

Table 1. Values of the Zeta Potential of Tween-grafted PC Lipid Vesicles at Different Temperatures with Various Amounts of Incorporated Tween 20 and Tween 80 (values are the mean $\pm$ standard deviation, $n = 3$).

Tween wt% (Tween /PC + VitE + Chol)	Zeta potential (mv) (298 K)
0 wt% Tween	-15.3 $\pm$ 3.0
4 wt% Tween 20	-15.5 $\pm$ 2.8
8 wt% Tween 20	-16.9 $\pm$ 1.9
4 wt% Tween 80	-16.1 $\pm$ 2.6
8 wt% Tween 80	-16.3 $\pm$ 1.2

lipid vesicles were determined by the dilution heat of the lipid vesicle suspension with the density of the lipid vesicle suspension.¹⁷ The b_2/B_0 value of the lipid vesicles can be applied to qualitatively explain the energy barrier that must be overcome before the lipid vesicles aggregate or fuse.

Results of the microcalorimetric experiments demonstrate (Table 2) that the interaction potential indices (b_2/B_0) of PC lipid vesicles (with and without Tween surfactants) are all positive, indicating that the net interactive forces of lipid vesicles (with and without Tween surfactants) are repulsive, and that the interaction potential is negative (energy barrier). However, incorporating Tween surfactants into the PC bilayer decreased the interaction potential of the PC lipid vesicles. A larger amount of additional Tween surfactants resulted in a smaller b_2/B_0 value, particularly when the Tween 80 surfactant was added to PC lipid vesicles. As far as the zeta potential is

concerned, the hydrophobic interaction (force) of $(CH_2-CH_2-O)_n$ groups on the Tween surfactant headgroup probably originates from the surface of lipid vesicles, which contributes to the decrease in the b_2/B_0 value.

The DSC Experiment

The phase transition temperature of egg-PC could not be accurately determined (it ranges from to 5 °C in previous literature³⁴), since egg-PC is a mixture comprised of various kinds of PCs having different degrees of saturation.

A DPPC lipid was selected for the DSC experiment rather than the egg-PC employed in the microcalorimetry experiment to determine how Tween surfactants affect the bilayer interaction of a lipid vesicle. According to our results (Table 3), adding Tween surfactants did not significantly influence the DPPC lipid phase transition temperature. We concluded that the added Tween surfactant molecules might not insert themselves in the proximity of the DPPC C_9 because of the bulky structure of the Tween polar head.

Changes of Particle Size

Figure 1 reveals that the initial lipid vesicle size decreases as the amount of Tween surfactants in the lipid vesicle composition increases. This finding resembles that of PEG-grafted into lipid vesicles. This result is thought to occur due to a steric repulsion among Tween surfactants because of exposure from the outer and inner leaflets of the bilayer of lipid vesicle membranes. The Tween surfactant exposure to the

Table 2. Values of b_2/B_0 of Tween-grafted PC Lipid Vesicles at Different Temperatures with Various Amounts of Incorporated Tween 20 and Tween 80

Tween wt% (Tween /PC + VitE + Chol)	b_2/B_0 (298 K)
0 wt% Tween	5.519×10^5
4 wt% Tween 20	3.245×10^5
8 wt% Tween 20	4.904×10^4
4 wt% Tween 80	9.046×10^4
8 wt% Tween 80	2.197×10^4

Table 3. Phase Transition Temperatures of Tween-grafted PC Lipid Vesicles with Various Amounts of Incorporated Tween 20 and Tween 80

Tween wt% (Tween /DPPC + Vit-E + Chol)	T_c (°C)
0 wt% Tween	42.39
4 wt% Tween 20	43.65
8 wt% Tween 20	41.80
4 wt% Tween 80	42.66
8 wt% Tween 80	42.61