Abstract

Vitamin-C enriched sodium-chloride (15% NaCl solution) from the Dead Sea and organically grown and extracted olive-oil samples with traces of supplemented Vitamin-D (containing 5μl) each were separately nebulized by ultrasonic atomizers in a therapeutic aerosol chamber constructed by Selsonics GmbH. Particle growth dynamics from aerosol processing reactions were measured with a Scanning Mobility Particle Sizer (SMPS) immediately after a 3 minute lung sample injection sequence. Scanning times with the SMPS covered a potential exposure window of at least 9 minutes in the size range of 0.1 to 1 μm. Based on the data obtained from the SMPS measurements, the stochastic lung particle deposition model IDEAL-2 (Koblinger & Hofmann, 1990; Hofmann & Koblinger, 1980) was applied and the associated particle deposition analyzed.

Introduction

Aerosol inhalation using Selsonics’ exposure chamber is achieved via two separate ultrasonic nebulizers. Two vials containing 5mL each - one filled with vitamin-C enriched saltwater from the Dead Sea, the other with vitamin-D enriched olive oil - are placed into separate drawers (see Fig. 1). Once the vials are in place, an automated procedure operates the nebulization routine starting with a 3 minute lung sample inhalation, followed by 3 minutes of actual nebulization, in which the chamber is ventilated. In-between the samples as well as at the end of the exposure, the chamber is flushed via two powerful ventilation fans.

Methods

Nebulization of both 5mL liquid salt and oil samples was carried out by atomizers using ultrasonic technology. Measurements of the nebulized samples were made with the SMPS model (Grissm Aerosol Technik). This mobile continuous nano-particle counter combines a Condensation Nucleus Counter (model #5403) and a Direct Mobility Analyzer “Vienna-Type,” (model #5500), using a L-DMA to detect a size range between 10 to 1000 nm.

Particle concentrations are documented in Fig. 2. It reveals a polydisperse distribution with the geometric mean located at around 140 nm. Particle concentrations peaked at around 7·10^3·10^3 particles·cm^(-3) and gradually decreased afterwards due to agglomeration to larger clusters. Here, the geometric mean was located at around 240 nm, while particle concentrations peaked at around 10^3·10^3 particles·cm^(-3) and gradually decreased afterwards due to agglomeration to larger clusters.

To investigate the fate of inhaled particles, we applied the stochastic lung model developed by Koblinger and Hofmann (1990a,b) to model deposition over the size range of 10 to 1000 nm using 44 output formulae. In addition, the airway geometry selection, the random walk of particles through this geometry and the methods of aerosol deposition calculation in conductive and respiratory airways during a full breathing cycle are incorporated in this model. Altogether, the model enables computation of total, regional and differential particle deposition in a stochastic lung structure.

Results

Particle deposition of the nebulized oil sample outlines the deep-reaching pulmonary properties of this aerosol. Due to the minute particle size of the load along with the hydrophilic attribute of this sample, bronchial deposition is negligible. Particle deposition of the nebulized NaCl sample follows a similar distribution pattern. However, a proportionally larger fraction is deposited within the tracheo-bronchial region, mainly due to the larger respiratory tract-qualifying almost 100%, the hydrophilic character of this sample results in additional deposition within the bronchial region.

Conclusions

Using nano-sized particles greatly enhances the penetration efficiency to evoke various responses of the human body. As observed in Fig. 2, the size range of the inhaled particles easily reaches the alveolar region well beyond the 15th lung generation. Alveolar congestion by the inhaled particle load can easily be inferred, as the detected nanoparticles are some 10^10 times smaller than the smallest alveolar duct-diameters (Burns, 1985). As shown in Fig. 2, the potentially huge bolus concentration of the olive oil spectrum is met in approx. 10^3·10^4 particles·cm^(-3) and spread over 27 lung generations further dividing the overall concentration by an approximated factor of 27. Considering particle kinetics after aerosol injection within the chamber along with the volume of air to be inhaled, one can expect a slightly elevated inhaled particle load as the SMPS sampled the chamber by a continuous flush of 0.3 L/min only. If a relaxed person inside the chamber would have a tidal respiratory volume of about 0.5 L along with roughly 12 in- and exhalations per minute, which yields a total of 6 L of inhaled respiratory air. In relation to the 0.3 L/min of the sampling device, this corresponds to a 20-fold increase of the inhaled particle load. Since total scanning windows of the SMPS lasted 9 minutes for each nebulized sample and the fact that a person would just be exposed to 5 minutes per sample – with flushing cycles in-between – the actual proportionality factor would just be 5/9 or 0.55 – roughly 11-times the detected in-between the samples, as well as at the end of the exposure, the chamber is flushed via two powerful ventilation fans.

Since there is no sharp threshold between these two regions in a realistic lung structure, for simplicity Yeh and Schomer (1980) separated these three regions by assigning those above the 13th generation alveolar status whereas below those belong to the bronchial region.

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URL: http://www.selsonics.com/Selsonics_Eprodukt_en.html

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