New Lecithin Organogels with Sugars of RNA and DNA

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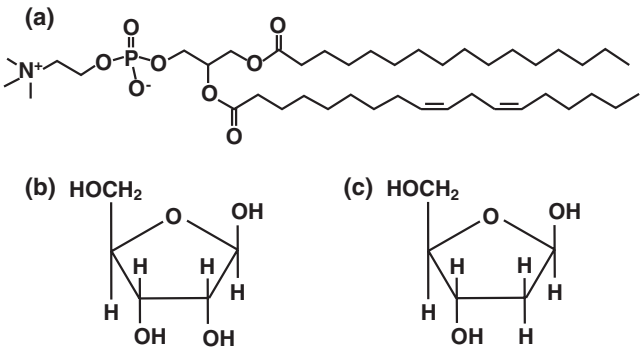
We report a new method for forming lecithin organogels that consist of reverse worm-like micelles. This method utilizes trace amounts of D-ribose or 2-deoxy-D-ribose in combination with lecithin and a nonpolar organic solvent.

Lecithin organogels that consist of reverse worm-like micelles are typically formed by the combination of lecithin and water in a nonpolar organic solvent.[1–7] Lecithin, a zwitterionic phospholipid with two alkyl tails, forms spherical or ellipsoidal reverse micelles when added to oil.[6] When trace amounts of water are added to this solution, the water molecules form a hydrogen bond with the phosphate group of neighboring lecithin moieties, thus reducing the interface curvature of the molecular assemblies, which is believed to induce the formation of reverse worm-like micelles. Other substances, such as glycerin, ethylene glycol, and formamide (all liquid at 25 °C), have been used as substitutes for this key ingredient of water.[6]

Recently, Raghavan et al.[8–10] have reported that bile salts can also induce the formation of reverse worm-like micelles from lecithin in nonpolar organic solvents; they were the first to report the use of a solid substance. In our previous studies,[11,12] in which we used urea and sucrose fatty acid esters, both of these solid substances also induced formation of reverse worm-like micelles from lecithin in nonpolar organic solvents.

In this paper, we report a novel method to form lecithin organogels through induction with D-ribose and 2-deoxy-D-ribose: the backbone sugars of RNA and DNA. These organic compounds occur widely in nature and are the most important sugars for living organisms.

First, the required amounts of soybean lecithin and D-ribose or 2-deoxy-D-ribose (Scheme 1) were dissolved in methanol in a vial. The solvent was completely removed using a desiccator equipped with a vacuum pump at room temperature. *n*-Decane was added to the vial and mixed overnight using a magnetic stirrer to dissolve the residue. Phase diagrams of the lecithin/D-ribose/*n*-decane and lecithin/2-deoxy-D-ribose/*n*-decane systems were visualized through crossed polarizers and by small-angle X-ray scattering (SAXS) analysis.



Scheme 1. Molecular structures of (a) soybean lecithin, (b) D-ribose, and (c) 2-deoxy-D-ribose.

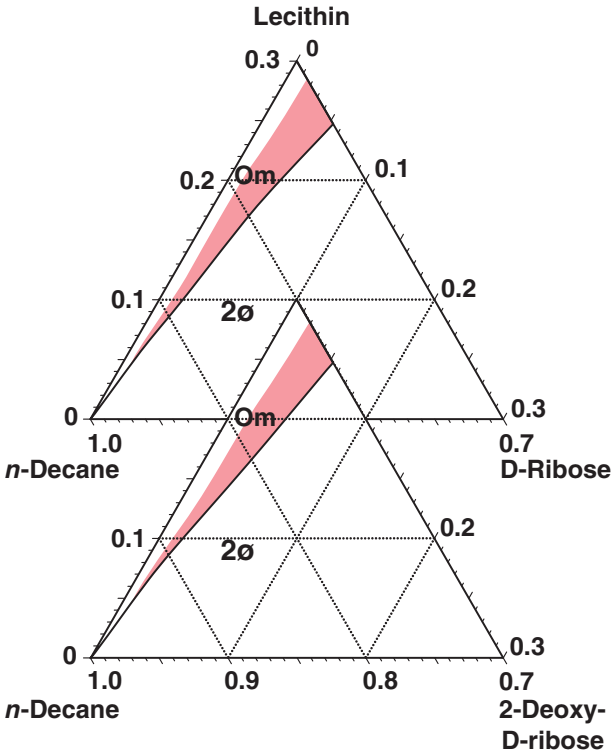


Figure 1. Partial phase diagrams of lecithin/D-ribose/*n*-decane and lecithin/2-deoxy-D-ribose/*n*-decane systems at 25 °C. The notations Om and 2ϕ represent a reverse micellar phase and two-phase region, respectively. The region of high viscosity within the Om phase is shown by the shading.

Figure 1 shows the phase diagrams in the dilute region of the lecithin/D-ribose/*n*-decane and lecithin/2-deoxy-D-ribose/*n*-decane systems. Reverse micelles (Om) formed upon addition of a small amount of either sugar. These reverse micellar regions enlarged with an increase in sugar and lecithin concentrations. Little difference was found between the two sugar systems. The appearance of a highly viscous region (shaded area) in the Om phase suggested the formation of reverse worm-like micelles. The solution separated into two isotropic phases (2ϕ) when the sugar concentration was further increased; the upper phase had a low viscosity similar to *n*-decane, and the lower phase had high viscosity similar to a reverse worm-like micellar solution, a phase separation observed in other systems.[1,8]

Figure 2 shows the effects on the solution surface of the lecithin/D-ribose/*n*-decane system when the sample vials are tilted from an upright position. As the concentration of D-ribose increased, the surface showed resistance to inclination, indicating

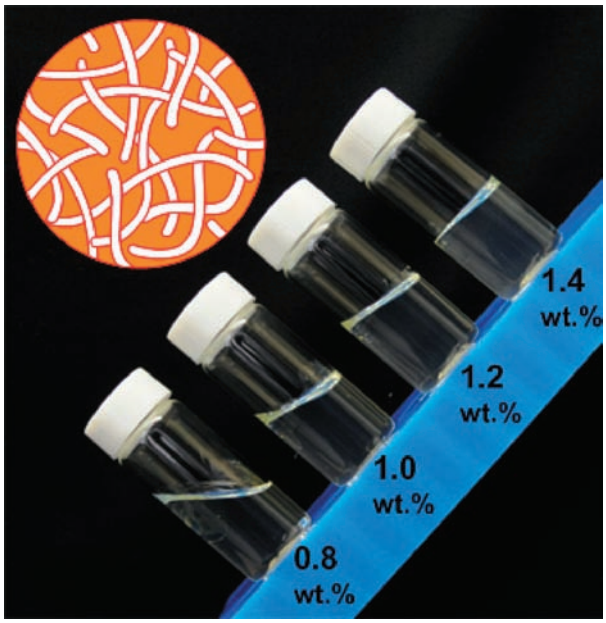


Figure 2. Effects on the surface of lecithin/D-ribose/*n*-decane systems at various D-ribose concentrations when vials are tilted from an upright position. Lecithin concentrations were fixed at 10 wt %.

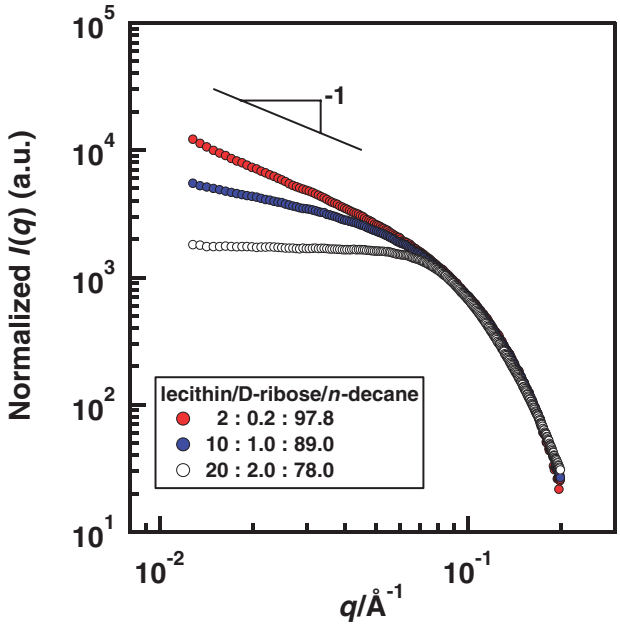


Figure 3. SAXS scattering intensity [$I(q)$] as a function of the scattering vector (q) for the lecithin/D-ribose/*n*-decane system.

an increase in viscosity and thus the formation of reverse worm-like micelles. All of the liquids were transparent and optically isotropic when stationary, but showed weak birefringence when moved.

Figure 3 shows SAXS scattering intensity [$I(q)$] as a function of the scattering vector (q) for the lecithin/D-ribose/*n*-decane system with different weight ratios (wt/wt/wt). None of the SAXS profiles showed a clear diffraction peak, indicating no formation of liquid crystals, such as reverse hexagonal liquid crystals or reverse cubic liquid crystals. In the SAXS profile of the lecithin/D-ribose/*n*-decane system with the lowest concentrations of lecithin and D-ribose (2:0.2:97.8), the slope of the double logarithmic plot in the low-q region was -1, indicating a cylindrical particle, i.e., the existence of a reverse worm-like micelle. Moreover, in the SAXS profiles of the systems with 10:1:89 and 20:2:78 ratios, the scattering intensity and slope of the low-q region decreased. Taken together, the number of reverse worm-like micelles per unit volume appears to increase with lecithin and D-ribose concentrations.

On the basis of our results, we propose a mechanism for the formation of reverse worm-like micelles in this system. Lecithin alone will form spherical or ellipsoidal reverse micelles in oil.[6] However, upon addition of D-ribose and 2-deoxy-D-ribose, the phosphate groups of the neighboring lecithin moieties will bind these sugars, reducing the interface curvature of the molecular assembly subsequently inducing the formation of reverse worm-like micelles. This reverse worm-like micelle maintained its stability without phase separation for at least 6 months. The formation of reverse worm-like micelles was confirmed in substances such as cyclohexane, liquid paraffin, isopropyl myristate, and isopropyl palmitate.

We conclude that D-ribose and 2-deoxy-D-ribose are useful additives due to their ability to induce the formation of lecithin organogels consisting of reverse worm-like micelles.

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References

1 R. Scartazzini, P. L. Luisi, *J. Phys. Chem.* **1988**, *92*, 829.
2 P. Schurtenberger, R. Scartazzini, P. L. Luisi, *Rheol. Acta* **1989**, *28*, 372.
3 P. L. Luisi, R. Scartazzini, G. Haering, P. Schurtenberger, *Colloid Polym. Sci.* **1990**, *268*, 356.
4 R. Angelico, G. Palazzo, G. Colafemmina, P. A. Cirkel, M. Giustini, A. Ceglie, *J. Phys. Chem. B* **1998**, *102*, 2883.
5 R. Angelico, A. Ceglie, U. Olsson, G. Palazzo, *Langmuir* **2000**, *16*, 2124.
6 Y. A. Shchipunov, *Colloids Surf., A* **2001**, *183–185*, 541.
7 F. Aliotta, M. E. Fontanella, M. Pieruccini, G. Salvato, S. Trusso, C. Vasi, R. E. Lechner, *Colloid Polym. Sci.* **2002**, *280*, 193.
8 S.-H. Tung, Y.-E. Huang, S. R. Raghavan, *J. Am. Chem. Soc.* **2006**, *128*, 5751.
9 S.-H. Tung, Y.-E. Huang, S. R. Raghavan, *Langmuir* **2007**, *23*, 372.
10 S.-H. Tung, S. R. Raghavan, *Langmuir* **2008**, *24*, 8405.
11 K. Hashizaki, T. Chiba, H. Taguchi, Y. Saito, *Colloid Polym. Sci.* **2009**, *287*, 927.
12 K. Hashizaki, H. Taguchi, Y. Saito, *Colloid Polym. Sci.* **2009**, *287*, 1099.

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