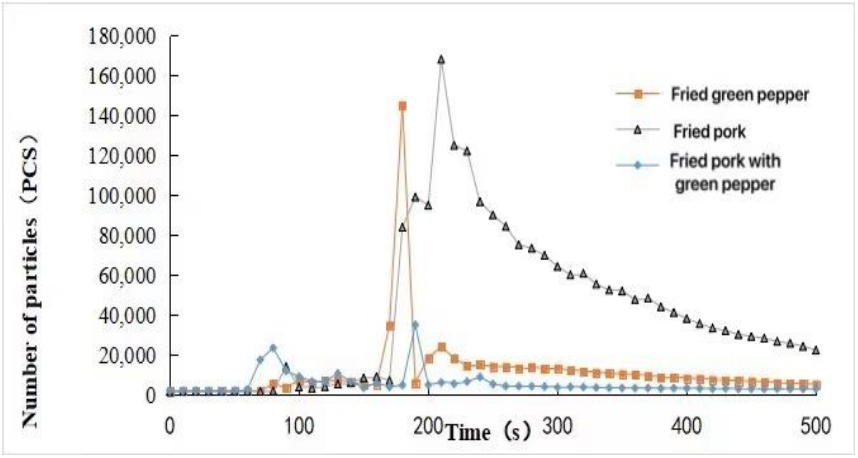
FIG. 4 Variation of concentration of different particles above the pot

3.2. Distribution of particle concentration at different locations

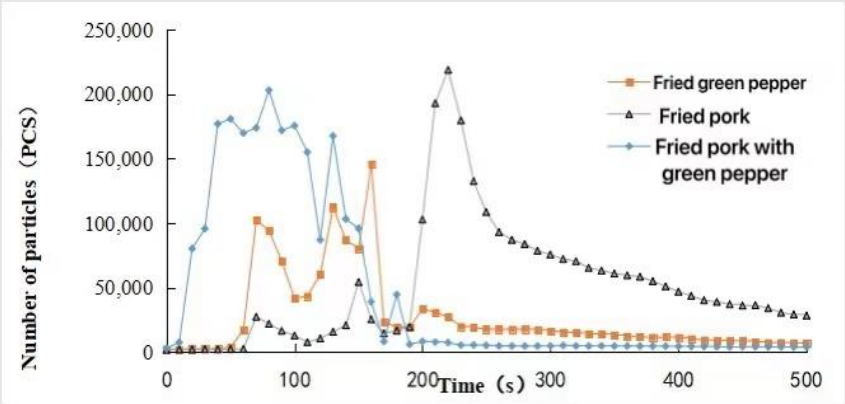
From the distribution diagram, it can be seen that the soot particles released from the top of the pot are the largest, followed by the chef's mouth and nose, and the ceiling is the lowest. This can interpret that in the process of cooking, influnced by the effect of exhaust air of range hood, lampblack particle flows obviously with vertical direction, most soot particles are discharged from the kitchen by the range hood.



(a)Ceiling



(b)The chef's nose and mouth

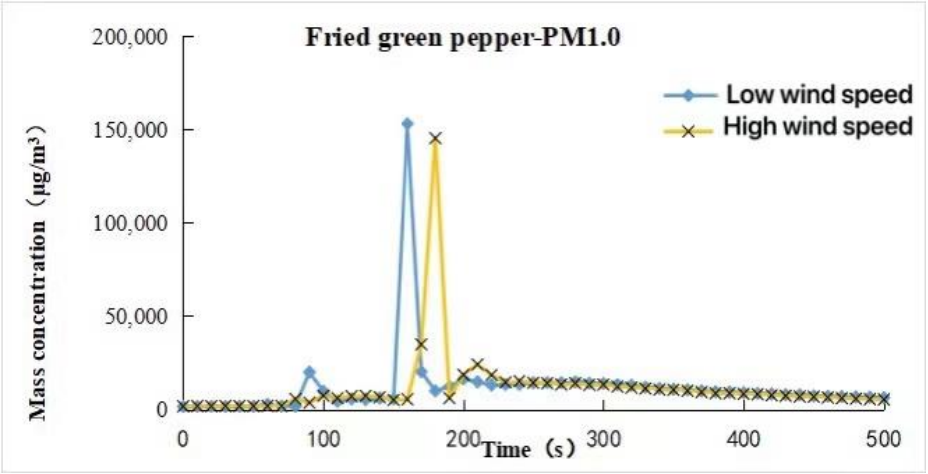


(a) over the pot

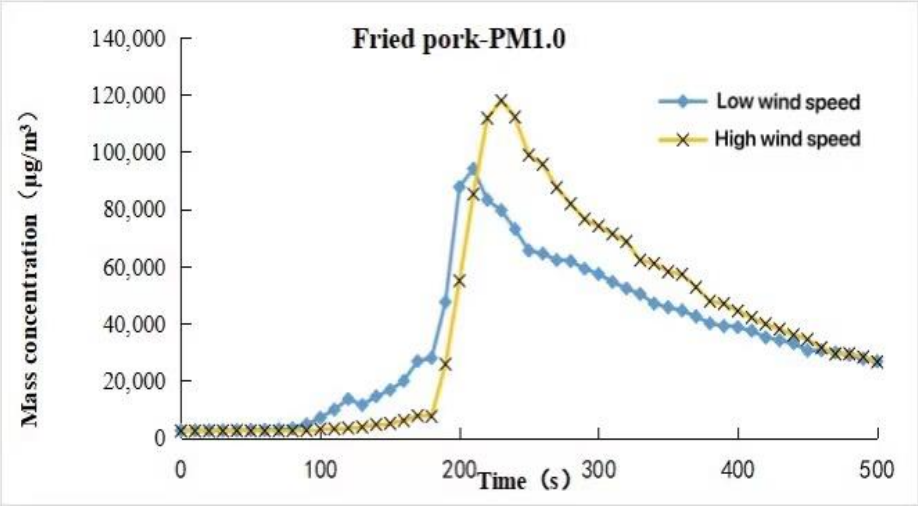
FIG. 5 Distribution of particulate matter under different working conditions

3.3. Influence of wind speed of range hood on particle concentration

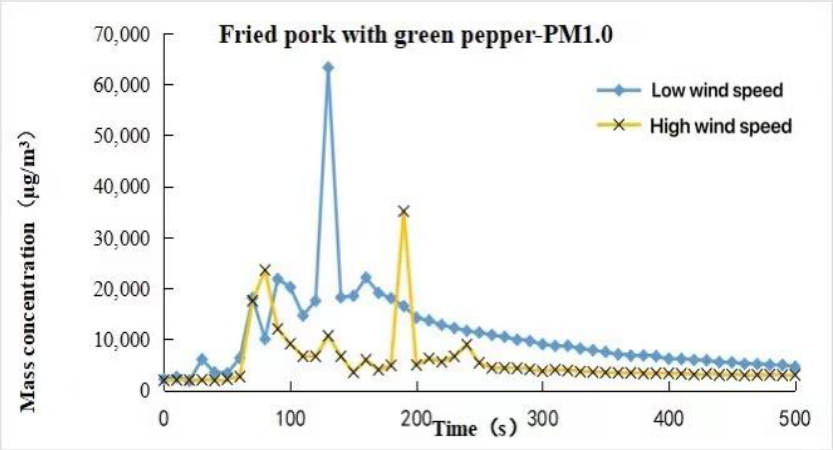
FIG. 6 takes PM1.0 as an example to show the concentration of particulate matter above the pot at exhaust wind speeds ofdifferent range hoods. It can be seen from FIG. 6 that under high wind speed, the concentration of PM1.0 in working condition 1 and working condition 3 is lower than the concentrationthat under low wind speed, while the concentration of PM1.0 released in working condition 2 is higher than thatthe concentration under high wind speed. The reason is that the range hood mainly exhausts water vapor, while less water vapor is released in fried meat. There are also less soot particles wrapped in water vapor, so the wind speed of the range hood has little effect on the emission of soot particles of pure fried meat, and can reduce the soot particles of vegetables and meat mixture,which with more water release.



(a)Working condition 1



(b)Working condition 2



(b) Working condition 3

FIG. 6 Concentration of particulate matter above the pot at different exhaust speeds

4. CONCLUSIONS

(1) The food material had a significant effect on the particle size distribution and time evolution of particles emitted during cooking.

(2) Food has no significant effect on the vertical distribution characteristics of particulate matter;

(3) The influence of exhaust speed of range hood on particulate matter in cooking process of different ingredients is different.

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