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Release properties on gelatin-gum arabic microcapsules containing camphor oil with added polystyrene

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Abstract

In this study, gelatin blended with arabic gum microcapsules containing camphor oil with added polystyrene were fabricated by a compound coacervation method. The parameters of oil/wall volume ratio, emulsification stirring speed, concentration of cross-linking agent, treated time and oil release properties were investigated. In order to improve the constant release effect of camphor oil, oil-soluble polystyrene (PS) was used as a sustained release agent. The camphor oil release curves were expressed by the exponential equation: $\psi(t) = C_{eq}(1-e^{-t/\tau})$, where $\psi(t)$ represent the variant of camphor oil concentration in the operation environment, C_{eq} as the equilibrium state, t as the release time and τ as time constant. C_{eq} and τ are significant factors pertaining to the camphor oil release properties. The results indicated that, for the microcapsules, the optimal oil/wall volume ratio was 0.75 to achieve the encapsulation efficiency of 99.6 wt.%. The average particle size were 294.7 ± 14.2 μm, 167.2 ± 11.2 μm, 85.7 ± 8.7 μm at the homogenization stirring speed of 500, 1000, and 2000 rpm, respectively. The effect of sustained oil release will increase whereas the stirring speed decreases and the concentration of glutaraldehyde (GA) and treated time increases. Along with the increasing of quantity of polystyrene added, C_{eq} decreased and τ increased, indicating that the sustained oil release amount and the release rate depend on the quantity of PS considerably.

Keywords: Complex coacervation method; Camphor oil; Polystyrene; Sustained release

1. Introduction

Camphor oil exudes in the process of extracting camphor, which is used for medicinal purposes. The therapeutic properties of camphor oil are analgesic, antidepressant, anti-inflammatory, antiseptic, cardiac, carminative, diuretic, febrifuge, hypertensive, insecticide, laxative, rubefacient, stimulant, sudorific, vermifuge and vulnerary [1,2]. However, the camphor oil for its volatility has a short life, affected by the application environment. Hence, to improve the sustained release effect, volatile oil encapsulated with some kinds of micro-porous wall membrane was considered by many researchers [3–6]. Chang and Dobashi reported the amount of the oil content released is initially large and then gradually become constant [7]. This controlled release behavior is very common among pharmaceutical and volatile essential oil [8–11]. However, it could possibly affect users' health due to excess inhalation in the processes if the initial controlled release rate is too high; and reduce the effectiveness if the controlled release rate is too low in the later stage. Therefore, to find a volatile oil or agent for a freely controllable constant release is a very important research topic.

The purpose of this study was to investigate the relationship between the sustained release behavior of camphor oil and the gelatin-gum arabic complex wall membrane fabricated in various conditions. Various quantities of oil-soluble polystyrene (PS) were also used as sustaining agent to improve the release properties.

2. Experiments

2.1. Preparation of microcapsules

Pour 20, 30, 40 and 50 ml of camphor oil (Yu-Li Chemical Co., Taiwan), respectively, into 40 ml solutions containing

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3 wt.% gelatin (First Chemical Co. Taiwan) and 3 wt.% arabic gum (F-Shan Chemical Co.,) mixture. Stir these mixtures with homogenizer (HG-300D + K12S, Shuang-Tai Co., Taiwan) for 10 min at 30 °C temperature with rotating speed of 500, 1000 and 2000 rpm to produce aqueous suspension. Then adjust the pH value to 3.7 by adding 10% acetic acid solution, slowly stirred for 20 min and lower the temperature to 5 °C and observe the forming status of the microcapsules. Follow by washing the residue on the microcapsules off with distilled water, poured in 2, 6, 10 ml of glutaraldehyde (GA) (37%, Waco Pure Chemicals) and processed for 5, 30, and 60 min to harden the wall membrane of microcapsules.

In order to improve the effect of sustaining release, low molecular polystyrene ($M_w = 5.0 \times 10^3$, Waco Pure Chemicals) was used as the sustained release agent. The resulting composite membrane microcapsules were washed twice with distilled water and incubated in a vacuum oven (TK30, Young-Chenn, Taiwan) at 30 °C overnight to evaporate the water on the microcapsules surface. The sample weight was then measured and defined as W_m.

2.2. Measurement of microcapsule

2.2.1. Determination of microcapsule size

The mean size of the microcapsules was determined from the average for 100 particles measured using an optical microscope connected with a digital video camera (ML-2300, SONY).

2.2.2. Determination of controlled release

The release of camphor oil from the microcapsules at the incubation process was estimated by measuring the time course of the weight $W_m(t)$ of the microcapsules placed in an Infrared Moisture Determination Balance (IMDB)(AD-4715, AND) at 37 °C. Here, t is the incubation time. Even tiny amount of vaporization of solvent could be detected by IMDB, as it's commonly used to determine the water content of fibers. The sample in the open box of IMDB was heated by using infrared set at desired temperatures. Temperature and weight of the sample were measured continuously and recorded automatically. The oil release content was defined as $\psi(\%) = [(W_m - W_m(t))/(W_m - W_0)] \times 100$, where W_0 denotes the weight of microcapsules measured after complete evaporation of camphor oil at 120 °C for 3 h. Therefore, the encapsulation efficiency can be defined as: $\varphi(\%) = (W_m - W_0)/W_m \times 100$.

3. Results and discussion

3.1. The formation and encapsulation efficiency of microcapsules

Fig. 1(a) is the micrographic picture of microcapsules prepared with homogenizer rotating speed at 500 rpm, 6 ml of cross-linking agent concentration, and 30 min cross-linking time. Fig. 1(b) is the micrographic picture of residual microcapsule shell after camphor oil has completely volatilized. It is clear from the pictures that, the microcapsules produced through GA hardening processes has slightly rough/uneven surface yet close to spherical shape as a whole, these results are consistent with reports from other researchers [6]. Once the inner core material (camphor oil) volatized completely, the residual outer shell will be irregular and uneven, which indicated that the inner camphor oil has all exhausted through volatilization.

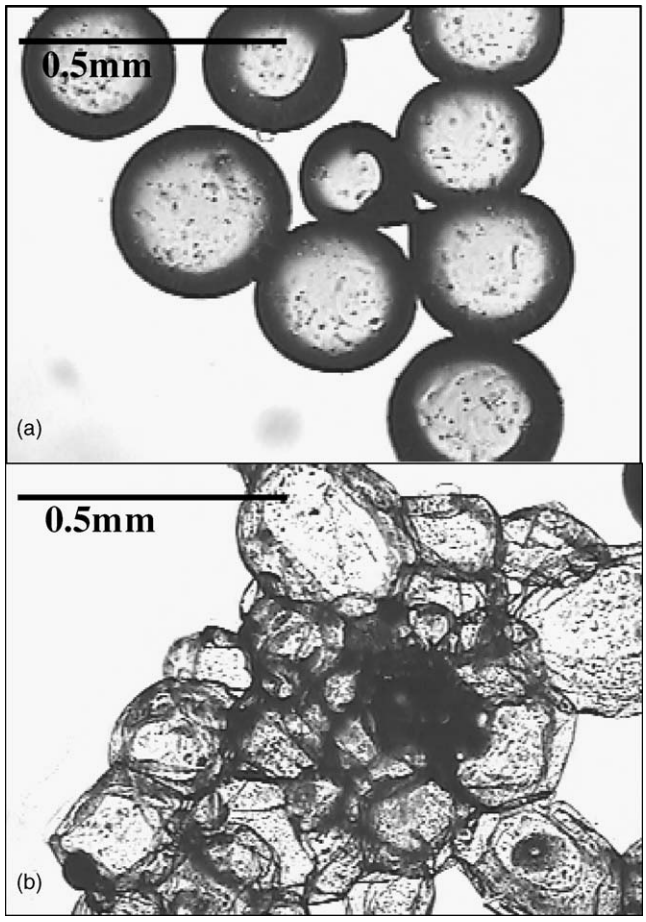

Fig. 1. The microphotograph of microcapsules before (a) and after (b) oil released (Treated with 6 ml of GA for 30 min while stirred at 500 rpm with homogenizer.) (80×).

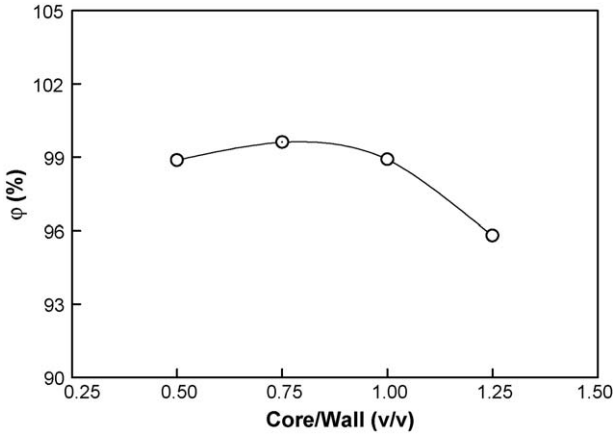

Fig. 2. The encapsulation efficiency of microcapsules prepared at various oil/wall volume ratio, which obtained by treated with 6 ml GA for 30 min while stirred at 500 rpm with homogenizer.

Fig. 2 shows the encapsulation efficiency of various oil/wall volume ratios. It shows the encapsulation efficiency that are between 0.5 and 1.25 of oil/wall volume ratios. During the processes of fabricating the microcapsules, excess camphor oil cannot be encapsulated if encapsulation efficiency is below 0.5 oil/wall volume ratio. However, higher oil/wall volume ratio may increase the thickness of wall membrane which makes it easier to produce much rigid microcapsules. Therefore, in this study, all the microcapsules produced were set at 0.75 oil/wall volume ratio. Microcapsules produced under different conditions would also have different encapsulation efficiency for inner camphor oil. In the study, microcapsules were produced with encapsulation efficiency between 80 and 100% by altering the emulsification stirring speed, concentration and treated time of cross-linking agent.

The changes in size and distribution of microcapsules produced by changing emulsification stirring speed appear as expected. Along with rotating speed increases, the average particle size of microcapsules gradually decreases, and the size of distribution becomes narrower. The average particle sizes were $294.7 \pm 14.2\,\mu m$, $167.2 \pm 11.2\,\mu m$, and $85.7 \pm 8.7\,\mu m$ at the stirring speed of 500, 1000, and 2000 rpm, respectively. The reason is that higher homogenizer rotation speed produces stronger shear force for its cutting head.

3.2. *Effect of changing concentration and treated time of GA*

Shown in Fig. 3(a) is the results of release rates by changing just GA concentration, while inner/core camphor oil were treated by cross-linked agent for 30 min and stirred at 500 rpm. When camphor oil becomes encapsulated in microcapsules, its release rate is always slower than that is not encapsulated. Because after the encapsulate processes, there will be wall membrane covering the inner/core material to sustain the release. Furthermore, during the wall membrane hardening processes, as the GA concentration increase the release rate tends to decrease simultaneously, because when GA agent were added there were cross-linking between the molecules of the wall membrane, which would causes difficulty for the inner/core camphor oil to release. And by increasing the quantity of GA agent, the cross-linking density between molecules becomes higher, and the release rate becomes slower.

Fig. 3(b) is the release rates curve of the microcapsules stirred with fixed rotation rate of 500 rpm and 6 ml cross-linking agent concentration. As the figure shows, longer cross-linking treatment time has slower release rate. The reason for this situation is similar to Fig. 3(a) that different cross-linking concentration has different release rate. For longer the treated time of cross-linking agent with complex membrane, higher the cross-linking density between the wall membrane molecules, till the functional group of cross-linking agent GA were completely processed. Fig. 3(c) shows the release rate curves of microcapsules at different stirring rate. The manufacturing condition was using 6 ml GA agent and treated for 30 min. In this figure it is demonstrated as the stirring speed increases, the controlled release rate tends to increase along. The reason as mentioned in Section 3.1, that faster stirring speed produces smaller microcapsules, thus produces larger total surface area and leads to higher release effect. The results were consistent with the theory published by Sato et al. [12].

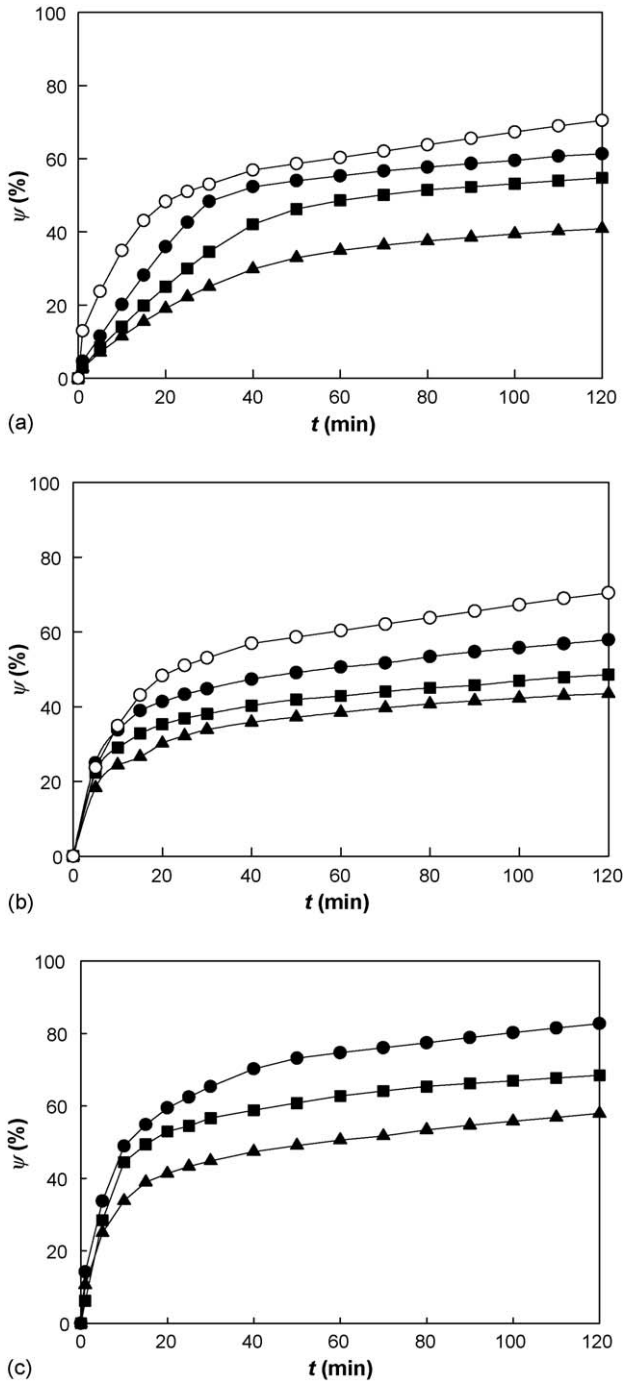

Fig. 3. Time courses of oil release from microcapsules at incubation process from the samples prepared at various conditions: (a) at different concentrations of GA for cross-linking time of 30 min after stirring speed of 500 rpm. The symbols (▲), (■) and (●) denote concentrations of cross-linking agent of 2, 6 and 10 ml, respectively. (b) At different cross-linking time, at camphor oil concentration 6 ml after stirring speed of 500 rpm. The symbols (●), (■) and (▲) denote cross-linking time of 5, 30 and 60 min, respectively. (c) At different stirring rate for cross-linking time of 30 min. The symbols (▲), (■) and (●) denote stirring rate of 500, 1000 and 2000 rpm, respectively.

3.3. Release properties of microcapsule after added PS

It can been seen through the release rates curves from Fig. 3(a–c), that the amount of the encapsulated camphor oil release content is initially large and gradually become nearly constant. During the first 20 min the camphor oil released appear to be more than 20% which is not expected better outcome. Therefore, in order to improve the outcome, we tried adding few sustained release agent into the camphor oil, and investigated the effect of added sustaining release agent to the release rate of camphor oil.

Fig. 4 is the release rate curve of microcapsules after added sustaining release agent into camphor oil. The samples are prepared in the condition of 0.75 oil/wall ratio, 2 ml GA, cross-linked for 5 min and incubated at 37 °C. As we can see that the camphor oil release rate when with added PS, is slower than that of pure camphor oil without added PS, furthermore it is obvious that as the quantity of PS added increased (3, 7, 10%) then the sustained release effect increased consequently. This is because of the inter-reaction between camphor oil molecules and added PS molecules would slow down the release of camphor oil, thus increases the effect of its sustained release.

If the experiment data were placed into the exponential function $\psi(t) = C_{eq}(1 - e^{-t/\tau})$ [12] to generate the solid line in the figure, the results are generally consistent with values obtained from the experiment. Thus, the oil release curves are fitted well to the exponential function as aforementioned.

It demonstrated that the analysis values are reliable because all the correlation coefficient in the exponential function are greater than 0.97, where C_{eq} means the concentration of oil released at the equilibrium state, τ as the time constant, t as the time release. As the results shown in Fig. 5(a and b), increasing the quantity of added PS would decrease C_{eq} while increase the value of τ. Thus, the results indicate that the release amount and release rate depend on the quantity of added PS considerably.

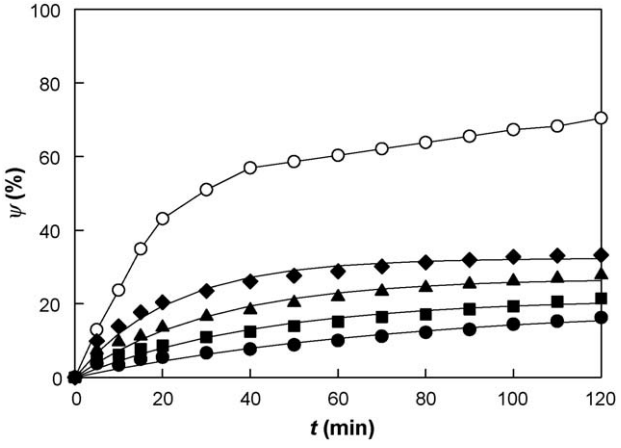

Fig. 4. Time course of oil release from microcapsules with various ratio of PS added. The samples were prepared in the condition of 500 rpm, 2 ml GA and treated for 5 min. The symbols (♦), (▲), (■) and (●) denote concentrations 0, 3, 7 and 10% of PS, respectively. Opened circle denotes the oil without encapsulated any membrane. The solid lines are calculated using exponential function.

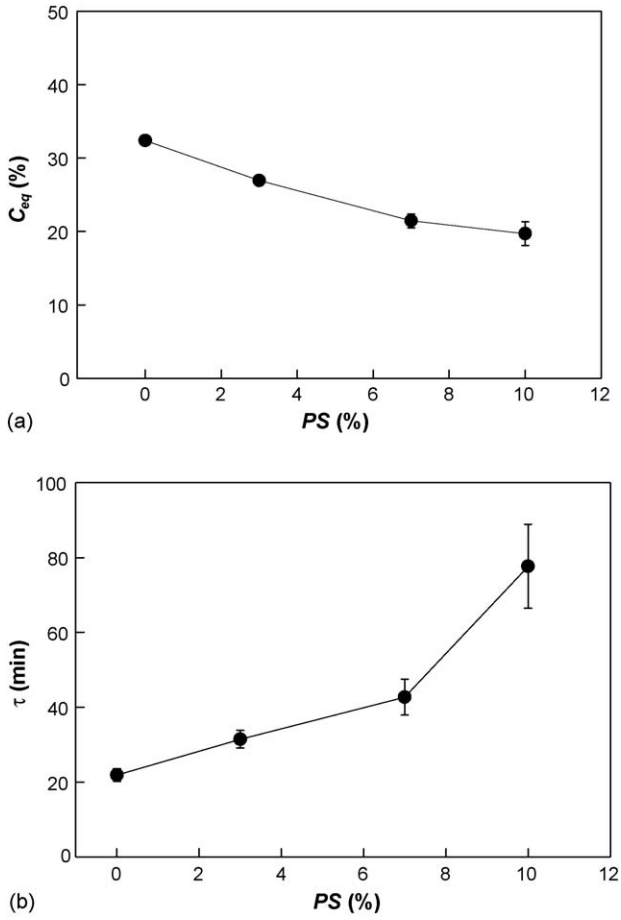

Fig. 5. Oil release from microcapsules at the equilibrium state (a), and the time constant (b) as a function of added PS ratio. The samples were prepared at the conditions of 0.75 oil/wall volume ratio, 500 rpm stirring speed and 2 ml GA treated for 5 min.

4. Conclusion

This study investigated in the optimal production conditions for gelatin-gum arabic complex membrane microcapsules, and the sustained release effects of encapsulated camphor oil with various ratio of polystyrene added. The results demonstrated that the optimal oil encapsulation efficiency was around 99.6% with 0.75 of oil/wall ratio, 500 rpm, 2 ml GA and 5 min treated time. The camphor oil release curve shows an exponential release normally at a higher rate in the beginning. After oil-soluble PS was added as a sustaining agent a nearly constant release was obtained. It appeared that the sustaining agent improves the release property of camphor oil substantially. Therefore, we can reasonably control the oil release by changing fabricating conditions and by adding various quantity of PS into the microcapsules to release camphor oil with nearly constant rate in amount and time.

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