A Simple Mechanochemical Method for Studying Structure and Dynamics of Biopolymer Fibers in Various Media

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A great deal of interest has been devoted to the influence of various chemicals on the structure and helix-to-coil transition of DNA. Recent publications have shown that ethanol can induce a B-to-A transition in DNA.[1-3] Ethanol is also known to influence the helix-to-coil transition.[4]

In this communication a simple mechanochemical method is described which can be used for studying structural and dynamic transitions in biopolymer fibers immersed in various media. In this method the length, l, of a fiber bundle is measured as illustrated schematically in Fig. 1. It hangs down from a thin glass hook positioned at the upper index of the measuring cylinder scale. The fiber is held straight by a small V-shaped Pt weight which is also used as marker for reading off the position of the lower end of the bundle on the measuring cylinder scale (a simple device with two parallel hairs serves to reduce parallax).

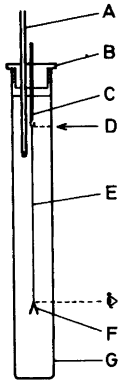

Fig. 1. The mechanochemical set-up. A, thermometer; B, Teflon-plug (cross-section); C, glass hook; D, upper index of the measuring cylinder scale; E, biopolymer fiber bundle; F, V-shaped Pt weight; G, 250 ml glass measuring cylinder with ethanol solution.

This set-up is very cheap and can easily be duplicated for simultaneous measurements.

The oriented biopolymer fibers are conveniently prepared with a wet spinning method.[5,6] The spinning of a nearly 20 m long DNA bundle laid out helically on a Teflon-coated cylinder has been described in detail previously.[7] A great number of "identical" fiber bundle samples, with length l_o typically 12–15 cm, can be taken from the cylinder[7] when immersed in 75 % ethanol (used as spinning bath for NaDNA) for successive or simultaneous measurements in the mechanochemical set-up.

The mechanochemical method will be illustrated with results from two different experiments on calf-thymus NaDNA fibers (Worthington) in ethanol solutions. In a first experiment the variation of relative length, l/l_o, with ethanol concentration was determined for bundles consisting of about 5000 DNA fibers. 10 mg Pt weights were used and the NaCl concentration was 0.01 M. As is seen in Fig. 2, the curve indicates a structural transition in the DNA fibers, occurring between 70 and 80 % concentration of ethanol. Since the A and B forms of DNA differ in axial translation per dinucleotide residue[8] (h_A=0.26 nm, h_B=0.34 nm) the decrease in fiber length can be taken as support for the ethanol-induced B-to-A transition suggested by various authors.[1-3] The clearest evidence comes from X-ray diffraction work.[2]

In a second type of experiment the temperature-induced helix-to-coil transition in DNA fibers in 75 % ethanol (0.15 M NaCl) was followed with the measuring cylinder immersed in a thermostated bath, the temperature of which was linearly increased with time (about 0.29 °C/min). Fig. 3 shows the relative change in length, $(l-l_o)/l_o$, of the DNA fiber bundle as function of ethanol temperature. The marked contraction at about 66.7 °C is taken as evidence for a helix-to-coil transition in the DNA fibers. After this contraction the fibers have lost most of their mechanical strength; cf. Ref. 7. This melting

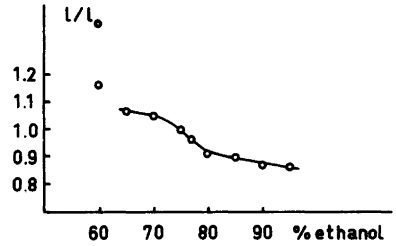

Fig. 2. Relative length, l/l_o, of NaDNA fibers in ethanol solutions containing 0.01 M NaCl.

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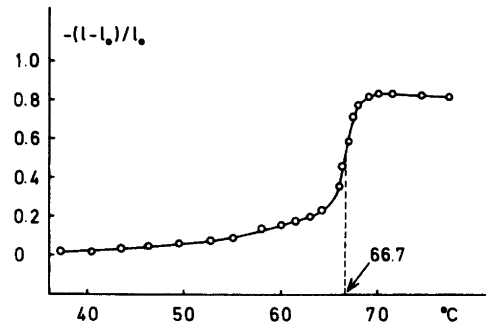

Fig. 3. Relative change in length , $(l-l_o)/l_o$, of NaDNA fibers in 75 % ethanol as function of temperature. Heating rate: 0.29 °C/min.

temperature in 75 % ethanol should be compared with a melting temperature of about 85 °C for DNA dissolved in 0.15 M NaCl(aq).[9]

The experiment illustrated in Fig. 3 was repeated with various concentrations of NaCl (0.00005–0.4 M NaCl) in the 75 % ethanol, but there was practically no salt effect on the melting temperature in this range. This differs considerably from measurements on DNA dissolved in water where a marked salt effect on the melting temperature is observed.[9]

Work is in progress to apply this mechanochemical method to DNA fibers with various counterions (Li^+, Na^+, K^+ and Cs^+), and a full report will be given later.

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