Exploring Structural Anisotropy of Mozzarella Cheese: A Multimodal

By Harshkumar Patel

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Cheese, with its historical background and widespread global consumption, serves as both an independent food source and a versatile culinary ingredient. It is also a significant provider of protein and calcium. Besides its characteristic flavor, Mozzarella cheese is recognized for its desirable melting, stretching, oiling, and browning properties upon cooking. These distinctive textural properties are linked to the pasta-filata structure of Mozzarella. Mozzarella production involves kneading and stretching of cheese curd at elevated temperatures, causing proteins to partially melt, and allowing proteins and fats to align in the direction of stretching. The result is a desired anisotropic texture. The anisotropy index has been used in establishing a connection between process conditions, functional properties, and consumer preferences.

In this study, a design with twelve Mozzarella cheeses was executed with variations in temperature, kneading speed, and the addition of calcium or citric acid. Fluorescence anisotropy (FA), a fast, robust, non-destructive, quantitative measure of fluorescent tumbling, was used to characterize the Mozzarella. Tryptophan, the prominent fluorescent molecule observed (excitation/emission wavelength of 295/335 nm), was analyzed with FA as 12 replicates per sample. The FA results showed a significant correlation with process conditions, functional properties, and sensory evaluation. To obtain a more in-depth understanding of microstructure, an isotropic Cagliata and three Mozzarella samples were selected. These cheeses were analyzed using THz cross-correlation spectroscopy with photoconductive antennas, a relatively novel technique to be applied to dairy products. In organic compounds, the THz (0.1-1 THz) electromagnetic spectrum provides insights into low-frequency molecular vibrations, molecular rotations, hydrogen bonding patterns, and conformational dynamics. THz spectra for each sample were recorded in two distinct orientations across a sampling area of approximately 50×50 mm. The THz images were generated by calculating the peak-to-peak value for each pulse of the scans. In parallel, the cheese structure over a 25×25 mm area using high field magnetic resonance imaging (MRI). The laser scattering 2D anisotropy mapping of Mozzarella revealed distinct differences between isotropic and anisotropic cheese samples. Diffusion tensor components, acquired by MRI (14T, time of flight, Δ=50ms) are plotted as deviations from the trace image (average diffusion, diagonal of the tensor) for each Cartesian axis. Comparing the diffusion rates in a specific plane revealed that water inside Mozzarella diffuses faster than in Cagliata, and it highlighted key anticipated differences among Mozzarella samples. In conclusion, FA, THz, and MRI complement each other, allowing researchers to explore the important (but difficult!) food property “anisotropy”.