



Study on Quantitative Generation Technology of Bio-fluorescence Calibration Particles Based on Inkjet Generator



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Introduction

Accurate measurements are critical for timely early warning and effective prevention of epidemics due to the continuing impact of bioaerosols on human health. In recent years, researchers have been focused on developing and calibrating online monitoring instruments. However, there is still a lack of laboratory-generated standard aerosol samples suitable for calibration. Conventional techniques are commonly employed to generate suspended or solid particle samples. Inkjet generation technology, a precise method for generating monodisperse droplets or solid particles that allows for adjustment of size and number concentration by manipulating instrument parameters, is extensively employed to obtain monodisperse aerosol samples for calibrating condensation particle counters (CPC) and optical particle counters (OPC). Therefore, in this study, we utilized a self-developed Ink Jet Aerosol Generator (H-IJAG) to achieve controllable generation of monodisperse aerosol standard particles, which are known bio-fluorescent materials. This optimized IJAG technique provides a promising solution for accurately calibrating bioaerosol monitors.

Materials and Methods

The following materials were required to complete the research:

- **Tryptophan (Trp)**
- **7-hydroxycoumarin-4-acetic acid (7-HCA)**

The following equations were used for statistical analysis:

$$d_{VED} = \frac{D}{10} \times \left(\frac{c}{\rho}\right)^{\frac{1}{3}} \quad (1)$$

$$C_s = \frac{N_s}{V} = \frac{N_d \times \eta_r}{Q \times \frac{1000}{60} \times t} = \frac{f \times t \times \eta_r}{Q \times \frac{1000}{60} \times t} = \frac{3f \times \eta_r}{50Q} \quad (2)$$

where c is the mass fraction of the solute in the inkjet solution (g/L), D is the diameter of the droplet (μm), ρ is the density of the solute (g/cm^3). C_s is the number concentration, N_s is the number of solid particles, N_d is the number of droplets generated, η_r is the relative transport efficiency, f is the frequency (Hz), Q is the flow rate (L/min), t is the time (s).

References

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Results

The optical particle size distributions of solid aerosol samples (Trp and 7-HCA) obtained by APSS are shown in **Fig.1**. In the range of (0.4~15) μm , monodisperse solid aerosol samples with different fluorescence properties could be generated by H-IJAG with geometric standard deviation for all samples less than 1.15, which meets the definition of monodispersity. Rapid evaporation of the solvent during droplet drying can lead to entanglement of solute molecules, resulting in the formation of solid monodisperse agglomerates that were near spherical after precipitation from the solution. Additionally, the rapid process can decrease the density of the solid particles. The particle size of Trp particles is slightly larger than that of 7-HCA.

It is noteworthy that the samples exhibit uniform particle size and roughly spherical shape as shown in **Fig. 2**. The SEM of results indicate Trp agglomerates exhibit a complex woven structure with irregular depressions on the surface. In contrast, 7-HCA agglomerates are more tightly packed with a fluffy structure and a smoother surface.

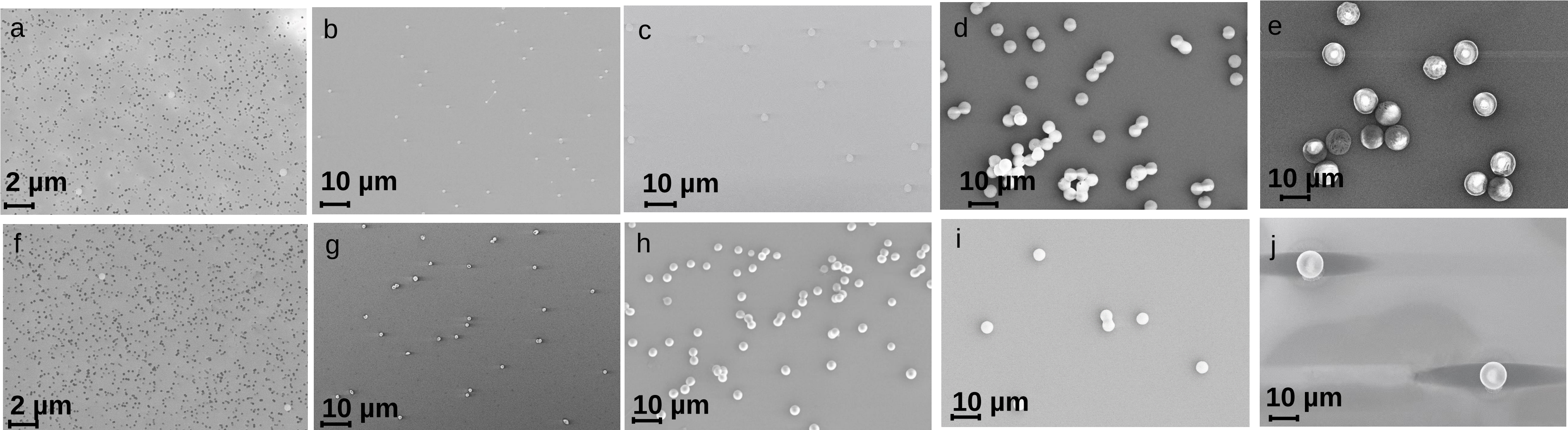


Fig. 2 SEM images of Trp at different concentrations(Trp (a: 5×10^{-4} g/L; b: 5×10^{-3} g/L; c: 5×10^{-2} g/L; d: 5×10^{-1} g/L; e: 5 g/L) ; 7-HCA (f: 5×10^{-4} g/L; g: 5×10^{-3} g/L; h: 5×10^{-2} g/L; i: 5×10^{-1} g/L; j: 5 g/L)

Table 1 The number of concentration 、 the ratio of fluorescence particle and transport efficiency of solid particles of different concentration

Concentration (g/L)	Trp				7-HCA			
	N_m	N_s	η_r (%)	The ratio of fluorescence particle /total particle	N_m	N_s	η_r (%)	The ratio of fluorescence particle /total particle
5×10^{-4}	79496	238488	99.37	98.6%	78400	235200	98.00	96.3%
5×10^{-3}	78600	235800	98.25	96.7%	79496	238488	99.37	99.7%
5×10^{-2}	78904	236712	98.63	97.5%	78600	235800	98.25	104.2%
5×10^{-1}	79800	239400	99.75	101.2%	79200	237600	99.00	97.3%
5	79200	237600	99.00	103.5%	78904	236712	98.63	98.1%

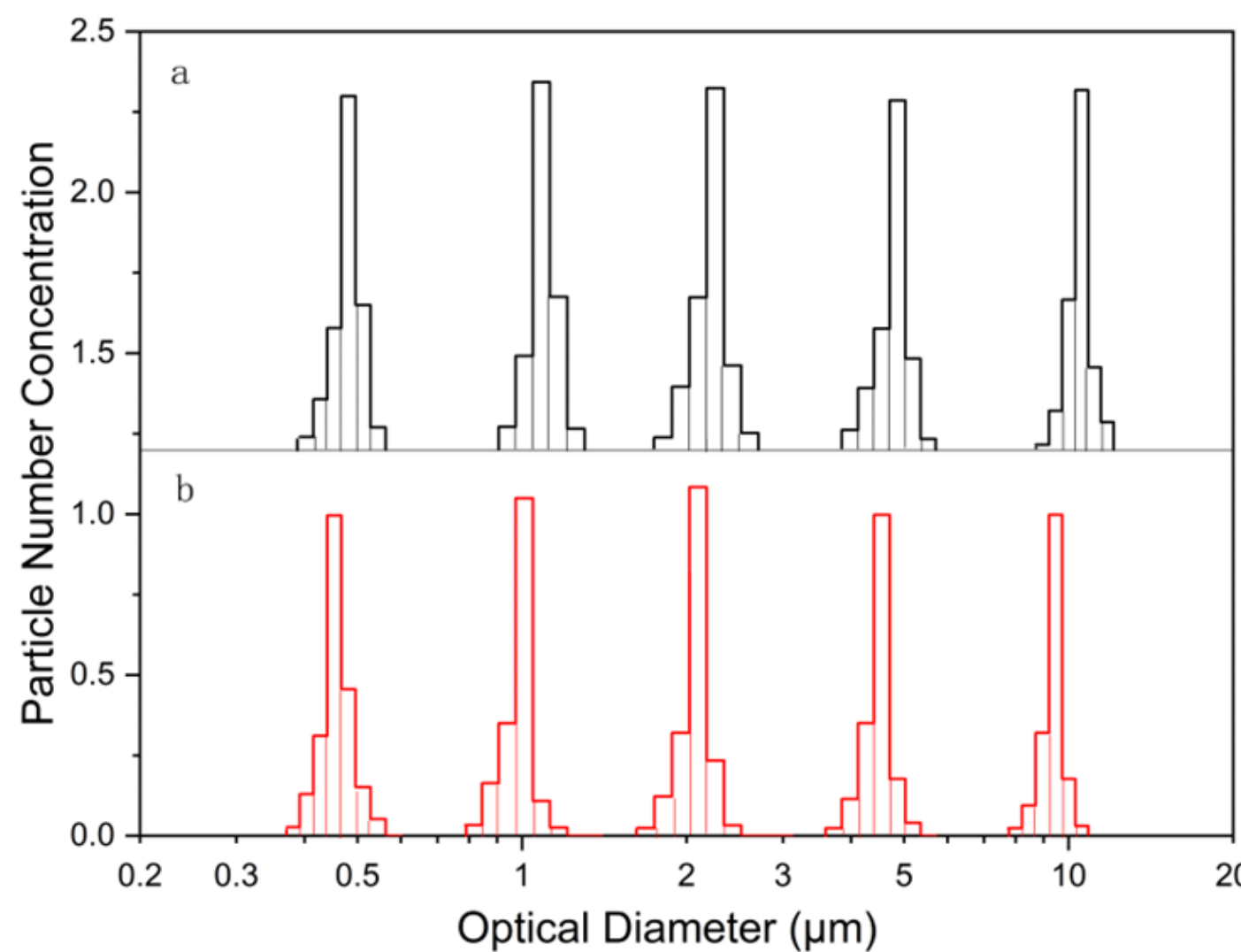


Fig. 1 Particle size distribution at different concentrations: (a) Trp (b) 7-HCA

The obtained APSS measurement values(N_m) and number of solid particles(N_s) results are consistent and independent of the solution concentration and solute type as shown in **Table 1**. By comparing to number of droplets generated (N_d), the associated η_r could be calculated, which ranges from 98.00% to 99.75%, with an average value of 98.83%. This average transport efficiency value can serve as a correction factor. By accurately controlling the voltage frequency and sheath flow rate of the H-IJAG system, the solid particle concentration (C_s) can be determined. This implies that H-IJAG could be recognized as a standard generator with a known particle size and number concentration.

The obtained ratios, ranging from 96% to 105%, are close to 100%, indicating that the generated solid aerosol particles exhibit good fluorescence response in the 330-420 nm and 420-650 nm wavelength ranges when excited by 280 nm and 405 nm lasers. This suggests that each particle in the aerosol sample has fluorescence characteristics.

Conclusions

- Experimental results demonstrated that under standardized inkjet parameters, H-IJAG exhibited good reliability and reproducibility, and generated solid particles within (0.4~15) μm .
- To better simulate the laser-induced fluorescence emission properties of ambient bioaerosol, tryptophan (Trp) and 7-hydroxycoumarin-4-acetic acid (7-HCA) were selected as solutes of the laboratory-generated aerosol samples, which are known bio-fluorescent materials.
- According to the law of propagation of uncertainty, the relative uncertainty of the volume equivalent diameter of Trp and 7-HCA solid particles by H-IJAG were 0.42%, while the relative uncertainty of the particle number concentrations of Trp and 7-HCA solid particles generated by H-IJAG were 1.4%.

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