

## Elucidating the Formation Characteristics of Melamine-Cyanuric Acid Complex

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Melamine and cyanuric acid have been implicated in the kidney-related disease in infants and in the death of a large number of cats and dogs that ingested tainted food containing melamine. Both incidents were caused by the willful adulteration of the raw ingredients with melamine in the dairy products and pet food, respectively, in order to boost the apparent protein content in the nutritional labels. Melamine and cyanuric acid can form extremely insoluble “needle-like” and “spoke-like” crystals, which are composed of hydrogen-bonded melamine-cyanuric acid complex or melamine-cyanurate [1]. Ingested melamine and cyanuric acid are absorbed in the gastrointestinal tract, distributed systemically, and precipitate as the melamine-cyanurate complex in the renal tubules, leading to progressive tubular blockage, degeneration, and acute renal failure [2, 3]. The U. S. Food and Drug Administration (FDA) reported that melamine is incorporated into melamine-formaldehyde resins for making food packaging materials, plastic tableware, and the coating of food tins but only residual amounts leach into food. Food and beverage have been found to contain melamine in the parts-per-million levels as a result of leaching from melamine-containing resins [4]. Like melamine, cyanuric acid can be formed as a degradation product of s-triazine pesticides. Trace levels of cyanuric acid can be present in food and water from the use of dichloroisocyanurate in drinking water, swimming pools, and water used in food manufacturing. Cyanuric acid derivatives are found in sanitizing solutions for sanitizing food processing equipment, utensils, and other food contact [5]. According to the FDA, the toxicity of the combination of melamine and cyanuric acid is a “concentration-dependent phenomenon,” in which only high doses will lead to the formation of the renal crystals [6].

The goal of this study is to investigate the histomorphologic characteristics of the crystals observed at various concentrations and temperatures using scanning electron microscopy (SEM). The morphology, size, and distribution of the crystals formed at temperature of 4°C, 25°C, and 37°C at initial melamine and cyanuric acid concentrations ranging from 50 ppm to 250 ppm were compared. Preliminary data indicated that the melamine-cyanurate crystals produced at 37°C were coarser and larger compared to those formed at 25°C (Fig. 1a and b). Furthermore, the proportion of “spoke-like” crystals decreased along with the accompanying increase in the proportion of “needle-like” crystals at the higher temperature of 37°C. The larger crystal sizes at higher temperature may be due to the slower rate of formation and smaller number of initial nucleation sites. Similarly, lower concentration of 100 ppm complex gave rise to crystal structures that were coarser and larger compared to crystals formed at the same temperature at higher initial concentration of 250 ppm for melamine and cyanuric acid (Fig. 1a and Fig. 2a). Samples containing melamine-cyanurate formed in bovine blood plasma and in the kidney tissue of catfish that had been fed daily for 3 days with 200 milligram per day of melamine-cyanuric acid complex per kilogram of body weight were also analyzed by SEM and Raman microscopy.

## References

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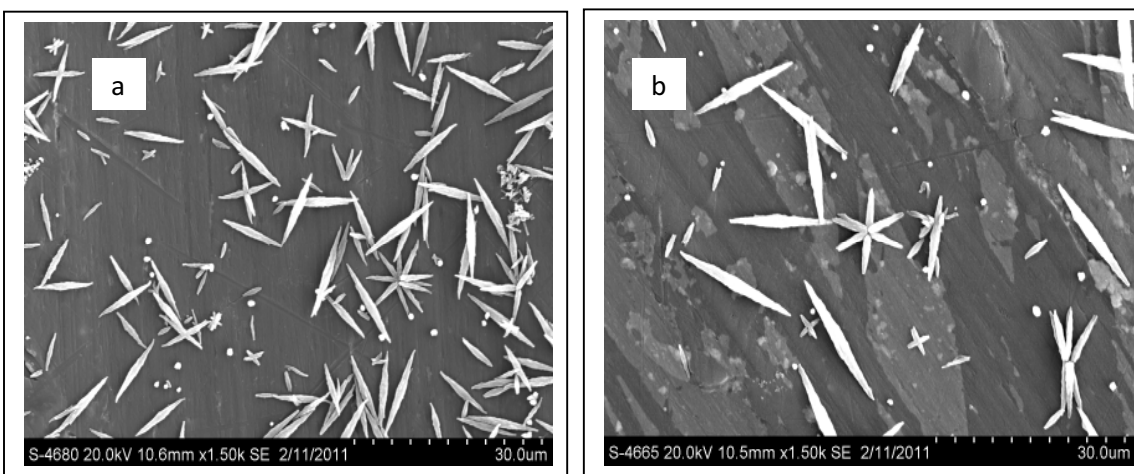


FIG. 1. SEM of melamine-cyanuric acid complex formed from initial 100 ppm solutions. a) Crystals of complex formed at 25 °C and b) Crystals of complex formed at 37 °C.

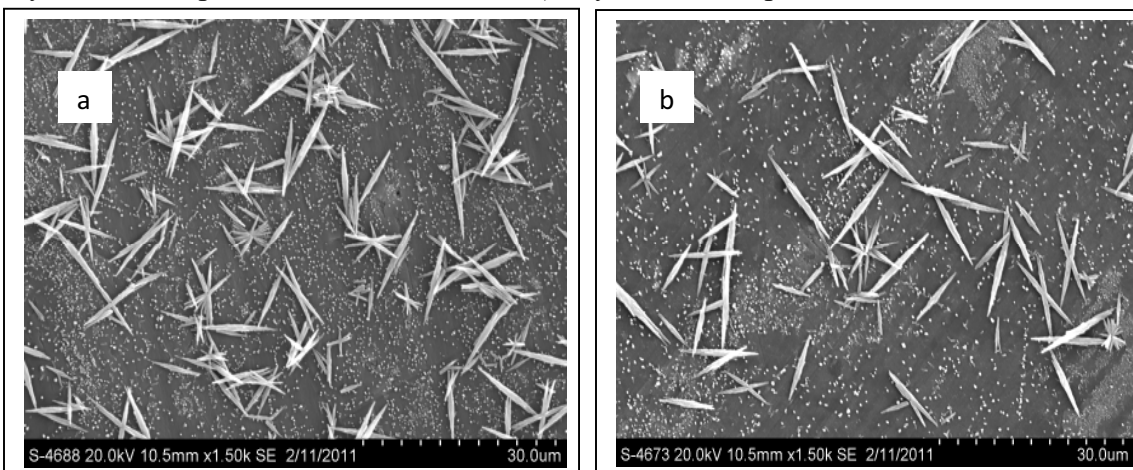


FIG. 2. SEM of melamine-cyanuric acid complex formed from initial 250 ppm solutions. a) Crystals of complex formed at 25 °C and b) Crystals of complex formed at 37 °C