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Optical and X-Ray Studies of Some Liquid Crystals Naturally Occurring in Plants

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X-ray and optical studies have been made on the naturally occurring fluid materials of plant systems Jatropha curcas, Calotropic gigantea, Carica papaya and Ficus carica. X-ray diffraction and refractive index and birefringence studies indicate that these materials have optically birefringent phases with three dimensional structures in them in their natural form.

INTRODUCTION

Liquid crystals have been of great importance these days due to their many applications such as optical displays etc., more so because of their existence in many biological living systems such as insects, plants, living tissues of many higher organisms. Michelson,[1] Gaubert[2] and Mathieu and Farragi[3,4] have shown by their experiments that the wings of certain beetles simulate cholesteric liquid crystalline properties.[5] Stewart[6] has discussed the liquid crystalline properties of tissues of several parts of living systems. Bernal and Frankuchen[7] have demonstrated for the first time by X-ray diffraction studies the liquid crystalline nature of tobacco mosaic virus. More recently it has been shown that there are quite a few amphiphilic-lyotropic liquid crystalline systems of biological origin.[8–17] The principles of the liquid crystalline physics have been successfully applied to the study and functions of biological membranes.[18] It is conceivable that such highly organized liquid crystalline phases existing in several living systems may play an important role in the biological activities. The study of liquid crystalline materials in biological systems is of great relevance to the understanding of the living systems and their functions.[19–22] In view of this we have undertaken to make a study of the liquid crystalline materials naturally occurring in plants.

COLLECTION OF MATERIALS

We can expect to come across "liquid crystal like" materials in certain plants which will contain fibers in the cytoplasm. These micro filaments due to their extended nature can have parallel alignment. Extensive survey was made to collect the fluid from several plants and presently we have studied the natural fluids extracted from Jatropha curcas, Calotropic gigantea, Carica papaya and Ficus carica. The branches of these plants were thoroughly cleaned and were cut across by sharp instruments and the cellular cytoplasmic fluid was taken in very pure form by directly collecting the fluid that oozed out from the cross sectional cut. The fluids thus collected were turbid and milky and were less mobile than the synthetic nematic materials.

EXPERIMENTAL

(*a*) *Optical studies*: Refractive indices and birefringence were measured only for three samples using a prism technique. We were not able to measure the refractive indices for Calotropic gigantea as it was not transparent enough to make measurements. A hollow prism of angle about 4° was used in the experiment. A Goniometer Spectrometer which could measure to an accuracy of 2″ was employed to measure the angles. Refractive indices were determined[23,24] for three different wavelengths to an accuracy up to ± 0.002. The refractive index and birefringence data for the different samples are tabulated in Table I. As we see from the table the naturally occurring materials are optically posi-

TABLE I

Refractive index data

Wavelength Å	n_e	n_o	Δn
Refractive indices of Jatropha curcas			
4358	1.664	1.405	0.259
5461	1.600	1.373	0.227
5893	1.543	1.358	0.185
Refractive indices of Carica papaya			
4358	1.589	1.384	0.205
5461	1.479	1.314	0.165
5893	1.434	1.308	0.150
Refractive indices of Ficus carica			
4358	1.547	1.367	0.180
5461	1.505	1.340	0.165
5893	1.469	1.313	0.156

tive. The refractive indices and birefringence decrease with the increase of wavelength. Also we notice that the order of magnitude of birefringence is comparable to those of smectic and nematic liquid crystals.[24]

(*b*) *X-ray investigations:* The samples of the materials were taken on a loop of pure copper wire which was normal to the X-ray beam. The photographs were recorded on flat film for at least three different sample-to-film distances and unfiltered copper radiation was used. Diffraction patterns for different samples are shown in Figures 1 to 4. The X-ray diffraction patterns that were obtained contain a few sharp rings close to the center of the diffraction pattern (inner rings) and several sharp outer rings. The values of interplanar spacings corresponding to the various observed inner and outer rings do not vary in simple ratios as observed for amphiphilic systems of one or two dimensional periodicity. Also, the rings do not contain any discrete structures on them, such as spots to identify any hexagonal periodicity. X-ray diffraction patterns just indicate that the structures have a three dimensional lattice[9,25-27] and are rather similar to those of some crystalline phases. It has not been possible to index the reflections and get unequivocal structures. The interplanar spacings corresponding to several rings for all the samples are tabulated in Table II.

CONCLUSIONS

We notice from the above X-ray and optical experimental investigations that the naturally occurring fluid in cellular cytoplasm is uniaxial positive and con-

TABLE II

X-ray data

Jatropha curcas (Å)	*Calotropic gigantea* (Å)
1. 4.384	1. 4.804
2. 4.991	2. 5.428
3. 6.093	3. 6.641
4. 6.922	4. 7.497
5. 7.871	5. 8.622
6. 8.837	6. 9.973
7. 31.80	7. 32.12
Carica papaya (Å)	*Ficus carica* (Å)
1. 4.347	1. 4.310
2. 4.969	2. 4.885
3. 6.157	3. 5.979
4. 30.76	4. 6.878
	5. 7.730
	6. 8.837
	7. 33.43

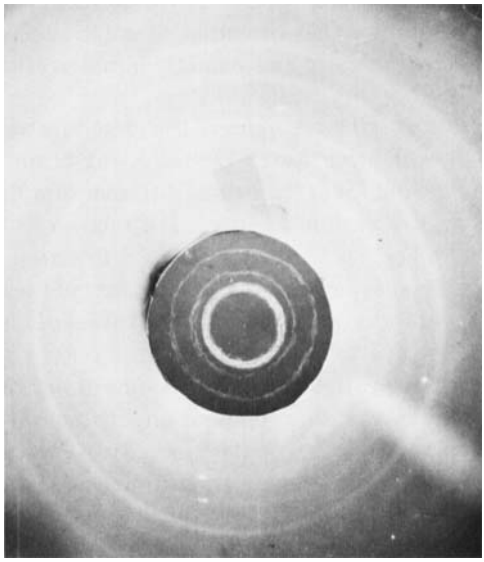

FIGURE 1 X-ray diffraction of Jatropha curcas.

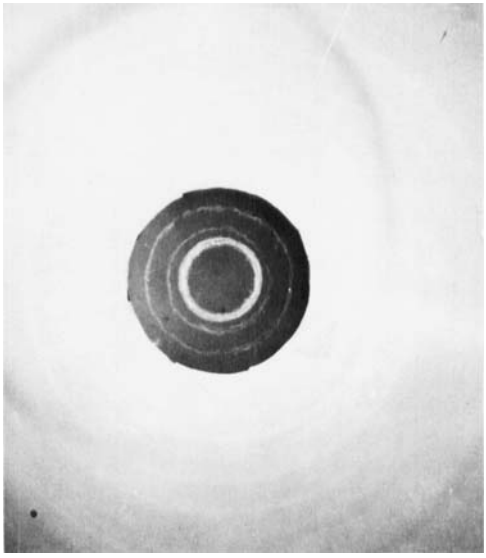

FIGURE 2 X-ray diffraction of Calotropic gigantea.

FIGURE 3 X-ray diffraction of Carica papaya.

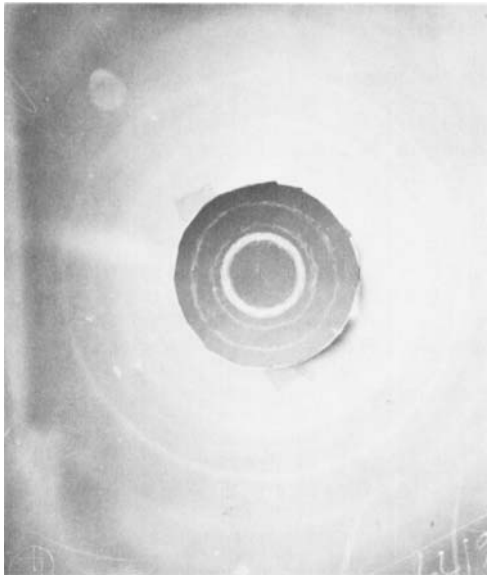

FIGURE 4 X-ray diffraction of Ficus carica.

tains three dimensional structures in it. At this stage we conclude that these fluids in cellular cytoplasm of plants are somewhat similar to birefringent amphiphilic systems of three dimensional structure in their natural form.[9]

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