Flow Control in Laminate Capillary-Driven Microfluidic Electrochemical Devices by Sponges for Viscous Solution Analysis

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The search for portable devices that allow the development of environmentally safe analytical methods and real-time information collection to carry out "in loco" analyses is a current trend in analytical chemistry [1]. Microfluidic systems are an attractive tool for achieving these goals. In addition to allowing analysis with low sample volumes, they enable the integration of analytical steps in the same platform and the manufacturing of sensors for direct analysis. Laminate capillary-driven microfluidic devices are an attractive approach that achieves all the features. In this device, the flow is driven by capillary force between the gap of two pre-cut paper or transparent film layers, wherein the microchannel is in the middle of these layers [2]. Despite significant advancements in capillary-driven microfluidic devices, analyzing viscous samples, particularly biological fluids, remains a challenge because the flow is highly dependent on the viscosity of the solution. Herein, we proposed an approach to overcome the flow issues using commercial sponges as passive pumps. A capillary-driven microfluidic device was coupled to electrochemical detection to enhance the selectivity. A polyurethane, cellulose, and resin sponges were evaluated based on the flow rate. After all systematic optimizations, sponges provide an effective control according to the material, which is the flow independent of the types of material used to fabricate the laminate microfluidic device. In addition, the proposed new microfluidic design enables analysis using the higher viscosity solution without affecting the peak profile. The analytical curves for nicotine, dopamine, and paracetamol in 0.5 % sodium carboxymethyl cellulose (SCMC) were constructed to simulate saliva viscosities. Finally, using a generator-collector mode, the proposed microfluidic device was used to quantify paracetamol in human saliva, with recovery close to 100%. An interesting finding presented in this research was the possibility of directly analyzing viscous saliva without a sample preparation step, such as dilution or protein precipitation. Also, the new design using the sponge as a passive pump opens the possibility of making the reactions (sample preparation steps) on the microfluidic channel since the flow could be controlled by simply replacing the passive pump. Therefore, these results pave the way for the development of capillary-driven microfluidic devices with electrochemical detection for saliva analysis outside the laboratory settings.

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