CHAPTER IV
RESULTS AND DISCUSSION

In this study, there are four parameters used to illustrate the efficiency of the foam fractionation. Results involving rates are on a unit cross sectional area basis for use in designing units of the enrichment ratio is defined as the ratio of the concentration in the collapsed foam solution to that in the feed solution (C_f/C_i). Foam wetness (W) is defined as the grams of collapsed foam solution per liter of foam. Volumetric foam production rate (V) is defined as the rate of foam formation (liter of foam/min.m^2). Rate of surfactant recovery (R) is defined as the amount of surfactant that is removed per unit time in the foam (g/min) and calculated by

$$R = W\,V\,C_f\,Mw$$

where

C_f = Concentration of the surfactant in the collapsed foam solution. (M)

M_w = Molecular weight of that surfactant. (g/mol)

4.1 Effect of Salinity

Table 4.1 gives the results for the foam fractionation experiments at 20 °C in which added salt concentration varies. The CMC of each surfactant is decreased with increasing the concentration of salt, as shown in Fig. 4.1.

This CMC depression effect is due to the compression of the electrical double layer around the micelle which causes a reduction in repulsion between the head groups of surfactant at the micelle surface (Rosen,1992; Wungrattanasopon, 1996; and Ruckenstein and Bhakta,1996). Therefore, micelles form at lower surfactant concentration as micelle formation is synergized. To avoid the formation of micelles in the system when salt was added, the initial concentration of CPC, SDS, and DADS were kept at 10%, 10%, and 20% of the CMC value in the absence of salt, respectively.

The effect of added salt on foam fractionation parameters is shown in Figs. 4.2-4.5. The volumetric foam production rate increases with increasing concentration of added salt, as seen Fig. 4.2. Increasing the salt concentration tend to increase the adsorbed surfactant at the air-water interface of the thin liquid film (lamellae) comprising the foam because the surfactant monolayer is more efficiently packed and the repulsion between two monolayers on each side of the liquid film decreases as electrolyte concentration increases. As a result, the liquid in the lamellae is more structured and surface viscosity is higher, leading to a decreased rate of film drainage (Okamoto et al., 1979; Rosen, 1992; Wungrattanasopon, 1996; and Ruckenstein and Bhakta,1996). The foam wetness increases as added salt concentration increases, as shown in Fig. 4.3, presumably due to the decreased rate of film drainage and the increased amount of water that contained in the thin liquid film of foam. The enrichment ratio decreases with increasing concentration of salt, as shown in Fig. 4.4 presumably also due to this decreased rate of drainage. Fig. 4.5 shows that increasing the concentration of salt increases the rate of surfactant recovery. By reason of the rate of surfactant recovery is proportional to the collapsed foam flow rate and the concentration of surfactant in the collapsed foam, and the collapsed foam flow rate, calculated by volumetric foam production rate (Fig. 4.2) times foam wetness (Fig. 4.3), increases with increasing the concentration of added salt. Therefore, a higher salt concentration resulted in a higher rate of surfactant recovery.

TABLE 4.1 Experimental Results : Effect of Added Salt on Foam Fractionation

[NaCl] (mol/L)	Enrichment Ratio C_f/C_i			Foam wetness (g/L)			Volumetric foam production rate (L/min.m^2)			Rate of surfactant recovery (g/hr.m^2)		
	CPC	DADS	SDS	CPC	DADS	SDS	CPC	DADS	SDS	CPC	DADS	SDS
0.000	58.85	97.96	69.54	0.14	0.11	1.02	19.15	12.78	21.93	5.06	0.48	25.57
0.025	50.93	56.49	59.24	0.17	0.32	1.23	20.53	15.94	22.41	5.84	0.98	28.04
0.050	47.68	37.26	44.11	0.23	0.47	1.54	21.21	18.71	22.92	7.43	1.13	28.43
0.100	41.37	29.49	36.15	0.28	0.83	2.00	22.49	20.16	23.58	8.69	1.76	31.56

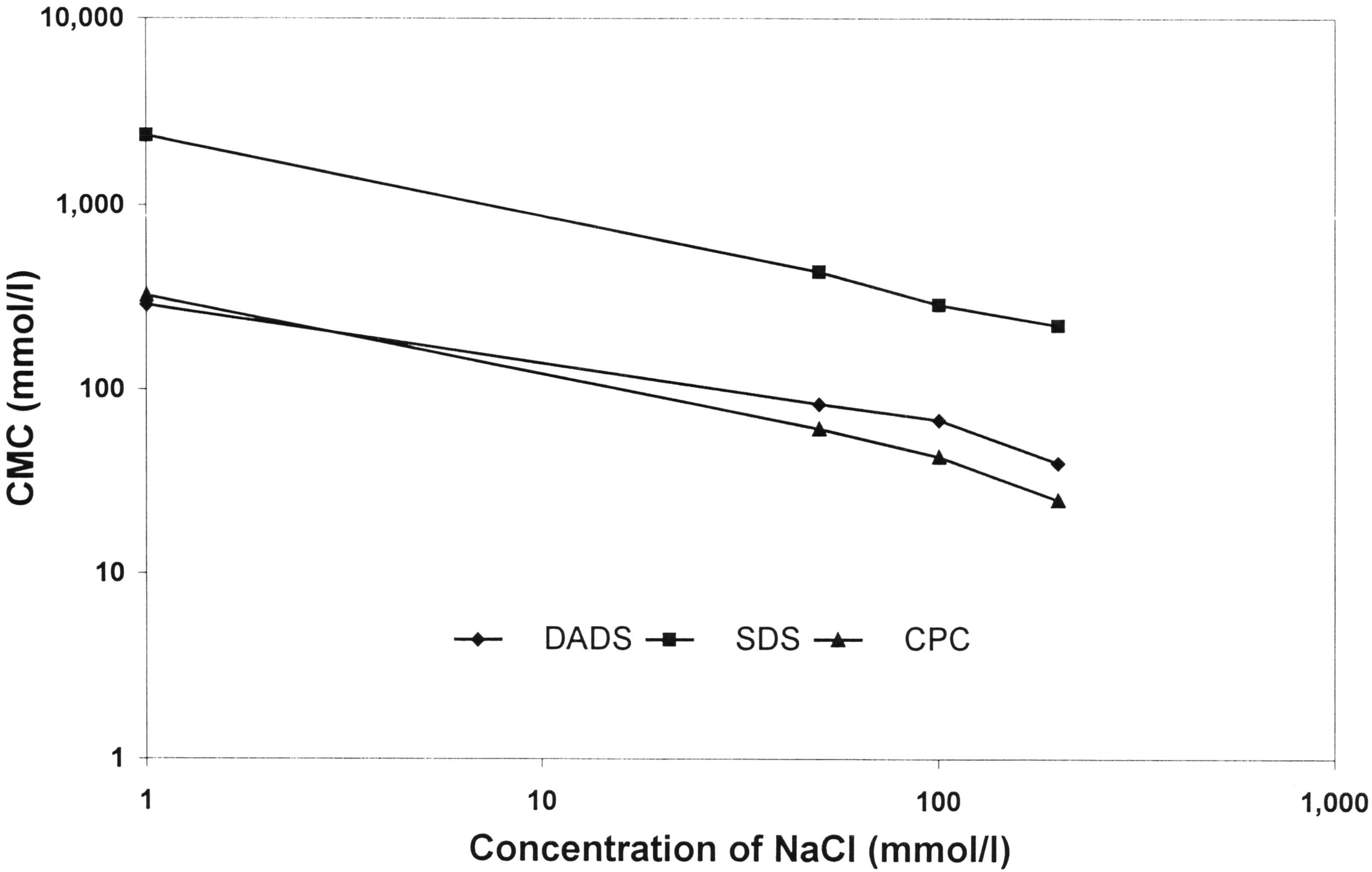

Fig. 4.1 Effect of NaCl concentration on the CMC of surfactants.

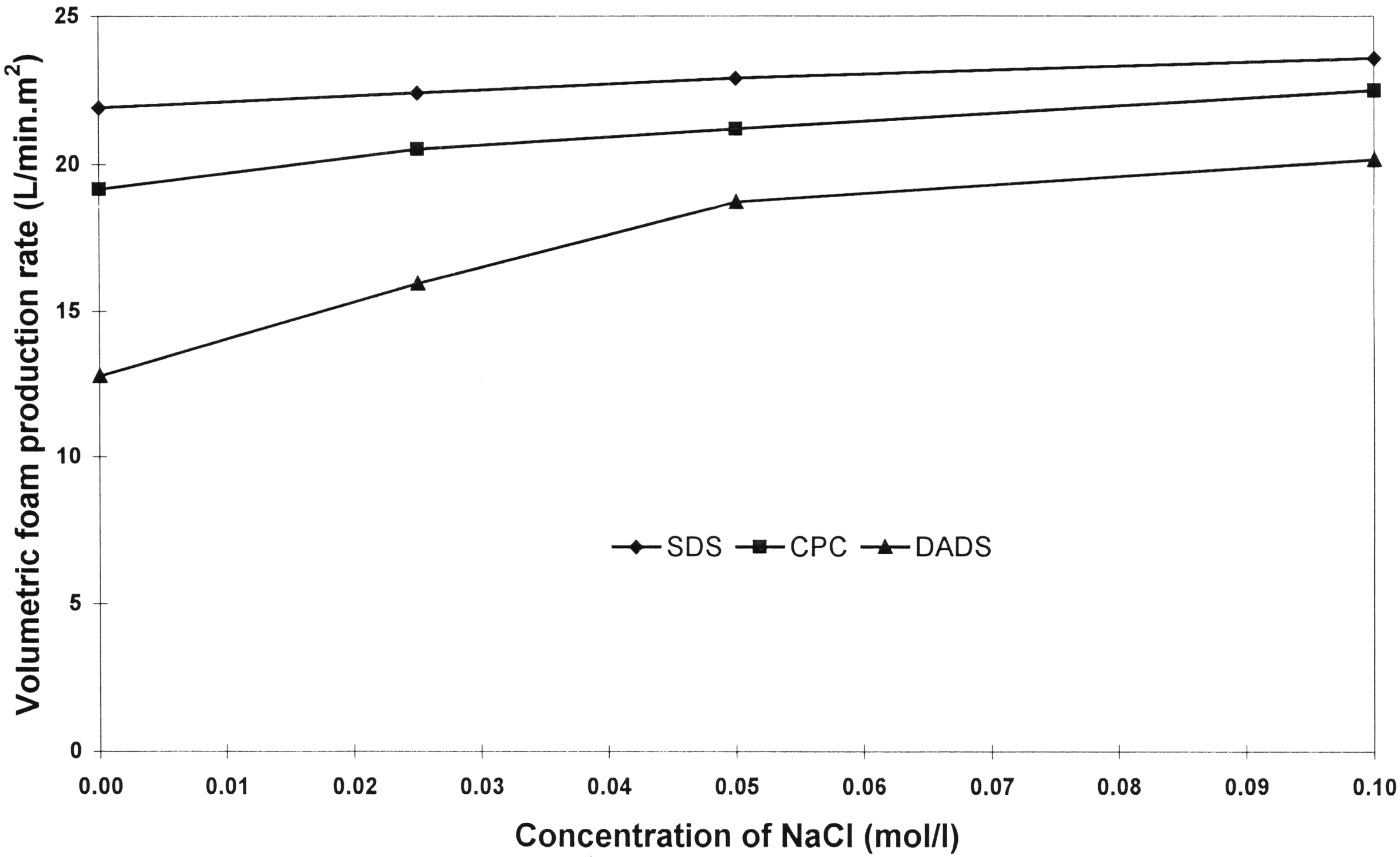

Fig. 4. 2 Effect of NaCl concentration on volumetric foam production rate.

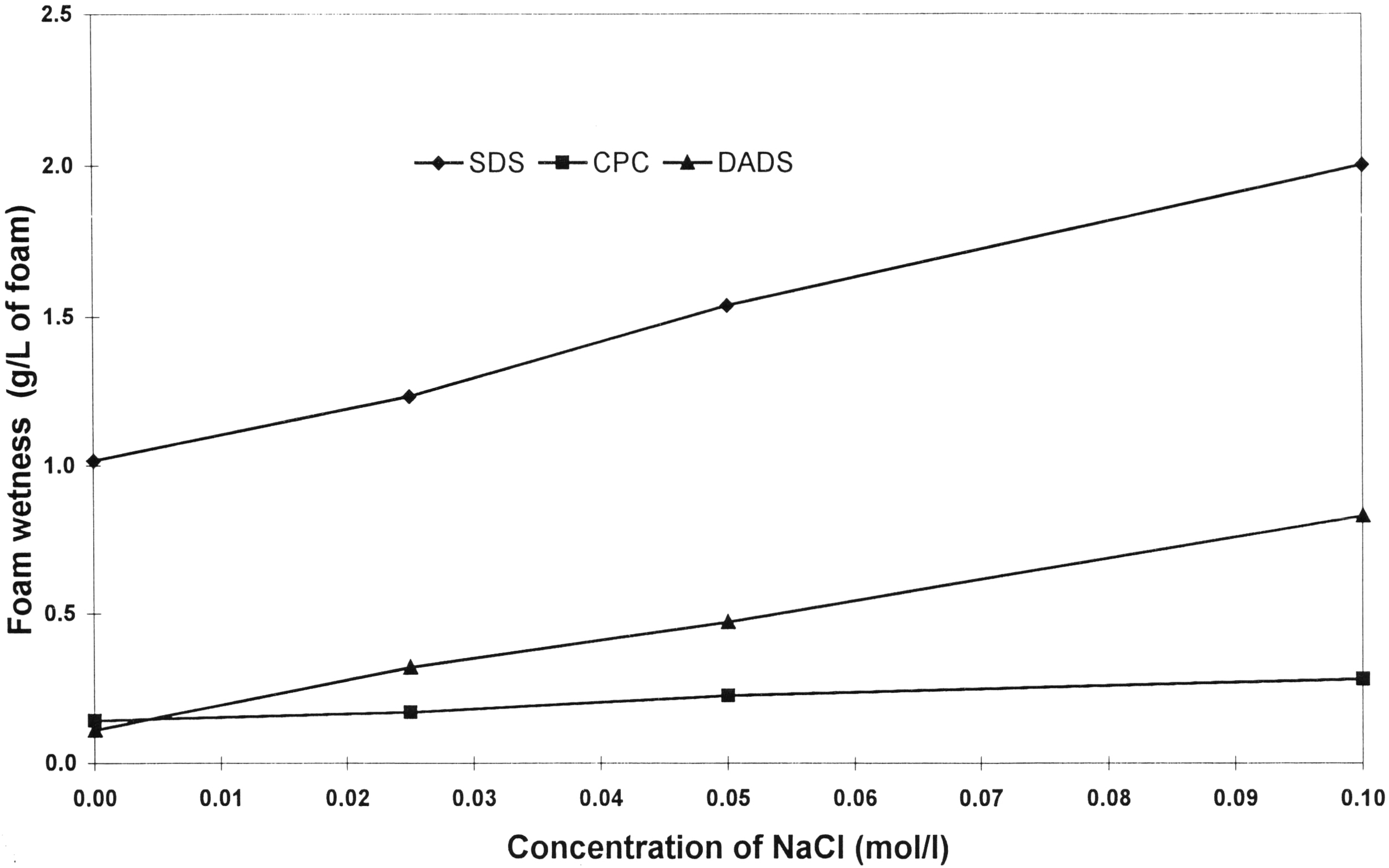

Fig. 4.3 Effect of NaCl concentration on foam wetness.

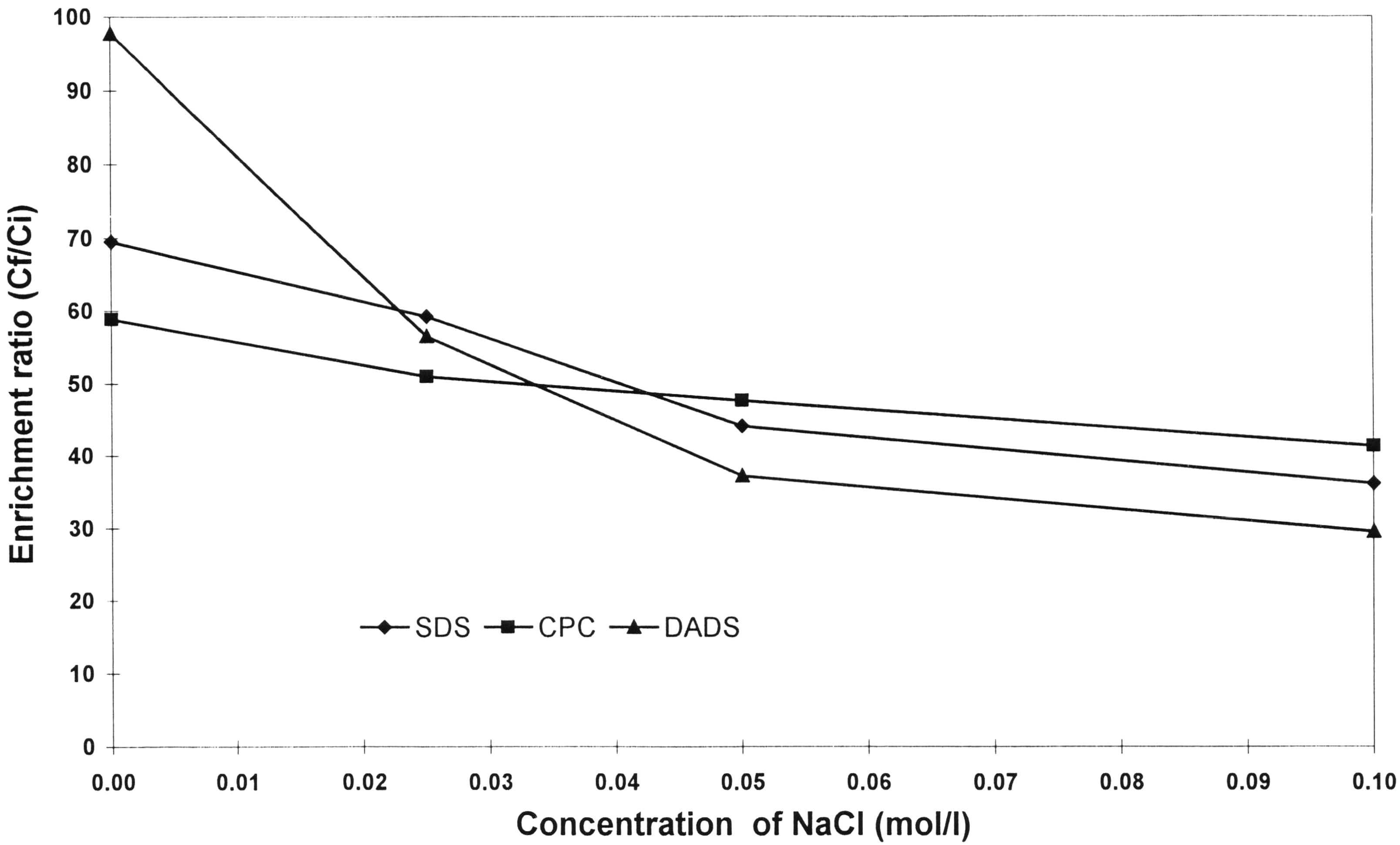

Fig. 4.4 Effect of NaCl concentration on enrichment ratio.

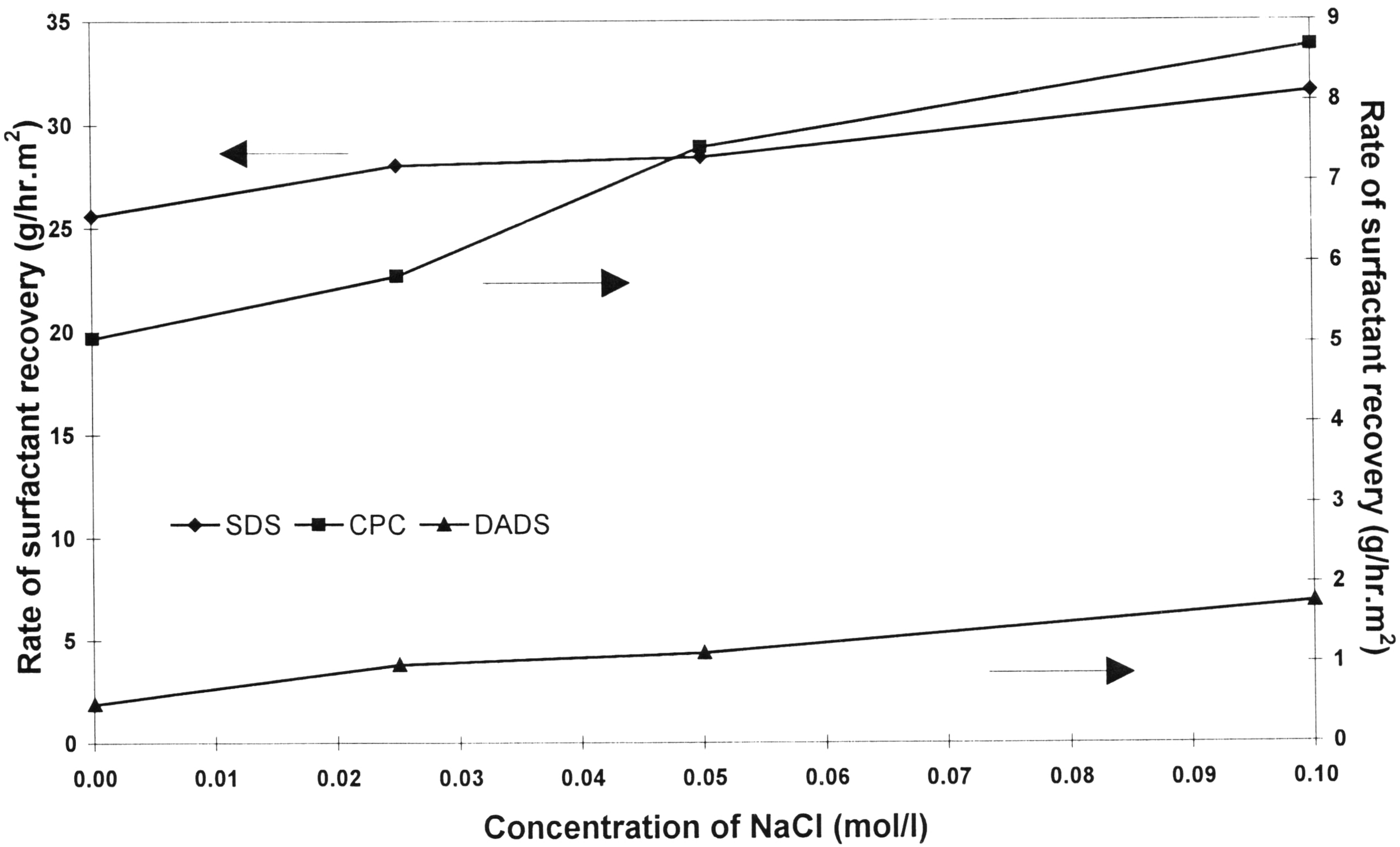

Fig. 4.5 Effect of NaCl concentration on rate of surfactant recovery.

4.2 Effect of Temperature

Table 4.2 shows the effect of temperature on foam fractionation parameters with no added salt. Fig. 4.6 shows that the volumetric foam production rate increases with increasing temperature. It may be due to the reduction in the surface tension of the thin liquid film lamellae with increasing temperature, which can increase foam formation (Sebba, 1987 and Porter, 1994). Increasing the temperature decreases the foam wetness, as shown in Fig. 4.7 perhaps because drainage rates increase as viscosity (bulk and surface) decreases and evaporation of lamellae water increases with increasing temperature, resulting in decreasing water content in the thin liquid film. This could also explain the increase in enrichment ratio when the temperature is increased, as seen in Fig. 4.8. As temperature increases, foam formation is generally enhanced, but foam stability (are formed) is generally decreased. These opposing effects make prediction of temperature effects on foam fractionation difficult. For SDS, the rate of surfactant recovery decreases with increasing the temperature, as shown in Fig. 4.9, because the decrease in the collapsed foam flow rate is much higher than the increase in the surfactant concentration in the collapsed foam as the temperature increases. These two counteracting effects appropriately cancel for CPC and DADS so the rate of surfactant recovery is almost independent of the temperature for these surfactants.

The effect of temperature on foam wetness, enrichment ratio and rate of surfactant recovery are in reasonable agreement with Grieves et al. (1964) and Bhattacharyya (1965), whereas the effect of temperature on volumetric foam production rate contrasts with that found in those works, probably because this effect is very system-dependent. Another possible explanation is that Grieves and Wood studied higher temperatures than used here.

Since different surfactant concentration were used in the experiments to avoid micelle formation and surfactant concentration can have a large effect on foam fractionation (Tharapiwattananon, et al., 1996), it is difficult to generalize about effect of surfactant structure. However, the removal of SDS seems to be more temperature dependent than that of CPC or DADS, possibly because the SDS CMC is so much higher (Fig. 4.1), so at a surfactant concentration which is a defined fraction of the CMC, the surfactant monomer concentration is higher for SDS.

TABLE 4.2 Experimental Results : Effect of Temperature on Foam Fractionation

Temp. (^oC)	Enrichment Ratio C_f/C_i			Foam wetness (g/L)			Volumetric foam production rate ($L/min.m^2$)			Rate of surfactant recovery ($g/hr.m^2$)		
	CPC	DADS	SDS	CPC	DADS	SDS	CPC	DADS	SDS	CPC	DADS	SDS
10	13.72	30.05	2.32	3.52	3.71	6.28	19.91	15.54	20.06	15.03	26.69	42.92
20	16.14	49.44	2.87	3.11	2.43	6.14	20.25	16.78	20.34	16.37	25.23	38.31
30	80.84	58.12	5.26	0.59	1.73	2.16	21.44	19.15	22.74	16.35	26.78	27.99
35	96.14	57.58	6.77	0.43	1.73	1.58	22.06	20.11	23.75	14.18	25.72	25.57

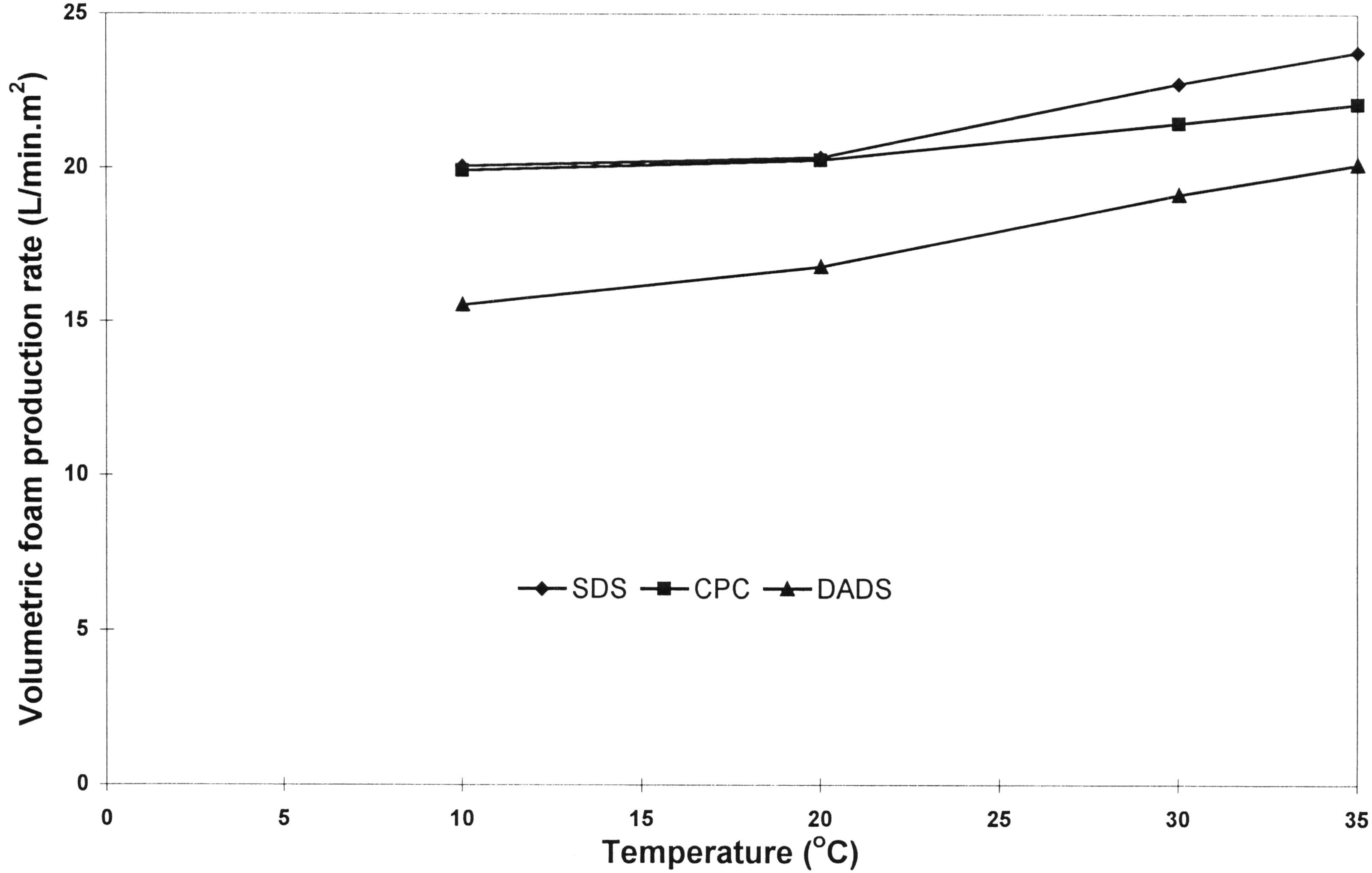

Fig. 4.6 Effect of temperature on volumetric foam production rate.

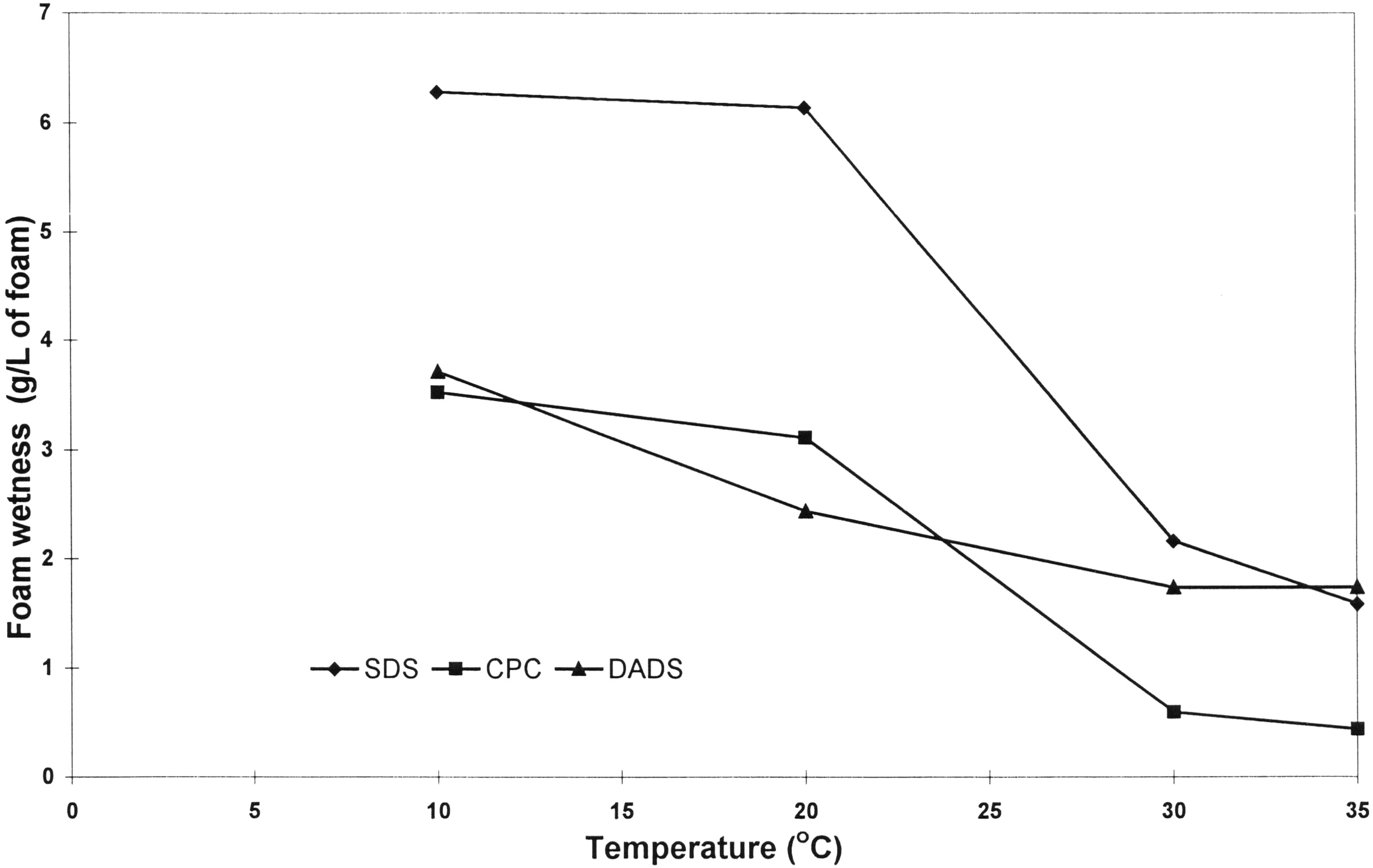

Fig. 4.7 Effect of temperature on foam wetness.

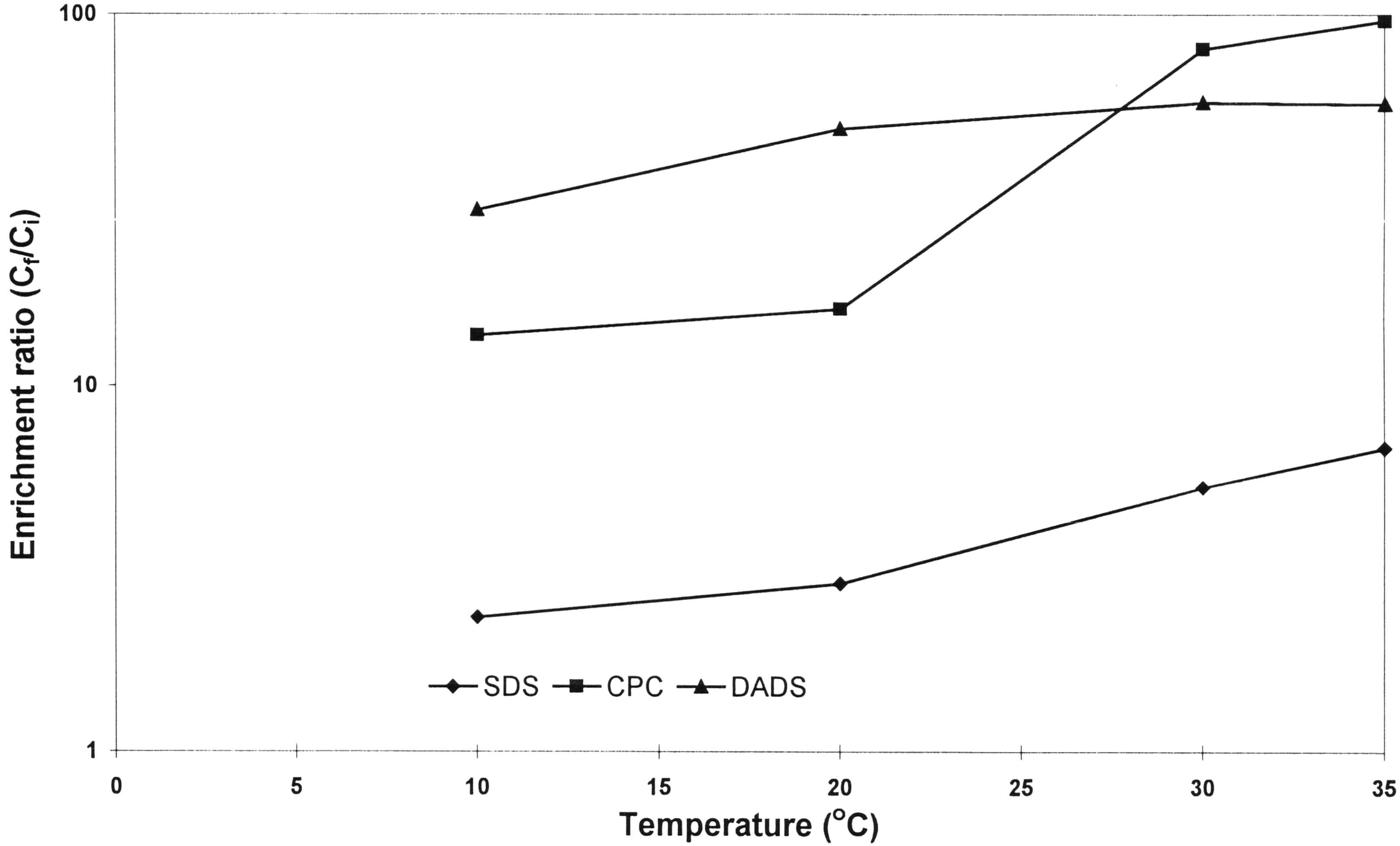

Fig. 4.8 Effect of temperature on enrichment ratio.

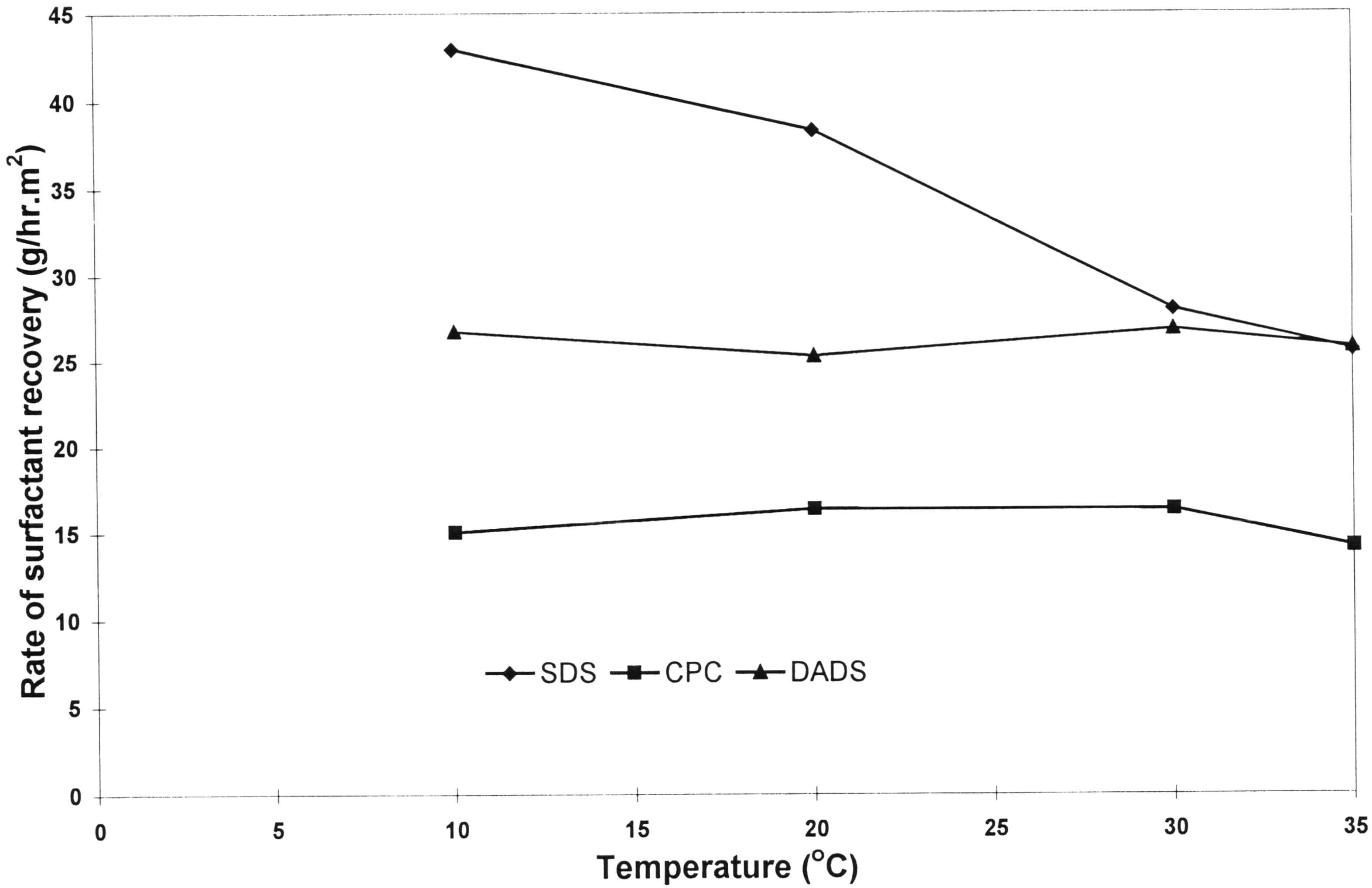

Fig. 4. 9 Effect of temperature on rate of surfactant recovery.