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A Flicking Method for Generation of Polymer Microbeads

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A variety of microencapsulation technology has been developed to encapsulate drugs, cells and food. However, previous microencapsulation systems were associated with complex design, requirements of high voltage supply, post cleaning process and consuming large volume of reagents. This work proposed a simple yet efficient flicking system for the production of calcium alginate microbeads. In the system, a flicking device was designed to disperse microdroplets of sodium alginate ejecting from a syringe pump and the microbeads were polymerised in the calcium chloride solution. The size of the microbeads produced using this system can be controlled by changing the flow rate (5, 10 and 15 µl/min) of the syringe pump and fixing the motor rotation speed of the flicking device at 90 rpm. The microbeads of calcium alginate produced using the flicking device were shown to be size controllable in a range of 270 to 430 µm and they have potential for the microencapsulation of cells.

1. Introduction

Microcapsules are widely applied in drug release, tissue engineering and food science [1]. There are various types of materials that can be used to produce the microcapsules such as agarose, collagen, alginate, chitosan and gelatin [2]. A few methods have been developed for the microencapsulation of cells that were based on microfluidic, emulsification, extrusion, electrospraying, electrostatic transfer and airflow [3]. However, previous methods were presented with some disadvantages such as complexity in design, requirement of high voltage supply, post cleaning process and the use of large volume of reagents. This created threats to the survival of the cells encapsulated in the microbeads. Therefore, the aim of this work is to develop a flicking device which is simple, economic, reagent saving and allows the production of calcium alginate (CaAlg) microbeads for safe encapsulation of cells.

2. Experimental Procedure

The flicking system developed consists of a flicking device and infusion pump system (Fig. 1). An Arduino Uno controller functions as a the main controller that controlled the flicking speed of the flicking device. Before flicking process, the syringe was filled with 2% w/v sodium alginate while the petri dish contained 5% w/v calcium chloride. While the syringe was ejecting sodium alginate solution, the flicking device with a direct current (DC) geared motor was rotated and tapped the needle of the syringe. Under the tapping motion, the droplets of sodium alginate were dispersed into smaller beads in air and polymerised into microbeads of calcium alginate upon dropping into the calcium chloride solution. During the polymerisation, the calcium ions replace the sodium ions and bind the alginate copolymer blocks [4]. Two of the alginate polymer strands can be cross-linked by a unit of calcium ion. The performance of the designed circuit was tested with various

flow rates (µl / min) of the syringe pump and flicking speed (revolutions per minute) of the flicking device. Images of the microcapsules from the flicking device was captured using a Nikon inverted phase contrast microscope (Eclipse TS100, Japan), fixed with a QImaging (Go-3, Canada) charge-coupled device (CCD) camera. Based on the images captured, the size of the microbeads generated by different flow rates was measured and characterised.

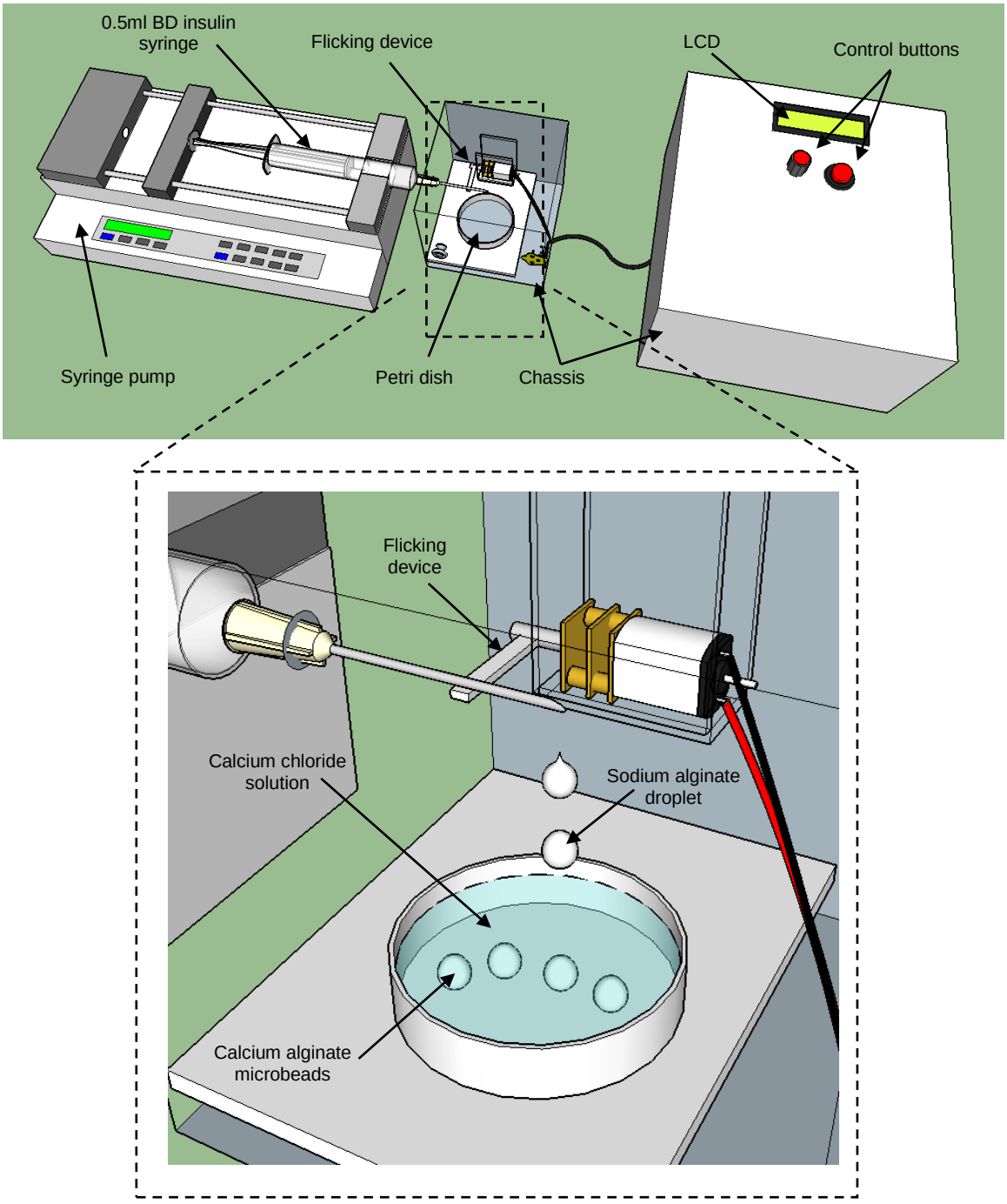

Fig. 1. The flicking system for generation of calcium alginate microbeads

3. Results and Discussion

Based on the pulse width modulation from 10 - 100%, the flicking speed of the flicking device is adjustable ranging between 60 and 150 revolution per minute (rpm) as shown in Fig. 2. The motor speeds increased gradually with respect to the pulse width modulation (PWM) duty cycles. However, the mini DC geared motor could not rotate when the PWM signal was lower than 10 % duty cycle. The minimum and maximum rotation speed of the motor was determined at 60 and 150 rpm, respectively. There seemd to be a saturation of motor speed when duty cycle of the PWM reached approximately 80 %.

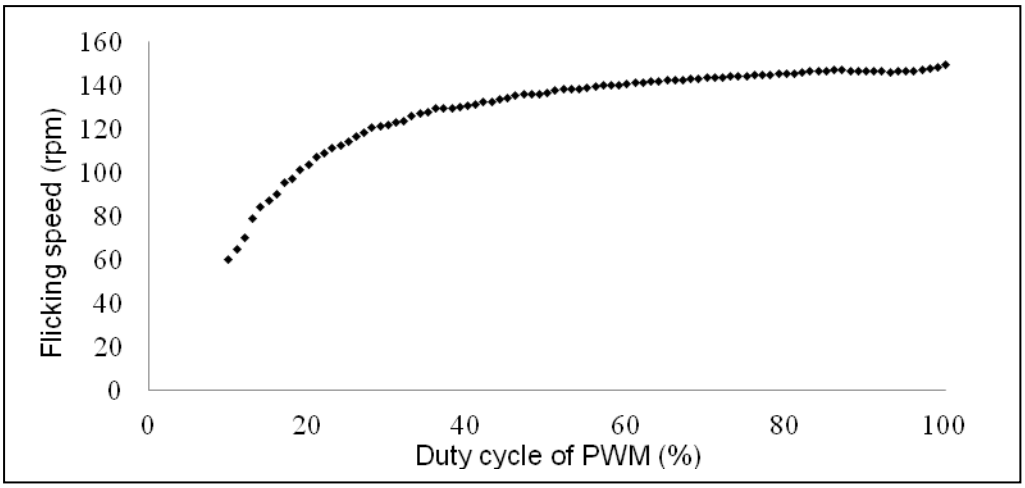

Fig. 2. The effect of duty cycle of PWM to flicking speed.

At a fixed motor speed of 90 rpm and variable flow rates of sodium alginate, the average sizes of calcium alginate microbeads generated (273.68 ± 22.72 µm, 370.88 ± 29.19 µm and 431.18 ± 43.66 µm) was found increased linearly with the flow rates of the infusion pump (5 µl/min, 10 µl/min and 15 µl/min) as shown in Fig. 3 and Fig. 4. The results show that the size of microbeads generated by the flicking method was greatly dependent on the flow rate and speed of the flicking motor. The proper choice of these two parameters can produce a desirable size of microbeads. Smaller microcapsules that are less than 300 µm offer many advantages for the encapsulation of cells leading to the microtissue formation [5, 6].

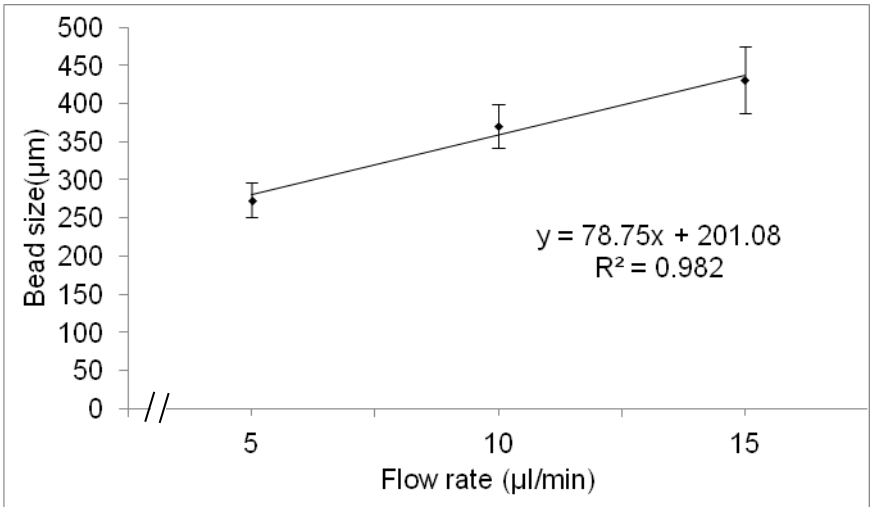

Fig. 3. The effect of flow rates to the microbeads size.

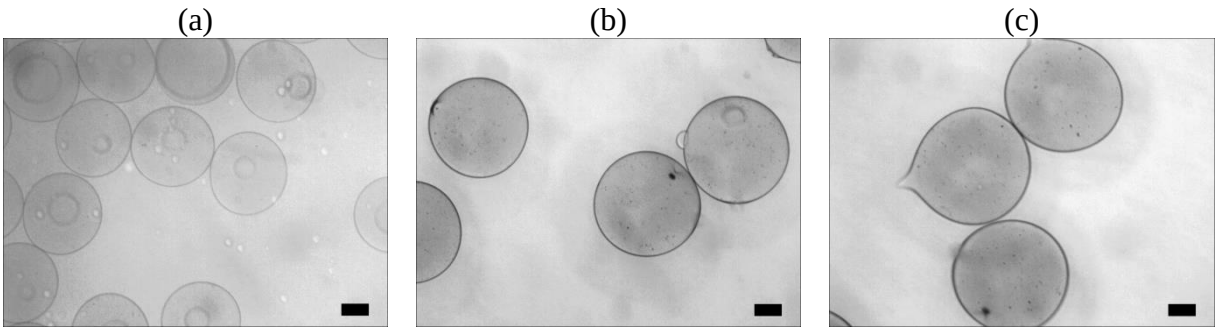

Fig. 4. Microbeads of calcium alginate generated by different flow rates: (a) 5 µl/min, (b) 10 µl/min and (c) 15 µl/min. (Scale bar: 100 µm)

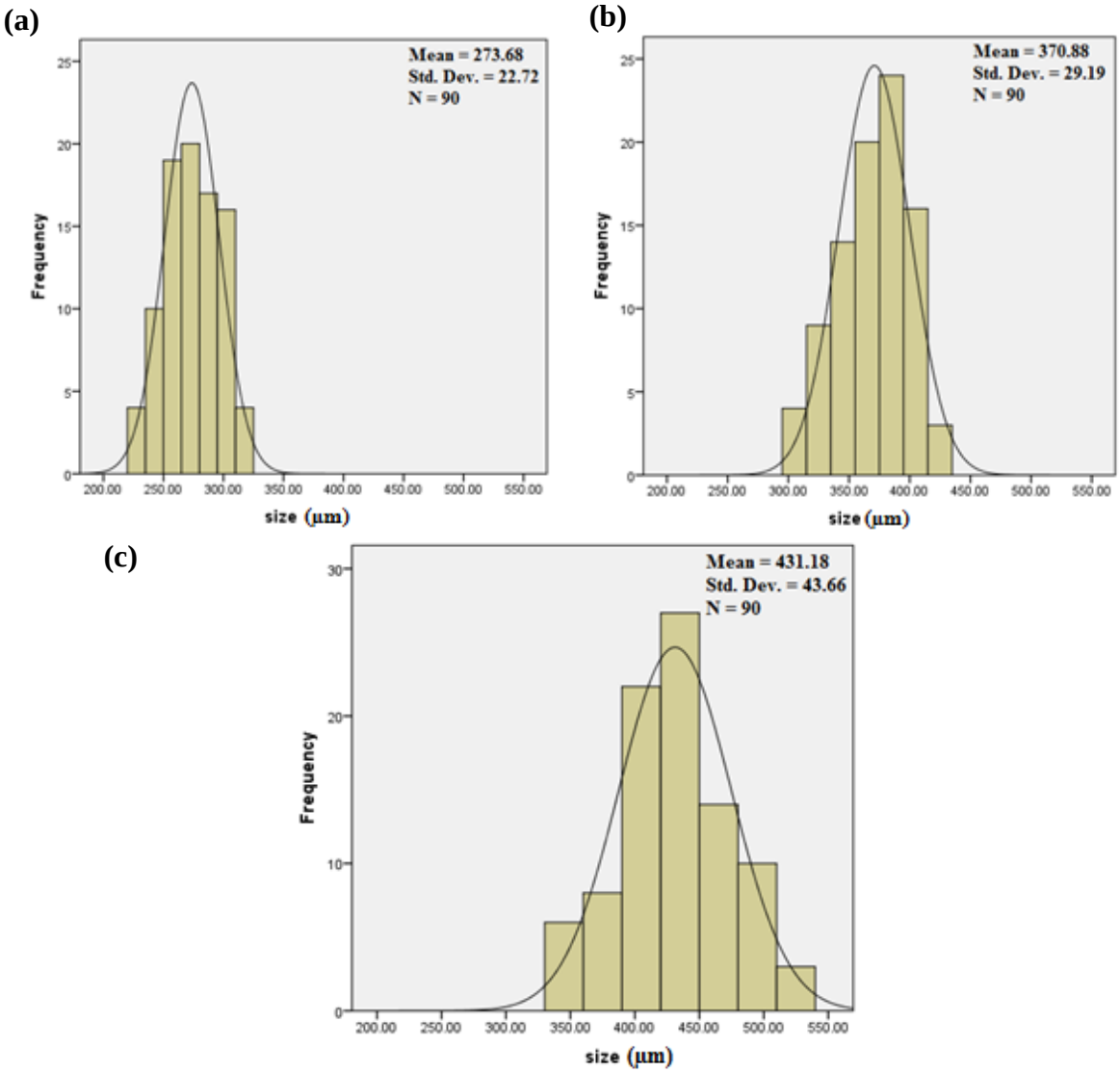

Fig. 5. The size distribution of microbeads produced at different flow rates of (a) 5, (b) 10 and (c) 15 µl/min.

Fig. 5a shows the size distribution of microbeads produced at a flow rate of 5 µl/min. At this flow rate, the microbeads produced in a narrow size window within 100 µm. The increase of flow rates (10 and 15 µl/min) shifted the size distribution of microbeads to larger size of microbeads (Figure 5b and 5c). The most uniform size distribution was obtained at a flow rate of 5 µl/min in a range from 220 to 320 µm.

4. Conclusion

A flicking system has been developed to fabricate the microbeads of calcium alginate with a diameter ranging from 270 to 430 µm at a flicking rate of 90 rpm and different flow rates of alginate ranging from 5 to 15 µl/min. At a fixed flicking speed, the flow rate of the syringe pump influenced the size of the microbeads generated. Larger size of microbeads can be produced with higher flow rate of syringe pump. The flicking system developed is a simple yet efficient method to generate calcium alginate microbeads without complex preparation procedures.

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